Comparison of the Floristic Composition and Diversity of Two Wetlands in Ethiopian

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Abstract

The main purpose of this study was to determine and compare the floristic composition and diversity indices of Washa and Borale Wetlands, located in Central Ethiopian. As revealed in the result, 74 species belonging to 26 families, and 57 genera were identified. Asteraceae and Poaceae were the most dominant families contributing 24.56% and 14.04% to the total genera, and 20.27% and 16.22% to the total species identified, respectively. Of the total, about 92% plant species were herbs, whereas 1% was climber, the least one. The alpha diversity of the Washa and Borale wetlands were 51 and 64, respectively. The average richness of the Washa and Borale wetlands were 12.3 ± 0.91 , and 15.35 ± 0.89 , respectively. Likewise, the Shannon diversity (H') and evenness (E) of Washa and Borale sites were 2.24 and 0.87, and 2.67 and 0.97 respectively. Accordingly, based on their average values, the diversity, evenness and richness indices were higher in Borale than Washa sites, and showed significance difference between the two wetlands ($P < 0.05$). Likewise, in both sites, especially in Borale, the majority of the species were native, annual and upland, implying the suitability of the wetlands to these native, but to annual and upland invaders due to the ecological and hydrological modifications of the wetlands, and competitive exclusion of the native aquatic plants by upland annual plants. Generally, many of the wetlands' species were annual and upland invaders. Hence, in-situ and ex-situ strategic plans are required for restoring the wetlands via giving priority.

1. Introduction

Wetland ecosystems are essential in conserving wetland-dependent biodiversity and in delivering important and vital services for human well-being. For instance, the wetlands like ponds/small reservoirs provide sustainable solutions to key issues of water management and climate change such as nutrient retention, flood regulation, and carbon sequestration (Ce'réghino et al 2014), besides supporting various plant species. Many Ethiopian wetlands provide significant contribution to the local people chiefly being the major source of water for irrigation, fish, livestock and human drink, and cleaning, as well as materials like grasses and fodders. Generally, they provide ecological, socio-economic and refreshment benefits to humans (Moges et al 2018, Menbere and Menbere 2018; Wondie 2018). However, the continuous conversion of wetlands into crop and grazing land, overfishing, drainage, eutrophication, and siltation threaten biodiversity, impair environmental functions of the wetlands and affect people's livelihoods (Gebresilassie 2014; Wondie 2018). Moreover, watershed degradation, overgrazing, invasion of alien species, urbanization and water diversion are other threats to wetland degradation (Soboka and Gemechu 2021). Similarly, agricultural practices such as farming, grazing, and extraction of water for irrigation are the major threat to the present study area. These all factors result in wetland degradation, which in turn has potential influences on biodiversity, climate, ecological security and human health (Bai et al 2013). Thus, the most direct and effective way of evaluating the biological conditions of wetlands is to directly monitor the biological components of wetlands via using bioassessments, which help diagnose the causes of degradation, provide data to make informed management decisions, and/or prioritize wetlands being restored. Therefore, the main objectives of this study were to: 1) identify and document the plant species, 2) analyze the species composition and diversity indices of the study wetlands and 3) conduct a parametric t-test for a non-null hypothesis of mean diversity indices or variables between the two wetlands.

2. Materials And Methods

2.1. Description of the study area

This study was carried out two mixed wetland types, locally called *Washa* and *Borale* wetlands in North Shewa Zone, Central Ethiopia, and situated at 145 and 150 Km away from Addis Ababa, respectively. Those two sites comprise man-made reservoirs, and natural wetlands at their downstream, located at 01 *Kebele* (it refers to county) of the *Debre Berhan Town* (DBT). The range of altitudes of the sites is 2767 to 2811 meters. Specifically, the *Washa* site is located at *Atakilit Got* ("Got" is a proportional term to a village in Amharic, which is a national language of the country) of *Kebele* 01, at about 10 Km away from DBT, towards the east (Fig. 1). However, *Borale* site is located in a *Got* called *Borale*, which is situated at about 15 Km away from DBT, towards north-east. The temperature of DBT ranges from the mean annual minimum to maximum temperature of 2.3⁰C to 22⁰C, respectively, and its mean annual rainfall is 906 mm. In 01 *Kebele*, about 690 total households (HHs) were living, of whom, 149 and 58 HHs of *Borale* and *Washa* villages, respectively, had irrigable lands at downstream, and cultivated various vegetables and cereal crops at least twice a year by extracting water directly from the reservoirs (personal communication with experts of the Urban Agricultural Office and local users). In *Borale* site, those 149 households are legal water users, and established an association, locally called *Merabie* Irrigation Users' Association. Thus, the study wetlands provided water, and supported diversified aquatic and upland plants, and other species.

2.2. Study site selection

The *Washa* and *Borale* sites were selected (Table 1, Fig. 1) due to their socio-economic services to the localities, and the problem of conversion of the upper catchments, and wetlands at downstream into agricultural and grazing lands, leading to reservoirs' water reduction and wetland degradation.

***Washa* Reservoir**

This reservoir was constructed in 1995 by local non-governmental organization (NGO) called Lutheran with the main aim of providing water for fishery, irrigation and livestock watering. The total area of *Washa* site was 56 ha, comprising a reservoir (12 ha), actual wetlands (surrounding and downstream) (16 ha) and irrigable land (28 ha) (Table 1). *Washa* reservoir is fed by seasonal flood, and small streams draining its catchment, particularly in the rainy season, from the end of June to the beginning of September. It was designed to hold 91, 875 m³ water with 14 m depth (as reported by Zonal agricultural experts). The catchment and its surrounding wetlands were characterized by farming, grass harvesting/grazing and settlement activities. There was also high water extraction from the reservoir for irrigation, and livestock watering, especially in the long dry seasons, from December to May.

