Research Article

Ecological Conditions and Ecosystem Services of Artificial Wetlands in Semiarid Ethiopian Highlands

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The main purpose of the study was to investigate the ecological status, ecosystem services (ESs) with their relative importance, and the local communities’ perception of the management of Washa and Borale artificial wetlands located in the Semiarid Ethiopian Highlands. The results revealed that many of the communities relied mainly on farming and livestock rearing with small land size (≤ 1 ha) and large family size. Grass harvesting, free grazing, farming, wetland conversion, and water extraction were the main anthropogenic factors causing the wetlands’ ecological disturbance. The ecological status of Washa and Borale wetlands were thus moderately (67) and highly degraded (80), respectively. Yet, the various ESs categorized as provisioning, regulating, cultural, and supporting services, were still delivered from both sites. Vegetables (carrots, potatoes, garlic), crops (barley, beans), grass, water, and crafting materials were the products obtained from the wetlands. Some educational, research, and recreational services were also delivered mainly from the Washa site. Still, erosion, flooding, carbon regulation, and biota (plants, birds, fish) supporting services were provided at both sites. Yet, many of the ESs provided had low and medium importance due to the wetlands’ impairedness. Yet, the water and food delivered from the wetlands had high and even higher importance than the other services due to their being designed for providing water mainly for irrigation and livestock watering. Still, Washa provided higher cultural, regulating, and supporting services than the Borale’s owing to its being moderately impaired and lesser buffer and catchment area disturbance. Overall, many of the ESs delivered had low and medium importance because of the wetlands’ biodiversity loss, ecological degradation, and water reduction chiefly in the dry season. Yet, the people had good perceptions of the wetlands’ management. Hence, for the wetlands’ restoration, urgent action is required via developing a management plan.

1. Introduction

1.1. Background of the Study. Wetlands are natural and/or man-made assets and the most productive environments. They provide several services like wildlife habitats, basic sources of food for humans, and regulating global warming and geochemical cycles; thus, they accomplish numerous functions from local to global scale [1]. The ecosystem services (ESs) provided by ecosystems lie at the heart of interactions between society and nature. The wetlands are, thus, critical for supporting human livelihoods in Africa [2]. Ethiopia, located in the Eastern Region of Africa, covers 1.13 million Km² and is endowed with several inland water bodies comprising mainly swamps, rivers, lakes, ponds, reservoirs, and other wetlands (bogs, marshes), which are generally termed as wetlands [3]. Such artificial wetlands are critical resources in providing paramount services including environmental, hydrological, and socioeconomic services. According to WCD [4] and Gunkel et al. [5], the main uses of the artificial wetlands/reservoirs are flood control, hydropower, and water sources for drinking of human and/or livestock, and irrigation, besides supporting biodiversity. The Ethiopian government presently highlights the development of small-scale irrigation schemes of <200 ha [6] via
constructing small reservoirs like the Washa and Borale artificial wetlands. Yet, their role in safeguarding water, food, and energy security and mitigating climate change is currently threatened via their poor protection and management [7]. Additionally, since some ESs such as climate, erosion, and flooding regulating services are not easily understandable for estimating their values, their role in human well-being was overlooked in development policy [8]. Thus, the present studied Washa and Borale artificial wetlands were similarly threatened by anthropological activities. Even since the country has not yet ratified the Ramsar Convention, there is no support for it [9, 10]. Moreover, inadequate data on current ecological conditions and biodiversity of wetlands, people’s perception, and wetland policy and policy interventions [3, 11] have aggravated the degradation of wetlands. Besides, the current state of the ESs of Ethiopian wetlands remains poorly understood [10, 12]. Particularly, the ecological status and delivered ESs of the Ethiopian artificial wetlands were not yet rated and investigated scientifically before this study, respectively. However, despite facing such highly critical and urgent problems, little or no study has been made so far on such artificial wetlands in Ethiopia. Therefore, the ESs also continued to be the main part of the research issue of ecological economics [13] of scholars. Thus, the main objectives of this study were to investigate (i) the anthropogenic factors and ecological status of the artificial wetlands using human disturbance gradient score (hereafter abbreviated as HDGS) and field observation, (ii) the ESs delivered by the study wetlands with their relative importance, and (iii) the perception of the local communities towards their experiences and interests in wetlands’ management in the future.

2. Materials and Methods

2.1. Description of the Study Area. This study was carried out in two sites, locally called Washa and Borale artificial wetlands, which are also positioned in 01 Kebele (which is proportional to a county), but at the periphery of Debre Berhan Town (DBT) being bordered by Basona-Werena District of North Shewa Zone, Semi-Arid Central Ethiopian Highlands (Figure 1). The Washa and Borale sites are also far away by 10 and 15 km from the center of DBT, with altitudes of 2763 and 2832 meters above sea level, respectively (Table 1). The Washa site is also located at 9°39′45″ latitude and 39°32′45″ longitude, whereas the Borale site is situated at 9°39′62″ latitude and 39°32′36″ longitude. The temperature of DBT ranges from the mean annual minimum to maximum temperature of 2.3°C to 22°C, respectively, and its mean annual rainfall is 906 mm [14]. In 01 Kebele, about 690 total households were living, of whom 149 and 58 households of Borale and Washa sites, respectively, had been irrigated land downstream/around and cultivated various vegetable and cereal crops at least twice a year by extracting water directly from the reservoirs (interviews made with experts of Urban Agricultural Office of DBT). Generally, the studied artificial wetlands provided water, besides serving being biota preservation areas for fish, birds, and plants.

2.2. Study Site Selection. The Washa and Borale sites were selected due to their socioeconomic services to the localities, and the problems of conversion of the upper catchments and wetlands downstream into agricultural, settlement, and grazing lands, leading to reservoirs’ water reduction and wetland degradation.

2.2.1. Washa Site. The total area of Washa site was 56 ha, comprising a reservoir (12 ha) and its surrounding wetlands (16 ha) and irrigated land (28 ha) (Table 1). The reservoir in this site was constructed in 1995 by a nongovernmental organization (NGO) called Lutheran with the main aim of providing water for fisheries, irrigation, and livestock watering.

The reservoir is fed by a seasonal flood and small streams drain 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 maximum depth (as reported by Zonal and urban agricultural experts). The catchment and its surrounding wetlands were characterized by farming, grass harvesting, grazing, and settlement. There was also high water extraction from the reservoir for irrigation and livestock watering, especially in the long dry season, from December to May.

2.2.2. Borale Site. The total area of Borale site was 154 ha, consisting of a reservoir (17 ha), surrounding wetlands (17 ha), and irrigated land mainly at downstream (120 ha) (Table 1). The reservoir was constructed in 2007 by the Bureau of Agriculture of the Amhara Region to provide water for irrigation, fishery, and livestock watering and fed by seasonal flooding and three small streams draining its catchment, particularly in the rainy season. It was designed to hold 280,000 m³ of water to 14 m depth; however, currently, its depth and amount of water are highly reduced. Grazing, grass harvesting, farming, and water extraction for irrigation were the main activities that occurred.

2.3. Study Design. Descriptive and vegetative surveys were the appropriate approach for collecting and analyzing the data of this study. A reconnaissance survey was conducted to familiarize with the landscape and hydrological situation of the study area along with development agents, and Kebele and district administrative bodies, in May and September 2020. A cross-sectional survey design was applied for collecting data using the household questionnaire, KI interview, FGD, and stakeholder survey. A vegetative systematic survey design was also made for plant specimens’ collection and identification. Therefore, since the data collected were quantitative and qualitative during their formal and informal surveys, both quantitative and qualitative data analyzing approaches were employed.

