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Plant species composition and diversity in wetlands under forest, agriculture and urban land uses

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ABSTRACT

We investigated the full range of vegetation diversity in six wetlands under different land uses of Ethiopia. In total, 122 vascular plant species that belong to 86 genera and 37 families were identified. The family Poaceae and Asteraceae contributed the highest number of species. The beta and Shannon diversity ranged from 3.7 to 10.7 and 1.5–3.4 and differed significantly across wetlands. When considering the land uses, the agricultural and urban wetlands could even be more diverse than the forested wetlands and therefore, were not significantly different. The ranges of plant species diversity among the impaired wetlands were observed to be related to disturbance and competitive exclusion processes, and environmental heterogeneity. As observed, disturbances due to drainage, overgrazing, cultivation and pollution reduced the plant diversity through removing sensitive species, and increase species diversity through creating diverse habitats suitable for invader species. The dominant (or characteristic) species of each wetland showed that the urban and agricultural wetlands were highly degraded when compared to forested wetlands. The principal component analysis revealed highest similarity between Boye and Merewa wetlands can be explained from their extensive environmental heterogeneity. Moreover, these impaired wetlands were invaded by upland weeds by outcompeting socioeconomically and ecologically important native species. Thus, data of species and their environmental stresses in wetlands of Ethiopia could be used to prioritize and develop management strategies for east African wetlands.

1. Introduction

Wetlands are fundamental in conserving biodiversity, regulating pollution and wastes, and in serving as being natural reservoirs of water (Woldu and Yeshitela, 2003; Ramsar Convention Secretariat, 2011). Wetlands are particularly critical natural resources in developing countries as they provide diverse ecological services and socio-economic benefits to locals. Ethiopia is one of the countries in the world with a high level of biodiversity due to diverse topography and climatic conditions (Ethiopian Biodiversity Institute, 2014). Though wetlands also harbor for a great number of animals, wetland plant communities are the vital components of these overall productive ecosystems. Wetlands in Africa, in general, are dominated by herbaceous plants and are characterized by wet soils during the dry season and standing water during the rainy season (Howard-Williams and Gaudet, 1985). Therefore, to undertake a detailed description of the vegetation types supported by a wetland is a starting point for a health assessment of the wetland (Kotze, 2005).

Several wetlands of Ethiopia have come under extreme pressures as human population pressure, socio-economic change and governmental policies have stimulated a need for more agricultural land (Wood 2000; Dixon and Wood, 2003). Ambelu et al. (2013) also reported that there is a high level of anthropogenic threats to wetlands of Ethiopia. At present time, drainage, soil and water extraction for brick-making, agricultural practices and misconceptions of people towards wetlands (Moges et al., 2016) all contribute to the negative impact on the health of wetland ecosystems. Consequently, many wetlands have been severely affected due to overexploitation. Many wetlands in Ethiopia are regarded as vulnerable zones, and some of the most exploited and mismanaged ones have lost their regenerating capacity and are at the verge of extinction (Alemayehu, 2006). In particular, the nat-

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ural vegetation including the hydrology of southwestern Ethiopia is altered due to continued drainage and cultivation of wetlands (Woldu and Yeshitela, 2003). Specifically, a lack of wetland policy (Hailu, 2007) and shortage of land for farming have aggravated conversion of wetlands into farmlands. Furthermore, intense land-use practices adjacent to wetlands bringing about physical changes to wetland ecosystems are affecting the plant species assemblages (Magee et al., 1999). Generally, anthropogenic activities in urban and agricultural land uses that threaten wetlands in many aspects of their biology remain unknown (Flinn et al., 2008). To the best of our knowledge, the plant species composition and diversity across wetlands located at different land uses in Ethiopia have not been well studied. Conducting inventory and diversity analyses of aquatic plants in Eastern Africa particularly in Ethiopia are, therefore, essential for understanding the existing conditions of the plant diversity and the status of the wetlands. Accordingly, the objectives of this research were (1) to determine the species composition and diversity of wetlands at different land uses and (2) to examine the status of wetlands to human disturbance factors. Results from this study are expected to serve as a steppingstone to initiate ecosystem-based management of wetlands in Africa in general and in Ethiopia in particular.

