Land Use Land Cover Changes and their impact on the lake ecosystem of the Central Rift Valley of Ethiopia

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ABSTRACT

LULC changes are major environmental challenges in many parts of the world which are adversely affecting ecosystem services. This study was aimed to analyse LULC changes on the ecological landscape of Ethiopia CRV areas from 1985 to 2015. Satellite images were accessed and pre-processing and classification is done. Major LULC types were detected and change analysis was executed. Nine LULC changes were successfully evaluated. The classification result revealed that in 1985, 44.34% of the land was covered with small scale farming followed by mixed cultivated/acacia (21.89%), open woodland (11.96%), and water bodies (9.77%). Whereas for the same study year open grazing land, forest, degraded savannah and settlements accounted the smallest proportion. Though the area varied among land use classes, the trend of share occupied by the LULC types in the study area remained same in 1995 and 2015. Increase in small and large scale farming, settlements and mixed cultivation/acacia while a decrease in water bodies, forest and open woodlands is noted. About 86.11% of the land showed major changes in land use/cover. Lastly, DPSIR framework analysis was done and an integrated land use and development planning and policy reform are suggested for sustainable land use planning and management.

Keywords: Central Rift Valley, Ethiopia, Landsat images, Lake, land use/land cover

1. INTRODUCTION

Ethiopia has a very diverse set of ecosystems ranging from humid forest and extensive wetlands to the desert (Tefera 2011) and within these mosaic environments LULC changes are pervasive and common phenomenon where agricultural activities and settlements dominate rural landscapes affecting ecosystem services. Ecosystems provide a wide range of multiple services that vary in quantity and quality depending on the type of ecosystems and their status (MA 2005). Land is finite and non-renewable resource deliver services needed for human wellbeing. Different land classes are quite different in their service provision and provides a unique service that cannot be replaced by others (Costanza et al. 2014; De Groot et al. 2012) and certain services are local specific (pollination of agricultural crops) and others are global in their nature (mitigation of global climatic change) (Tolessa et al. 2017). Many of the land resource services are important for sustaining life on earth and maintaining the integrity of the ecosystem. However, land resources are falling under threat and stress in time.

Land use land cover change (LULCC) is one among the main driving forces (Lambin et al. 2000; Lasanta et al. 2006) on global and local environmental changes though its impact vary across space and time (Bryan 2013; Costanza et al. 2014). Expansion of agriculture, urbanization, deforestation and the day to day activities of mankind resulted in temporal and spatial changes in the land use land cover which in turn affects ecosystem services such as hydrological regulation and soil erosion losses (Rawat and Kumar 2015).

In Ethiopia, empirical evidences show that there have been considerable LULC in different parts of the country (Girmay et al. 2010).These changes have important environmental consequences at local, regional and global scales (Bewket and Abebe 2013). At the local scale, land use changes affect watershed runoff, micro-climatic resources, groundwater tables, processes of land degradation and landscape level biodiversity (Lambin and Geist 2008). Few decades ago, the Central Rift Valley (CRV) basin is known for its dense acacia woodlands that have now been transformed into agricultural and grazing lands (Gebreslassie, 2014). These has a serious eco-environmental problems threatened the region's sustainable social and economic development (Collier and Dercon 2014; Peng et al. 2011).

LULCC is driven by multiple factors from environmental and social dimensions in a land system (Gong *et al*. 2015). Reasons for these changes are many faceted, however, the major among others are lack of proper land use policy (Teka et al. 2013). Thus, land cover dynamic becomes concern of the 21st century with the dramatic implication for human survival. Water bodies (specially, wetlands and lakes) are, an important environmental components of the terrestrial landscape which cover significant portion of the country total land area, performing significant ecosystem services (Amsalu and Addisu 2014) like climate regulation, pollutant reduction, flood storage, drought control, water supply, and biodiversity conservation (Haslam 2004; Mitsch and Gosselink 2000). However, water body degradation is becoming more and more serious thereby accelerating the degradation ecological balance and environmental quality (Day Jr et al. 2003; Dimitriou et al. 2008) and their biota are at risk from the combined effects of changes in Ethiopia. As a result of faulty use the area has experienced fluctuations in lake level of tens to hundreds of meters in the past 200 years (Olaka *et al*. 2010). Many authors reported also as climate changes coupled with water for domestic use, fisheries, small and large scale agriculture (floriculture and horticultural farms) have altered the lakes hydrodynamics (Geheb and Abebe 2003; Hengsdijk and Jansen 2006; Olaka *et al*. 2010; Zeray *et al*. 2006).

Hence, to this end, this research was initiated to analyse the land use and land cover changes in the CRV at three different temporal scales viz. 1985, 1995 and 2015 with a close look to the empirical and statistical relation of the LULC changes, mainly focusing on the ecological landscapes of CRV zone and its lakes likely to generate updated data and supplement the already recorded information that ultimately guide restoration and/or conservation intervention in the CRV areas. Therefore, the main objective of this research work was to characterize GIS-supported LULC changes of the CRV Ethiopia and was addressed the following specific activities: (i) Conduct GIS supported LULC change analysis over three periods (1985; 1995 and 2015) and characterize LULC classes, (ii) Detect changes in the area of LULC classes over time based on the image analysis, (iii) Analyze and Prepare LULC change map and accompanying data for LULC classes, (iv) Identify the drivers and analysing impacts of LULC changes using DIPSIR framework.

