Effects of Land-use on Birds Diversity in and around Lake Zeway, Ethiopia

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Abstract

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Anthropogenic factors can have major impacts on ecosystem functioning and stability, which are often reflected in changes to the biodiversity that includes wildlife. Land-use is a dynamic process that changes in space and time depending on prevailing socio-economic and biophysical conditions. This study aims at investigating anthropogenic effects of land-use on bird species diversity and abundance in and around Lake Zeway. Systematic random sampling techniques at an interval of 4km were used to select sampling blocks. A transect line of 1.65km and a sighting distance of 300m on both sides of a given transect, depending on species and habitat types, were laid along each block to count birds. Satellite images and Environment for Visualizing Image (ENVI) were used to analyze and detect land-use and cover changes in the surrounding areas of the Lake. The study revealed that land-use and cover related to bird community have changed during the analysis period in the area. Relatively low bird species diversity was recorded in blocks with less vegetation cover as compared to blocks with relatively intact vegetation cover. Bird species diversity showed significance difference among different species ($F = 39.326$, $df = 11$, $P < 0.05$). In terms of feeding guild, carnivorous had the highest species richness and diversity, while Piscivorous feeding guild had the least. Diversity of birds community with changes in vegetation cover showed significant difference ($F = 6.613$, $df = 21$, $P < 0.05$). Moreover, abundance of bird species was relatively higher in dense vegetation cover sites and areas with permanent ponds. From the results, it can be concluded that variations in the diversity and abundance of bird species variably affected by land-use and land cover types. The major reason for such change is conversion of land to irrigated agricultures in the surrounding areas of the lake. Thus, urgent conservation measures that could reduce the impact of land-use/cover changes are needed to conserve the bird species at the lake.

Key words: Abundance, birds, diversity, impacts, land-use

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INTRODUCTION

Anthropogenic factors can have major impacts on ecosystem functioning and stability, which are often reflected in changes to biodiversity that includes wildlife. This because abundance and diversity of the ecosystem community are changed. Biological community is an assemblage of populations of two or more different species occupying the same geographical area and characterized by type of species present, species diversity and their relative abundance (Ricklefs and Miller, 2000). Land-use is a dynamic process that changes in space and time depending on prevailing socio-economic and biophysical conditions (Esikuri, 1998); and changes in land-use have strong impacts on biological communities (Brambilla *et al*., 2010). Different literature have noted that changes in surface water as a result of land-use changes, have made a significant impact on local biodiversity like birds, other wildlife species and subsequently erode local economies reliant on those resources (Ayenew, 2001; Sisay, 2003; and Esikuri, 1998). Among wildlife, birds have been more susceptible to and affected by environmental changes such as land-use changes (Kolecek *et al*., 2010). Particularly, alteration of environment of freshwater lakes by land use changes is known to have negative effect on water-bird community structure (Hill-Lukkarinen *et al*., 2011).

Ethiopian Central Rift Valley (ECRV) area is known to have a number of lakes and hydrological features (Jensen *et al*., 2007); and along with their associated watershed areas the lakes are known to harbor millions of resident and migratory water-birds. However, these natural resources have been under threat by unregulated land-use changes happening in the area (Aynew, 2009). The study area, Lake Zeway, is one of such lakes that are under great threat of land-use changes mainly due to extensive and irrigation based agricultural farms surrounding the lake. Changes in land-use associated with the farms in the surrounding areas have known to have negatively affected the Lake's hydrodynamics (Aynew 2009). Large-scale irrigation farms were established in early 1970s in the Lake Zeway's catchment by diverting water from the lake and its two main feeder rivers (Ayenew, 2002). Moreover, large scale commercial plantation forest around the Lake has been established using water for irrigation from the lake (Muzien, 2006). These changes thought to have put the lake and its surrounding bird's habitats under great pressure (Wetland International, 2002). Lake Zeway consists of congregated waterbirds. As a result, the lake is recognized as an Important Bird Area (IBA), and a potential Ramsar site of Ethiopia (EWNHS, 1996; BirdLife International, 2002). It supports over 20,000 numbers of water-birds on a seasonal basis (EWNHS 1996; BirdLife International, 2012). The lake water, its shoreline, riverine woodland and wet grassland habitats also serve as roosting and stop-over sites for a diverse and abundant assemblage of resident and Palearctic migratory bird species (EWNHS, 1996). Although the lake and its associated habitats harbor various species of birds in large numbers, a combination of socio-economic and climatic factors has resulted in the loss of biodiversity of the lake (Abebe, 2003; Legesse *et al*., 2003).