2. Methods and materials

2.1. Study area

Wetlands are situated in Jimma Highlands of Ethiopia with latitude of 7°15′N and 8°45′N and longitude of 35°30′ E and 37°30′ E (Fig. 1). Jimma Zone covers a total area of 18, 412.54 km^2, of which 15% is covered with highlands from 880 to 3340 m.a.s.l. (Moges et al., 2016). The mean annual rain fall of Jimma is between 1800 and 2300 mm with heavy rainfall months from June to September. The air temperature of the study area also ranges from 8 to 28 °C with an annual mean of 20 °C so that the area has characteristics of a sub-humid, warm to hot climate.

2.2. Wetland selection

Bonchie, Duda, Agaro, Boye, Haro and Merewa were the study wetlands of Jimma Highlands (Table 1) and were selected based on their accessibility to the road and locations, and the availability of reference/forested wetlands (U.S. EPA, 2002; Moges et al., 2016). These six wetlands are located from 1656 to 2028 m.a.s.l. and ranged from about 1.5–70 ha in size (Table 1). The six wetlands were grouped into three catchment land use categories (2 forested, 2 agricultural, 2 urban) with varying levels of disturbance (Moges et al., 2016).

Agricultural impacted wetlands: Merewa and Haro wetlands were selected as agricultural impacted wetlands (Table 1), and are located in rural catchments, where cultivation, grazing and brick-production were common activities (Moges et al., 2016). In addition, some parts of both wetlands were drained for cultivation during dry season (Moges et al., 2016). Particularly, such highland wetlands have been subjected to drainage during dry season for maize cultivation in most parts of the southwestern Ethiopia (Woldu and Yeshitela, 2003).

Urban impacted wetlands: Boye and Agaro are wetlands influenced by urban-human practices (Moges et al., 2016), and were situated near the towns Jimma and Agaro, respectively (Table 1). Kitto and Awetu streams, crossing Jimma town, receive untreated urban wastes generated by the community of Jimma and storm water, and drain them into Boye Wetland. Additionally, overgrazing, plantation, urbanization and grass-harvesting were the main causes of wetland degradation. Likewise, a stream called Birr-Gedele carries the urban wastes from the Agaro town to Agaro Wetland.

Forested wetlands: Bonchie and Duda wetlands were situated in the Gera natural forest area covering approximately 913 km^2 (Moges et al., 2016). These shallow permanent swamps were fed by small streams that originated from their respective catchments of the natural forest (Moges et al., 2016).

2.3. Study design and vegetation sampling method

The study design was a two cross-sectional type survey conducted at the end of September 2013 and in February 2014. Plant specimens were collected in detail for identification during September when most of the vascular plants flourish. A second round of plant specimen collection was carried out during dry season in February.

For plant inventories, a transect-quadrat method was used to assess species composition and to estimate their percent-cover (Shannon and Weiner, 1949). Transects up to 150 m were laid based on the preliminary survey characterization of the wetlands, where there were variations of plant communities within each wetland. For this, wetland boundaries were delineated to the maximum extent of flooding or the edge of depressions. Accordingly, transects were located at both sides of the wetlands along the moisture gradient using belt transect method (Misra, 1968). Since almost all vegetation types of the study wetlands were dominated by herbaceous plants, 1 m × 1 m quadrat sizes (Magee et al., 1999; Ruto et al., 2012) were considered except for one quadrat (5 m × 5 m) at the middle of the 3rd transect of Merewa Wetland, where there were shrubs including very few trees. Along each transect, therefore, the quadrats were laid out at the two sides near to the edges (upland) and at the center (open water or aquatic area) of the majority of the study wetlands after demarcating the quadrat boundaries of each wetland from the uplands (Yimer and Mengistou, 2009). Still, the distribution of some quadrats of the wetlands (e.g., at Haro and Duda) varied due to the depth of the water at the center and/or to the land use practices around the wetlands. For instance, in Haro Wetland, where the center was deep, only two quadrats close to the edges of the wetland were considered following each transect line. A total of 51 quadrats were sampled from all study wetlands. Geographical coordinates of transects' starting points and quadrats of each were recorded into Global Positioning System (GPS) of Garmin and in notebook for ensuring the next round of visits.

