INTL J BONOROWO WETLANDS
Volume 14, Number 2, December 2024
Pages: 74-82
P-ISSN: 2775-8052
E-ISSN: 2775-8044
DOI: 10.13057/bonorowo/w140203

The status of wetlands in seasonally flooded plains in eastern part of Lake Tana, Ethiopia

AKLILU AGIDIE[1,♥], AYALEW WONDIE[1], GETACHEW BENEBERU[2]
[1]College of Agriculture and Environmental Science, Department of Fisheries and Aquatic Science, Bahir Dar University. PO Box 79, Bahir Dar, Ethiopia. Tel.: +251-583-20-9653, ♥email: aklilubet@gmail.com
[2]College of Science, Department of Biology, Bahir Dar University. PO Box 79, Bahir Dar, Ethiopia

Manuscript received: 15 September 2024. Revision accepted: 20 November 2024.

Abstract. *Agidie A, Wondie A, Beneberu G. 2024. The status of wetlands in seasonally flooded plains in eastern part of Lake Tana, Ethiopia. Intl J Bonorowo Wetlands 14: 74-82.* Understanding the challenges and conditions of wetland ecosystems has become more critical. Wetland area coverage has gone through dramatic change, and multiple anthropogenic and natural processes threaten it ever so now. To this end, the study aims to evaluate the changes in wetland area coverage from 1990 to 2022, assess their current status based on multi-influencing factors, and analyze the drivers and pressures within a Driving-Pressure-State-Impact-Response (DPSIR) framework. Data were gathered through transect walks, focus group discussions, key informant interviews, and household surveys. The wetland area's land cover change was examined using the Landsat photos retrieved from Google Earth Engine. The result indicated that wetlands were lost at a higher rate, from 0.55 to 0.17%, while cultivated land expansion has substantially increased from 87.35 to 89.71%, respectively. The primary reason for the area's changing land cover was the population's explosive growth. Decreased production, the loss of biodiversity, and land scarcity were the main drivers. To encourage soil and water conservation, farmers must be trained in sustainable land management techniques, native vegetation plantation, and the restoration of wetlands and riverbanks through thoughtful land use planning.

Keywords: Agricultural expansion, climate change, human pressure, land conversion

INTRODUCTION

Wetlands are among the world's most valuable natural resources because they support a range of ecosystem services such as water and wetland products, flood mitigation, groundwater recharge, carbon sequestration, and nutrient removal (Heckwolf et al. 2021). Despite providing a wide variety of services, they are severely threatened ecosystems on our planet. Globally, 69-75% of the inland wetlands have been lost in the 20th century. The loss of inland wetlands has also been aggravated in the 21st century (Reis et al. 2017).

The loss of inland wetlands has been aggravated in the 21st century due to the influence of anthropogenic pressures and climate change. These ecosystems have dramatically changed due to agricultural expansion, urbanization, industrial development, and unsustainable water management. Wetlands have been especially impacted by these pressures because of their vital roles in flood control, water purification, and biodiversity conservation (Wondie 2018; Kingsford et al. 2021).

With global food demand increasing, fueled in part by population growth, many wetlands are drained and given over to agriculture. Such intensive farming associated with rice paddies and other water-consuming crops utilizes vast amounts of land and water resources, which destroys the wetlands. This trend is particularly pronounced in developing countries, where wetland areas are often seen as unused land for agricultural conversion (Jamal et al. 2023).

The functioning of wetland ecosystems, biodiversity, socioeconomic vulnerability, and environmental systems are all impacted by changes in land use (Anteneh et al. 2012). The Land use/land cover (LULC) change research in wetland ecosystems has received much less attention than the importance of these changes to ecosystem health and function. Since the 2020s, many studies have used elaborate remote sensing, GIS, and spatial modeling methods to track LULC variation and its impact on wetlands (Zhu et al. 2023).

Therefore, to perform wetland status assessments of land cover change challenges, various researchers are utilizing satellite remote sensing integrated with the DPSIR (Driving forces, Pressures, State, Impacts, and Responses) approach. For instance, satellite remote sensing can provide near-real-time information on land use changes, climate conditions, and ecosystem dynamics (Gedefaw et al. 2020) that may help researchers monitor environmental conditions over time. Meanwhile, the DPSIR framework is an organized approach to understanding relationships between human activities and environmental outcomes that facilitates a holistic study of cause-and-effect pathways (Obubu et al. 2022). These two approaches together allow researchers to adjoin the benefits of satellite data at a large spatial scale with qualitative DPSIR detail, leading to more reasonable policy recommendations and environmental management strategies (Carnohan et al. 2023).