Development schemes, such as pumping of water from Lake Abijata for soda ash extraction and utilization of water from feeder rivers and the lake for irrigation has rapidly reduced water levels of the lake (Ayenew, 2001). This is threatening the lake's viability for suitable nesting/roosting/stopover habitats of birds. Irrigation activities around Lake Zeway also had a considerable effect of increasing soil salinity (Ayenew, 2001). Recently, the problem is aggravated due to uncontrolled pumping of the lake water by private investors for floriculture and horticulture development. As irrigation in this area is a year-round process, its effect on the water level is magnified, especially during times of low precipitation and high evaporation during the months of November or December (Gebemariam and Delebo, 1989). This uncontrolled over-irrigation, if unabated, might bring the same disastrous effects on the fertile plains around the lake. The likely irrigation of this land characterized by shallow groundwater levels might induce large-scale soil salinization either by capillary rise from the shallow groundwater or due to inappropriate irrigation methods (Hengsdijk and Jansen, 2006).

Knowledge about land-use and land cover has become important as the Nation plans to overcome uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, and destruction of important wetlands and loss of fish and wildlife habitat (Anderson *et al*., 1976). However, critical information of the effect of land – use/ -cover on the abundance and diversity of bird species of both resident and migrants in the area are least known and documented. Therefore, this study aimed at understanding the impacts of land-use/land-cove on the bird species diversity and abundance at Lake Zeway and its surroundings

MATERIALS AND METHODS

The study area

Lake Zeway is located some 163 km south from the capital city of Ethiopia, Addis Ababa. It is situated between $07^0$51'- 08^0 07'N latitude and $38^0$43'- $38^0$50'E longitude (Fig. 1). The Lake has an open water surface area of 434 km^2, which makes it the third largest Rift Valley Lake; and has two small Islands of 6.9 km^2 area size together. The islands at the Lake are used as breeding grounds and roosting areas for water-birds, but affected by land-use change impacts. The open and shallow Lake Zeway has catchments of about 6834 km^2, a maximum depth of 9 m, and a corresponding average surface and volume of 485 km^2 and 1.7 km^3 respectively (Legesse *et al.*, 2005). The lake is mostly used for irrigation in the central Rift Valley area. The lake is bordered by swamp, except along the south-eastern and southern margins where the shores are relatively steep.

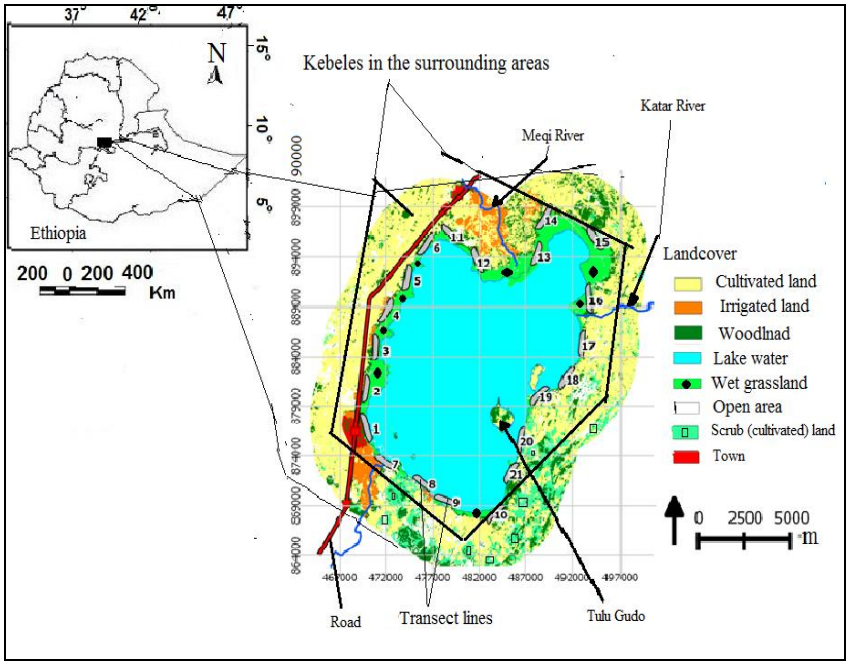

Figure. 1. Map showing location of the study site and the surrounding areas land-use and land-cover types. (Note: - The grid a line with numbers represents transects line selected for the study).