2. METHODS AND MATERIALS

2.1.The Study Area

Figure 1 presents the Central Rift Valley (CRV) region where this study was conducted. Geographically, CRV is located between 38º15'E and 39º25'E and 7º10'N and 8º30'Ncoordinates. The CRV in Ethiopia makes an area of about 1.3Mha and encompasses four large lakes, Ziway, Abijata, Shala and Langano (Hengsdijk and Jansen 2006).This is a section of the Main Ethiopian Rift comprises a significant part of the great African Rift Valley system that stretches from the Red Sea to Mozambique crossing Ethiopia, Kenya and Tanzania. It is divided into three subsystems: Chew Bahir (Lake Stephanie), the CRV and the Afar triangle (Muzein 2006). The central rift valley comprising Ziway-Langano-Abijata-Shalla Lakes from the Ethiopian rift valley basin and the lower sub-basin comprising Hawassa- Abaya-Chamo-Chew-Bahir lakes. These lakes, which once formed one large water body, support important biodiversity resources that have global significance. The CRV basin contains unique fauna and flora species of which a significant number are endemic. The area is an important breeding and feeding site for some rare species of resident and migratory birds. A good example is Lake Abijata and Lake Shala form together a National Park, which has been submitted as candidate site by the Ethiopian Government to the Ramsar convention on wetlands.

2.2. Data Sources and Method of Analysis

2.2.1 Satellite Images

In order to unravel the land cover dynamics of the area, cloud free spatiotemporal data of 2 landsat 5 TM 30 m (1985 and 1995) images and one landsat 8 OLI-TIRS 30 m (2015) image were downloaded from open access Landsat imagery services at http://glovis.usgs.gov. The specific date and year (January, February and December) for acquisition was selected because of the availability of cloud free Landsat imagery across the study area. GIS data on administrative boundary, road network, towns, and river network were obtained fromthe GIS department of the Ministry of Water, Irrigation and Electricity (MoWIE), Ethiopia.

A 30 m resolution Digital Elevation Model (DEM), based on Aster imagery was also employed. In addition, ancillary data were also utilized during analysis. All data were projected to the Universal Transverse Mercator (UTM) projection system zone 37N and datum of World Geodetic System 84 (WGS84), ensuring consistency between datasets during analysis.

2.2.2. Image pre-processing and classification

Before image processing, extraction, layer stacking, georeferencing and change detection were performed on the Landsat TM/OLI images obtained fordifferent dates in order to create multi-band composite images. Data were pre-processed in ERDAS imagine for geo-referencing, mosaicking and sub setting of the image on the basis of Area of Interest (AOI). Satellite image re-processing was conducted to establish a more direct affiliation between the acquired data and biophysical phenomena. Then land use and land cover change detection was analysed for the last 30 years in GIS environ through hybrid classification technique. The overall work flow is summarized in Figure 2.

2.2.3 Major land use and land cover types detected

The image analysis has found nine land use and land cover type (Table 1), namely, water bodies, small-scale farming, settlements, open woodland, open grazing land, mixed cultivated/ acacia wood lands, large scale farming, forests and wood lands and degraded savannah. Large scale farming is a recent phenomenan introduced in to the area in the past two decades with the establishment of large foreign horticulture and floriculture farms largely Dutch-based investments.

2.2.3 Land use/land cover change analysis

Land use change analysis was conducted using post-classification image comparison technique (Lillesand et al. 2014). Images of different reference years were first independently classified. The classified images were compared between each study periods, i.e., 1985–1995, 1995–2015 and 1985-2015. Transitions between different land use/land covers were evaluated by comparing image values of one data set with the corresponding value of the second data set in each period to measure areas converted among the different land uses. Quantified values of the changes between the different LULC classes were used for statistical analysis to reveal the extent of the dynamics in the study areas. The percentage of change within the same LULC class between two time points is calculated as follows, the values were presented in terms of hectares (Ha) and percentages (%). Positive values suggest an increase whereas negative values imply a decrease in extent of a given land use type.

$$Change\ (\%) = \frac{(A_{rt} - A_{pt})}{A_{pt}} * 100 \quad \ldots\ldots (1)$$

Where change (%): percent change in the area of specific land use land cover class between times t_n and t_{n-1}; $\mathbf{A_{rt}}$ is recent area extent of a given LULC type at time *t* and $\mathbf{A_{pt}}$ is previous area of LULC at earlier time *t.*

2.2.4 Ground Truth Data and Accuracy assessment

One of the first steps in making LULC products useful is to evaluate its quality (Giri 2012). The performance of LULC classification was verified using ground truth data collected using Geographical Positioning System (GPS) reading. This was carried out from January to February 2015 for 2015 image analysis and by using Google-Earth map for 1985 and 1995 imagery classification for accuracy assessment of the classified images.

if a supervised based classification method will be used (Hasmadi et al. 2017). The method of accuracy assessment used in this study is based on the pixel scale to derive the accuracy of classification in the remotely sensed data. Thus, for this study Grounds Control Points (GCPs) of target LULC types were collected to check their accuracy. The kappa coefficient is used in order to evaluate the overall accuracy of the classified images. It is generally known as a precision measure since it is considered as a measure of agreement in the absence of chance (Lillesand et al. 2014). The Kappa coefficient, which measures the difference between the actual agreement of classified map and chance agreement of random classifier compared to reference data, was also calculated as:

$$Khat = \frac{N\sum_{i=0}^{r} - \sum_{i=0}^{r} * (X_{i+} * X_{+i})}{N^2 - \sum_{i=0}^{r}(X_{i+} * X_{+i})} \quad \textbf{(2)}$$

Where r is the number of rows, x_i is the number of observations in row i and column i, x_{i+} and x_{+i} are the marginal totals of row and column, and N is the total number of observed pixels (Congalton 1991). The value greater than 0.80 represents strong or good classification; the value between 0.40 and 0.80 means moderate classification and the value less than 0.40 represents poor classification (Unger Holtz 2007).Thus, the overall accuracy and kappa coefficient for this study was 86.11% and 0.83, respectively suggesting 86.11% of the land use/ land cover classes are correctly identified and classified. Moreover, while doing the ground truthing we have also conducted Focus Group Discussion with stakeholders on the environmental impacts of horticulture investments and the land use land cover changes in the area particularly in the area of water bodies.