Within each quadrat, all different vascular plant specimens available (Alvarez et al., 2012; Ruto et al., 2012) were collected according to their perspective wetlands. The ground cover-abundance values (%) of all herbaceous species located within each quadrat of all wetlands were determined using ocular (visual) estimate. All specimens collected and pressed were taken to the National Herbarium (ETH), Addis Ababa University, for identification using the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edwards et al., 1995; Phillips, 1995; Edwards et al., 1997; Edwards et al., 2000; Hedberg et al., 2003; Tadesse, 2004; Hedberg et al., 2006). Finally, the voucher specimens were deposited at the National Herbarium (ETH).

2.4. Human disturbance score (HDS) estimation from wetland land use catchments

Here, the study wetlands were assessed using the protocol of Gernes and Helgen (2002) for estimating their degrees of ecological/human disturbances. For this, field assessments were conducted for assessing the degree of disturbance to wetlands from landscape, physical and chemical stressors including biological data (fish) using checklist, 1–2 l of bottles for taking water samples from each wetland for chemical analyses, and fish net for capturing fish.

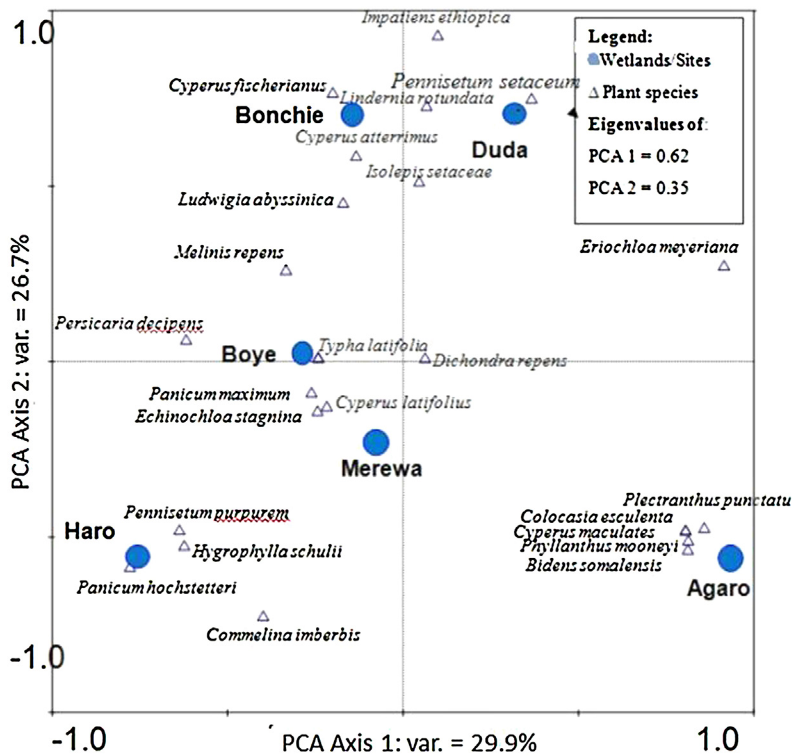

Fig. 1. A PCA diagram showing the species distribution following the patterns of the study wetlands.

Table 1
Locations and characteristics of wetlands surveyed from Jimma Highlands, Ethiopia (2013–2014).

District	Name of wetlands	Wetland type	Locations		Altitude (m.a.s.l.)	[a]Distance (km)	Wetland area (~ha)
			Easting	Northing			
Jimma	Boye	Urban	7°38′56”	36°52′09”	1705	4	60.00
Jimma	Haro	Urban	7°36′47”	36°49′58”	1712	8	7.00
Kersa	Merewa	Agricultural	7°41′01”	36°54′01”	1822	10	70.00
Gomma	Agaro	Agricultural	7°50′57”	36°35′14”	1656	45	2.00
Gera	Bonchie	Forested	7°44′49”	36°15′18”	2028	98	4.00
Gera	Duda	Forested	7°45′47”	36°16′21”	2010	94	1.50

[a] Distance here refers to the remoteness of the study wetlands from Jimma town center.

Accordingly, for calculating HDS, these sources of data were again grouped into six factors: factor one measured the buffer landscape disturbances within 50 m radius; factor two assessed the landscape disturbances within 500 m radius; factor three evaluated the habitat and vegetation alternations; factor four measured the hydrological alteration; factor five assessed the extent of the chemical pollution from phosphorus, nitrogen and chloride, and factor six measures the presence/absence of fish using fish net. The water samples were analyzed in a Laboratory of Jimma University for scoring the extent of chemical pollution in each wetland. Finally, each factor was evaluated and rated (scored) in one of four categories ranging from best to poor with the values ranging from zero to eighteen/twenty one, respectively (Table A). Finally, all scored values of the six factors were summed to each study wetland to get their human disturbance gradient scores (HDSs).