The study was comprised the Lake and areas around it (Figure 1). The altitudinal range of the study area varies between 1636 m asl in the east and 1880 m asl in the south encompassing Mount Aletu, which is a major centre of volcanic activity during the Quaternary period (EWNHS, 1996). Rainfall occurs throughout the year except during the months of November and December. Twenty seven years record in the area showed that the mean annual rainfall and temperature are about 600 mm and 20.6 ^{0}C, respectively. The wettest months are July and August. The short rainy season occurs during March to May. This coincides with a reduction of the Arabian high wind as it moves towards the Indian Ocean causing warm, moist air with a southerly component to flow over most of the country including Lake Zeway area (Norton-Griffiths, 1978).

Bird species count or estimation methods

Bird species in the area was counted and identified using a spotting scope technique that covered a total area of 51.5 km^2 areas of the wetland including shoreline and riverine habitats. The same (51.5 km^2) of the open water was sampled from 434 km^2 to count or estimate bird species. A representative (calculated from each area) area of 10.4 km^2 (2.97 km^2 from the west, 2.97 km^2 from the east, 2.5 km^2 from the north and 1.98 km^2 from the south) that accounted to 20.2% of the wetland habitats

were sampled. Then, a systematic random sampling technique was used and observations were made from the shore of the lake side along a transect line at every 4 km. The length of each of the transect line was 1.65 km and the width 50-150 m along the shoreline (Fig. 1). The sighting distance varied between 50-150 m on either side of the transect depending on the species and habitat types as used by Pomeroy, (1992) in similar situation. In the open area of the lake, a long transect of 29 km and width of 300 m on both sides were sampled to count birds using a boat. Along the lake, boat was slowly (2.5 km/hour) driven to allow counting of birds. At each sampling station, observations of: 1) the presence of colonies, approximate size and species composition; 2) the presence of roosts, their approximate size and species composition; 3) the number and species of flying birds and 4) the number and species of foraging birds (Bibby and Burgess, 1992; Sutherland, 2004) were carried out. The location of observed bird species was recorded using GPS.

Moreover, photographs were taken for further identification of birds and to capture corresponding habitat types. Field identification of birds was aided by binoculars and field guide books (Perol, 1995; Sinclair and Ryan, 2003). Observations were carried out early in the morning (6:00-10:00 a.m.) and late in the afternoon (4:00-6:00 p.m.) when birds known to be active. Additional information were gathered by inquiring indigenous and local people living around to document birds local names and their occurrence range in the area. Secondary raw data on water-bird census done by Birdlife International (BLI) in regular basis were also considered since their censuses have been conducted every year from 1999-2008 except in 2006. observations on the type of land-use/land-cover in each of the blocks and transects and observations concerning government and private irrigation based agricultural activities; that depend on the water of the lake and their impacts on the lake hydrodynamics were carried out. In addition, secondary information from literature was gathered. Information related to the current and previous water points (where water reaches) and the dry and wet seasons water points were also collected using GPS, marks (stages left) and local elders. Local elders were also used to provide land-use history.

Two of the fundamental parameters of biological communities, i.e. the number of species (species diversity) and the number of individuals within each of those species (species richness) (Hamilton, 2005) were assessed in the study area. Both the species richness and diversity were measured for broader understanding of bird species richness and diversity, and to relate these with the impact of land-use/land-cover change and climate variability in and around Lake Zeway. Species richness was measured using Margalef (d= S-1/Log (N)), and species diversity by Shannon-Wiener diversity index ($H'=-\sum pi \ln pi$) and Simpson index = $1-\sum$ (Ni x (Ni-1/N x (N-1) across transects in and around Lake Zeway.

Vegetation covers in the study area were measured on 4 survey plots of 30m x 30m using remote sensing image of, Landsat taken in 2011 and aerial photo as described in Buyantuyeu *et al*. (2007). Field observation data were also used to quantify vegetation cover of each plot.

Identification of habitat in relation to land-use type and bird species richness, diversity and distribution

Along with counting birds, observation point of each species and colonies were marked using GPS. Observation points marked using GPS were imported into Arc View GIS software to make spatial and temporal analysis of distribution, abundance and location of colonies, and to relate these to identify foraging behavior and critical habitats of birds at the study area. Satellite images of the study area of 1986, 2003and 2011 were used to assess land-use and land cover changes. Land-use type was first classified into mapable land-use types. Then, the classified images of 1986, 2003 and 2011 were compared for each of the land-cover types in the surrounding areas and water of the Lake. Consistency was maintained when assessing images within and between by going through three iterations: 1) Desk/laboratory interpretation of images that was cross matched with available vegetation and wetland of the map of the study area, 2) systematic random selection of sites that showed changes in land-cover type and carefully mapping these on topographic maps of the study area, and 3) Field Visit of the sites in order to check for consistency and aid in amending the classification and identification of land-use/land-cover type in the study area.