2.4. Respondents’ Selection and Their Sampling Techniques. Households, KIs, stakeholders, and members of FGD were the participants of this study, who, except stakeholders, represented more than 20% of the total households of
01 Kebele (690), where the two study sites were located. Accordingly, for the household survey, a total 100 household respondents (50 households per site) living and/or having land within a 5 Km radius of Washa and Borale wetlands were selected using a clustered random sampling technique [9, 15]. This is because those people living within a 5 Km radius have direct contact and influence on wetlands in harvesting and/or grazing grasses, encroaching wetlands for farming and settlement, extracting/using water for different purposes, and even in conserving practices of the wetlands. Moreover, two groups of KIs (24), who are proposed to be more interactive and knowledgeable individuals about their Kebele from Washa (12) and Borale (12) site communities, were selected purposively through consulting development agents and Kebele administrative bodies. The other 12 respondents were purposively selected from stakeholders of

| Name of study sites | Distance from DBT | Location | Altitude (in meter) | Depth in meter | Area size (ha) |
|---------------------|------------------|----------|---------------------|----------------|--------------|
| Washa               | 15               | 9°39′45″  | 39°32′45″          | 2763           | 12           |
| Borale              | 10               | 9°39′62″  | 39°32′36″          | 2832           | 17           |

Table 1: The name, location, and land size of the study area, including irrigated land.
the study area (8 experts from zonal and urban agricultural offices, Nongovernmental Organization (NGO), and Debre Berhan University (DBU); 2 development agents, and 2 Kebele administrative bodies). Additionally, 16 farmers (eight per site) for the two FGDs were randomly selected. Hence, a total of 152 respondents were participants in this study. However, since the responses of five households from both study sites were rejected for their incompleteness, the data of a total 147 participants were made ready for analysis.

2.5. Data Collection Methods

2.5.1. Household Survey, KI and Stakeholder Interviews, and FGD. Based on the perceptions of the household survey, KI and stakeholder interviews, the data collection on ESs and their relative importance and interest in wetland management were carried out. However, regulating and supporting services are somewhat challenging concepts for understanding and interacting with farmers. Thereby, the importance of wetlands relating to these services was assessed by clarifying the concepts of the terms to those household respondents. Moreover, for validating the responses of the households and getting additional information, questions relating to regulating and supporting services were asked to stakeholders and key informants. Furthermore, the relative importance of ESs was rated using 5-Likert points (not sure, very low, low, medium, and high importance). Moreover, FGD and field observations were employed for validating the data collected via household survey, besides collecting the missed data. Thus, structured and semistructured questionnaires comprising open- and close-ended items were prepared, besides checklists. Additionally, the plant specimens were collected using the quadrat method at 50-meter intervals and then pressed and taken to DBU for identification.

2.5.2. Protocols for Estimating the Ecological Status of Wetlands. The degree and severity of the ecological condition of wetlands could be estimated and determined using different ecological disturbance assessment methods. For this study, therefore, mainly the protocols of human disturbance gradient score (HDGS) of Gernes and Helgen [16] and the field observation checklist were applied. Consequently, repeated ecological assessments during the wet and dry seasons, from October 2020 to May 2021, were conducted. Accordingly, the physical buffer landscape disturbance (within 50 m radius), and further landscape disturbance up to 500m radius from the edges of the wetlands were made, where the habitat, vegetation, and hydrological alterations were assessed. Moreover, chemical pollutants such as phosphate, nitrate, dissolved oxygen (DO), and electric conductivity (EC), and biological data on the presence or absence of birds and fish were also assessed and evaluated. Repeated field visits and fish nets were also used for determining the presence of birds and capturing fish, respectively. Moreover, three bottle composite water samples (with one litter volume of each), besides in situ measures (for DO and EC), were taken for water chemical analysis from each referenced, mid-impacted, and high-impacted sampling sites of the study area.

Thus, to determine the HDGSs of each study wetland, various data sources were categorized into six-factor groups as follows:

1. Factor 1: Focused on the assessment of buffer landscape disturbances within 50 m radius from the edge of the wetland, where the degree of disturbance varies from 0 to 18 points.
2. Factor 2: Measured extent and intensity of landscape disturbance within 500 m radius from the edge of the wetland, where the degree of disturbance varies from 0 to 18 points.
3. Factor 3: Evaluated the severity and extent of habitat and vegetation alterations of the whole study wetland area, where the severity and extent of alteration range from 0 to 18 points.
4. Factor 4: Measured degree and severity of hydrological alteration, where the alteration rate varies from 0 to 21 points.
5. Factor 5: Assessed the extent and severity of chemical pollution using mainly phosphate, nitrate, EC, and DO, where the degree of chemical pollution ranges from 0 to 21 points.
6. Factor 6: Focused on assessing with additional points added to the cumulative disturbance, such as the presence/absence of fish and birds in the wetlands, where the extent of presence or absence of them ranges from 0 to 4 points.

The water samples were analyzed in the laboratory of Addis Ababa University to score the extent of chemical pollution of the wetlands (Factor 5). Finally, each factor was evaluated and scored into one of the four categories ranging from best to poor, with values ranging from zero to eighteen/twenty-one, respectively. At the end, all scored values of the six factors were summed up to the study wetlands to get their total HDGSs. Based on the values, each wetland falls within the potential range of 0–100 HDGS. Those study wetlands with the values of HDGS falling in the categorical ranges of 0–33, 34–67, and 68–100 are considered the least impacted, mid-impacted, and most impacted sites [16], respectively.

2.6. Data Analysis. For framing the ESs, the conceptual model (Figure 2) of De Groot et al. [16] and Moges et al. [9] was adopted and is more appropriate to analyze the ESs by bringing various services into their limited categories: provisioning, cultural, regulating, and supporting services. Moreover, the data collected based on the protocol and field checklist were analyzed to rate the ecological status of these artificial wetlands. Furthermore, for some water quality parameter analyses, APHA [18] laboratory procedures were used.

Moreover, plant identification was performed using the flora volumes of Ethiopia and Eritrea [19–23]. Finally, to analyze plant communities’ similarity between the two
artificial wetlands, the Sorenson Similarity index ($J$) was
defined as:

$$J = \frac{2a}{2a + b + c},$$

where $J$ = Sorenson similarity Index, $a$ = the number of species in site 1, $b$ = the number of species in site 2, and $c$ = the number of common species in both sites (wetlands), and where the index ranges from 0 (no similarity) to 1 (complete similarity), corresponding to 0 to 100% [24]. For all these analyses, SPSS, PAST, and Microsoft Excel 2010 softwares were employed. Hence, besides content analysis for narrating qualitative data, descriptive and inferential statistics such as frequency, percentage, HDGS, and similarity index were made.

### 3. Results

#### 3.1. Background Information of the Respondents.

This background information mainly focused on the characteristics of household respondents, who were the major primary data source of this study, carried out from December 2020 to April 2021. Thus, the total household respondents were 95, drawn from Washa (46) and Borale (49) sites and comprised 13 females (~14%) and 82 males (~86%). Of the total, many respondents (~35%) had from five to six family sizes per household, followed by three to four (~30%) and seven to eight (~22%) family sizes, respectively (Table 2). The least number of households (2%, on average) had more than eight family sizes. Regarding the age categories of the households, more than half of them in this study (~55%) fell in the age group of >45–60, followed by >30–45, with the least participants in the 20–30 age groups (~6%) (Table 2).