Empirical studies have explored the factors contributing to wetland loss, with many identifying several key drivers. Among these, the conversion of wetlands into agricultural land due to population growth and increased demand for food products (Obubu et al. 2022; Zekarias and Gelaw 2023), infrastructure expansion and urbanization, overexploitation of biological resources, the spread of invasive species (Assefa et al. 2023), alterations to hydrological regimes for irrigation (Gedefaw et al. 2020), and climate change have been highlighted as major threats. Collectively, these factors have been recognized as significant contributors to the ongoing degradation and loss of natural wetlands (Plain et al. 2018; Mereta et al. 2020).

In Ethiopia, research over the past two decades has extensively examined changes in LULC, including their causes and impacts on hydrology and land degradation (Mereta 2013). However, many of these studies have either been conducted in watersheds without wetlands or have classified wetlands merely as water bodies (Guelmami et al. 2023). To accurately predict environmental changes and obtain reliable land use statistics across various administrative levels, effective monitoring of wetland ecological land use is essential (Tewabe and Fentahun 2020).

Limited comprehensive information exists on the dynamics of land use and land cover surrounding seasonally flooded wetland areas. Therefore, this study aims to assess the spatiotemporal changes in the basin's wetlands over the period from 1990 to 2022 and identify the key factors contributing to wetland degradation. By conducting an LULC analysis, this research will help bridge the knowledge gap, providing valuable insights into land-use trends that can inform strategies for wetland restoration and conservation.

MATERIALS AND METHODS

Description of the study area

Lake Tana sub-basin, with its rich wetland, is found in the upper Abay basin, which is the highland freshwater body in northwest Ethiopia (Figure 1). Rainfall is unimodal, with the highest portion occurring between June and September, with a total annual precipitation of 1100 and 1530 mm (Ndue et al. 2023). The Lake Tana Basin is home to a variety of biodiversity with pervasive flora and fauna, including fish, birds, and vegetation. It comprises more than thirty islands and has numerous seasonal and permanent wetlands. The lake provides different services to the community by supplying irrigation, hydroelectric power, transportation, agricultural services, and harvested goods (Heide 2012). The biomes are in the afro-tropical highland zone groups (Mereta 2013). The two main enormous rivers, Gumara and Rib, overrun and strengthen the permanent wetlands while producing a large number of seasonal ponds. Lake Tana sub-basin wetlands have deteriorated from time to time due to heavy human involvement and a recent invasion by water hyacinth (*Eichhornia crassipes*), affecting the overall ecological integrity of the system.

Procedures

Remote sensing data and preprocessing

Land cover maps of the study area were produced from Landsat 5 TM satellite imagery for 1990 and Sentinel-2 satellite imagery for the period 2017-2022. Landsat images were garnered through the United States Geological Survey (USGS) when Sentinel-2 data was extracted from ESRI (Guelmamni et al. 2023). ArcGIS 10.2.2 software was used for analysis, and map preparation. Sentinel-2 satellite platforms supply high-resolution images, which makes them ideal for time series land-cover classification.

To maintain the correct classification, we performed a long data capture process before carrying out the segmentation and visual collection of reference data based on observations from Google Earth time lapses. By using pure pixel values, this method was able to diagnose land cover types at Landsat (30 × 30 m) and Sentinel-2 (10 × 10 m) resolution criteria (Dang et al. 2022). Reference data were compiled independently for 1990 and 2022 across a total of 1,500 points (500 more specifically dedicated to land cover class stratification). The other 1,000 points were reserved for assessing the geographical accuracy of the maps derived from this Conducting this data collection to validate classifications is an essential step in ensuring the reliability of the land cover assessments. The accuracy of the classification was assessed using randomly selected reference sample points. Overall accuracies, kappa coefficients, user's and producer's accuracies measures were calculated based on (Chaaban et al. 2022).