The location of the current major irrigation scheme was determined and checked that they existed in 2005. It was done using the 2011 and 2005 land cover map supported with field visit in 2011. The analysis focused on the major irrigation sites covering larger areas. The sampled habitat was divided in to two and two analysis models were established taking into consideration the location of the irrigation sites (Fig 2). First, they are of different irrigation types; second the Meki irrigation site is located at the input side whereas the Zeway site is located near to the outlet of the lake, third there are bird habitats located between the two sites which makes difficult to establish a common model for both sites. The hypothesis that the type of land use (in this case the irrigation) affects the diversity of the bird habitats was tested using linear model (lm). The model has the diversity index as response and the distance of the habitat from the major irrigation scheme (Fig. 2). The distance was computed in (Geographic Information Systems) GIS environment from the irrigation site (centroid of the polygon) to each habitat. Similar to the diversity, a model was established for the abundance of the bird habitat in relation to the location of the irrigation sites(Fig2).

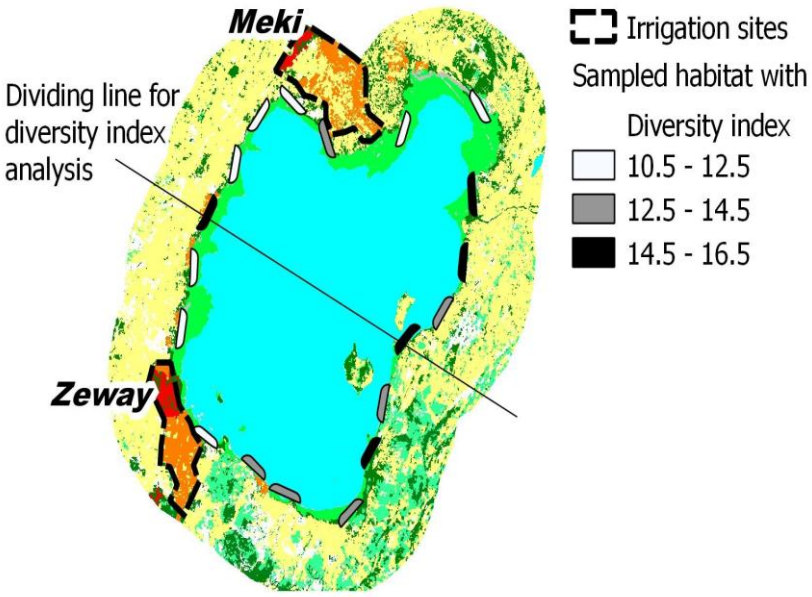

Figure 2. The location of irrigation sites as related to current land use type in the surrounding areas of Lake Zeway

Data Analysis

Bird species diversity and abundance were analyzed using PRIMER 6 statistical software (Clarke and Gurley, 2009). One way ANOVA was used to test variation in bird species diversity and feeding guild and across blocks. For the analysis of land-use/cover changes, Arc View 9 GIS software was used. Moreover, image processing software, ENVI (Environment for Visualizing Image) was used for the analysis of land-use/cover detection.

RESULTS

Bird species diversity

A total of 233 bird species that categorized under 52 families were recorded along the lake shore, riverine woodland and wet grassland habitats of the Lake. Among these 54 were migrants, 8 were threatened and 3 were endemic bird species. The highest bird species diversity were recorded along transect number 4 (western habitat) side and 17 of eastern habitat (Table 1)

Table 1. Species diversity of birds along transect lines in the study area.

Sample	S	N	J'	Fisher-α	H'	1-Lambda'
T1	54	172	0.9118	27.06	3.637	0.9699
T2	64	190	0.9475	33.96	3.94	0.9819
T3	60	147	0.9399	37.72	3.848	0.9793
T4	86	252	0.9396	46.09	4.185	0.9845
T5	59	159	0.9499	34.01	3.873	0.9805
T6	60	164	0.9485	34.02	3.884	0.9808
T7	59	181	0.9535	30.4	3.888	0.9811
T8	72	189	0.9565	42.36	4.091	0.9846
T9	74	222	0.936	38.88	4.029	0.9802
T10	70	196	0.9428	38.88	4.005	0.9818
T11	56	149	0.9541	32.53	3.841	0.9808
T12	71	186	0.9461	42.01	4.033	0.9827
T13	61	155	0.9454	37.11	3.886	0.9807
T14	58	244	0.8777	24.07	3.564	0.9575
T15	63	195	0.9242	32.27	3.829	0.9744
T16	90	254	0.918	49.76	4.131	0.9752
T17	93	265	0.9488	51.05	4.301	0.9856
T18	73	172	0.95	47.81	4.076	0.9833
T19	76	168	0.9499	53.34	4.114	0.9849
T20	68	188	0.9458	38.35	3.991	0.9819
T21	79	184	0.9503	52.37	4.152	0.9851