***Borale* Reservoir**

This reservoir was constructed in 2007 by Bureau of Agriculture of the Amhara Regional State to provide water for irrigation, fishery and livestock watering. The total area of *Borale* site was 154 ha, consisting of a reservoir (17 ha), actual wetlands (17 ha) and irrigable lands at downstream (120 ha) (Table 1). This

reservoir including its surroundings is fed by seasonal flooding and three small streams draining its catchment, particularly in rainy season. It was designed to hold 280,000m³ of water with 14m depth (Experts communication). Grazing, grass harvesting, farming and water extraction for irrigation were the main activities executed in and around the site.

Table 1
The name, ownership, location and land sizes of the study area including irrigable lands

Name of the study site	Type and ownership of the study site	Location		Altitude (in meter)	Area size (ha)			
		Northing	Easting		Reservoir (depth in meter)	Actual wetland	land converted to irrigable ones	Total
<i>Washa</i>	Mixed	9°39'45"	39°32'45"	2763	12 (14)	16	28	56
<i>Borale</i>	Mixed	9°39'62"	39°32'36"	2832	17 (14)	17	120	154
Total					29 (14)	27	148	210

2.2. Sampling design and data collection procedures

Field survey is the appropriate approach for collecting the floristic data. To familiarize with, or to observe the changes in plants and ecological conditions in the study wetlands during the dry and wet seasons, and finally, determine the sampling design, reconnaissance survey was carried out for two weeks, in May and September 2019. Accordingly, systematic sampling design was employed for laying out the quadrats in both sites. For floristic survey, the quadrat method is used to take the plant specimens and estimate the percent-cover of plants for identifying their botanical names and determining the diversity indices (Shannon and Wiener, 1949). For this, wetlands boundaries were firstly delineated to the maximum extent of flooding or the edge of depressions (Flinn et al 2008; Moges 2016). Since almost all plants of the wetlands were herbaceous, 1 m x 2 m quadrat sizes (Mulatu et al 2014) was fixed. Then, the quadrats were laid out in the peripheries of the reservoirs, and at downstream wetlands following the transect lines. The transect lines were laid out along the longest axis of each wetland (Du Toit et al 2017) using a 50 meters interval between the two consecutive quadrats. Yet, where wetland sites were wide enough, adjacent quadrats were aligned parallel to one another, 50 m apart. Hence, 40 total quadrats (20 per site) were the total sampled plots of the study area. Geographical coordinates and altitude of each quadrat were recorded in Global Positioning System (GPS) of Garmin and in a notebook for facilitating the second round of data gathering.

The specimens of all vascular plant species encountered (Alvarez et al 2012; Ruto et al 2012, Moges et al 2017) in each quadrat of the study area were collected. Additionally, the percent cover of every species met in each quadrat was estimated (Murillo-Pacheco et al\ 2016). Accordingly, the specimens were collected at

the end of rainy and dry seasons. October is a month of the end of the rainy season, and of good flowering time for most of the vascular plant species, whereas February is one of the dry months, in which the plants favoring the dry conditions grow up in Ethiopia. Accordingly, the first round plant specimens' collection was made in October 2020, and the second round, in February 2021. The aerial ground cover-abundance value of each herbaceous species was determined in percent (%) using ocular estimation, and immediately converted into the Braun-Blanquette (BB) scales ranging from 1 to 9 (as modified by Van der Maarel 1979): 1 for 1-3 individuals; 2 for few individuals (0.5-1.5%]; 3, (1.5-3%]; 4, (3-5%]; 5, (5-12.5%]; 6, (12.5-25%]; 7, (25-50%]; 8, (50-75%]; 9, (75-100%]. Additionally, wetland indicator species (obligate, facultative wetland, facultative, facultative upland and upland plants), perennial, annual and native/non-native species were determined being assisted by experts and published document (US fish and Wildlife 1996, Moges et al. 2016, 2017, Flora volumes of Ethiopia and Eritrea (1-7)). Then, the whole specimens collected, dried and pressed were taken to Debre Berhan University for identification using the Flora of Ethiopia and Eritrea (Edwards et al 1995; Edwards et al 1997; Edwards et al 2000; Hedberg et al 1989; Hedberg et al 2003; Hedberg et al 2006; Hedberg et al 2009; Phillips 1995; Tadesse 2004). However, for further identification being assisted by expert mounted specimens and microscope, the whole specimens were taken to the National Herbarium of Addis Ababa University (ETH). Finally, the voucher specimens were placed there.

3.2.4 Data analysis

For vegetative data analysis, statistical tools, diversity indices, and parametric test were made using SPSS version 21, R version 4 and Stata version 14 softwares, respectively.

The diversity of the wetland plants were analyzed and measured using species richness (S), diversity (H'), evenness (J) and Sorensen's similarity coefficient (SSC) indices of Shannon and Wiener (1949). Species richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as a number of species per sample unit (Whittaker 1972). The Shannon diversity (H') and evenness (E') indices were also determined as a measure to incorporate both species richness and evenness (Magurran 1988; Kent 2012). The Shannon diversity index (H') was calculated from the equation:

$$H' = - \sum_{i=1}^S p_i \ln p_i \quad (\text{Eq. 1})$$

Where p_i is the proportion of individuals found in the i^{th} species. The values of Shannon diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran 1988, Kent 2012). The Shannon evenness index (J) is calculated from the ratio of observed diversity to maximum diversity using the equation:

$$J = \frac{H'}{H_{\max}} = \frac{H'}{\ln S} \quad (\text{Eq. 2})$$

Where $H_{\max}$ is the maximum level of diversity possible within a given population, which equals $\ln$ (number of species). J is normal between 0 and 1, and with 1 representing a situation in which all species are equally abundant (Magurran 1988).