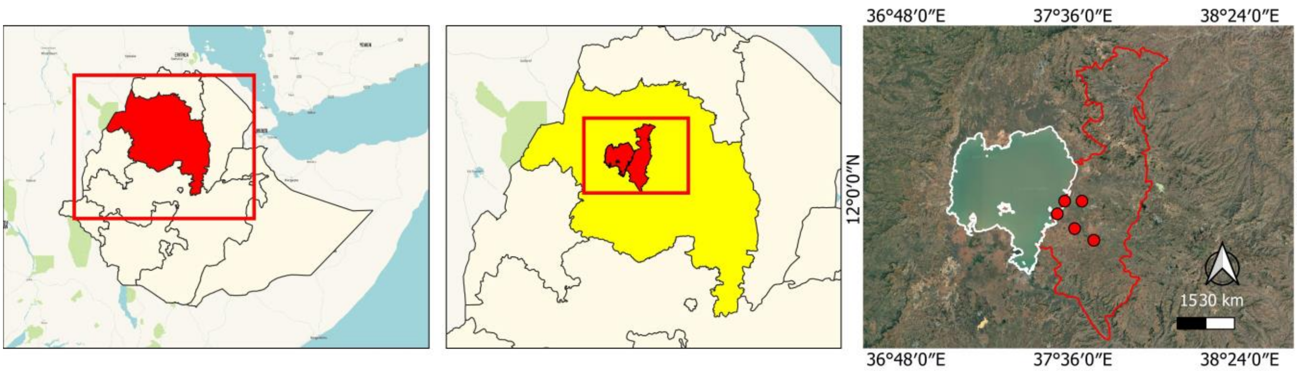

Figure 1. Map of Lake Tana sub-basin showing the study locations

Field data collection

In the study area, ground reference data were collected to validate each land cover type. Although there is no single accepted criteria for the minimum size of a sample, Karimi and Talebi (2023) suggest at least 50 samples per class, especially for regions smaller than 4,000 km^2 and having fewer than six classes. In order to attain a strong representation, samples for each of the six defined land cover categories (Assefa et al. 2021; Mulatu et al. 2024) (Table 1) were collected in at least 80 different locations. These cover types are wetland/flooded vegetation, water bodies, cultivated and grazing land, forest, settlement area, and bare/shrub land as described in (García-Álvarez et al. 2022).

Data analysis

Land cover classification

The land cover classifications for three years (1990, 2017, and 2022) were completed with supervised pixel-based classification and a maximum likelihood classifier (MLC). This technique was chosen because, under Karimi and Talebi (2023) (Gedefaw et al. 2020), it computes the statistical likelihood that a given pixel value corresponds to a specific land cover type using the regular distribution of a cloud of points and parameters. The reference data included spectral signatures for each type of land cover.

Land cover change analysis

ESRI ArcGIS 10.2.2 software was utilized to perform picture classification and image processing procedures. Calculations were made of the percentage changes for each type of land cover throughout time (Dixon et al. 2021). Gains and losses for particular classes, as well as overall and net changes in the research area, were evaluated. Furthermore, as per (Rahmawaty et al. 2022), annual change rates were computed for every kind of land cover category (Table 1).

Household survey and data analysis of DPSIR framework of land cover change

We conducted household surveys among landholder households to gain insight into the DPSIR of land cover change and to understand how the land cover situation has evolved. A two-stage sampling procedure was used to choose household respondents. A random selection of 150 household respondents was made, taking into account the total number of household respondents in each selected kebele. The sample size was calculated using the equation provided by Cochran (1977). Household respondents' perspectives on land cover dynamics were collected through a semi-structured questionnaire. Statistical tools were employed to investigate the records. Additionally, qualitative insights had been amassed from focus group discussions (FGDs) and interviews with key informants.

DPSIR frame in the identification of factors of land cover changes

The DPSIR framework was applied to apprehend the elements using land cover modifications, together with pressures and drivers, which might be critical for sustainable land control. International organizations have extensively applied the DPSIR framework (Bradley and Yee 2016).

This model helps to elucidate the interactions and interfaces that affect environmental conditions. Drivers refer to social and cultural forces that shift in response to demands for essential resources, while human actions that stress the environment can be considered drivers as well. These environmental driving forces create pressures, which include modifications in land cover. The 'State' denotes the modern-day composition of land use, which those stresses may also modify. The 'Impacts' refer to changes in land cover that affect human welfare, and 'Responses' are the actions taken in reaction to perceived land use changes. These responses can range from nearby remediation efforts to broader policy adjustments aiming to address stresses or enhance land use situations.

Changes in land cover have been diagnosed, quantified, and analyzed via classifying satellite photo time collection. The accuracy of the land cover classification supported a qualitative evaluation of the wishes, states, pressures, influences, and responses related to land cover changes within the have-a-look-at-the location.

Table 1. The land use/land cover (LULC) categories

Categories	Description
Wetland and flooded vegetation areas	Habitat comprised of marsh fields and meadows that are either seasonally or permanently inundated with water sustain hydrophytic plant life but are frequently subjected to human disruption. These habitats are vegetated wetlands, primarily of herbaceous plants and fodder grasses that develop in marshy areas along littoral areas of water bodies or massive structures.
Waterbody	Water bodies are lakes, rivers, springs, ponds, and open water located in the basin.
Cultivated and grazing lands	Land under cultivation is where annual crops, vegetables, and fruits are grown. Cattle are pastured on landscapes of grass and occasional trees called grazing lands.
Trees/Forest	The landscape comprises a mosaic of closed and open forests, shrublands, church forests (indigenous forest patches protected by Christian churches), urban trees, riverine forests, and *Eucalyptus* plantations.
Settlements	Built-up areas contain all buildings serving residential, commercial, and industrial purposes, as well as transport infrastructure like roads.
Bare/Shrubs	Since the terrain is mostly bare soil and exposed rocks in some areas, there are shrubs and isolated vegetation with small trees (almost half of the area), thorny bushes, and short shrub grasses.