Note: T **=** transect, S = total number of species, N = Total number of individuals, d = species richness, J = Pielous evenness, H' = Shannon – Weiner index, 1-lambda = Simpson index.

Analysis of variance of the bird species diversity in and around lake Zeway showed significance difference between groups ($F = 39.326$, $df = 12$, $P < 0.05$ (Table 2) i.e. transects grouped below Table 2.

Table 2. Diversity between and within groups of bird species in the study area.

	Sum of squares	df	Mean square	F	P-value
Between Groups	0.254	1	0.254	39.326	0.002*
Within Groups	0.032	5	0.006	-	-
Total	0.287	6	-	-	-

* Significance difference at 0.01
Groups= Ts= Transect (T1-7, T8-11, T11-14 and T15-21)

In terms of feeding guild, carnivorous had the highest species richness and diversity while Piscivorous had the least species diversity (Table 6). The test of variation for diversity among vegetation cover showed significant difference of ($F = 6.613$, $df = 21$, $P<0.05$).

Table 3. Major types of feeding guilds of bird species in the study area.

Feeding guild	S	H'	1-Lambda'	Vegetation cover (%)
Piscivorous	3	0.87	0.5317	15
Omnivorous	4	1.37	0.7468	40
Carnivorous	10	2.96	1.99	70
Insectivorous	4	1.17	0.6636	46
Herbivorous	4	1.32	0.7278	65

Note: - S= Seasons sampled, d= richness, H' Shannon- Wiener diversity index, 1-lambeda = Simpson index

Land use-land cover change

There has been significance changes in land-use and cover in and surrounding areas of the lake during the observed 19 years period (Figs. 2, 3 and 4). During 1986, the surrounding areas close to the lake had less irrigated land except along the north and southwestern parts (Fig.3).

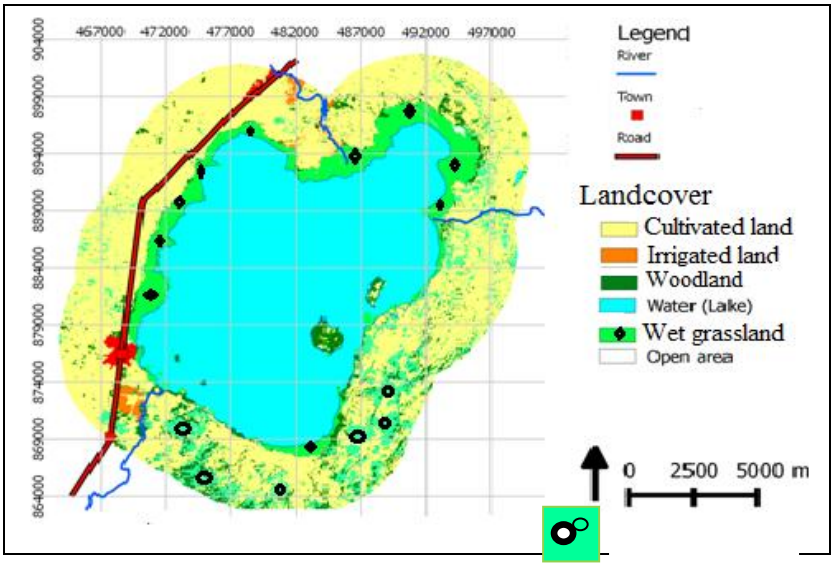

Figure 3. Land-use and cover types of the study area in 1

In the north as shown on the map there was there was small irrigated private farm land. Furthermore, there were intact wet grassland and riverine woodland vegetation in the surrounding areas of the lake during this time. Nonetheless, by 2003, the irrigated land, wet grassland and cultivated large government farm and in the southwest land (in the west) showed a significant increase (Fig. 4). Consequently, there was a decrease in riverine woodland vegetation cover and increase in swamp habitats with scattered grasses.