2.5. Data analysis

2.5.1. Plant diversity analysis

The diversity of plant species in the wetlands were analyzed and measured using the standard equations for species richness, diversity, evenness and similarly indices of the Shannon and Weiner (1949). These diversity indices provide information about species commonness, rarity and endemism (Mueller-Dombis and Ellenberg, 1974). The total count of each species with their cover within each plot along transects at each wetland was used to calculate the plant species diversity (H′). The Shannon diversity index (H′) is used to estimate the diversity and relative abundance across the wetlands. The species evenness (distribution) was also calculated using the Shannon evenness index (J). Species richness (S) is also the most frequently used index (Magurran, 2004), and can be used to compare diversity between sites (wetlands) (Woldu, 1985). Species richness can be calculated in terms of alpha and/or beta diversity. The species richness for individual habitats (wetlands) was made and called alpha diversity (Whittaker, 1972; Rosenzweig, 1995). However, there are difficulties for comparing the species richness of the two habitats having different area size based on the data obtained (1) from different sample (quadrat) area size of the two habitats (Rosenzweig, 1995), or (2) from the number of quadrats (with their equal area size) strongly differ between the two habitats (Gotelli and Colwell, 2001). Thus, a habitat being surveyed using a large number of quadrats should be pooled (rescaled) to compare with other habitat surveyed with small number of quadrats (Gotelli and Colwell, 2001). Because of this, the species-area curve is recommended for comparison of species richness between the two habitats that differ in their total number of

Table 2
Beta diversity, Shannon diversity and evenness across the study wetlands.

	Agaro	Boye	Haro	Merewa	Bonchie	Duda
Beta diversity (S)	6.33	9.33	3.67	10.67	6.44	7.17
Shannon diversity (H')	2.09	3.00	1.49	3.36	2.17	2.40
Evenness (J)	0.67	0.82	0.62	0.79	0.70	0.76

quadrats (Norden et al., 2009). Based on this principle, the average species richness through pooling the respective sampling sites of each study wetland and the wetland land use categories were also analyzed, which is called beta diversity (Whittaker, 1972; Rosenzweig, 1995). For all other analyses of diversity including similarity index, average cover-abundance values of each species of all sample sites for each wetland were transformed to relative percentages. For hypothesis testing to most ecological multivariate data sets, non-parametric methods are preferable as the assumptions of normality may not be achieved. Thus, to compare the differences of the species richness, Shannon diversity (H′) and evenness (J) across the six wetlands and the three wetland categories were tested using Kruskal-Wallis test (KWT) from STATISTICA (version 7). A *p*-value of < 0.05 was considered statistically significant.

2.5.2. Similarity and ordination analyses

For comparison of community similarities among the six wetlands, Sorensen similarity index was used. The Sorensen index is preferred to that of the Jaccard as it gives more weight to the species that are common to both sites (wetlands) than to the unique species to either of the wetlands. This index ranges from 0 (no similarity) to 1 (complete similarity) corresponding to 0–100% (Shannon and Weiner, 1949).

For illustrating wetland patterns and the floristic relationship with their sites, ordination methods are more appropriate than clustering when the sites come from three different land uses (Kindt and Coe, 2005). Therefore, a principal component analysis (PCA) from Canoco Software version 4.5 was applied for this study (Galatowitsch et al., 2000; Mulatu et al., 2014). However, before running PCA, species data of flora were transformed using log (x + 1) to down weight abundant species (Leps and Smilauer, 2003; Kindt and Coe, 2005).