3. RESULTS AND DISCUSSIONS

3.1. Land Use land Cover Maps the CRV (1985 -2015)

The Landscapes of the study area has undergone and experienced some major land use /land cover changes over the last 30 years.5 (Figure 3a-c, Table 2) The LULC changes occurred during the period under consideration and area extent of those changes are Table 4. The data show that there is a change in land cover/use over time. Land use systems are dynamic in response to population and economic growth, public and private investments , and market and government actions (Berke and Kaiser 2006). The central rift valley region of Ethiopia has experienced a marked change in land use and land cover over the past three decades (1985 – 2015).

In 1985, 44.34% of the land was covered with small scale farming followed by mixed cultivated with interspersed growth of acacia woods (21.89%), open woodland (11.96%), and water bodies (9.77%). The area under crop fields covered about 75 % of the total areas in 2015 particularly following the introduction of large scale floricultures and horticulture farms though small scale farming seem decreasing but was shifted to large scale farming and water bodies were declined to 8.64% (Table 2). The overall expansion of at the same time, small scale irrigated farming has expanded considerably with establishment of irrigation water user associations that grow vegetables for the central market around Addis Ababa.

The expansion of irrigated agriculture has cause some serious environmental problems including pollution fresh water lakes, reduction in the levels of the lake water. Hengsdijk and

Jansen (2006)explained this problem as, “an extensive scale of horticultural cultivation and floriculture greenhouse complex (with a Dutch holder) has been built along the shore of lake Ziway giving new and severely needed employment chances of the nearby population, which basically relies on smallholders farming system. This development will further increase the pressure with respect to nearby water assets likewise those greenhouses rely on upon surface water from Lake Ziway for irrigation, same time other inputs (nutrients and biocides) might expand the hazard of environmental contamination”.

The expansion in agricultural extent might be associated with the increasing of small scale irrigated land and expansion of large scale farming (vegetable and flower farms) which might in turn affects the water bodies. A study conduct at Yezat Watershed, North Western Ethiopia (Lemlem Tadesse et al. 2017) and in the Ethiopia Rift Valley (Ariti et al. 2015; Daniel A.M et al. 2012) reported similar result of cultivated land as result of increasing human population, which required additional agricultural land for food production. Authors (Assefa and Bork 2016) also report similar reslutsfor Chencha and Arbaminch areas revealing that farmland scarcity has already caused farmers to cultivate marginal land areas and fragile ecosystems. Research finding of (Muzein 2006) also confirm that agriculture was responsible for the loss of more than 4/5 of the total terrestrial productive ecosystem for the Ethiopian central rift valley.

The study also indicates loss of water body. The change results explain continual decline in water bodies, open grazing land, forest and degraded savannah all over the study periods. The water bodies were decreased by 3.16% and 8.69%, respectively during the first two periods and an overall decline of 11.57% was recorded in the third period. The highest rate of turn down of water bodies were recorded during the second period which might be associated with the expansion of industries (like water abstraction of soda ash), small scale irrigated lands and large scale faming (vegetable and floriculture farms) around the water bodies which consumes a lot of water for their activity. Many authors (Ayenew 2004; Legesse and Ayenew 2006) confirm that the rift valley lakes and Feeder Rivers are used for irrigation, soda extraction, commercial fish farming, and recreation, and they support a wide variety of endemic birds and wild animals and levels of some of these lakes have changed dramatically over the last three decades.

The highest rate of decline of forest lands was also observed during the second period, which might be associated with a regime change which is in conformity with other studies (Demissie et al. 2017; Eshetu 2014; Kindu et al. 2015) and deforestation through cutting acacia trees for charcoal production has also become a common phenomenon, as it is an easy cash source for some farmers since the main road that connects Addis Ababa to the Southern Regions provides an opportunity for roadside charcoal and wood sellers (Muzein 2006). Conversely, settlements, mixed cultivated/acacia lands and large scale farming depict an escalating trend though vary and fluctuate in values. As (Ariti et al. 2018) indicated that forests, grasslands, and water have declined in the past four decades mainly due to the 1975 land proclamation, the 1995 constitution, and water, irrigation, and investment policies, respectively.

To calculate annual rate of change for each land use class, the difference between final year to initial year which represents magnitude of change between corresponding years was divided by the number of study years i.e. 1985–1995 (10 years), 1995–2015 (20 years), and 1985–2015 (30 years) respectively using the following Equation as stated by(Meshesha et al. 2016):

$$AnnualR\Delta\ (\%) = \frac{\text{change }(\%)}{\Delta \text{T}} \quad \ldots\ldots (3)$$

Where: RΔ = Annual Rate of change, Change (%) = % change in the area of specific land use land cover class (eqn. 1) and ΔT = time interval between initial and previous LULC class in years**.**

Analysis of the annual LULC change revealed that settlement and mixed cultivated/acacia experienced an increasing trend whereas water bodies show a continous decline throughout the entire study period (Table 3).