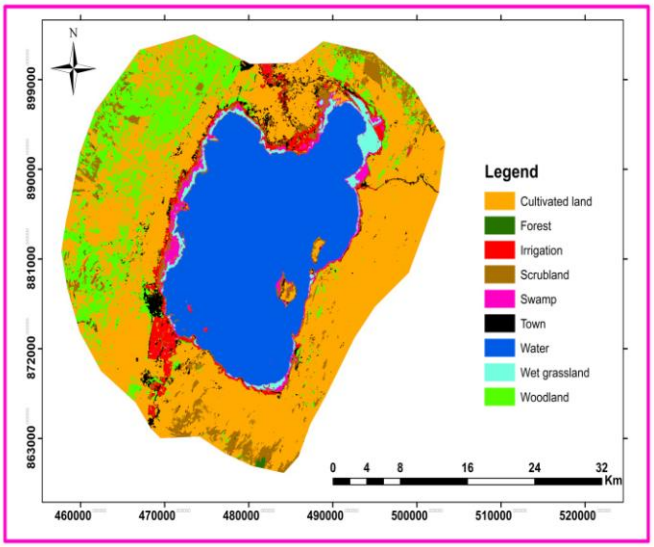

Figure 4. Land-use and cover of the study area in 2003.

The cultivated land in the surrounding area of the lake also increased specifically in eastern part of the lake in 2003 observation as compared to 1986. This increase was happened in the expense of woodland vegetation cover decrease in 2003. In year 2011, there was an increase in the wet grassland in the surrounding area of the lake accompanied with shrinkage in the size of open water (Fig. 5). Between year 2003 and 2011, woodland vegetation cover decreased while cultivated land cover increased, especially in the south, north and eastern side of the lake.

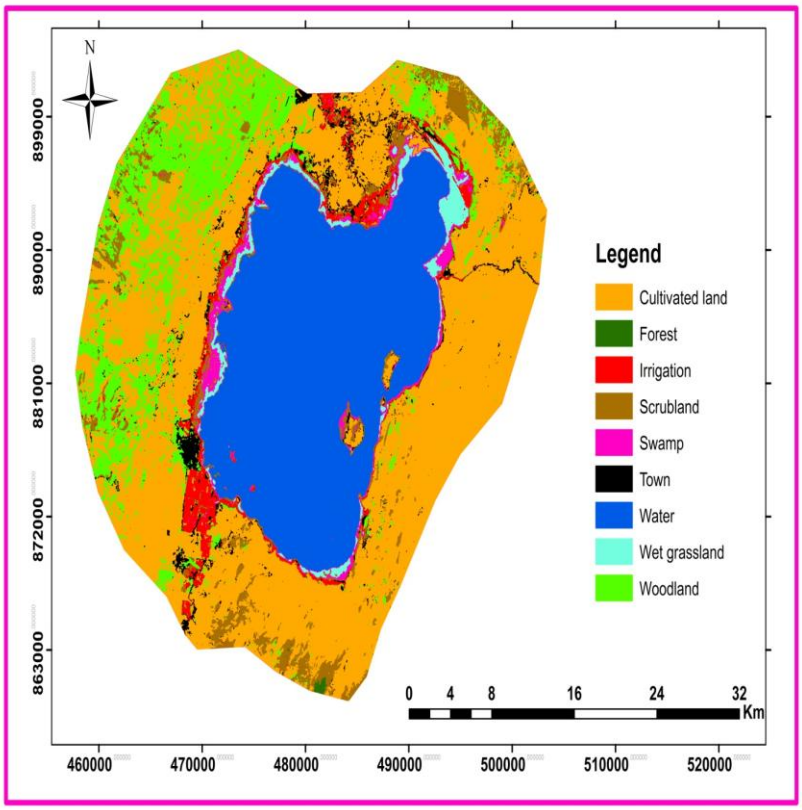

Figure 5. Land-use and cover of the study area in 2011.

The land-use and cover changes detection revealed an increase in rate of cultivated land by6.9% and irrigated land by 32.3% between 2003 and 2011 (Table 3). In the same period, the lake water size was reduced by 4.5%, whereas woodland vegetation decreased by 37.5%, and wet grassland increased by 96.9% (Table 3).

Table 4. Existing Land-use and land cover between 2003 and 2011.

