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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.