Moreover, for comparison of community similarities between the two study sites, Sorensen similarity index was used. The Sorensen similarity index is preferred to that of the Jaccard as it gives more weight to the species that are common to both sites (quadrats) than to the unique species to either of the wetlands. The Sorensen similarity index is calculated from the equation:

$$SSC = \frac{2a}{2a+b+c} \text{ (Eq. 3)}$$

Where SSC = Sorensen similarity coefficient, a = the number of species common to both sites, b = the number of species present in one of the sites to be compared and c = the number of species present on the other site. Often, the SSC is multiplied by 100 to give a percentage similarity. The SSC values range from 0 (complete dissimilarity) to 1 (total similarity). For hypothesis testing to the most ecological data, non-parametric test is recommended since the uniformity of the data distribution might not be achieved. Yet, as the data sources of the two wetlands are independent, and the extreme data of the wetlands were minimized via transforming the percentage data to the BB scales (1-9) for bring them into uniformity, the paired parametric (T-) test was preferred. Statistical significance was considered when the *p*-value was < 0.05.

3. Results

3.1. Plant species composition and habits

Totally, 74 plant species, belonged to 26 families and 57 genera, were identified from both *Washa* and *Borale* Wetlands (Appendix A). Among the total, the most dominant family was *Asteraceae* followed by *Poaceae* (Table 2). Thus, *Asteraceae* and *Poaceae* contributed 14 and 8, and 12 and 15, genera and species, respectively (Table 2). The next important families considered as co-dominant families were *Commelinaceae*, *Lamiaceae* and *Apiaceae* (Table 2), of which the family *Lamiaceae* contributed three and four genera and species, respectively. Still, the families including *Cyperaceae*, *Fabaceae*, *Onagraceae*, *Polygonaceae* and *Schrophulariaceae* consisted of two genera each with variable number of species. Of those families, *Cyperaceae* contributed the largest number of species (seven) next to *Asteraceae* and *Poaceae*. The remaining families (18) comprised one generum with species ranging from one to two. Further, three and nine families were found in only *Washa* and *Borale* sites, respectively; but 14 families, in both sites (Table 2).

Table 2

The distribution of family, and number of general and species in the study area (n = number of genera or species, % = percentage of genera or species)

Family	Genera in:		Species in:		Study sites
	n	%	n	%	
<i>Apiaceae</i>	3	5.26	3	4.05	W, B
<i>Asphodelaceae</i>	1	1.75	2	2.70	B
<i>Asteraceae</i>	14	24.56	15	20.27	W, B
<i>Commelinaceae</i>	3	5.26	3	4.05	W, B
<i>Cucurbitaceae</i>	1	1.75	1	1.35	B
<i>Cyperaceae</i>	2	3.5	7	9.46	W, B
<i>Fabaceae</i>	2	3.5	4	5.41	W, B
<i>Geraniaceae</i>	1	1.75	1	1.35	W, B
<i>Iridaceae</i>	1	1.75	1	1.35	W, B
<i>Juncaceae</i>	1	1.75	1	1.35	B
<i>Lamiaceae</i>	3	5.26	4	5.41	W, B
<i>Malvaceae</i>	1	1.75	1	1.35	B
<i>Onagraceae</i>	2	3.5	3	4.05	B
<i>Orobanchaceae</i>	1	1.75	1	1.35	B
<i>Papaveraceae</i>	1	1.75	1	1.35	W, B
<i>Phytolaccaceae</i>	1	1.75	1	1.35	W
<i>Plantaginaceae</i>	1	1.75	1	1.35	W, B
<i>Poaceae</i>	8	14.04	12	16.22	W, B
<i>Polygonaceae</i>	2	3.5	3	4.05	W
<i>Rosaceae</i>	1	1.75	1	1.35	W, B
<i>Rubiaceae</i>	1	1.75	1	1.35	W
<i>Salicaceae</i>	1	1.75	1	1.35	B
<i>Schrophulariaceae</i>	2	3.5	2	2.70	W, B
<i>Sinopteridaceae</i>	1	1.75	1	1.35	W, B
<i>Typhaceae</i>	1	1.75	1	1.35	B

Family	Genera in:		Species in:		Study sites
	n	%	n	%	
<i>Verbenaceae</i>	1	1.75	1	1.35	B
Total	57	100	74	100	

While considering the plant habits, 68 species (91.89%) were herbs, followed by shrubs (6.75%) and climbers (1.35%), which had a very small share (Fig. 2).

3.2. Species richness, diversity and evenness of the study sites

The alpha diversity (richness) of the study area, drawn from 40 total plots, was 74. The species richness distribution in 40 plots of the study area was ranging from eight species in each plot of 20 and 21 to 20 species in each plot of 7 and 12 (Table 3). The beta diversity (average richness) via pooling the whole sampling sites (40 plots) of the study area was 14.55. Similarly, the richness of *Washa* and *Borale* sites were 51 and 64 species, respectively (Table 2). The minimum, maximum and average richness of the two study sites were different. The minimum and maximum richness of the plant species in *Washa* Wetland were eight (in plot 8), and 17 (in each plot of 25 and 28), respectively (Table 3). The beta diversity through pooling the richness of the 20 plots of *Washa* Wetland was 13.2. Likewise, the minimum and maximum plant richness in *Borale* Wetland were eight (in plot 20) and 20 (in each plot of 7 and 12), respectively, but the beta diversity was 15.9 (Table 3).