Habitat types (ha)	Yr. 2003	Yr. 2011	Change in surface cover (ha)	Proportion of change (%)
Cultivated land	63163	67523	4360	6.90
Forest	131.0	093.00	38.00	-41.5
Irrigated land	4100	5422	1322	32.3
Scrubland	7560	3823	-3737	-49.4
Swamp	2520	1431	-1090	-43.2
Town	3219	1963	1256	39.0
Lake Water	41010	39153	-1857	-4.5
Wet grassland	2534	4991	2456	96.9
Woodland	17109	10689	-6420	-37.5

According to Shannon-Wiener diversity index (H'), bird species diversity and abundance were significantly different among sample transects (Figs.5 and 6). Very high bird species diversity was recorded on transects 4 of the west and 17 of the eastern side (Fig. 6). Most of the transects on western side had very low to medium bird species diversity (Fig. 6).

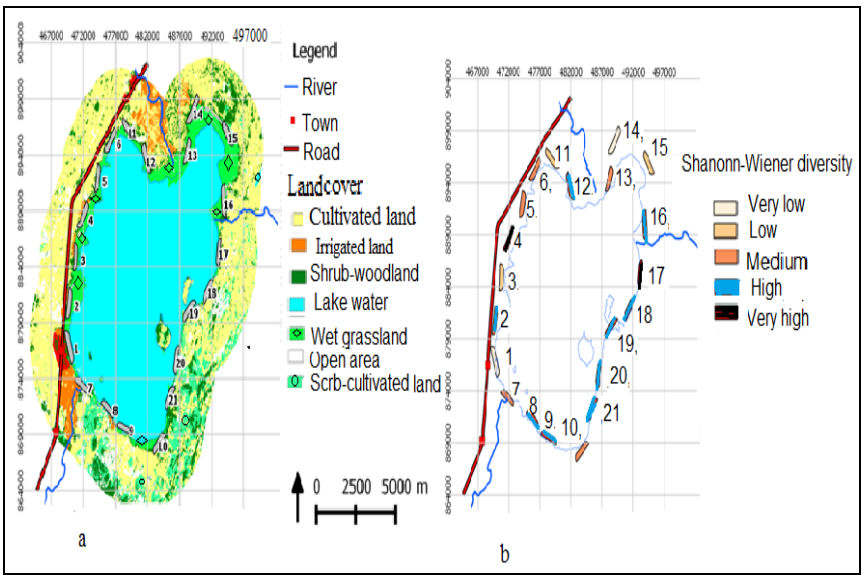

Figure 6 (a & b): Bird species diversity in relation to land-use and cover types of the study area.

When abundance was computed against land-use and cover types, birds abundance were high on transects 4, 14, 16 and 17 but very low on transects 3, 5, 6, 11 and 19 (Fig. 7a and b).

Satellite imagery analysis and observation revealed that large wet grassland pond along transect 4 and 14 and more vegetation cover on transects 16 and 17 were observed.

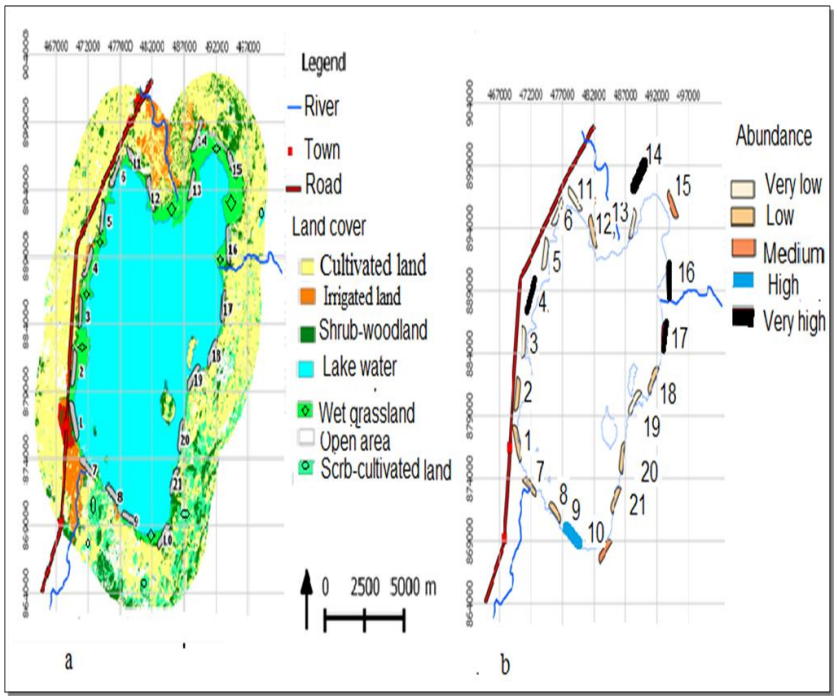

Figure 7 (a & b): Abundance of bird species in relation to land-use and cover types of the study area.