#### 3.2. Economic and Livelihood Conditions of the Community.

The educational status of the household participants included almost all individuals ranging from illiterates to higher literates. However, many of the respondents comprised individuals who completed their education from Grades 1–4 (~22%) and Grades 5–9 (~22%), who can write and read (21%), and illiterates (21%) (Table 2). Yet, the least participants were those who completed their higher education (≥diploma) (~2%).

### Figure 2: A conceptual model was used as a framework for the assessment and analysis of ESs [9, 17].
Table 2: Background information of the participants of the study.

| Study site | Family size | Age categories | Educational status |
|------------|-------------|----------------|--------------------|
|            | 1–2 | 3–4 | 5–6 | 7–8 | >8 | 20–30 | >30–45 | >45–60 | >60 | Total |
| Washa      | 6   | 13.0 | 7   | 15.2 | 17 | 36.9 | 15 | 32.6 | 1 | 2.2 | 46 | 100 |
| Borale     | 5   | 10.2 | 21  | 42.8 | 16 | 32.6 | 6  | 12.2 | 1 | 2.0 | 49 | 100 |
| Total      | 11  | 11.6 | 28  | 29.5 | 33 | 34.7 | 21 | 22.1 | 2 | 2.1 | 95 | 100 |

| Washa | Borale | Total |
|-------|--------|-------|
| Illiterate | Who can read and write | Educational status |
|        |        |        |        |        |        |        |        |        |        |        |        |        |
| n     | %     | n     | %     | n     | %     | n     | %     | n     | %     | n     | %     | n     | %     |
| Washa | 3     | 6.5   | 7     | 15.2  | 15   | 32.6  | 13   | 28.3  | 7     | 15.2  | 1     | 2.2   | 46    | 100   |
| Borale| 17    | 34.7  | 13    | 26.5  | 6    | 11.2  | 8    | 16.3  | 4     | 8.2   | 1     | 2.1   | 49    | 100   |
| G. total| 20   | 21    | 20    | 21    | 21   | 22.1  | 21   | 22.1  | 11    | 11.6  | 2     | 2.1   | 95    | 100   |
around Washa and Borale wetlands, there were some variations in terms of their income sources. For instance, farming and livestock rearing were relatively larger practices in the communities surrounding the Borale than Washa wetlands, whereas small trade and fuel wood collecting activities were more practiced vice versa (Table 4).

In the study area, roughly 1%, 71%, 37%, and 48% of them did not have their own farmland, bush land, grazing land, and wetlands, respectively (Table 5). Still, of the total households having their own farmland, bush land, grazing land, and wetland, 75.8%, 29.5%, 63.2%, and 51.6% had small landholdings with \( \leq 1 \) ha, respectively (Table 5). As depicted in Table 5, except for some in farmland, the majority of the households did not have more than one ha size of the land use system. Of course, the surroundings and/or downstream wetlands of the reservoirs were privatized, whereas the reservoirs were communal; thus, the ownership of the study sites was mixed and only 51.6% of individual farmers had a wetland with \( \leq 1 \) ha size per head (Table 5).

### 3.3. Anthropogenic Factors and Ecological Status of Wetlands

#### 3.3.1. Anthropogenic Factors
Grass harvesting, free grazing, farming and settlement (within the catchment), livestock watering, conversion of wetlands into cultivated/irrigated land (at downstream), large water extraction for irrigation, and inappropriate soil and water conservation practices were the common anthropogenic activities observed in both wetlands (Figures 3 and 4). Yet, the severity of those activities was lesser in Washa (Figures 3(e)–3(f)) than Borale sites (Figure 4(e)) as assessed frequently by researchers using the field checklist and rated using HDGS protocol during the field survey of the study (Table 6). Especially, as developed a LULC (Figure 1) made two FGDs with discussants and observed during the field survey, almost all except a few parts of the catchment of Borale Wetland were converted into farmland till the margin of the wetland (Figures 1 and 4(e)), but not as such extreme in the case of Washa site (Figure 3(c)–3(e)).

#### 3.3.2. Ecological Status of Wetlands
Based on the survey made using the HDGS format and field checklist, the HDGS values of each factor of Washa and Borale sites ranged from 3 to 14 and 3 to 21, respectively (Table 6). For instance, the HDGS of landscape disturbance (factor 2) were 12 and 18 for Washa and Borale sites, respectively (Table 6). SQ_hus, the total HDGSs were 67 and 80 to Washa and Borale wetlands, which in turn are referred to as mid-impacted and most impacted wetlands, respectively (Table 6). Compared with other factors, hydrological change (Factor 4) and chemical pollution (Factor 5) were high in both wetlands, besides having very high landscape disturbance (Factor 2) in Borale site (Table 6).

#### 3.4. ESs Provided by the Studied Artificial Wetlands
Using the model (Figure 2), each ES identified and provided by the studied wetlands, with their descriptions, indicators, and roles, were presented in this section (Table 7).

### Table 3: Number of households who had different land use types across the study sites.

| Study sites | Farmland plus irrigated land | Grazing land | Bush land | Wetland | No land at all | Total households, who have land |
|-------------|------------------------------|--------------|-----------|---------|---------------|---------------------------------|
|             | n %                           | n %          | n %       | n %     | n %           | n %                             |
| Washa       | 46 100                        | 20 43.5      | 7 15.2    | 16 16.3 | 0 0            | 46 100                          |
| Borale      | 48 97.9                       | 39 79.6      | 21 42.9   | 33 67.3 | 1 2            | 48 97.9                         |
| Total       | 94 98.9                       | 59 62.1      | 28 29.5   | 49 51.6 | 1 1            | 94 98.9                         |

Note. \( n \) refers to the number of household respondents, while \( \% \) stands for household percentage.

### Table 4: Major income source diversification based on the household survey in the study area.

| Study sites | Income source diversification |
|-------------|------------------------------|
|              | Farming | Livestock rearing | Fuel wood collection | Small trade | Daily labor | Total households |
|             | n %     | n %             | n %                 | n %        | n %        | n %              |
| Washa       | 25 54.3 | 25 54.3         | 13 28.3             | 8 17.4     | 0 0        | 46 100           |
| Borale      | 38 77.6 | 37 75.5         | 8 16.3              | 2 4.0      | 1 2        | 49 100           |
| Total       | 63 66.3 | 62 65.3         | 21 22.1             | 10 10.5    | 1 1        | 95 100           |

3.4. ESs Provided by the Studied Artificial Wetlands. Based on the results of the study, the major provisioning services provided by the study sites were again classified as food and raw materials.

#### (1) Food Provisioning Services
Agricultural crops, vegetables, and fish are mostly considered as food provisioning services (Table 7). Accordingly, more than 86% of the households reported that vegetables such as garlic, potatoes, and carrots with sometimes cabbages and lentils were produced in the study area (Figure 5, Tables 7 and 8). While considering those products to each study site, close to 72% and 100% of the households agreed that the local communities cultivated...
them in the surroundings and downstream irrigated land of Washa and Borale wetlands, respectively (Table 8). As also reported by key informants and observed in the field, the vegetables were cultivated in those same lands of Washa and Borale wetlands via drawing water from those reservoirs of the study sites (Figure 5).