3.2.Changes in Surface Area of the CRV Lakes (1985 -2015)

The Rift Valley Lakes Basin is one of the major river basins in Ethiopia with a total area of about 52,000 km^2(MoWR 2010).The basin is characterized by a chain of lakes varying in size as well as in hydrological and hydrogeological settings. It constitutes nine lakes viz, Lake Ziway, Lake Langano, Lake Abiyata, Lake Shalla, Lake Hawassa, Lake Abaya, Lake Chamo, Lake Abbe and Lake Beseka (Alemayehu et al. 2006). However, significant changes have been observed in the hydrology of the Rift Valley lakes in Ethiopia over the past decades (Seyoum et al. 2015). The CRV encompassing Lake Ziway, Lake Abjiata, Lake Langano and Lake Shala which forms a complex and vulnerable hydrological system with unique ecological characteristics (Jansen et al. 2007)that are feed by streams of Meki and Ketar Rivers in the upstream portions of the catchments. These rivers drain into Lake Ziway travelling long distances and from Lake Ziway water is discharged into the Bulbula River, which flows to Lake Abjiata. But, regarding Lake Shalla, the available literature is very limited. This might be due to the little interest in the lake water because of its alkaline nature which discourages its use for irrigation purpose (Belete et al. 2015; Raventós Vilalta 2010).

These lakes support a considerable wide variety of aquatic and terrestrial biodiversity and are habitat to different kinds of edible fish. Despite of their services, human-induced and natural factors affect water quality of the lakes (Ayenew 2008; Ridgeley et al. 2012; Tefera 2002). The change detection shows that water mount of Lake Abijata, Ziway, Langano and Shalla showed a reduction of surface area during the entire study periods by 25.92%, 0.52%, 0.81% and 0.02% (Figure 4; Table 4) from their 1985's size, respectively. Such kind of drastic change (e.g. Lake Abjiata) in surface area may have long lasting negative consequences because the reduction in surface area of the four lakes intertwined negative impact on ecosystems, biodiversity and livelihood of the community. This result is supported by (Olaka et al. 2010) who reported the fluctuations for Lake Zeway in lake level of tens to hundreds of meters in the past 200 years. Others reported similar trend as some lakes have shrunk due to excessive abstraction of water like Lake Abjiata dropped significantly over three decades because of the extraction of water for soda and an upstream diversion for irrigation (Hengsdijk et al. 2007; Legesse and Ayenew 2006; Yohannes et al. 2017). Many studies indicate that the

CRV Lakes and their watershed support unique ecological and hydrological characteristics which host to a wide array of economic, domestic and recreational activities, including the flower industry, soda abstraction and fish farming (Ayenew 2007) and support the livelihoods of approximately 2 million people (CSA 2013) and populate 1.9 million livestock (Meshesha et al. 2012). Therefore, the reduction in area of these lakes will have impact on fisheries and lake-related ecosystems and causing the shrinkage of outflows of these lakes which is associated with environmental degradation, particularly the loss of aquatic bird life, water users along the rivers for domestic and livestock and irrigated farms.

The annual rate of lakes area change is also experienced a decreasing trend through. As presented in Table 5 Lake Abjiata takes the lion share in annual reduction by 12.07% during the first decades and by 13.39% by the next two decades. This result is in conformity with different findings of since the 1980s, as the water level of Lake Abjiata has significantly dropped due to the investment policies which affect the water resources of the area, especially river Bulbula and Lake Abijata and in response to natural condition variability. The use of river Bulbula, which is the main tributary for Lake Abjiata, for irrigation and factories, has caused the river to dry up, contributing to the shrinkage of Lake Abjiata. According to (Ayenew 2002), uncontrolled water abstraction from Lake Ziway and the irrigation scheme on the River Bulbula significantly affects the water level of Lake Abijata. The fishery in Lake Abijata has totally collapsed and birds such as Lesser Flamingo (*Phoeniconaias minor Geoffroy*) and Great White Pelican (*Pelecanus onocrotalus roseus*) have been migrating to nearby lakes (Yohannes et al. 2017). If it continues like this, the lake will be facing imminent threat of collapse and the existence of the Park would be unlikely and will be expected to share the bad history of Haramaya Lake. Hence, the minimum water flow on river Bulbula should be maintained through an integrated water resource management practices on a basin-wide scale to maintain the life in the Lake Abjiata.

3.3. Drivers of Land Use/Cover Changes in Ethiopia CRV

Many recent studies indicate that there have been substantial environmental and economic impacts of rapid LULC change in Ethiopia (Gashaw et al. 2017; Miheretu and Assefa 2017).Likewise LULC changes of Ethiopia CRV are governed by a combination of environmental, geographical and socio-economic factors. The interview done with FGD and field observation results has indicated multiple effects of LULC change in the study area between1985 and 2015. Although the primary reason for change is population growth, the contribution of other causes such as environmental factors and economic development are also contributing significantly. The drivers of land-use and land-cover changes are often classified into proximate and underlying causes (Lambin et al. 2003). Both proximate and underlying driving forces caused the observed changes in land cover in the study area. The proximate causes are the immediate actions of local people such as agricultural expansion since the coverage of total cultivated land is increased overtime. Author (Molla 2015)further explained that the major causes of acacia woodland, shrub/bush land and other vegetation change is directly related to agricultural activities and was a driving force for 20.4% and 27.8% of natural vegetation loss during 1973 to 2010 periods due to the increasing demand for food for the increasing household members. wood extraction, infrastructure expansion and others which change the physical state of land cover are also part of the proximate causes as of (Lambin and Geist 2008) study.

The underlying factors push the proximate causes into immediate effect (Geist et al. 2006). The underlying factors include changes in demographic pressure, economic condition and technological and institutional factors (Riebsame et al. 1994). In the CRV area population pressure is found as one of the major underlying causes of land use/cove changes which contribute more to resources degradation through shrub/tree cutting for fuel consumption and charcoal production. Many authors confirmed (Kabba and Li 2011; Lambin et al. 2003) that human population growth pressures are expanding the area of land-uses such as agriculture and settlement into natural habitats in all parts of the world to meet the demand for food and housing. Generally, drivers/causes of LULC changes can be from a range of biophysical, demographic, economic, infrastructural and technological factors.