Table 3
Species richness in each plot of *Borale* and *Washa* wetlands

<i>Borale</i> site				<i>Washa</i> site			
Plot no.	Richness	Plot no.	Richness	Plot no.	Richness	Plot no.	Richness
1	12	11	17	21	8	31	13
2	14	12	20	22	9	32	9
3	14	13	15	23	10	33	12
4	17	14	16	24	9	34	12
5	19	15	14	25	17	35	12
6	18	16	18	26	13	36	14
7	20	17	13	27	13	37	9
8	15	18	12	28	17	38	14
9	15	19	11	29	16	39	13
10	19	20	8	30	10	40	16

The Shannon diversity (H') of *Washa* and *Borale* sites were 2.24 and 2.67, respectively. Similarly, the evenness (J) values of *Washa* and *Borale* sites were 0.87 and 0.97, respectively. While considering the dominance of the species based on their average cover values, the most dominant species of the *Borale* site were *Eleocharis marginatum* Hochst. ex Steud, Raven, *Geranium dissectum* L., *Cyperus fischerianus* G.W. Schimp. ex A. Rich., *Pennisetum thunbergii* Kunth, *Alchemilla abyssinicum* and *Snowdenia polystachya* (Fresen.) Pilg. Similarly, *E. marginatum*, *L. stolonifera*, *G. dissectum*, *C. fischerianus*, *Ludwigia stolonifera* (Guill. & Perr.) and *Eleusine floccifolia* (Forssk.) Sprimng were the most dominant species of the *Washa* site.

3.3. SSC and Paired T-test between the two study wetlands

The SSC between *Washa* and *Borale* wetlands was 0.71, which means the two wetlands were similar by 71% in their plant species composition. However, the paired (parametric) t-test was made between the mean values of richness, Shannon diversity (H') and evenness of *Washa* and *Borale* wetlands (Table 4). Accordingly, based their average richness, Shannon diversity and evenness values, there were high ($p = 0.0113$) and very high ($p = 0.0000$) significant differences between the two wetlands, respectively (Table 4).

Table 4
The paired t-test for diversity indices between *Washa* and *Borale* sites

Wetland site	Plot no.	Mean $\pm$ SE	Degree of freedom	P-value
Richness (R)				
<i>Washa</i>	20	13.2 $\pm$ 0.91	19	0.0113**
<i>Borale</i>	20	15.9 $\pm$ 0.89		
Diversity (H)				
<i>Washa</i>	20	2.24 $\pm$ 0.05	19	0.0000***
<i>Borale</i>	20	2.67 $\pm$ 0.056		
Evenness (J)				
<i>Washa</i>	20	0.87 $\pm$ 0.00	19	0.0000***
<i>Borale</i>	20	0.97 $\pm$ 0.010		

NB **and *** indicates high and very high significant difference at $P < 0.05$, respectively.

3.4. Characteristic and common species

Characteristic species are species which are unique to a specific site, or habitat. Accordingly, the characteristic species, or the species found only *Washa* Wetland, were 10, and some of them were *persicaria decipens* (R.Br.) K.L.Wilson, *Cyperus pauper* Rochat. ex A. Rich. *Cyperus brevifolius* (Rottb.) Hasskn, and *Commelina diffusa* Burm.f. The characteristic species of *Borale* Wetland were 23, of which *Typha latifolia* L., *Laggera tomentosa* (Sch. Bip. ex A. Rich.) Oliv. and Hiern, *Guizotia scarba* (Yis.) Chiov., *Plectranthus punctatus* (Lf) L 'Her., *Rumex abyssinicus* Jacq, and *Sida schimperiana* Hochst. ex A. Rich. (Table 5) were some of them. Thus, totally, 33 plants were the characteristic species of the two sites (Table 5). Among those species (33), 90.9% and 54.54% were native and perennials, respectively. Regarding the wetland indicators of those characteristic species, the majority (57.57%) was *upland species* [obligate upland (42.42%) plus facultative upland (15.15%)] (Table 5). However, the *wetland species*, consisting of obligate wetland (18.18%) and facultative wetland (21.21%) species, were 39.39%, and were less than the uplands. Still, the *facultative species* was very few (1.3%) (Table 5).

Table 5

Characteristic species to Washa and Borale sites with their average cover values (CV), nativity, life cycle and wetland indicators

Characteristic species of <i>Washa</i> site	Native	Life cycle	Wetland indicators
<i>Anthemis tigrensensis</i> J. Gay ex A. Rich.	Yes	P	OU
<i>Commelina diffusa</i> Burm.f.	Yes	P	FW
<i>Cyperus brevifolius</i> (Rottb.) Hasskn	Yes	P	FU
<i>Cyperus pauper</i> Rochat. ex A. Rich.	Yes	A	OW
<i>Emilia leptcephala</i> (Mattf.) C. Jeffrey	Yes	A	FU
<i>Galium acrophyum</i> Hochst. ex	Yes	P	FW
<i>Periscaria dicipens</i> (R.Br.)	Yes	A	OW
<i>Senecio myriocephalus</i> Sch. Bip. ex A. Rich.	Yes	P	OU
<i>Taraxacum officinale</i> Webber ex Wiggers	No	P	OU
<i>Thymus schimperi</i> Ronniger	Yes	P	OU
Characteristic Species of <i>Borale</i> site			
<i>Cyanotis barbata</i> D.Don	Yes	A	FW
<i>Cyperus elegantulus</i> Steud.	Yes	A	OW
<i>Epilobium hirsutum</i> L.	No	A	OW
<i>Ferula communis</i> L.	Yes	A	OU
<i>Guizotia scarba</i>	Yes	A	OU
<i>Helichrysum stenopterum</i> DC.	Yes	P	OU
<i>Inula confertiflora</i> A. Rich.	Yes	P	FU
<i>Juncus effuses</i> L.	Yes	A	FW
<i>Kniphofia foliosa</i> Hochst.	Yes	A	OU
<i>Laggera tomentosa</i>	Yes	P	OU
<i>Ludwigia abyssinica</i>	Yes	P	OW
<i>Medicago lupulina</i> L.	Yes	A	OU
<i>Orobanche minor</i> Smit	Yes	A	FU
<i>Peucedanum mattirolii</i> Chiov.	Yes	P	FW