Relationship between Bird and land use

The relationship between land use land cover and bids indicated that the bird species diversity is higher in areas far away from irrigation scheme and decrees in areas close to irrigation and towns (Fig.8).

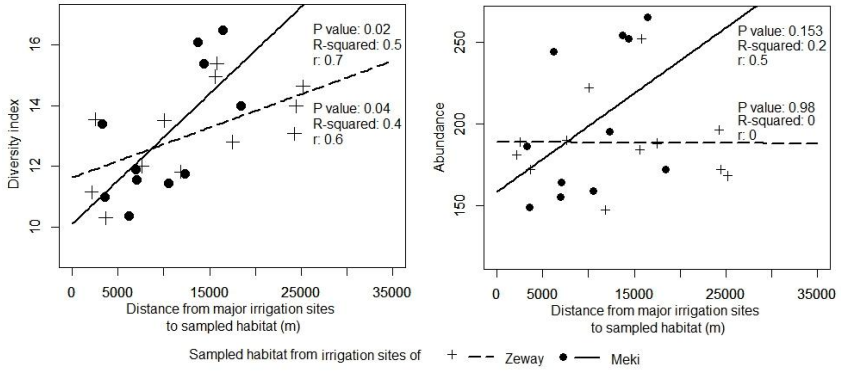

Figure 8. Relationships between bird species diversity (left), abundance (right) and land use in and around Lake Zeway

DISCUSSION

Understanding the composition and abundance patterns of bird species across sites is a central question in community ecology (Guadagnin *et al*., 2005). This study also strives to understand bird species diversity and abundance along the wetland area of Lake Zeway that have experienced diagrammatic land use/cover change during the last two decades. Generally, the study raveled change in land-use/cover around the lake with increase in cultivated and irrigated lands and decrease in forest and woodland vegetation cover. Moreover, the study showed less vegetation cover in the western side of the lake as compared to the east. This is similar to the finding by Hengsdijk and Jansen (2006) that indicated conversion of land covered by woodland vegetation in the eastern side of Lake Zeway to large scale floriculture and horticulture industries.

Biodiversity in wetlands has been affected by; inter alia, changes in land-use and land cover, that stem from anthropogenic factors (Finlayson *et al*., 2006). The result of this study also showed irrigation based agricultural activities have reduced vegetation cover, particularly in the western side of Lake Zeway. These could have led to low bird species diversity and abundance in this side of the lake except in some areas where there is large permanent pond. Thus, the low-medium bird species diversity and abundance in most of transects (areas) might be due to less vegetation cover due to anthropogenic pressures. Therefore, the presence of high bird species diversity and abundance in transect 4 and 17 could be because of the presence of large pond formed by irrigation practices and relatively intact vegetation cover in the 17 of the eastern side. Similar study by Reinkensmeyer *et al*. (2007); also reported high bid species density and diversity in area of more vegetation (plants) covered. The decrease in vegetation cover and significant difference in bird species diversity among the sampled sites may be associated with intensity of land-use/cover changes in the area. Accordingly,

finding by Brambilla *et al*. (2010) showed that bird community structure is negatively affected by changes in land-use and land cover. Waltert *et al*. (2004) also indicated significant decline in bird species diversity with increase in habitat modification. Thus the land-use/ cover change that modified the bird habitat at Lake Zeway might have led to the decline in bird species diversity and abundance of those transects with low records.

The corresponding decline in vegetation cover and diversity of birds in feeding guild at the lake could have also been linked to decline in the vegetation covers indicating significance of intact vegetation cover for the existence of diverse feeding guild in the area. The significant high vegetation cover for foraging guilds of birds was also shown by Liordos (2010). The decrease in size of the lake while irrigated land increased could also be contributed to the differences in diversity and abundance of birds in and around Lake Zeway. Finding of Legesse *et al*. (2004) reported increase in intensive irrigation in the area of Lake Zeway and this support the idea that lake size is decreasing and this might have affect birds supported by the lake.

CONCLUSION

The study revealed that anthropogenic pressures of land use and cover surrounding the lake have negatively impacted wetland bird diversity and abundance in the area. Relatively high bird species diversity and abundance were observed in areas where there was good vegetation cover relatively around undisturbed areas. Conservation measures should be taken to avert negative pressures posed on birds' diversity and their habitat in the area.

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