The results from FGDs and field observations realized that the large portions of the study areas are intensively cultivated upon the expansion of investment on horticultural production and increasing of vegetable irrigating by farmers too. The other noted and mentioned problem by FGD is the vegetation clearance for charcoal production. This all occurrences cause soil degradation down to the main lakes of the CRV. As a result, most part of the lakes watersheds become less capable of absorbing and holding the rainfall water, which in turn enabled the removal of the top fertile soils and frequent flooding. The finding is in agreement with the results of (Teklemariam et al. 2017a) who explain problem of sedimentation at down streams due to intensive farming at upstream areas. Expansion of urban due to the population growth and movement of people to towns to search job in the commercial farms established around the study areas has resulted in the acquisition of most suitable agricultural lands for urban development. Finding of (Moges and Bhat 2018) confirm that also urban expansion has resulted in increased price of agricultural lands, overconsumption of irrigable water, and increased price of food and fuel.

3.4. Analyses of land cover change using DPSIR framework

DPSIR (Driving, Pressure, State, Impact and Response) analysis was employed in assessing the land use/cover change of CRV and the results from land cover change detection using remote sensing are placed in the context of the DPSIR framework as a platform for explanation. The decision cycle (Figure 6) starts from the problematization (Table 6) of the issue to the final decision. Based on the analysis framework, the linkages between problems and their immediate causes, sector activities/intermediate causes, and the root causes i.e.

human activities leading to the creation of the problem were identified. Accordingly, the following five clusters were identified as prime concern to discourse the aquatic environment deterioration and for possible remedial action platform in the CRV (Table 6).Therefore, the overall framework revealed that there is a need for land use policy considerations, conservation and rehabilitation of land resources, use of monitoring and early warning system, commitment to international conventions on land use, investments in land and water resources, and applying appropriate land use planning.

4. CONCLUSION AND PLICY IMPLICATIONS

4.1. Conclusion

This study provided information of how land-use and land cover changed in 30 years from 1985 to 2015 in CRV. The CRV is one of the regions in Ethiopia where degradation of natural resources firmly intertwined and expressed in poverty prone society. Hence, severe poverty forces people to deplete natural resources in their struggle against survival particularly for the predominant subsistence rain-fed farmers. The degraded natural resources together with the unfavourable and highly variable climatic conditions aggravated poverty. Generally, rapid population growth, agricultural expansion, environmental fluctuations, degradation of natural resource and loss of biodiversity are the most visible socio-economic and environmental problem in the CRV area.

Over the last 30 years' period (1985 to 2015), major LULC changes were recorded in the CRV and the classification result revealed that about 86.1% of the land showed there is a change in LULC. The intensively cultivated land was expanded in the expense of forest woodland/acacia. The water resources have been shrinking in size and depth significantly. More specifically, Lake Abijata showed a progressive decline by 25.9% resulting in severe degradation of the fragile ecosystems that has sustained the unique biodiversity (fauna and flora) for long. Consequently, the Abjiata-Shalla National Park is at the verge of collapse, the second episode of lake collapse in the nation next to Lake Haramaya if serious measurement is not taken on time.

4.2. Policy Implications

Based on the finding and DPSIR framework analysis, an integrated land use and development planning and policy reform were suggested to encourage the ongoing and planned ecosystem restoration, degraded land rehabilitation, and biodiversity conservation intervention in the CRV Lakes of Ethiopia.

- An effective water management plan and practice should be employed at the landscape level breaking down major river basin into sub-watersheds and prioritizing the sub-watershed for conservation and management based on degradation level.
- Integrated land use and development planning should be done for the watershed prior to any developmental project being conducted in the area and must be preceded by a proper Environmental Impact Assessment (EIA) considering the impact on water resources,

- Groundwater abstraction (the process of taking water from a ground source, either temporarily or permanently) is another problem since most water is used for irrigation or treatment. Depending on the environmental legislation (in Ethiopia), controls may be placed on abstraction to limit the amount of water that can be removed. Over abstraction can lead to rivers drying up or the level of groundwater aquifers reducing unacceptably. Thus, the science of hydrogeology should be used to assess the safe abstraction levels.

List of Abbreviations;

CRV: Central Rift Valley
DPSIR: Driver, Pressure, State, Impact and Response
LULCC: Land Use Land Cover Change
OECD: Organization for Economic Co-operation and Development

DECLARATIONS

Ethics approval and consent to participate

The study was designed for better documentation of LULC information for the central Rift Valley areas which will supply important information for further environmental management. Thus, the study has no any negative impact on human, and animals, and the environment. Therefore, there is no need of ethical clearance since data will be taken without affecting the society and the environment and information collected would be treated confidentially, analysed anonymously, and only used for the purposes of this research.

Consent for publication

Not applicable

Availability of data and material

The data supporting the results presented in this study are available from the corresponding author upon reasonable request.

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Authors' contributions

All authors participated in conceiving, designing and coordination. All the authors also involved to draft the manuscript as well as approved the final manuscript. Finally, all authors read and approved the final manuscript.

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***Competing interests*;**

The authors declare that they have no competing interests.