3. Results

3.1. Floristic composition

In total, 122 vascular plant species belonged to 37 families and 86 genera were identified from the six wetlands of Jimma highlands, Ethiopia (Table B). Poaceae and Asteraceae were the most dominant families contributing 17.2% and 16.4% to the total number of species, respectively. Poaceae and Asteraceae were also observed in all wetlands. The families of Cyperaceae (10.7%), Fabaceae (9.8%), Lamiaceae (4.1%) and Commelinaceae (4.1%) were the co-dominant families and recorded from the majority of wetlands. These Asteraceae, Poaceae and Fabaceae families also contributed 16, 13 and 9 genera, respectively, to the total genera (n = 86). Regarding the genera dominance, the genus *Cyperus* contributed most to the species diversity with 11 species. The genera *Commelina*, *Pennisetum*, *Persicaria* and *Trifolium* were the co-dominant genera comprised four species each. The remaining genera contributed one to three species (Table B).

Considering the plant species habits, 100 (81.9%) species were herbs [of which, 3 were herbaceous ferns and 21 were grasses], 14 (11.5%) species were shrubs, 7 (5.7%) were trees and 1 (0.8%) was a liana.

3.2. Species richness, diversity and evenness

The results revealed that the average values of the vascular plant species richness (beta diversity) of the six wetlands were ranged from 3.7 (Haro) to 10.7 (Merewa) (Table 2), whereas their total number of species (alpha diversity) were 11, 72, 22, 23, 24 and 39, respectively for Haro, Merewa, Bonchie, Agaro, Duda and Boye wetlands. The average species richness (beta diversity) through pooling the sampling sites across the wetland types of the forested, agricultural and urban wetlands were 6.8, 7.4 and 7.4 (Table 3), respectively. Regarding the Shannon species diversity of the wetlands, they were ranged from 1.5 at Haro Wetland to 3.4 at Merewa Wetland. Likewise, the species diversity across the wetland land use categories was ranged from 1.2 to 1.3.

3.3. Characteristic species

From the total species (n = 122), there were dominant and/or unique species characterizing only urban, agricultural and forested wetlands (Table C). *Ipomoea cairica* belonging to the family Convolvulaceae was unique to urban impacted wetlands. *Colocasia esculenta* was the most dominant species (~28%) followed by *Eriochloa meyeriana* (~24%) found only in Agaro Wetland. There were still some species including *Cyperus maculates, Eragrostis cilianensis*, *Sacciolepis africana* and *Satureja paradoxa* that were unique to Agaro Wetland, whereas *Typha latifolia* and *Lythrum rotundifolium* were unique to Boye Wetland. *Typha latifolia* was the second dominant species (13.8%) next to *Melinis repens* (14.3%) in Boye Wetland. The other common aquatic plant species that were restricted to Boye Wetland were *Commelina africana*, *Cyperus pauper*, *Cyperus rotundus*, *Emilia leptocephala*, *Falkia oblonga* and *Pennisetum longistylum* (Table C).

There were also some species that were characteristic of the agricultural impacted wetlands of Haro and Merewa. *Pennisetum purpureum* and *Panicum hochstetteri* (~26%) were the dominant species in Haro Wetland, whereas *Cyperus latifolius* (~15%) and *Eriochloa meyeriana* (~10%) were relatively the most dominant plants in Merewa Wetland. Common speicies found in agricultural wetlands were *Panicum hochstetteri, Commelina diffusa, Cyperus latifolia,* and *Hygrophila schulii* (Table C). Most of those species were also found in at least one of the urban impacted wetlands.

Forested wetlands were characterized by *Impatiens ethiopica*, *Cyperus fischerianus, Persicaria setosula, Lindernia rotundata* and *Oenanthe palustris*. Bonchie Wetland was, however, mainly dominated by *Impatiens ethiopica* (~18%), and co-dominated by *Persicaria decipiens* (~14%) and *Cyperus latifolius* (~9%), whereas

Table 3
Kruskal-Wallis Test (KWT) for diversity indices computed using mean cover values and standard deviations (SD) pooled from all sampling sites across the three wetland types.

Diversity indices	Mean ± SD			KWT (H)	*P*-value
	Forested wetland (n = 12)	Urban wetland (n = 21)	Agricultural wetland (n = 18)		
Beta diversity (S)	6.86 ± 3.20	7.42 ± 3.65	7.44 ± 5.84	0.30	0.86
Shannon diversity (H′)	1.23 ± 0.58	1.28 ± 0.48	1.32 ± 0.64	0.05	0.97
Evenness (J)	0.62 ± 0.23	0.71 ± 0.21	0.69 ± 0.21	1.66	0.43

Duda Wetland was highly dominated by *Cyperus fischerianus* and *Eriochloa fatmensis* (~20% each), and co-dominated by *Impatiens ethiopica* (~19%) and *Lindernia rotundata* (~9%). *Commelina latifolia*, *Cyperus latifolius* and *Ludwigia abyssinica* were also characteristic species of the forested wetlands.