Additionally, in the same irrigated parts of the wetlands, agricultural crops such as barley, shalom, beans, and lentils

| Land size in ha | Farm land | Bush land | Grazing land | Wetland | Other land if any |
|----------------|-----------|-----------|--------------|---------|-------------------|
|                | n     | %     | n     | %     | n     | %     | n     | %     | n     | %     |
| 0 (no land)    | 1     | 1     | 67    | 70.5   | 35    | 36.8  | 46    | 48.4  | 95    | 100   |
| ≤1             | 72    | 75.8  | 28    | 29.5   | 60    | 63.2  | 49    | 51.6  | 0     | 0     |
| 1.1–2          | 20    | 21    | 0     | 0      | 0     | 0     | 0     | 0     | 0     | 0     |
| 2.1–3          | 1     | 1     | 0     | 0      | 0     | 0     | 0     | 0     | 0     | 0     |
| 3.1–4          | 1     | 1     | 0     | 0      | 0     | 0     | 0     | 0     | 0     | 0     |
| >4             | 0     | 0     | 0     | 0      | 0     | 0     | 0     | 0     | 0     | 0     |
| Total          | 95    | 100   | 95    | 100    | 95    | 100   | 0     | 0     | 95    | 100   |

Figure 3: Partial views of Washa site during wet (a, b, c, d) and dry (e, f) seasons with the reservoir filled fully with water (a, c, d), downstream wetlands (b), surrounding wetlands with herbaceous species and birds (c–d), and cattle watering with some birds (e) and high water reduction and silt sedimentation (f), where the photos were taken at the end of the rainy season (September 2020) and in the dry season (May 2021).
were cultivated during the dry season from February to May, as reported by respondents and as practically observed by the researchers in the field (Figure 6(a)–6(c)). Roughly 57% of the households answered that the communities of the study area also cultivated and harvested those crops. Of which about 39% and 74% of the households replied as the communities of Washa and Borale wetlands cultivated and harvested them, respectively (Table 8). As also reported during FGD by the local farmers, nowadays barley, shalom, beans, and lentils were cultivated on irrigated land as crop
rotations to increase soil fertility and minimize the disease and productivity problems of the vegetables the landowners face.

Fish, introduced at the time of the establishment of the two wetlands, had also been found in both wetlands (Table 7) until the end of this study. More than 26% and 12% in *Washa* and *Borale* wetlands, respectively, and totally close to 20% of the households reported that fish was available and harvested in the study area (Table 8). All respondents, however, agreed that there was no beekeeping practiced by

| Categories and ESs | Explanation of ESs provided by the wetlands | Indicators for rating the relative importance | Role |
|--------------------|---------------------------------------------|---------------------------------------------|------|
| Provisioning services | Provision of cultivated food: vegetables (carrots, cabbage, garlic), crops (bean, barley, shalom lentils) from irrigated land, and fish from both reservoirs | Amount and number of species | Well-being, socioeconomic |
| a) Food (vegetables, crops, and fish) | Provision of fresh water for irrigation, livestock, and domestic uses from both sites | Quality and volume of water | Socioeconomic, well-being |
| b) Water supply (for irrigating, drinking, and bathing) | Fodder and grazing provision from grasses including *Typha* sp., by-products of cultivated crops | Amount and number of species | Socioeconomic |
| c) Animal fodder and grazing | Provision of thatch grasses for house roofs and *Typha* sp., *Eleusine* sp. and *Pennisetum* sp. for making house utensils, decoration and mattresses | Amount and quality of grass types | Socio-economic, well-being |
| d) Thatching and crafting materials | Provision of firewood and house construction materials from *Eucalyptus globules*, *Capersus lasianica* and *Buddleja* sp. growing in catchments Medicinal plants such as *E. globules*, *Rumex nepalensis*, *Inula* sp., *Verbacum sinaicum*, *Echinops kebeircho* for pharmaceutical and drug production | Amount and quality of wood and its products | Socioeconomic, Well-being |
| e) Construction materials and firewood | Wetlands’ green sites, water, towers, and birds used for recreational activities and ecotourism opportunities | Number of visitors and visual quality of sites | Socioeconomic |
| f) Medicinal plants | Serving as being study area for graduate students and scholars | Researchable issues (water quality, flora fauna, ecological status) | Socioeconomic |
| Cultural services | Informal and formal education/training opportunities | Number of students/trainees visited | Socioeconomic |
| a) Recreation and ecotourism | Wetlands’ green sites, water, towers, and birds used for recreational activities and ecotourism opportunities | Number of visitors and visual quality of sites | Socioeconomic |
| b) Research services | Informal and formal education/training opportunities | Number of students/trainees visited | Socioeconomic |
| c) Educational services | Informal and formal education/training opportunities | Number of students/trainees visited | Socioeconomic |
| Regulating services | The vegetation of wetlands and reservoirs regulate the water flow, runoff, and flooding, thereby recharging ground and surface water, discharging water throughout the year (for drinking and irrigation) | Continuous water flow, low runoff/flooding downstream, water quality and quantity | Environmental conservation, well-being |
| a) Water regulation | Vegetation cover prevents sheet, gully, and wind erosion Vegetation and water surface regulate the microclimate (rainfall and temperature) via evapotranspiration and sequesterate carbon being sunk | Vegetation coverage | Environmental management |
| b) Soil erosion regulation | Wetland vegetation and macro- & microorganisms use to purify waste and polluted water via digesting and absorbing them as food, thereby regulating diseases | Clean water discharging from wetlands | Well-being, environmental management |
| c) Microclimate regulation and carbon sequestration | The vegetation and reservoirs facilitate the deposition of silts in wetlands, thereby preventing sedimentation and flooding of downstream | Silt accumulation | Environmental management |
| d) Water purification and disease control | Habitat for phytoplankton and zooplanktons, wild animals, mainly birds, and vascular plants Reproduction and growth place for wild animals, including birds, fish, and zooplanktons, and wild flora | Number and volume of wild fauna and flora | Biodiversity conservation |
| Supporting services | Number and cover of young animals, seedlings | Number and cover of young animals, seedlings | Regeneration management |
the locals of the study area being supported by wetland resources.

**Raw materials.** Water, grasses, medicinal plants, firewood, and construction materials harvested within and around the study wetlands are considered as raw materials (Tables 7 and 8). Accordingly, 100%, 86%, and 51% of the households replied that the water of the study area was used for livestock watering, irrigation, and washing/cleaning of clothes (Table 8), respectively. While considering those water services provided by the two sites independently, 100% and more than 71% and 28% of the households living around Washa Wetland consumed water for livestock watering, irrigation, and cloth washing, respectively. Similarly, 100%, 100%, and >73% of the households of the Borale Wetland surroundings used water for livestock watering, irrigation, and cloth washing, respectively (Table 8). No report was made as honey and fruits were harvested for food, and water was used for human drink (Table 8).

About 99%, 38%, and 37% of the households reported that the various grass and other plant species growing in the present study area were used for fodder and grazing, thatching, and crafting work, respectively. Roughly 19% of the households used some other plant species for fuel wood; of those, more than 30% and 8% of the households in Washa and Borale wetlands were used for fuel wood (and construction) purposes, respectively. There were still other plant species used for medicinal purposes. About 32% of the households living in the surroundings of the study sites used some plant species for medicinal values (Table 8).