REFERENCES

Alemayehu, T., Ayenew, T., & Kebede, S. (2006). Hydrogeochemical and lake level changes in the Ethiopian Rift. *Journal of hydrology, 316*, 290-300

Amsalu, T., & Addisu, S. (2014). A review of Wetland Conservation and Management Policy in Ethiopian. *International Journal of Scientific and Research Publications*, 656

Ariti, A.T., , J.v.V., & , P.H.V. (2015). Land-use and land-cover changes in the Central Rift Valley of Ethiopia: Assessment of perception and adaptation of stakeholders. *Applied Geography, 65*, 28–37

Ariti, A.T., van Vliet, J., & Verburg, P.H. (2018). Farmers' participation in the development of land use policies for the Central Rift Valley of Ethiopia. *Land Use Policy, 71*, 129-137

Assefa, E., & Bork, H.-R. (2016). Dynamics and driving forces of agricultural landscapes in Southern Ethiopia–a case study of the Chencha and Arbaminch areas. *Journal of Land Use Science, 11*, 278–293

Ayenew, T. (2002). Recent changes in the level of Lake Abiyata, central main Ethiopian Rift. *Hydrological sciences journal, 47*, 493-503

Ayenew, T. (2004). Environmental implications of changes in the levels of lakes in the Ethiopian Rift since 1970. *Regional Environmental Change, 4*, 192-204

Ayenew, T. (2007). Water management problems in the Ethiopian rift: Challenges for development. *Journal of African Earth Sciences, 48*, 222-236

Ayenew, T. (2008). The distribution and hydrogeological controls of fluoride in the groundwater of central Ethiopian rift and adjacent highlands. *Environmental Geology, 54*, 1313-1324

Belete, M.D., Diekkrüger, B., & Roehrig, J. (2015). Characterization of water level variability of the main ethiopian rift valley lakes. *Hydrology, 3*, 1

Berke, P., & Kaiser, E.J. (2006). *Urban land use planning*. University of Illinois Press

Bewket, W., & Abebe, S. (2013). Land-use and land-cover change and its environmental implications in a tropical highland watershed, Ethiopia. *International journal of environmental studies, 70*, 126-139

Bradley, P., & Yee, S. (2015). *Using the DPSIR framework to develop a conceptual model: technical support document*. US Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division

Bryan, B.A. (2013). Incentives, land use, and ecosystem services: synthesizing complex linkages. *Environmental science & policy, 27*, 124-134

Collier, P., & Dercon, S. (2014). African agriculture in 50 years: smallholders in a rapidly changing world? *World development, 63*, 92-101

Congalton, R.G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote sensing of environment, 37*, 35-46

Costanza, R., de Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., & Turner, R.K. (2014). Changes in the global value of ecosystem services. *Global environmental change, 26*, 152-158

CSA (2013). Statistical Abstract, Ethiopian Central Statistical Authority. (Addis Ababa Ethiopia). In

Daniel A.M, Daniel K.W, & Muluneh W. (2012). Detection and analysis of land-use and land-cover changes in the

Midwest escarpment of the Ethiopian Rift Valley. *Journal of Land Use Science, 7*, 239–260

Day Jr, J.W., Arancibia, A.Y., Mitsch, W.J., Lara-Dominguez, A.L., Day, J.N., Ko, J.-Y., Lane, R., Lindsey, J., & Lomeli, D.Z. (2003). Using ecotechnology to address water quality and wetland habitat loss problems in the Mississippi basin: a hierarchical approach. *Biotechnology Advances, 22*, 135-159

De Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., & Hein, L. (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem services, 1*, 50-61

Demissie, F., Yeshitila, K., Kindu, M., & Schneider, T. (2017). Land use/Land cover changes and their causes in Libokemkem District of South Gonder, Ethiopia. *Remote Sensing Applications: Society and Environment, 8*, 224-230

Dimitriou, E., Karaouzas, I., Sarantakos, K., Zacharias, I., Bogdanos, K., & Diapoulis, A. (2008). Groundwater risk assessment at a heavily industrialised catchment and the associated impacts on a peri-urban wetland. *Journal of Environmental Management, 88*, 526-538

Duadze, S.E.K. (2004). *Land use and land cover study of the savannah ecosystem in the Upper West Region (Ghana) using remote sensing*. Cuvillier Verlag

Eshetu, A.A. (2014). Forest resource management systems in Ethiopia: Historical perspective. *International Journal of Biodiversity and Conservation, 6*, 121-131

Fetahi, T. (2016). Greening a Tropical Abijata-Shala Lakes National Park, Ethiopia-A Review. *J Ecosys Ecograph, 6*, 2

Gabrielsen, P., & Bosch, P. (2003). Environmental indicators: typology and use in reporting. *EEA, Copenhagen*

Garedew, E., Sandewall, M., Söderberg, U., & Campbell, B.M. (2009). Land-use and land-cover dynamics in the central rift valley of Ethiopia. *Environmental management, 44*, 683-694

Gari, S.R., Newton, A., & Icely, J.D. (2015). A review of the application and evolution of the DPSIR framework with an emphasis on coastal social-ecological systems. *Ocean & Coastal Management, 103*, 63-77

Gashaw, T., TaffaT., A., M., & W.W., A. (2017). Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. Environmental Systems Research, 6(1). https://doi.org/10.1186/s40068-017-0094-5.

Geheb, K., & Abebe, Y.D. (2003). *Wetlands of Ethiopia: Proceedings of a Seminar on the Resources and Status of Ethiopia's Wetlands*. IUCN

Geissen, V., Sánchez-Hernández, R., Kampichler, C., Ramos-Reyes, R., Sepulveda-Lozada, A., Ochoa-Goana, S., De Jong, B., Huerta-Lwanga, E., & Hernández-Daumas, S. (2009). Effects of land-use change on some properties of tropical soils—an example from Southeast Mexico. *Geoderma, 151*, 87-97

Geist, H., McConnell, W., Lambin, E.F., Moran, E., Alves, D., & Rudel, T. (2006). Causes and trajectories of land-use/cover change. *Land-use and land-cover change* (pp. 41-70): Springer

Giri, C.P. (2012). Remote sensing of land use and land cover change: Principles and applications. London, New York: Taylor and Francis Group.

Girmay, G., Singh, B.R., & Dick, Y. (2010). "Land-Use ChangesandTheirImpactsonSoil DegradationandSurfaceRunoffofTwoCatchmentsofNorthernEthiopia,". *Acta Agriculturae Scandinavica, Section B – Plant Soil Science, 60*, 211–226.