3.4. Species composition similarity and ordination

The average species composition similarity index among all six wetlands was low (21.7%). The lowest similarity was observed between Duda and Haro (5.7%) followed by between both Agaro and Haro (11.8%) wetlands. However, the highest similarity index (36.0%) was recorded between Boye and Merewa wetlands followed by between Bonchie and Duda wetlands (34.8%) (Appendix C). When considering the similarity between wetlands of similar land use, the highest similarity (34.8%) was recorded between the forested wetlands followed by between urban wetlands (25.8%). The lowest similarity was observed between agricultural impacted wetlands of Merewa and Haro.

Using the average cover-dominant values of 25 plant species pooled from 51 plots of all study wetlands, we produced a biplot PCA/ordination diagram using correlation matrics. The first two axes, PCA 1 and 2 extracted 29.9% and 26.7% variance of the floristic data set, respectively (Fig. 1). The PCA diagram illustrated the patterns of wetlands (Fig. 1). The Boye and Merewa wetlands were relatively placed closely. Similarly, Bonchie and Duda wetlands placed closely. Contrarily, Haro and Agaro wetlands were placed far away from each other and from other wetlands (Fig. 1).

The distribution of plant species in relation to the wetlands as obtained in the PCA showed that *Pennisetum purpureum* (~45%) and *Panicum hochstetteri* including *Hygrophila schulii* and *Commelina imberbis* were widespread around Haro Wetland. Likewise, some of the most dominant plant species (e.g., *Colocasia esculenta*, *Phyllanthus mooneyi* and *Eriochloa meyeriana*) were scattered around Agaro, an urban wetland type.

In this study, *Phyllanthus mooneyi, Satureja paradoxa, Crassocephalum picridifolium* and *Cirsiumschimperi* that are known to be endemic plant species for Ethiopia were also detected (Table C).

The status of wetlands in relation to human disturbance

The disturbance assessment of the wetlands suggests a relationship with composition of the aquatic plant communities. The HDSs indicated that Boye (73), Agaro (75), and Merewa (81) wetlands were highly impacted by human activities. Haro Wetland (65) was moderately impacted, while Bonchie (15) and Duda (18) wetlands were least impacted.

4. Discussion

4.1. Floristic composition and diversity

Although wetlands are productive and the most biologically diverse ecosystem (Ramsar Convention Secretariat, 2006), they have been degraded and even some of them were changed into terrestrial land uses due to anthropogenic activities. In this study, out of the total (n = 37), the families of Poaceae and Asteraceae were the most dominant. These two families were also the most dominant wetland plants in Uganda (Odull and Byaruhanga, 2009) and in Ethiopia (Belachew and Tessema, 2015). Relating to the genera dominances, the genus *Cyperus* was the most dominant as it contributed 11 species to the total species of this study. This genus is also dominant in Eastern Africa, and has 110 species in the Flora of Ethiopia and Eritrea and 450 species in Flora of Tropical Eastern Africa (Lye, 2001). The species composition of wetland plant communities is also strongly influenced by the extent of land-use activities and urbanization (Ehrenfeld and Schneider, 1991). Accordingly, the most dominant plant species in urban and agricultural influenced wetlands were *Melinis repens*, *Typha latifolia*, *Dichondra repens*, *Hygrophila schulii*, *Pennisetum purpurem*, *Panicum hochstetteri*, *Commelina imberbis*, *Bidens somalensis*, *Cyperus maculatus*, *Colocasia esculenta*, *Plectranthus punctatus* and *Phyllanthus mooneyi*. Most of these species were found in the upland and some were invasive, representing good indicators of impaired wetlands. In contrary, in forested wetlands, *Impatiens ethiopica*, *Cyperus fischerianus*, *C. atterrimus*, *Ludwigia abyssinica* and *Isolepis setaceae* were common native wetland plants and indicators of good wetland conditions. While observing the plant habits in the study wetlands, herbs were dominant followed by shrubs and trees. Other studies also reported herbs as the dominant flora of wetlands (Gichuki et al., 2001; Mulatu et al., 2014).