Data from three acquisition years (1990, 2017, and 2022) provided valuable insights for assessing landscape conditions, land use changes, and potential management responses. The DPSIR model proves to be an effective tool for evaluating cause-and-effect relationships among the interacting elements of social, economic, and environmental systems.

RESULTS AND DISCUSSION

Land cover changes

Temporal analysis revealed that the extent and changes in land cover over the past three decades varied according to land cover type. The LULC (Land Use/Land Cover) maps for the eastern part of the Lake Tana sub-basin, spanning three reference years (1990, 2017, and 2022), are illustrated in Figure 2, and Tables 2 and 3.

In this study area, there has been a marked increase in cultivated land and settlements, while wetland and flooded vegetation areas have declined. These changes highlight the significant impact of land cover transformations on wetland ecology, as evidenced in Figures 2 and 3, and Table 3.

Between 1990 and 2017, cultivated land increased by 21,115.89 ha (5.48%), while wetland area decreased by -1,271.88 ha (-52.69%). The main cause of this change was the transformation of wetlands into pasture and agricultural land. While settlement areas increased by 11,892.13 ha (51.88%) between 2017 and 2022, wetlands and water bodies further decreased by -386.73 ha (-33.86%) and -6.93 ha, (-0.18%) respectively. As a result, between 1990 and 2022, the pace of wetland loss was -51.83 hectares per year, whereas the rate of expansion of cultivated land was 342.2 hectares per year. The rate of increase in settlement areas was 41.34 hectares per year (Table 3).

Accuracy of land cover maps

Table 4 presents the accuracy assessment for the supervised land cover classification, showing an overall accuracy of 87.1% for 1990, 86.3% for 2017, and 89% for 2022, respectively. The kappa coefficients are 0.83 for 1990, 0.83 for 2017, and 0.86 for 2022, respectively. These accuracy levels meet the required standards, making the land cover maps suitable for further analysis and change detection.

Table 2. Total land cover hectares and the percentage between 1990, 2017, and 2022

Land cover type	Area					
	1990		2017		2022	
	(ha)	%	(ha)	%	(ha)	%
Wetland and flooded veg.	2,414.08	0.55	1,142.20	0.26	755.46	0.17
Waterbody	2,007.04	0.45	3,891.10	0.88	3,884.17	0.88
Cultivated and grazing	385,623.50	87.35	406,739.38	92.01	396,573.97	89.71
Trees/Forest	8,160.42	1.85	7,177.61	1.62	6,047.90	1.37
Settlement	33,492.84	7.59	22,923.48	5.19	34,815.61	7.88
Bare/shrubs	9,793.59	2.22	207.45	0.05	3.25	0.001

Table 3. Land cover changes, net change, and rate of changes

Land cover type	Change (%)			Net change (ha)			Rate of change (ha/year)		
	1990-2017	2017-2022	1990-2022	1990-2017	2017-2022	1990-2022	1990-2017	2017-2022	1990-2022
Wetland and flooded veg.	-52.69	-33.86	-68.71	-1,271.88	-386.73	-1,658.61	-47.11	-77.35	-51.83
Waterbody	93.87	-0.18	93.53	1,884.06	-6.93	1,877.13	69.78	-1.39	58.66
Cultivated and grazing	5.48	-2.50	2.84	21,115.89	-10,165.41	10,950.48	4,485.77	-2,033.08	342.20
Trees/Forest	-12.04	-15.74	-25.89	-982.80	-1,129.71	-2,112.51	-36.40	-225.94	-66.02
Settlements	-31.56	51.88	3.95	-10,569.37	11,892.13	1,322.77	-4,095.16	2,378.43	41.34
Bare/shrubs	-97.88	-98.43	-99.97	-9,586.14	-204.20	-9,790.34	-355.04	-40.84	-305.95

Table 4. Accuracy assessment (in %) of land cover maps (1990, 2017 and 2022)

Land cover type	1990		2017		2022	
	User's accuracy calculation	Producer's accuracy	User's accuracy calculation	Producer's accuracy	User's accuracy calculation	Producer's accuracy
Wetland and flooded veg.	100	100	100	100	100	100
Waterbody	76.8	100	100	78.6	64.9	100
Cultivated and grazing	100	55.6	95.3	92.4	100	50.00
Trees/Forest	73.4	100	70.5	82.1	100	100
Settlement	100	86.4	100	94.1	100	100
Bare/shrubs	78.2	100	64.7	72.1	77.42	100
Overall accuracy	87.1		86.3		89	
Kappa statistics	0.83		0.83		0.86	