Gong, J., Yang, J., & Tang, W. (2015). Spatially explicit landscape-level ecological risks induced by land use and land cover change in a national ecologically representative region in China. *International journal of environmental research and public health, 12*, 14192-14215

Haslam, S.M. (2004). *Understanding wetlands: fen, bog and marsh*. CRC Press

Hasmadi, M., Pakhriazad, H., & Shahrin, M. (2017). Evaluating supervised and unsupervised techniques for land cover mapping using remote sensing data. *Geografia-Malaysian Journal of Society and Space, 5*

Hassan, A.A.M. Implementation of land-use-cover change Analysis into megacity management Response by using the DPSIR model

Hassan, A.A.M. (2013). Implementation of land-use-cover change Analysis into megacity management Response by using the DPSIR model

Hatch, N., & Wells, L. (2012). . Multilevel Environmental Governance-The Case of Ethiopian Floriculture

Hengsdijk, H., & Jansen, H. (2006). Agricultural development in the Central Ethiopian Rift valley: A desk-study on water-related issues and knowledge to support a policy dialogue. *Plant Research International BV, Wageningen, 22*, 28-36

Hengsdijk, H., & Jansen, H. (2006). Ecosystems for water, food and economic development in the Ethiopian central rift valley (BO-10-006-22). Report of inception mission to Ethiopia and Workplan.

Hengsdijk, H., Legesse, D., Herco, J., Ayenew, T., Petra, S., & Petra, H. (2007). Land and water resources assessment in the Ethiopian Central Rift Valley Project: ecosystems for water, food and economic development in the Ethiopian Rift Valley

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K., & Johnson, C. (2001). Climate Change 2001: the scientific basis third assessment report of the intergovernmental panel on climate change. In: Cambridge: Cambridge University Press

Jansen, H., Hengsdijk, H., Legesse, D., Ayenew, T., Hellegers, P., & Spliethoff, P. (2007). Land and water resources assessment in the Ethiopian Central Rift Valley: Project: Ecosystems for water, food and economic development in the Ethiopian Central Rift Valley. In: Alterra

Kabba, V.T.S., & Li, J. (2011). Analysis of land use and land cover changes, and their ecological implications in Wuhan, China. *Journal of Geography and Geology, 3*, 104

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2015). Drivers of land use/land cover changes in Munessa-Shashemene landscape of the south-central highlands of Ethiopia. *Environmental monitoring and assessment, 187*, 452

Lalande, N., Cernesson, F., Decherf, A., & Tournoud, M.-G. (2014). Implementing the DPSIR framework to link water quality of rivers to land use: methodological issues and preliminary field test. *International Journal of River Basin Management, 12*, 201-217

Lambin, E.F., & Geist, H.J. (2008). *Land-use and land-cover change: local processes and global impacts*. Springer Science & Business Media

Lambin, E.F., Geist, H.J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual review of environment and resources, 28*, 205-241

Lambin, E.F., Rounsevell, M., & Geist, H. (2000). Are agricultural land-use models able to predict changes in land-use intensity? *Agriculture, Ecosystems & Environment, 82*, 321-331

Lasanta, T., González-Hidalgo, J.C., Vicente-Serrano, S.M., & Sferi, E. (2006). Using landscape ecology to evaluate an alternative management scenario in abandoned Mediterranean mountain areas. *Landscape and Urban Planning, 78*, 101-114

Leblanc, M.J., Favreau, G., Massuel, S., Tweed, S.O., Loireau, M., & Cappelaere, B. (2008). Land clearance and hydrological change in the Sahel: SW Niger. *Global and Planetary Change, 61*, 135-150

Legesse, D., & Ayenew, T. (2006). Effect of improper water and land resource utilization on the central Main Ethiopian Rift lakes. *Quaternary International, 148*, 8-18

Legesse, D., Woldu, Z., Mebrate, A., Mengistou, S., & Ayenew, T. (2005). A Review of the current status and an outline of a future management plan for Lakes Abiyata And Ziway. *The Federal Government of Ethiopia*

Lemlem Tadesse, K.V. Suryabhagavan, G. Sridhar, & Legesse, G. (2017). Land use and land cover changes and Soil erosion in Yezat Watershed, North Western Ethiopia. *International Soil and Water Conservation Research, 5*, 85–94

Lillesand, T., Kiefer, R.W., & Chipman, J. (2014). *Remote sensing and image interpretation*. John Wiley & Sons

MA, M.E.A. (2005). Ecosystems and Human Well-being: A Framework For Assessment. Island Press, Washington.

Maxim, L., Spangenberg, J.H., & O'Connor, M. (2009). An analysis of risks for biodiversity under the DPSIR framework. *Ecological economics, 69*, 12-23

Maynard, K., & Royer, J.-F. (2004). Effects of "realistic" land-cover change on a greenhouse-warmed African climate. *Climate Dynamics, 22*, 343-358

Meshesha, D.T., Tsunekawa, A., & Tsubo, M. (2012). Continuing land degradation: cause–effect in Ethiopia's Central Rift Valley. *Land Degradation & Development, 23*, 130-143

Meshesha, T.W., Tripathi, S., & Khare, D. (2016). Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia. *Modeling Earth Systems and Environment, 2*, 168

Miheretu, B.A., & Assefa, A.Y. (2017). Determinants of farmers' adoption of land management practices in Gelana sub-watershed of northern highlands of Ethiopia. Ecological Processes, 6(19). https://doi.org/10.1186/s13717-017-0085-5.

Mitsch, W.J., & Gosselink, J.G. (2000). The value of wetlands: importance of scale and landscape setting. *Ecological economics, 35*, 25-33

Moges, D.M., & Bhat, H.G. (2018). An insight into land use and land cover changes and their impacts in Rib watershed, north-western highland Ethiopia. Land Degrad Dev., *29*, 3317-3330. https://doi.org/3310.1002/ldr.3309.