Species richness was lowest at Haro and highest at Merewa agricultural wetlands. Although both wetlands were extensively impaired by grazing, drainage, cultivation, bricks-making and grass-harvesting during the dry season, they were considerably different in their hydrological features. Haro is a permanently flooded wetland with considerable depth at the center and with some emergent wetland grass species towards the uplands and the drained parts of it, whereas Merewa is semi-permanently flooded wetland with much disrupted vegetation. These might be the basic reasons for great differences in species richness between these two wetlands. Deep flooding and long period of standing water can decrease vegetation diversity (Dwire et al., 2006). Contrarily, Padgett and Crow (1995) stated that due to its mosaic habitat nature, the natural wetland with shallow water depth harbored more plant species than the other natural wetlands. The forested wetlands of Bonchie (6.4) and Duda (7.2) were comparable in species richness and composition as they were least impacted. On the other hand, the urban impacted Boye wetland had largest beta diversity (9.3) next to Merewa Wetland. This might be due to the characterization of Boye Wetland by fairly permanent water and less disturbance as compared to Merewa Wetland. While considering the beta diversity across the wetland land use categories, the beta diversity was lowest in forested wetland type, may be due to low human activities. Still, the beta diversity of the urban wetland category was a little bit less than agricultural wetland category. This might be due to the variations of some anthropogenic activities conducted between the two wetland types. For instance, the urban wetland land catchments were engaged in and highly influenced by urban activities such as waste discharge from garages, car wash, bus station and fuel station centers, asphalt road constructions, hotels and hospitals, among others, as compared to agricultural wetland type. Such activities, as we observed, discharged many acidic wastes that might exclude more sensitive species from urban wetland type than agricultural wetland type besides their hydrological features. This indicated that the hydrological nature and some wastes are one of the determinant factors for variation in species richness among wetland land use categories. Wherever wetlands engaged in extensive use without fertilizer or pesticide application, the diversity of the wetland landscape may be high (Verhoeven and Setter, 2010) though the species composition and setting differ highly from its pristine situation. Cultivated wetlands have been reported to support more diversified plant species than the uncultivated wetlands in Kenya and Tanzania (Alvarez et al., 2012) and in Ethiopia (Mulatu et al., 2014). Moreover, eutrophication is aggravated due to urban settlement in Hyena Dam, which supports more number of species than the natural Nalogomon Wetland of Kenya (Ruto et al., 2012). This finding was also in agreement with that of Magee et al. (1999) as the mean species richness of disrupted wetlands was higher than the naturally occurring wetlands in USA.

Similarly, in this study, Shannon species diversity of the wetlands ranged from 1.5 at Haro Wetland to 3.4 at Merewa Wetland. This finding was in the range of most values of the Shannon species diversity (H′) (ranging from 1.5 to 3.5, and rarely exceeding 4.5) as reported by (Kent and Coker, 1992; Kent, 2012). The mean diversity in agricultural (1.3) and urban (1.3) wetland types were higher than in the forested wetland type (1.2) (Table 3). This might be due to anthropogenic activities being conducted within the agricultural and urban wetlands and especially throughout their catchments. The plant community composition would be related to the environmental conditions of the surrounding land use activities associated with wetlands (Magee et al., 1999). Ruto et al. (2012), Alvarez et al. (2012) and Mulatu et al. (2014) also reported disturbed wetlands having more diversity compared to the undisturbed natural wetlands in Kenya, Kenya and Tanzania and in Ethiopia, respectively.

In general, there are three vital processes determining the diversity of an ecosystem: disturbance, competitive exclusion and environmental heterogeneity (Connell, 1978). Disturbances like drainage, overgrazing, cultivation and/or pollution can reduce plant species diversity by removing disturbance-sensitive species; however, might also increases species diversity by creating open area for other colonizer species, and change spatial heterogeneity in plant community composition. Competitive exclusion reduces species diversity by suppressing and later leading to extinction of the lesser competitors. It has been suggested that more frequently disturbed ecosystems through drainage and de-vegetation have a wider range of plants by creating microhabitats suitable to other invader plants (Woldu and Yeshitela, 2003; Handa et al., 2012).