### 3.4.2. Cultural Services

As also reported by roughly 62%, 38%, and 34% of the households, the study area provided recreational, educational, and research services, respectively. While comparing the two studied wetlands, 97.8%, 56.5%, and 52.2% of the households replied that recreational, educational, and research services were provided by Washa site, respectively. Only 1% of the households reported that spiritual service was provided by Washa, but not from Borale Wetland.

### 3.4.3. Regulating Services

Both Washa and Borale wetlands provided regulating services, including water storing and continuous water flow, flood, sediment, and microclimate regulating (carbon sequestrating), water purification, and disease controlling services (Table 7).

### 3.4.4. Supporting Services

Biota conservation, namely, nursery and habitat services, were the main supporting services provided by the studied wetlands (Table 9). Plants
Table 8: Provisioning services provided by the study sites using the household survey.

| Provisioning services                      | Washa |       | Borale |       | Total |       |
|-------------------------------------------|-------|-------|--------|-------|-------|-------|
|                                           | n     | %     | n      | %     | n     | %     |
| Food provisioning services                |       |       |        |       |       |       |
| Vegetables                                | 33    | 71.7% | 49     | 100%  | 82    | 86.3% |
| (i) Garlic                                | 15    | 32.6% | 20     | 40.8% | 35    | 36.8% |
| (ii) Potatoes                             | 6     | 13%   | 10     | 20.4% | 26    | 27.4% |
| (iii) Carrots                             | 10    | 21.7% | 15     | 30.6% | 25    | 26.3% |
| (iv) Cabbage                              | 2     | 4.3%  | 4      | 8.2%  | 6     | 6.3%  |
| Crops                                     | 18    | 39.1% | 36     | 73.5% | 54    | 56.8% |
| (i) Bean                                  | 8     | 17.4% | 20     | 40.8% | 28    | 29.5% |
| (ii) Barely                               | 6     | 13%   | 6      | 12.2% | 12    | 12.6% |
| (iii) Shalom                              | 2     | 4.3%  | 3      | 6.1%  | 5     | 5.3%  |
| (iv) Lentils (misir in local language)    | 2     | 4.3%  | 7      | 14.3% | 9     | 9.5%  |
| Fruit                                     | 0     | 0%    | 0      | 0%    | 0     | 0%    |
| Fish                                      | 12    | 26.1% | 6      | 12.2% | 18    | 18.9% |
| Honey harvesting (bee keeping)            | 0     | 0%    | 0      | 0%    | 0     | 0%    |
| Raw material provision                    |       |       |        |       |       |       |
| Water for                                 |       |       |        |       |       |       |
| (i) Livestock drinking                    | 46    | 100%  | 49     | 100%  | 95    | 100%  |
| (ii) Irrigation                           | 33    | 71.7% | 49     | 100%  | 82    | 86.3% |
| (iii) Washing/cleaning                    | 13    | 28.3% | 36     | 73.5% | 49    | 51.6% |
| (iv) Human drinking                       | 0     | 0%    | 0      | 0%    | 0     | 0%    |
| Grass for                                 |       |       |        |       |       |       |
| (i) Fodder and grazing                    | 45    | 97.8% | 49     | 100%  | 94    | 98.9% |
| (ii) Thatching                            | 22    | 47.8% | 14     | 28.6% | 36    | 37.9% |
| (iii) Crafting (house utensils, mattresses)| 21    | 45.6% | 14     | 28.6% | 35    | 36.8% |
| Fuel wood and construction materials      | 14    | 30.4% | 4      | 8.2%  | 18    | 18.9% |
| Medicinal plants                          | 18    | 39.1% | 12     | 24.5% | 30    | 31.6% |

Figure 6: The crops, barley in Washa (a), and shalom and beans in Borale (b, c) under cultivation (Photos taken in May 2020).
like Cyperus species, C. dactylon, M. repens, and A. abyssinica were found in Washa Wetland (Figures 3(b)–3(d)). Likewise, Cyperus sp, C. dactylon, M. repens, A. abyssinica, L. tomentosa, and A. Mexican, besides wild animals (fish and many birds), were available in and around Borale wetland but less abundant, as assessed during the field survey and KI interviews. Moreover, Cyperus elegantulus Steud, Cyperus brevifolius (Rottb.) Hasskn, Eleocharis marginulata Hochst. ex Steud, Commelina diffusa Burm f., Cyperus esculantus L., Eleusine floccifolia (Forssk.) Spring, Geranium dissectum L., Cynodon dactylon L. Pres, and Adropogon abyssinica Fresen were common plants identified and conserved, among others, in the wetlands. Based on the calculation made using Sorenson Similarity index (J), the two wetlands were, therefore, similar by 0.71 or 71% in their plant composition.

3.5. The Relative Importance of ESs Provided. The provisioning of agricultural crops and vegetables and water for irrigation and cattle watering had higher importance than the other provisioning services provided by both wetlands. Still, these services mentioned here above had higher importance than the other ESs provided at the two sites (Table 9). Otherwise, almost all other provisioning services provided by both Washa and Borale wetlands had proportional/equal, ranging from very low (e.g., fish) to medium (e.g., fodder provision) importance. Yet, there was no fruit and honey production in both wetland sites (Table 9).

However, while comparing the regulating and cultural services between Wash and Borale wetlands, Washa mostly provided better (medium) regulating and cultural services than that of Borale’s (Table 9). Even though the Borale Wetland had no importance in providing spiritual and research center services, Washa site had a very low service importance (Table 9).

3.6. The Perception of Local People and Stakeholders towards the Management of Wetlands. Regarding the experiences of the local people on SWC activities for the past 10 years, the households were asked as follows: “Was there an experience of SWC activities in the catchments of the artificial wetlands for restoring them?” The majority of them (67.4%) said ‘Yes’, while the remaining ones (32.6%) said ‘No’. Almost all stakeholders were also reported as they were many experiences of SWC activities at catchment level for restoring of wetlands, despite not yet successful.

Moreover, concerning the future fate of the wetlands, approximately 74% and 90% of the households of Washa and Borale wetlands were interested in the artificial wetlands to be as they are “wetlands,” respectively (Table 10). Still, about 22% and six percent of the households from Washa and Borale sites’ communities were interested in them being “recreational center” and “forest land”, respectively. However, about 2% and 2% of the households of Washa community preferred the wetlands to be “forest” and “grazing land”, respectively. In the case of Borale Wetland, approximately 4% and 0% of the community preferred the artificial wetlands to be recreation centers and communal grazing land, respectively (Table 10).

Finally, the households and other respondents were also asked about their interest in restoring the artificial wetlands and/or their catchments in the future. The majority of them (on average, 87%) agreed to conserve them. Yet, some of the households did not have an interest in protecting the wetlands. Similarly, all KIs, stakeholders, and discussants of the FGD reported as they were interested in protecting/conserving them.