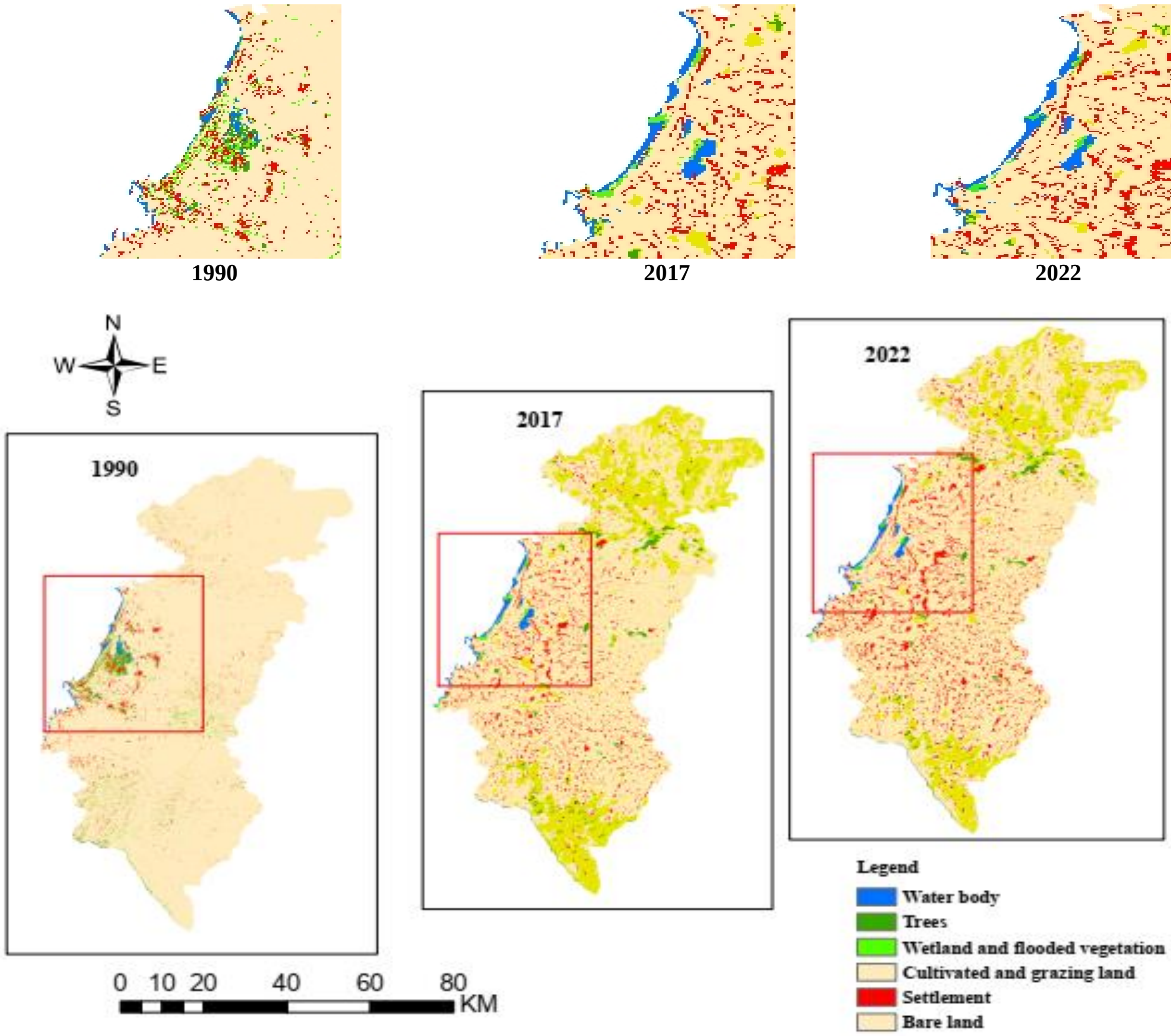

Figure 2. Land use land cover map of the study area from 1990 to 2022

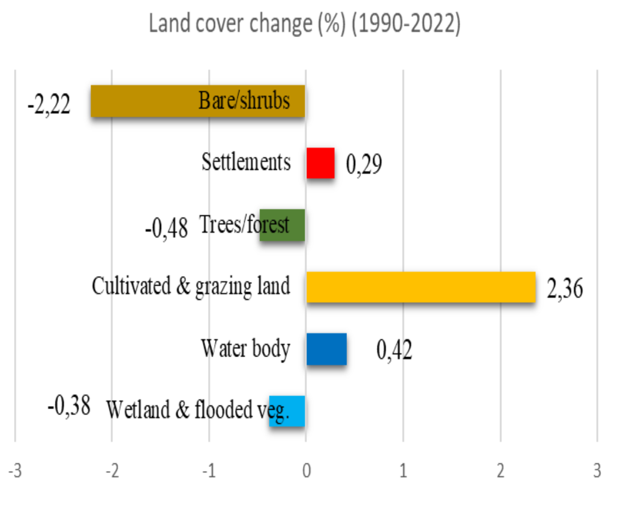

Figure 3. Land cover change of the study area over the study period

DPSIR indicators in relation to land cover change

Moreover, 81% of respondents observed a boom in cultivated land and settlements over the last 32 years. Meanwhile, 82% believed that vegetations, which includes shrubland recovery and tree planting, had additionally increased at some stage in this period. Additionally, 86% of participants noted a reduction in the area of bare land. These perceptions gathered through interviews were compared with the quantitative results from remote sensing-based land cover mapping (Figure 4).

Drivers for the change in land cover

Various factors drive land cover changes. In the research sites, the primary contributors were population growth (98.67%), a shortage of grazing land (98%), excessive land use (94.67%), reductions in farm size (70%), and climate change (66.67%) (Figure 5). The increasing populace intensifies the call for land, leading to tremendous land cover modifications through the years due to rapid human growth.

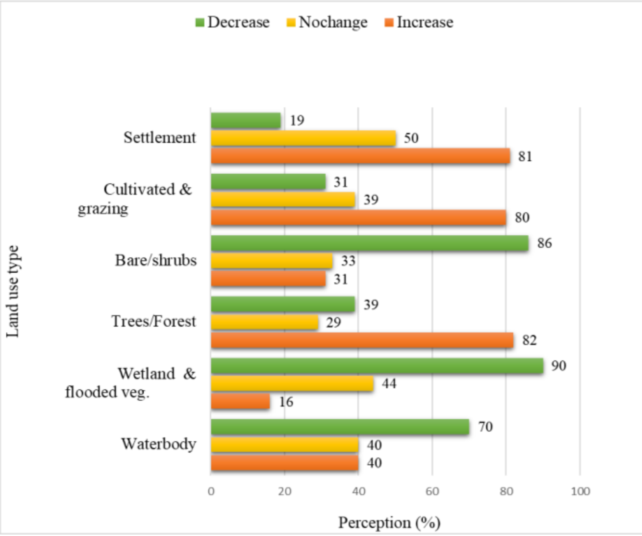

Figure 4. Respondent's perception of LULC changes for (1990-2022) (N=150)

Pressures resulting from changing land cover

According to household respondents, the pressures imposed by land use alternate highlight the need for stakeholder cooperation. These include a high demand for wetland products (98%), agricultural land demand (94.67%), seasonal flooding (78%), overgrazing (90%), competition on common land (60%), and stakeholder interests (50%) (Figure 5). The increasing population is adding more pressure on the already limited wetland resources that are now available, particularly on agricultural land, fuel wood, building supplies, and harvesting goods. The basin is under pressure because of the demand for land resources.

States of the land as a result of the change in land cover

The respondents in the study area reported the following current states (conditions) as a result of changing land cover: Change in agricultural system from animal husbandry (livestock) to cropping (94.67%); wetland degradation (85.3%), biodiversity loss (83.33%), increased land fragmentation (76.67%), poor water quality (68%), soil erosion (63.33%), rainfall variability (53.33%), loss of soil fertility (50.67%) (Figure 4). These findings underscore the importance of the audience's expertise in solving these issues. Respondents stated that the current state (condition) of land in the study area was caused by changes in land cover, including shifts from raising animals to raising crops, rainfall variability, loss of soil fertility, and soil erosion.

Impacts of land cover change

According to household respondents and as illustrated in Figure 5, the primary effects observed in the subbasin included decreased land productivity (91.33%), increased resource consumption (96%), population changes (98%), loss of biodiversity (83.33%), and reduced soil quality (74.67%). The effects of land cover change have worsened habitat loss and biodiversity fragmentation, making biological populations more liable to speculative risks due to human-brought changes in land cover.