Species most often characterize one ecosystem (wetland) from the other (Padgett and Crow, 1995; Devictor et al., 2010) in terms of their uniqueness and/or dominance. For example, in this study, *Ipomoea cairica* was unique to the urban impacted wetlands. This species is mostly found in impaired urbanized landscape (Manral et al., 2013). The majority of agricultural and urban wetland taxa including *Melinis repens*, *Ageratum conyzoides*, *Sacciolepis africana*, *Bidens*, *Commelina* and *Galinsoga* were typical upland weeds in the present study. They were also common upland weeds in Eastern Africa (Alvarez et al., 2012). Galatowitsch et al. (2000) found that native herbaceous and graminoid perennials had declined in impaired agricultural and urban wet Meadows of Minnesota, U.S.A. and the current study found similar findings. *Impatiens ethiopica*, *Cyperus fischerianus*, *Lindernia rotundata,* and *Oenanthe palustris* were mainly native plants (Woldu and Yeshitela, 2003; Alvarez et al., 2012; Mulatu et al., 2014) that characterized the forested wetlands.

4.2. Floristic similarities and wetland status

As a general principle, any two plant communities having greater than 50% similarity represents the same association (Barbour et al., 1987). However, our finding revealed as there were low species similarities among natural wetlands ranging from ∼6% to ∼36%. This finding is in agreement with Padgett and Crow (1995), who reported low similarities in plant species composition among natural wetlands in New Hampshire. As also illustrated in the PCA diagram Boye and Merewa, and Bonchie and Duda wetlands were fairly close-placing each other because these wetland groups had relatively more common species. However, because of very low occurrences of the common species in Haro (agricultural) and Agaro (urban) impaired wetlands, the PCA placed these sites far away from each other and from the other wetlands. Two sampling plots lay near to each other in an ordination diagram when the two sites are much more similar in their common species (Shannon and Weiner, 1949; Leps and Smilauer, 2003). The PCA diagram also showed as the species occurring in a particular site are scattered around that site (Ter Braak and Verdonschot, 1995) of the present study wetlands.

Regarding the status of the wetlands, Merewa, Agaro and Boye wetlands were seriously impaired by human activities, carried out within the wetlands and throughout their catchments. Hence, they belonged to the high impaired wetlands followed by Haro Wetland, grouped as mid-impaired wetland (Moges et al., 2016). However, Bonchie and Duda wetlands were least impaired as they were parts of the Gera forest (Moges et al., 2016). The aquatic plant composition of wetlands could greatly be affected by the extent of human disturbances. As a result, the plant composition in urban and agricultural impaired wetland types was different from the forested wetland type. As also reported in many papers (e.g., Alvarez et al., 2012; Ruto et al., 2012), human factors are the major contributors for wetland degradation and alteration of biological community composition.

5. Conclusion

Agricultural and urban impaired wetland types showed higher levels of species richness, diversity and evenness than the forested wetlands and this can be explained from the anthropogenic activities. The activities such as drainages, urbanization, harvesting, overgrazing, waste discharge and cultivation resulted in creating diverse microhabitats that enhance establishment of colonizer species while exterminating native plant species. Hence, extensive and more frequent human disturbances were the most determinant factors for altering wetland plant composition and diversity. Likewise, the highest similarity in floristic composition was observed between Boye and Merewa wetlands despite their extensive anthropogenic factors and environmental heterogenity. Generally, the urban and agricultural wetlands considered to be highly impaired category except Haro, categorized as mid impaired wetland. Therefore, both urban and agricultural impaired wetlands need much attention to restore them, particularly the flora and fauna they support. However, the urgent action should target the documentation of species status with their environmental stresses in wetlands of Ethiopia. The data could be used to prioritize and develop management strategies for rehabilitation of the wetlands.

Authors' contributions

AM originated the research idea and set the objectives. AM, AB, AA, ST, LT and EK designed the methods and collected the data. All authors performed the statistical analysis, drafted the manuscript and finalized it. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.aquabot.2016.12.001.

Appendix C. Species composition similarity among study wetlands using Sorensen index

Wetlands	Agaro	Boye	Merewa	Haro	Bonchie	Duda
Agaro	100					
Boye	25.8	100				
Merewa	21.1	36.0	100			
Haro	11.8	24.0	14.5	100		
Bonchie	26.7	26.2	17.0	18.2	100	
Duda	29.8	12.7	20.8	5.7	34.8	100

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