4. Discussion

4.1. Socioeconomic Condition of the Study Area. Of the total respondents for this study, the majority of them were males, which might be due to that males are mainly responsible for those activities done outside the home based on the culture of Ethiopian society. The average family size of the community of the study area, which was extended from one to nine per family, was 5.5. This family size is proportional to 4–6 family members of Amhara Regional State [10], resulting in high population growth. This population growth, in turn, could create high pressure on natural resources, i.e., intensive water consumption and encroachments towards wetlands for getting new settlements, farms, and grazing lands with their environmental unfriendly practices. Concerning age-wise, more than half (∼55%) of

| Main ESs provided by: | Washa | Borale |
|----------------------|-------|--------|
| Provisioning services |       |        |
| Food (crop, vegetation) | **** | ****  |
| Fish                  | *     | *      |
| Water for livestock drinking | **** | ****  |
| Water for irrigation   | **** | ****  |
| Water for domestic use (washing, cleansing) | ** | **    |
| Medicinal resources    | ***   | ***    |
| Crafting materials     | *     | *      |
| Honey and fruits       | Nil   | Nil    |
| Fodder/grass provision | ***   | ***    |
| Grazing services       | ***   | ***    |
| Regulating services    |       |        |
| Flood regulating       | ***   | **     |
| Maintaining water flow | ***   | **     |
| Climate regulation     | ***   | **     |
| Water purification     | ***   | **     |
| Disease control        | ***   | **     |
| Pollution regulation   | ***   | **     |
| Cultural services      |       |        |
| Spiritual celebration  | *     | Nil    |
| Recreation center      | ***   | *      |
| Educational visit      | ***   | **     |
| Research center        | ***   | Nil    |
| Supporting services    |       |        |
| Nursery site for plants and animals | *** | **    |
| Habitat for plants and animals | *** | ***   |

Note. nil refers to ‘not sure’, ‘∗’, very low, ‘∗∗’, low, ‘∗∗∗’, medium and ‘∗∗∗∗’, high importance.
the respondents were under the age category of 45–60 years old, followed by 30–45 years old, who are considered as active participants in the economy of the study area. The educational status of the respondents was also ranging from illiterate to grades 9–12, with those few holding their diplomas/degrees, of which the total literate group covered about 69%. This means the majority of the households could well write and read so that it could be simple to provide extension services of agriculture and health in the study area to improve their agricultural productivity and health standards.

Concerning the economic condition of the local people, almost all (∼99%) had farmland, followed by grazing land (62.1%) and wetlands (51.6). This shows that farmland, grazing, and wetlands are the main natural properties of the study area communities. That is why the income sources (livelihoods) of the local communities in the study area were dominated by farming (66.3%) and livestock rearing (65.3%), i.e., mixed agriculture. This agricultural economic background was also found similar in the rural areas of sub-Saharan African countries, including Ethiopia. Besides this mixed agricultural income source, fuel wood collection (22.1%) and small trade (10.5%) were additional income source activities for the communities. This implies that the main livelihoods of the communities were aided by additional income source activities to support their subsistence life. This is because both farming and livestock rearing practices are traditional and so do not productive compared to the modern ones. This report agrees with the findings of Moges et al. [9] from southern Ethiopia and of Wondie [10] from northern Ethiopia, where the local people were also engaged in additional activities like pottery making, sand, and wetland grass retailing, and daily labor. As also evidenced by many articles, agriculture is the backbone of the Ethiopian economy, contributes 47.40% to the GDP [26], and shares 83% of employment [27].

Regarding the landholding size of the communities in the study area, about 76% of them had small landholdings with ≤1 ha; 21%, from 1.1 to 2 ha, and 1%, from 2.1–3 to 3.1–4 ha per head. These all show that although 99% of the households had farmland, the majority of them had very small land size (≤1 ha per family), resulting in less income. The current report is almost similar to the report of Di Falcon and Veronesi [7], and Moges et al. [9] about land size per family of Ethiopian farmers. Similarly, only 63.2% of the total households had grazing land of ≤1 ha size per head. Likewise, close to 52% of households had their own wetlands, but with the land size still ≤1 ha. These wetlands were, therefore, pressurized by the local communities through harvesting wetland plants for fodder, thatching, and crafting materials, and using them as grazing sites during the dry season, which all led to wetland degradation. The most horrible thing is also that 71%, 37%, 48%, and 1% of the households did not have any bushland, grazing land, wetlands, and farmland at all, respectively. This smallness of the land size and the absence of land at all enforce the local farmers for encroaching wetlands and/or bushland for getting additional farmland and grazing land (or for reducing their livestock number), despite illegal. Moreover, besides these human activities, the majority of the households had a large family size (5.5, on average), resulting in increasing the total population size. Thus, the land holding and population sizes are the major factors determining the agricultural sector’s productivity and food security of the people.

As also reported during the FGD and KI interviews, smaller landholding situations were found to expose those small landholdings to repeated and intensive tillage, which resulted in depletion of nutrients, totally called land degradation. As a result, there was less agricultural production in amount and type, which aggravated the food insecurity of the communities. However, the agricultural sector is still playing a central role in poverty reduction and employment in Ethiopia [25, 27]. Thus, the need to improve the productivity of the agricultural sector is indisputable.

### 4.2. Anthropogenic Factors and Ecological Status of the Study Area

Based on the findings of the study, the two sites had almost similar artificial geographical and altitudinal settings. Additionally, human activities such as free grazing, grass harvesting, and farming within their catchments, wetland conversion, water extraction, and improper SWC activities were widely practiced in the present study area. These all are important factors leading to wetland degradation. Yet, the two wetlands were unlike in their severity of land degradation and adjacent urbanization. For instance, in Washa site, there was a buffer zone covered with grasses/vegetation up to 50 m radius, despite farming scarcely in between (Supplementary file 1e). Some parts of the catchment of this wetland were also left nontilled land. Yet, due to cattle intrusion for drinking and grazing in the catchment and buffer zone of Washa (Figure 3(e)), the water quality of Washa’s site was relatively poor than the Borale’s (Supplementary file 2). Contrarily, the farming activity in the catchment of Borale was intensive and extended to margins of the wetland, except being covered by small grazing and plantation parts in the north-east and south-east directions.

| Alternative response | Washa | | Borale | | Total |
|----------------------|--|-----------|-----------|-----------|
|                     | n | % | n | % | n | % |
| To be forest land    | 1 | 2.2 | 3 | 6.1 | 4 | 4.2 |
| To be grazing land   | 1 | 2.2 | 0 | 0 | 1 | 1.0 |
| As they are (wetlands)| 34 | 73.9 | 44 | 89.8 | 78 | 82.1 |
| To be a recreational center | 10 | 21.7 | 2 | 4.1 | 12 | 12.6 |
| Total                | 46 | 100 | 49 | 100 | 95 | 100 |

Table 10: What was your preference for the artificial wetlands to be in the future?
of the Wetland. Following this, there could be more silt loaded in Borale than Washa reservoirs. Moreover, there was more extensive wetland conversion into irrigated land at downstream of Borale (120 ha) than Washa (28 ha) wetlands. As a result, there was also more water extraction for irrigation from Borale than Washa wetlands. Those all, in turn, led to more degradation of the Borale Wetland, and its upper catchment, besides the higher water volume reduction in Borale than Washa wetlands. Many authors [9, 12], from Ethiopia and [5], from Brazil, also reported that the major factors speeding up the ecological changes in wetlands are anthropogenic activities that are continuously changing the land use in and around wetlands. Hence, the two study sites were different depending on the extent and severity of their habitat, vegetation, hydrological alterations; buffer and upper catchment landscapes; chemical stressors (Supplementary file 2). According to Campbell [28], the change of shape (landscape) and land sizes of wetlands are indicators of ecological degradation.

Accordingly, the total values of HDGSs of Washa and Borale sites were 67 and 80, which fell in the categories of mid- and most impacted wetlands, respectively. Similarly, many authors [9, 27, 29] also reported that overgrazing, agriculture, mining in and around agricultural impaired wetlands, and extraction of water for agricultural and domestic uses were the major threats to wetland degradation. According to Acreman et al. [30] and Campbell [28], changes in hydrology are the leading causes of wetland degradation. Thus, carrying out wetland inventories and assessing their extent of degradation [16] and ESs can be used to establish local or national priorities for restoration [1, 31].