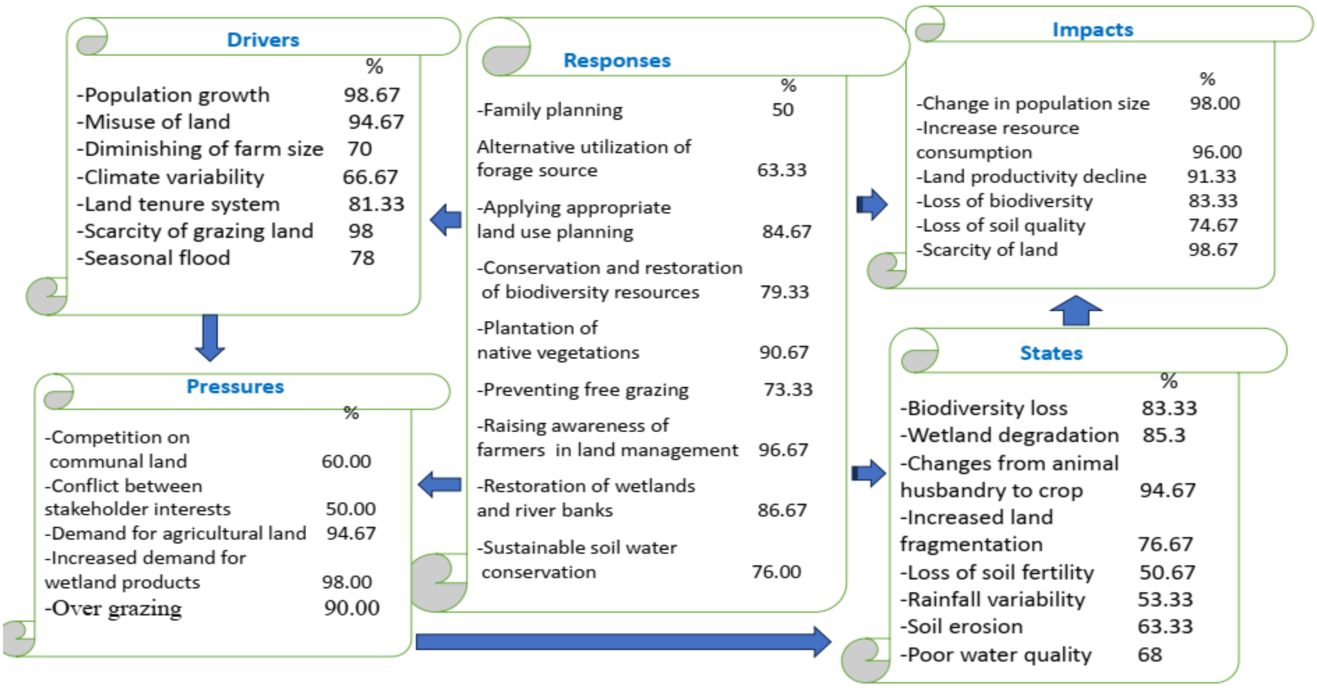

Figure 5. DPSIR framework model of land use land cover (LULC) change and respondents' reaction (%) (N=150)

Respondent's inspiration concerning the impact of the land cover change

Respondents recommended several measures to cope with land cover modifications, such as raising farmers' awareness about land management (96.67%), planting native plants (90.67%), restoring wetlands and riverbanks (86.67%), imposing effective land use-making plans (84.67%), keeping and restoring biodiversity sources (79.33%), practicing sustainable soil and water conservation (76%), preventing free grazing (73.33%), utilizing alternative forage sources (63.33%), and promoting family planning (50%) (Figure 5).

Wetlands status and major threats

Field surveys and satellite imagery have been applied to identify diverse land uses and covers, including wetlands, flooded vegetation flora, water bodies, agriculture, grazing lands, settlements, bare lands, and trees. These land covers show temporal modifications of spatial distribution.

The local community notes a decrease in wetland areas over time, which agrees with the results of satellite image investigations. They observed that the wetland had been shrinking periodically, with water being pumped and tired for irrigation to sustain crop and vegetable production in the dry season.

Wetland ecosystems face massive environmental pressures, consisting of in-depth agricultural activities, urban and rural settlement expansion, the introduction of invasive species, pollutants, climate change, human disturbances, and excessive pesticide use. These threats undermine wetland biodiversity and the critical environmental offerings, which include water purification, flood control, and carbon sequestration. Additionally, *Eucalyptus* tree plantations had been identified as extensive participants in wetland loss in some areas.

Since the 1990s, rice production in the floodplain has increased, leading to encroachment of wetland areas through agriculture and pasturing. The practice of recession agriculture, particularly within the lake's coastal region at some point in the dry season, appreciably exacerbates environmental destruction.

Discussions

Land cover changes

Various factors contribute to the dynamic changes in wetland and aquatic-framed land cover. Seasonal flooding and silt deposition from the Gumara and Rib rivers have brought about the buildup of sediment on wetlands, riverbanks, and the lake. Additionally, non-stop agricultural activities at higher and mid-altitudes inside the surrounding regions have notably degraded the wetland's pristine nature.

Land cover change maps indicate a steady decline in wetlands coverage while cultivated land and settlements have elevated. As highlighted by various researchers (Obubu et al. 2022; Zekarias and Gelaw 2023), it's clear that human activities, along with agriculture and settlement expansion and climate variability, have periodically contributed to the shrinking of wetland areas.