Molla, M.B. (2015). Land Use/Land Cover Dynamics in the Central Rift Valley Region of Ethiopia: Case of Arsi Negele District. *African Journal of Agricultural Research, 10*, 434-449

MoWR (2010). Rift valley lakes basin integrated resources development plan study project. *Lake Hawassa sub-basin integrated watershed management feasibility study. Main report, 1*

Muzein, B.S. (2006). Remote sensing & GIS for land cover/land use change detection and analysis in the semi-natural ecosystems and agriculture landscapes of the Central Ethiopian Rift Valley

Olaka, L.A., Odada, E.O., Trauth, M.H., & Olago, D.O. (2010). The sensitivity of East African rift lakes to climate fluctuations. *Journal of Paleolimnology, 44*, 629-644

Omann, I., Stocker, A., & Jäger, J. (2009). Climate change as a threat to biodiversity: An application of the DPSIR approach. *Ecological economics, 69*, 24-31

Patrício, J., Elliott, M., Mazik, K., Papadopoulou, K.-N., & Smith, C.J. (2016). DPSIR—two decades of trying to develop a unifying framework for marine environmental management? *Frontiers in Marine Science, 3*, 177

Peng, J., Xu, Y., Cai, Y., & Xiao, H. (2011). The role of policies in land use/cover change since the 1970s in ecologically fragile karst areas of Southwest China: A case study on the Maotiaohe watershed. *Environmental science & policy, 14*, 408-418

Pullanikkatil, D., Palamuleni, L., & Ruhiiga, T. (2016). Assessment of land use change in Likangala River catchment, Malawi: A remote sensing and DPSIR approach. *Applied Geography, 71*, 9-23

Rahman, S.H., Faisal, B., Rahman, M.T., & Taher, T.B. (2016). Analysis of VIA and EbA in a River Bank Erosion Prone Area of Bangladesh Applying DPSIR Framework. *Climate, 4*, 52

Raventós Vilalta, E. (2010). Water resources management in the Central Rift Valley in Ethiopia

Rawat, J., & Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science, 18*, 77-84

Ridgeley, R., Allnutt, T., Brooks, T., NcNicol, D., Mehlman, D., Young, B., & Zook, J. (2012). BirdLife International. 2012. *Digital distribution maps of the birds of the Western Hemisphere, version, 5*

Riebsame, W.E., Meyer, W.B., & Turner, B. (1994). Modeling land use and cover as part of global environmental change. *Climatic change, 28*, 45-64

Sarmin, N., Hasmadi, I.M., Pakhriazad, H., & Khairil, W. (2016). The DPSIR framework for causes analysis of mangrove deforestation in Johor, Malaysia. *Environmental Nanotechnology, Monitoring & Management, 6*, 214-218

Seyoum, W.M., Milewski, A.M., & Durham, M.C. (2015). Understanding the relative impacts of natural processes and human activities on the hydrology of the Central Rift Valley lakes, East Africa. *Hydrological Processes, 29*, 4312-4324

Smeets, E., & Weterings, R. (1999). *Environmental indicators: Typology and overview*. European Environment Agency Copenhagen

Solomon, D., Lehmann, J., & Zech, W. (2000). Land use effects on soil organic matter properties of chromic luvisols in semi-arid northern Tanzania: carbon, nitrogen, lignin and carbohydrates. *Agriculture, Ecosystems & Environment, 78*, 203-213

Tefera, B. (2002). *Nature and causes of land degradation in the Oromiya Region: A review*. ILRI (aka ILCA and ILRAD)

Tefera, M. (2011). Wildlife in Ethiopia: endemic large mammals. *World Journal of Zoology, 6*, 108-116

Teka, K., Van Rompaey, A., & Poesen, J. (2013). Assessing the role of policies on land use change and agricultural development since 1960s in northern Ethiopia. *Land Use Policy, 30*, 944-951

Tekle, K. (1999). Land degradation problems and their implications for food shortage in South Wello, Ethiopia. *Environmental management, 23*, 419-427

Teklemariam, Lanckriet, S., H., A., T.G., A., M., H., F., W., & J., N. (2017a). Effects of land deals on peak discharge and sediment transport in the catchments around the Grand Ethiopian Renaissance Dam. Land Degradation & Development, 28, 1852–1861. https://doi.org/10.1002/ldr.2654.

Tolessa, T., Senbeta, F., & Kidane, M. (2017). The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. *Ecosystem services, 23*, 47-54

Unger Holtz, T.S. (2007). Introductory Digital Image Processing: A Remote Sensing Perspective. In: Association of Environmental & Engineering Geologists

Van Hall, R., Cammeraat, L., Keesstra, S., & Zorn, M. (2017). Impact of secondary vegetation succession on soil quality in a humid Mediterranean landscape. *Catena, 149*, 836-843

Vargas Amelin, E. (2016). Effects of climate change in Mediterranean water resources and their economic implications= Efectos del cambio climático en los recursos hídricos mediterráneos y sus implicaciones económicas

Vitousek, P.M. (1994). Beyond global warming: ecology and global change. *Ecology, 75*, 1861-1876

Yohannes, H., Mohammed, A., & Elias, E. (2017). Land Use/Land Cover Dynamics and Its Impact on Biodiversity Resources in the Abijata Shalla National Park, Central Rift Valley Lakes Region, Ethiopia. *Environ Sci Ind J, 13*, 152

Zeray, L., Roehrig, J., & Chekol, D.A. (2006). Climate change impact on Lake Ziway watershed water availability, Ethiopia. In, *Conference on International Agricultural Research for Development*