4.3. The Main ESs. As revealed in the results of the study, the ESs provided by the study area were displayed and grouped into four categories as bolded hereunder.

4.3.1. Provisioning Services. The majority of the households (>86%) reported that carrots, potatoes, and garlic were the most vital agricultural vegetables produced from the irrigated land of the study sites. Thus, the farmers supplied and sold these vegetables to DBT community, thereby increasing their income for supporting their subsistence livelihoods. Besides, as reported during the FGD, when the productivity of vegetables in the irrigated land was reduced, the farmers began cultivating agricultural crops (or used crop rotation) to increase the soil fertility (locally called ‘Meker’) and minimize the diseases damaging the vegetables, which could be made to grow in the next round of cultivation. Thus, roughly 57% of the households reported that agricultural crops such as beans, barley, and shalom were cultivated in the irrigated land of Washa and Borale sites (Figure 5). Moges and his colleagues [9] also reported as crops and vegetables were provided from wetlands. Remarkably, such crop rotation practices are commonly done by Ethiopian farmers in rural areas to restore the fertility of their farmlands and diminish the diseases found in the soil. Hence, wetlands largely contribute to the livelihoods of adjacent communities and can provide incentives for their engagement in wetlands conservation [32]. Regarding fish, it was rarely harvested and used by communities, although fishery was one of the main purposes of establishing those reservoirs. That is why only <20% of the households reported as fish was found and harvested in the study area: more fish (Oreochromis niloticus and Labeobarbus Spp) was harvested from Washa (26%) than Borale (12%) wetlands (O. niloticus sp.). As also made dialogues with focus group discussants and key informants, fish was seldom harvested and used by locals due to their being very small and quantity and lack of attention for fishery management from both the local people and government sides. Similar reports were made by Estifanos [33] and Moges et al. [9] from the southern lowlands and southwestern highlands of Ethiopia, respectively. However, the use of reservoirs for aquaculture is a common practice in many countries (e.g., [5], from Brazil; [6, 29], from Ethiopia). This is because fish is the main source of protein for over a billion people globally, and 80% of the global fishery production occurs in developing countries [1]. Concerning honey and fruits, all respondents reported that there were no honey and fruit harvesting done by local communities being supported by the studied wetland resources, which might be due to the absence of suitable trees used for hanging beehives, and fruit trees and the lack of attention of the local people towards these activities. Yet, despite minor apiculture and fruits are reported from other Ethiopian wetlands [9, 10, 33].

As the results revealed, more than 50% of the households reported that water was used for livestock watering, irrigation, and cleaning of clothes. As also reported during KI interviews, FGD, and field survey, water was one of the most raw materials provided from both wetlands and was mainly used for irrigation, livestock watering, and washing. This report also agrees with the findings of Gunkel et al. [5], who reported that the water delivered from the Itaparica reservoir in Brazil is abstracted mainly for irrigation (>50% of the total usage). According to Alexander and McInnes [1], wetlands play a vital role in the delivery of water resources to human populations, including irrigation, mining, and industry. However, for drinking, the local communities did not directly use water from the reservoirs; rather, there were small groundwater hand pumps and springs developed within and/or in the peripheries of the wetlands. That is why, no households reported the importance of water for human drink. These all imply that despite understanding the limitations of the local people, those wetlands are also the main sources of domestic water use at both household and community levels. Even for domestic uses, the whole community of DBT has obtained water from large groundwater reservoirs drawn from the surrounding wetlands of DBT. Kakuru and his colleagues [32] also reported as wetlands are the main sources of natural wells, springs, artificial dams, boreholes, and shallow wells, from which local communities draw water for their domestic use.

Different grass and other plant species growing in the studied wetlands were used for fodder and grazing, thatching, and making domestic tools, as reported by
households. This finding is in line with Estifanos [33]. Andropogon abyssinica Steud, Pennisetum thunbergii Kunth, Pennisetum sphacelatum (Nees) Th. Dur. and Schinz, E. floccifolia, and Medicago lupulina L. were the plant species identified and mainly grown in both wetlands and mostly used for fodder and grazing purposes. There was also a report from Itaparica reservoir of Brazil [5] and from natural wetlands of Ethiopia [9, 10] that the use of plants for domestic use and animal feeding are possible. Some of the grasses such as T. latifolia, E. floccifolia, and P. sphacelatum were still used for crafting, i.e., making different house utensils such as locally called “Sefod”, “Agelgli”, and “Lemat” in Amharic, and other small materials used for house decoration, besides mattresses made from T. latifolia. Additionally, some plant species such as Eucalyptus globules Labill, Juniperus procera Hockst. ex Endl, and Cupressus lusitanica Mill were grown in the catchments of the study area and were used for house construction, fuel wood, and farm tools, as reported during FGD.

Similarly, close to 32% of the households living nearby the study sites used some plant species for their medicinal value. This report agrees with Estifanos [33], Moges et al. [9], and Wondie [10]. As reported during FGD, KI interviews, household, and field surveys, commonly used medicinal plants included Thymus schimperi Ronnier, Hagenia abyssinica (Bruce) J.F. Gmel, E. globules, Rumex nepalensis Spreng, Inula confertiflora A. Rich., Verbascum sinatum Benth, Vernonia amygdalina Del., Laggera tomentosa, Urtica simensis Stedel., and Echinops kebeireho. Thus, local healers have used these medicinal plants for several years to treat various human and/or livestock diseases.

4.3.2. Cultural Services. As also reported by households, the study area provided recreational, educational, and research services. Other Ethiopian wetlands also provide such services despite varying in the extent of services provided [9, 33], while comparing the two study wetlands, the recreational, educational, and research services provided by Washa site were more than Borale Wetland’s. However, little spiritual service was provided by Washa, but not by Borale Wetland. Surprisingly, the majority of the households (65.3%) living nearby Borale Wetland did not even recognize the cultural services being provided by Borale Wetland. As seen during the field survey, local young individuals and students from DBU visited the Washa Wetland in their weekends, particularly on Sundays (Supplementary file 1). Thus, Washa Wetland exceptionally provided recreational services to the surrounding communities.

4.3.3. Regulating Services. It was supposed that many households faced the problem of understanding the regulating and supporting services. Constanz et al. [8] also reported as it was difficult to perceive regulating services by individuals. Hence, the KIs and stakeholders were invited to respond to those services coupled with field visits. Hence, they reported that both wetlands provided water purification, carbon sequestration, pollination, flood, sediment, erosion, and disease regulating services (Supplementary file 3). Similar findings were also reported by many authors [10, 34, 36]. Despite supposing their limitations, it was amazing about the households’ understanding relating to the regulating services of the wetlands since they faced practically the problems of flooding, continuous water flow, sedimentation, and drought before the creation of the wetlands. However, now they could minimize those challenges due to the presence of these artificial wetlands.