Note: OW refers to obligate wetland; FW, Facultative wetland; F, Facultative; FU, Facultative upland; Up, Upland; p, perennial, A, annual, B, biannual

Characteristic species of <i>Washa</i> site	Native	Life cycle	Wetland indicators
<i>Plectranthus punctatus</i> (Lf) L 'Her.	Yes	A	FW
<i>Rumex abyssinicus</i>	Yes	A	OU
<i>Salix subserrata</i> Willd.	Yes	P	FW
<i>Sida schimperiana</i> Hochst. ex A. Rich	Yes	P	FU
<i>Snowdenia polystachya</i> (Fresen.) Pilg.	Yes	A	OU
<i>Sphaeranthus suaveolens</i> var. <i>abyssinica</i> (Forssk .) DC	Yes	P	OU
<i>Typha latifolia</i> L.	No	P	OW
<i>Verbena officinalis</i> L.	Yes	P	OU
<i>Zehneria minutiflora</i> (L.f.) Sond.	Yes	P	FW
Note: OW refers to obligate wetland; FW, Facultative wetland; F, Facultative; FU, Facultative upland; Up, Upland; p, perennial, A, annual, B, biannual			

Contrarily, of the total, 41 (55.4%) were common species to the two wetlands. Of these, 92.68% and 56.1% were native and annual species, respectively (Appendix B). Regarding those indicator species of the common plants to the two wetlands, 2 (4.88%), 8 (19.51%), 10 (24.39%), 12 (29.27%) and 9 (21.95%) were obligate wetland, facultative wetland, facultative, facultative upland and upland species, respectively (Appendix B, Table 6). The common wetland (OB + FW) and upland (FU + OU) species to the two study wetlands were 10 (24.39%) and 21 (51.22%), respectively (Table 6).

Table 6
Common wetland indicator species to the two
wetland sites

Wetland indicator status	<i>In both sites</i>
OB	2
FW	8
F	10
FU	12
OU	9
Wetland species (OB and FW)	10 (24.39%)
Upland species (FU and OU)	21 (51.22%)
Total	41

Moreover, the total number of the *wetland species* of *Washa* and *Borale* sites were 14 (27.45%) and 19 (29.68%), whereas the total number of the *upland species* of *Washa* and *Borale* sites 27 (52.94%) and 34 (53.12%), respectively (Table 7).

Table 7
Wetland indicator species categories and their number across
each study wetland

Wetland indicator status	<i>Washa</i> site	<i>Borale</i> site
OB	4	6
FW	10	13
F	10	11
FU	14	15
OU	13	19
Wetland species (OB and FW)	14 (27.45%)	19 (29.69%)
Upland species (FU and OU)	27 (52.94%)	34 (53.12%)
Total	51	64

4. Discussion

The present study was carried out in *Washa* and *Borale* reservoir-based wetlands, located in highlands of DBT of North Shewa Zone, Central Ethiopia. Thus, the plant species (and other related data) were sampled from both the surroundings of the reservoirs, and their downstream natural wetlands so that the study sites were mixed types of both man-made lacustrine reservoirs and flooded natural wetlands. Accordingly, the discussion on comparison of the floristic composition, richness, Shannon diversity, characteristic and common species to the two wetlands, the SSC, and paired T-test was made via considering those two mixed wetlands types.

3.1. Plant composition

As the result revealed, 74 plant species belonging to 26 families and 57 genera were identified and documented. This might be because the wetlands are the most important habitats for biodiversity conservation (Menbere and Menbere 2018). Moreover, while wetlands are disturbed, they create many microhabitats and microclimates, which could create suitable media for growth of various species such as upland, wetland, non-native and native plant species so that the species richness could increase up. Further, among 26 families identified, *Asteraceae* and *Poaceae* were the most dominant ones, which contributed 20.27% and 16.22% to the total species of the study area. This finding is in line with the report of Moges et al (2017) from Ethiopia, and of Odull and Byaruhanga (2009) from Uganda. Additionally, those *Asteraceae* and *Poaceae* families shared 24.56% and 14.04% of the total genera (57) of the plant species, respectively. Next to those families, *Lamiaceae*, *Commelinaceae* and *Apiaceae* were the co-dominant families, and contributed 5.41%, 4.05% and 4.05% to the total plant species, respectively. Those all dominant and co-dominant families have the adaptation potential of both terrestrial and aquatic ecosystems. In fact, based on the assessments made and rated, the *Washa* and *Borale* were ecologically mid- and high- impacted sites, respectively (Supplementary file 1). This implies that such impacted wetland sites support dominantly those plant species resisting the ecological disturbance factors. Because of those dominant and co-dominant families, the other 16 families sharing about 62% of the total identified families had the least contribution (1 genus, 1.75%) and (1 species, 1.35%) to the total genera and species, respectively, with the exception of only one family (*Asphodelaceae*) contributing two species (2.70%). This might also be due to the hydrological and ecological modifications of the study wetlands, resulting in creating suitable microhabitats for growing many upland and native, but less abundant in their coverage, might be owing to the shortage of time for their invading the study area dominantly.