4.3.4. Supporting Services. The supporting services maintain the conditions for life on Earth [37] and are the basis for the production of all other ESs. Yet, the household respondents mainly focused on wetlands’ breeding and habitat services. Consequently, they reported that plants such as C. dactylon, M. repens, Cyperus species, A. abyssinica, and others were found in both Washa and Borale wetlands with less coverage in Borale Wetland. This was because almost all the area of Borale Wetland’s catchment (Figure 6) was totally converted into farmland. However, the downstream wetland of Borale site supported different aquatic plants such as T. latifolia and Cyperus species. Moreover, wild animals such as fish (Oreochromis niloticus and Labeobarbus sp.), macroinvertebrates, and various birds Blue winged goose, Egyptian goose, Spot breasted lapwing, White-collared pigeon, Wattled ibis, and White-collared pigeon were found within the buffer zone of Washa and Borale Wetlands (Supplementary file 1). That is why this category of supporting services was replaced by refugia or habitat ones to emphasize the importance of the ecosystem in providing habitat for fauna such as migratory birds [8] and flora as well. Thus, assessing wetland vegetation is a good indicator of ecological status [38]. As the results revealed, the commonly growing plant species in both artificial wetlands were dominant, and the Sorenson’s similarity index was, therefore, high (71%). This might be due to the similarity of the wetlands in terms of their altitudinal and climatic conditions. Yet, in the reports made by Mulatu et al. [39] and Moges et al. [39] in the south and southwestern Ethiopia, the results of the similarity index among natural wetlands were very low or dissimilar.

4.4. The Relative Importance of the ESs. The relative importance of ESs was rated using repeated field visits, households, KIs, FGD, and stakeholders’ perceptions after adopting the matrix of MA [34] and Moges et al. [9]. The relative importance of the ESs provided by the study wetlands varies depending upon the extent of the ecosystem degradation: the more the ecological degradation, the less the ESs provided. Hence, the provisioning of water for irrigation and livestock drinking, vegetables, and crops had high and even higher importance than the other provisioning services provided by the two sites, which might be due to the moisture guaranteed even during the dry season. Kakuru et al. [32] from Ugandan wetlands also reported that the yields from wetland crop farming were higher. Moreover, Das et al. [40] reported that the provisioning ESs was of the highest importance, followed by regulating ESs for Tribal communities of the Barind Region in India. Different kinds of vegetables were cultivated in the two irrigated sites,
especially in the dry season, via drawing water from the artificial wetlands; thereby, they provided these vegetables to the urban people of DTB. The provisioning services of the study wetlands were the sources of medicinal plants, and fodder grasses, and the grazing area had medium and even proportional importance between the two sites. This might be because of the impairedness (devegetated) of the two sites. Contrarily, the fish, honey, and fruit provisions in the study area had very low and zero importance, respectively, which might be due to the smallness of the fish size and amount, lack of fish variety, absence of fruit and other trees used for beekeeping and lack of awareness and giving less attention from both the local people and government sides. The regulating services provided by Washa and Borale wetlands had medium and low importance, respectively, which might be related to the variation of the extent of the two wetlands’ degradation. Similarly, the cultural services, namely, recreation, research, and educational services provided by Washa site, had medium level importance, whereas those same services provided by Borale site had at low, very low, and even at zero level importance. Still, no spiritual service was provided at all by Borale, except very low by Washa. This is because the Washa Wetland is endowed with a variety of natural attractions and is preferred by endemic birds [14], whereas the Borale site was highly impaired and less accessible. However, tourism benefits from such wetlands (1) if they get attention. Generally, in Ethiopia, there are no adequate cultural services, despite using wetlands for eco-tourism activities [41]. Concerning supporting services, Washa Wetland provided better biota conservation services than Borale Wetland. This might be because Washa Wetland was relatively less impacted due to having a better buffer zone than Borale Wetland. This finding is in line with Moges et al. [9] and Wondie [10] from Ethiopia. Overall, based on the findings of the study, except for water and food provisioning services, many of the ESs provided at Washa and Borale sites were of medium and low level importance, respectively, due to their extent of variation of ecological disturbance. Beddoe and his colleagues [42] also confirmed as there have been losses of ESs due to their rapid natural ecosystem degradation since the second half of 20th C.

Relating to the wetlands’ future fate, while summing up, 82.1% of the total households of the two study sites had an interest in using them as they are “wetlands,” followed by “recreation center” (12.6%). Similar interest was heard during the interview from stakeholders. Lastly, the majority of the households and other respondents agreed to restore the artificial wetlands and/or their catchments in the future. As observed during field visits and interviews, particularly the present irrigation users were highly interested in engaging themselves in protecting the study sites because the sites provided water and livestock drinking and fodder/grazing services, besides cultivating vegetables and crops using irrigation during the dry season. The present finding agrees with Wondie’s [10] finding, who reported from the northwestern part of Ethiopia that many households are interested in participating in wetland conservation; however, Moges and his colleagues [9] from southwestern Ethiopia reported the reverse, as the community did not have an interest in conserving wetlands. This might be owing to a better awareness of the people living in the northern and central than the southern parts of the country in conserving wetlands, which in turn is due to the problem of shortage of rainfall (water) in the North and central parts of Ethiopia. This might also be due to the active involvement of NGOs and government’s experts in training local people in the North and central parts of the country, despite the similarity in the scarcity of land with large family size at country level.

5. Conclusions

To sum up, the local communities of the studied Washa and Borale artificial wetlands relied mainly on mixed farming with small land size (≤1 ha) versus large family size, which led to sustenance livelihoods and scarcity of land. Those study sites were impaired at moderately and highly, respectively, mainly due to agricultural encroachment, over-grazing, seasonality, and water abstraction. The study sites delivered different ESs. Vegetables like carrots, potatoes, and garlic and crops like beans, barley, and shalom were cultivated in the irrigated land of the study sites as food provisioning services. Of the raw materials delivered, water was the most important one provided by those two wetlands and mostly used for irrigation and livestock watering. Moreover, grasses and other species like T. latifolia, E. floccifolia, and P. sphacelatum were harvested and used for fodder, thatching, and making house utensils locally called Ageligil, Sefed and Lemat, and mattress. Additionally, the wetlands provided recreational, educational, and research cultural services, despite minor. Furthermore, they provided water purification, carbon sequestration, pollination, flood, sediment, erosion, and disease regulating services. Additionally, they served as nursery and shelter sites for all fauna, including birds and other macroinvertebrates and flora. While comparing ESs, the provisioning services (food and water) were better than the other services provided by the study area. However, the overall ESs delivered by the study sites were less, even though it was much less and/or absent in the case of fish, apiculture, and highland fruit trees. This was because both study sites were impaired, resulting in a serious
reduction of water volume, loss of biodiversity, and ecological degradation/water pollution due mainly to human factors. The respondents, however, had a positive interest in conserving wetlands in the future. The implication of all these, despite having good respondents’ perception towards conserving the study sites, the present study wetlands, especially Borale, would totally disappear after some years unless an urgent management action is taken. Therefore, for restoring the studied wetlands, in-situ and ex-situ conservation approaches are recommended.

Data Availability

The data are included in supplementary files and the result section as well.

Disclosure

Finally, a preprint has been previously published [43].

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Supplementary Materials

Supplementary file 1: Photos illustrating weekend recreation (a, b), Earth dam dismantled, tower ruined (b), a preliminary survey made in September 2020 (c), fish taken out from the reservoir (d), and birds in and around Washa, and Cyperus sp, woodlot consisting of Eucalyptus and Cupressus trees and new settlement in the catchment (e) of Washa as well as common birds living in both Washa and Borale wetlands (f). Supplementary 2. Supplementary file 2: The average water quality parameters of the study area. Supplementary 3. Supplementary file 3: The main ESs delivered by the study wetlands. (Supplementary Materials)

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