While comparing the two study sites in terms of their dominant families, *Borale* Wetland supported a larger number of families than that of *Washa* Wetland (Fig. 3). This might be due to the variations of their ecological status, i.e., *Borale* site was more disturbed than *Washa* site. Mulatu et al (2014) and Moges et al (2017) also reported from the southwestern highlands of Ethiopia that the disturbed wetlands support more plant species than the non-disturbed ones. Despite unlike in their extent of their ecological disturbances, the two wetlands had common physiognomies in their climate (moisture and temperature) and agro-ecological zones, resulting in having more than half common families growing in the two sites (~54%) (Table 1, Fig. 3). This might be because climate and altitude are the most determinant factors for such same plant species growth.

Regarding the plant habits, there were only three habits (herbs, shrubs and climbers) identified in the study area. Of those, the majority of the species (~92%) was herb, followed by shrub (~7%). Contrarily, climber/liana (~1%) was found to be the least number of species. This report also agrees with the findings of Mulatu et al (2014) and Moges et al (2017). This might be due to that the wetlands having surface or subsurface water mostly support more herbs than the other plant habits.

3.4.2. Richness, Shannon diversity, evenness and similarity between *Washa* and *Borale* sites

Richness is an apt measure of diversity, and the richness of a range of habitats (of both wetlands) is also termed as gamma diversity (Whittaker 1972), but the average richness is called beta diversity (Whittaker 1972, Kent 2012). However, the total number of species per wetland site is called alpha diversity (Du Toit et al 2021). Thus, the species richness (S) is the most repeatedly used index (Magurran 2004) for comparing the diversity between sites (wetlands) (Woldu 1985) and may be used gamma, beta and alpha diversity interchangeable and accordingly for this paper.

Therefore, the gamma diversity of the present study area was 74. The richness per plot (2m²) in the study area was also ranged from eight (8) to twenty (20) with 14.55 average richness (beta diversity). This means that close to 15 plant species were found per 2m² (~ 8 species per 1m²), showing a large number of species per 1m² compared to other land use systems. Still, there were the variations of species richness between *Washa* and *Borale* wetlands. Accordingly, the alpha diversity of *Wash* and *Borale* sites were 51 and 64, respectively. Moreover, the maximum richness values of *Washa* and *Borale* wetlands were 17 and 20, respectively, but the minimum richness values of *Washa* and *Borale* were equal (8). Additionally, the beta diversity values of *Washa* and *Borale* wetlands were 13.2 and 15.9, respectively. These all indicated that *Borale* site supported more plant species than *Washa* site. Murillo-Pacheco et al. (2016) also reported similar results that in aquatic plants, there are marked differences in total alpha diversity in the two wetlands among all study sites. This was also confirmed by paired t-test made for the mean richness of the two sites ($p = 0.0113$), as there was a high significant difference between the two sites.

While also considering the Shannon's diversity and evenness of the *Washa* and *Borale* sites, there were medium diversity, and high uniformity in distributions of the species. However, the Shannon diversity values of *Washa* ($H' = 2.24$) and *Borale* ($H' = 2.67$) were somewhat different. Similarly, the distribution of the plant species or evenness in the *Washa* ($J = 0.87$) and *Borale* ($J = 0.97$) was still dissimilar. Thus, based on the mean values of the Shannon diversity and evenness indices, there was a very high significant difference between the two wetlands ($p = 0.0000$). This is because wetlands by nature are dynamic ecosystems; there are always ecological changes or disturbances in wetlands due to anthropogenic activities (Menbere and Menbere 2018). Connell (1987) and Moges et al (2017) also reported that environmental heterogeneity, disturbance and competitive exclusive processes are the determinant factors for either increasing or decreasing the diversity of an ecosystem. As also reported during the ecological assessment of the two study sites, *Borale* site was highly impacted compared to *Washa* site due to the

anthropogenic activities taking place within and around the two study sites (Supplementary file 1). Generally, diversity patterns seem to be driven by high landscape heterogeneity and wetland management.

Concerning the dominant species found in the two study sites, the species *E. marginatum*, *G. dissectum*, *C. fischerianus*, *P. thunbergii*, *Alchemilla abyssinicum*, and *L. stolonifera*, were the most dominant species in *Borale* study site. Similarly, the most dominant species in *Washa* site were *E. marginatum*, *L. stolonifera*, *G. dissectum*, *C. fischerianus*, *P. thunbergii* and *Eleusine floccifolia*. Thus, the species *E. marginatum*, *C. fischerianus*, *L. stolonifera*, *P. thunbergii* and *G. dissectum* were the most common dominant species to the two study wetlands. This result indicated that the dominant species in the two wetlands are almost similar, and more than half of them were obligate wetland species. Of course, the SSC between the two sites was about 71% similarity, and confirmed this finding. Barbour et al., (1987) also reported that any two plant communities those have more than 50% similarity shows the same association. Additionally, Kent (2012) stated that when calculated between all pairs of quadrats of a study area, or between two sites, a similarity or dissimilarity matrix is produced. Thus, based on this general rule, the *Washa* and *Borale* sites had similarity in their plant composition. However, Murillo-Pacheco et al (2016) from Colombia, and Moges et al (2017) from Ethiopia reported the opposite result that the similarity in composition of aquatic plants among the study sites was low. These also imply that although the SSC showed similarity between the present study sites due to their similar agro-ecological and climatic factors, the two study sites could have significance difference owing to the variations of the extent of ecological disturbances, resulting in creating heterogeneous microhabitats, which in turn, leading to support different species.

3.4.3. Characteristic and common species of the study area

The characteristic species are species that characterize the specific site or habitat being unique to only that of other sites of the study area. Thus, *persicaria decipens*, *Cyperus pauper*, *Cyperus brevifolius*, *Commelina diffusa*, *Anthemis tigreansis*, *Emilia leptoccephala*, *Galium acrophyum*, *Senecio myriocephalus*, and *Taraxacum officinale* were the characteristic species to *Washa* Wetland since they were found only from *Washa* site. Particularly, the first four plant species were common wetland plants in *Washa* and other less or non-impacted wetlands despite having many uplands (Table 5). Contrarily, the plant species including *T. latifolia*, *L. tomentosa*, *Guizotia scrob*, *Plectranthus punctatus*, *Rumex abyssinicus*, *Sida schimperiana* and some others listed (Table 5) were unique to only *Borale* Wetland. Many characteristic species of *Borale* wetland were also uplands, and are considered as good indicators of disturbed sites. Even, some aquatic plants such as *T. latifolia* and *Emilia leptoccephala* (Mattf.) C. Jeffrey are important characteristic plants being indicators of water pollution or ecological degradation in *Borale* Wetland. As also reported from *Jimma* Highlands, *Boye* Wetland was highly impaired and invaded by *T. latifolia* (and *Emilia leptoccephala*) (Moges et al 2017).

Additionally, from the total characteristic species (33), 90.9% and 54.54% were native and perennials, respectively. Contrarily, of the total (74), 41 (55.4%) species were common to the two wetlands. Of these common species, 92.68% and 56.1% were native and annual species, respectively (Appendix B). Seventeen species (41.46%) were perennials, and only one (2.44%) was biannual. Regarding these wetland indicator species of the common plants to the two sites, 10 (24.39%), 10 (24.39%), and 19 (51.22%) were wetland

species (OB + FW), facultative (F), and upland species (FU + UP), respectively. This also indicates that the majority of the wetland indicator species growing in both wetlands were uplands. This finding is in line with Thompson et al (2007). These all imply that the invasion of alien species in the study sites was very low; however, due to their ecological disturbances, many of the aquatic plants were replaced by native and annual upland invaders. Still, those OB, FW and F characteristic species together represented about 41%, which grow and easily adapt the wetland ecosystems, and which indicate the restoration potential of the study sites.

3.3.4. Conclusion

Seventy four plant species were identified and documented from the two wetlands, located at Central Ethiopia. *Asteraceae* and *Poaceae* were dominant families, and contributed the largest number to the total species. The species diversity, richness and evenness of *Borale* were higher than *Wash* site, and showed significant differences between the two sites since *Borale* site was highly disturbed due to anthropogenic activities. Additionally, the study sites largely supported native and annual species, but many of them were uplands, considered as native invaders due to the hydrological and ecological changes in the study sites, creating a good environment for widely growth of upland species by excluding wetland species. Thus, if apt measures are not taken soon, both wetlands, especially *Borale* site would reach unrestored conditions. Therefore, to ensure a long-term conservation and sustainable use of wetlands, it is essential to develop and implement *in-situ* restoration and management strategic plans that take both reservoirs and natural wetlands with their catchments into consideration.

Declarations

Competing Interest:

The authors have no relevant financial or non-financial interests to disclose.

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Author contributions:

Admasu Moges proposed and designed the research project and the first draft of the manuscript written by Admasu Moges. However, material preparation, data collection, species identification and analysis were performed by both Admasu Moges and Abyot Dibaba. Both authors commented on previous versions of the manuscript, and read and approved the final manuscript. The datasets generated during and/or analyzed during the current study are available from the corresponding author on the reasonable request.

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References

1. Amsalu A (2006) Caring for the Land. Best practices in soil and water conservation in Beresa watershed, highlands of Ethiopia. Tropical resource management papers 76. Wageningen University, The Netherlands.
2. Bai J, Cui B, Cao H, Li A, Zhang B (Eds.) (2013) Wetland Degradation and Ecological Restoration, *The Scientific World Journal*, doi.org/10.1155/2013/523632.
3. Barbour MG, Burk JH, Pitts WD (1987) Terrestrial Plant Ecology, 2nd ed. The Benjamin /Cummings Publishing Company, Inc., Reading, Maine.
4. Brinson MM (1993) A hydrogeomorphic classification for wetlands. Wetlands Research Program Technical Report WRP-DE-4. PP 1-103.
5. Ce´re´ghino R, Boix D, Cauchie HM, Martens K, Oertli B (2014) The ecological role of ponds in a changing world. *Hydrobiologia*, 723:1–6, DOI 10.1007/s10750-013-1719-y.
6. Connell JH (1978) Diversity in tropical forests and coral reefs. *Science* 199, PP. 1302–1310.
7. Du Toit, M.J, Du Preez C, Cilliers SS (2021) Plant diversity and conservation value of wetlands along a rural–urban gradient, *Bothalia* 51(1), a4. <http://dx.doi.org/10.38201/btha.abc.v51.i1.4>
8. Edwards S, Demissew S, Hedberg I (Eds.) (1997) Flora of Ethiopia and Eritrea: Hydrocharitaceae to Arecaceae, The National Herbarium, Addis Ababa University, Vol. 6, Addis Ababa, Ethiopia,
9. Edwards S, Tadesse M, Demissew S, Hedberg I (eds.) (2000) Flora of Ethiopia and Eritrea: Magnoliaceae to Flacourtiaceae. The National Herbarium, Addis Ababa University, Vol. 2(1) Addis Ababa, Ethiopia, PP. 1-532.
10. Edwards S, Tadesse M, Hedberg I (Eds.) (1995) Flora of Ethiopia and Eritrea: Canellaceae to Euphorbiaceae. The National Herbarium, Addis Ababa University, Vol. 2 (2), PP. 1-456.
11. Heberg I, Edward S (Eds.) (1989) Flora of Ethiopia: Pittosporaceae to Araliaceae. Vol. 3, The National Herbarium, Addis Ababa University, PP. 1-660.
12. Hedberg I, Friis I, Persson E (2009) Flora of Ethiopia and Eritrea: Lycopodiaceae To Pinaceae. The National Herbarium, Addis Ababa University, Vol 1, PP. 1-305
13. Hedberg I, Kelbessa E, Edwards S, Demissew S, Persson E (Eds.) (2006) Flora of Ethiopia and Eritrea: Gentianaceae to Cyclocheilaceae. The National Herbarium, Addis Ababa University, Vol. 5, PP. 1-690.

14. Hedberg, Edwards and Nemomissa (2003) Flora of Ethiopia and Eritrea: Apiaceae to Dipsacaceae. The National Herbarium, Addis Ababa University, Vol. 4 (1), Addis Ababa, Ethiopia, PP. 1-354.
15. Israel Petros Menbere, Timar Petros Menbere (2018) Wetland ecosystems in Ethiopia and their implications in ecotourism and biodiversity conservation, Review. *Journal of Ecology and The Natural Environment*, 10(6), 80-96, DOI: 10.5897/JENE2017.0678. *Journal of Environment and Earth Science*, 4(11):40–48.
16. Kent M. (2012) *Vegetation Description and Data Analysis: A Practical Approach*, 2nd ed., John Wiley and Sons, Ltd. pp. 414.
17. Kent, M., Coker, P (1992) *Vegetation Description and Analysis: A Practical Approach*. Bolhaven Printing Press, London.
18. Magurran, AE (2004) *Measuring Biological Diversity*, 2nd ed. Blackwell, Oxford.
19. Moges A (2016) Flora and fauna composition and development of plant-based monitoring tool for the improvement of ecosystem services and ecological state of wetlands of Jimma Highlands, Ethiopia, PhD thesis, Jimma University, Ethiopia.
20. Moges A, Beyenea A, Ambelua A, Mereta ST, Triestc L, Kelbessa E (2017) Plant species composition and diversity in wetlands under forest, agriculture and urban land uses. *Aquatic Botany*, 138, 9–15.
21. Mulatu, K, Hunde, D, Kissi, E (2014). Impacts of wetland cultivation on plant diversity and Soil fertility in South-Bench District, Southwestern Ethiopia. *African Journal of Agriculture and Research*, 9:2936-2947.
22. Murillo-Pacheco J I, Rös M, Escobar F, Castro-Lima F, Verdú JR and López-Iborra GM (2016) Effect of wetland management: are lentic wetlands refuges of plant-species diversity in the Andean_Orinoco Piedmont of Colombia? *PeerJ* 4:e2267; DOI 10.7717/peerj.2267.
23. Odull, MO, Byaruhanga, A (Eds.) (2009) *Ecological Baseline Surveys of: LakeBisina- Opeta Wetland Systems and LakeMburo-Nakivali Wetland Systems*. Nature Uganda, pp. 1–157.
24. Phillips S (1995) Flora of Ethiopia and Eritrea: Poaceae (Gramineae). Vol. 7, The National Herbarium, Addis Ababa University, Vol. 6, Addis Ababa, Ethiopia. PP. 1-420.
25. Shannon, CE, Wiener, W (1949) *The Mathematical Theory of Communication*. University of Illinois Press, Urban.
26. Soboka DM, Gemechu LH (2021) Identifying Cause and Drivers of Wetland Degradation in Ethiopia: A Review. *Journal of Environment and Earth Science*, 11(2), ISSN 2224-3216.
27. Tadesse M (2004) Flora of Ethiopia and Eritrea: Asteraceae (Compositae). The National Herbarium, Addis Ababa University, Vol. 4(2), Addis Ababa, Ethiopia. PP. 1-409.
28. Thompson K, Miller MC, Culley TM (2007) Comparison of Plant Species Richness, Diversity, and Biomass in Ohio Wetlands. *OHIO J SCI* 107 (3): 32-38.
29. US Fish and Wildlife (1996) National list of vascular plant species that occur in wetlands. Available at: <http://wetlands.fws.gov/bha/list96.html>.
30. Whittaker, RH (1972) Evolution and measurement of species diversity. *Taxon* 21,213–251.

31. Woldu, Z (1985) Variation in Grassland Vegetation on the Central Plateau of Shewa, Ethiopia in Relation to Edaphic Factors and Grazing Conditions. Dissertation. Uppsala University.
32. Wondie A (2018) Ecological conditions and ecosystem services of wetlands in 4 the Lake Tana Area, Ethiopia. <https://doi.org/10.1016/j.ecohyd.2018.02.002>

Figures

Figure 1

Map of the study area (Washa and Borale Wetlands), North Shewa Zone, Ethiopia

Figure 2

The diagram illustrating the habits of the species in the study area

Figure 3

The diagram showing the number of families found in Washa, Borale, and both sites

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