Between 1990 and 2022, cultivated land and settlements increased by 10,950.48 ha (0.03%) and 1,322.77 ha (0.04%), respectively. This expansion primarily resulted from the conversion of wetlands and flood-prone vegetation into farmland and residential areas. According to (Assefa et al. 2021), wetlands and water bodies have steadily diminished over the years while cultivated land has expanded significantly. Similarly, Gebresllassie et al. (2014) observed the widespread conversion of wetlands into agricultural land in various regions.

The accuracy assessment of supervised land cover classification revealed an overall accuracy of 87.1% for 1990, 86.3% for 2017, and 89% for 2022, with corresponding Kappa coefficients of 0.83, 0.83, and 0.86, respectively. These accuracy levels met the required standards for further analysis and change detection. Consistent with these findings, various studies (Gedefaw et al. 2020) confirmed that overall classification accuracy typically ranges from 86.3 to 93.4%, with Kappa coefficients between 0.83 and 0.91.

DPSIR indicators for changes in land cover

Household respondents identified several key pressures linked to changing land cover: a rise in demand for wetland resources (98%), heightened demand for agricultural land (94.67%), and overgrazing (90%). Gebresllassie et al. (2014), Mabidi et al. (2017), Obubu et al. (2022), Guelmami et al. (2023), and Karimi and Talebi (2023) have further highlighted those urgent problems.

Land use changes have exacerbated soil fertility depletion, habitat loss, and biodiversity decline, escalating the vulnerability of biological populations to potential dangers. Similar studies by Heide (2012), Mereta et al. (2020), and Zekarias and Gelaw (2023) have all confirmed these alarming findings.

According to participants, the most crucial steps to mitigate these challenges include investing in land resources, implementing effective land-use planning, and raising community awareness of sustainable land management, conservation, and rehabilitation practices. Comparable recommendations were also suggested by Plain et al. (2018) and Rahmawaty et al. (2022).

Wetlands health and major threats

The local community's observations align with the satellite image analysis, confirming the degradation of wetlands. Respondents are well aware of the diminishing wetlands, often noting that their size fluctuates. During the dry season, the local society employs irrigation by pumping and draining marsh water for crop and vegetable production. This emphasizes how the society role is very important to the preservation of wetlands (Worku 2014; Dixon et al. 2021; Fetene and Teshager 2020).

Various factors and significant environmental risks have impacted the wetland quality of Ethiopia's Lake Tana sub-basin, particularly affecting biodiversity. Wetland ecosystems face numerous threats that disrupt their ecological functions. Several studies (Worku 2014; Elo et al. 2018; Zhang et al. 2023) have identified human activities as the primary pressure on these ecosystems. Watershed degradation and *Eucalyptus* plantations are significant contributors to wetland loss in certain areas, a finding consistent with research by (Mereta 2013; Plain et al. 2018).

The major wetlands, Shesher, Welela, Sendye, Dilmo, Bebeks, littoral zones, and seasonal ponds within the basin have been declining due to natural pressures and human activities. Over time, most wetlands in the basin have experienced a decline in-depth, along with the littoral zones of lakes and riverbanks. For instance, the Shesher wetlands, which had a maximum intensity of 1.75 meters in 2012 (Anteneh et al. 2012), have now decreased to a depth of just 0.5 to 1 meter. Similarly, the Welala Wetland, although deeper than different areas with a recorded depth of 2.5 meters at some point in the wet season (Anteneh et al. 2012), has its depth decreased at most to just one meter. This decline is attributed to climate variability, human interference, and erratic rainfall patterns.

Intensive agricultural practices, such as rice farming, the spread of invasive alien species, soil and water pollution, recurrent climate variability, human disturbances, and the great use of fertilizers and insecticides in wetland crop fields, have caused massive biodiversity loss and the degradation of surroundings services in wetland ecosystems. Studies by Gebresllassie et al. (2014), Winn and Thu (2021), and Zekarias and Gelaw (2023) highlight that invasive species and climate alternates are key drivers of land degradation and wetland ecology loss.

Implementing effective land use mitigation strategies is vital to addressing those demanding situations. These encompass supervising and observing natural reserves, promoting natural revegetation, securing and safeguarding wetlands, and raising public focus through outreach initiatives. Restoring the degraded wetland ecosystems around Lake Tana is important. Implementing sustainable land use practices will mitigate degradation, even as promoting the regeneration of local vegetation and controlling invasive species will help to restore the wetlands' health.

Limitations of the study

Despite presenting treasured insights, this study has some limitations. One of the primary demanding situations turned into appropriately categorizing water bodies, wetlands, and flooded vegetations, in particular while working with 30-meter Landsat imagery, which lacked the readability needed for unique land cover identification. Differentiating wetlands from water bodies, flooded vegetations, grazing land, and newly cultivated regions proved specifically hard. Additionally, distinguishing forests from recently planted trees and restored vegetation posed further demanding situations in satellite photograph classification. These limitations may also have caused both overestimations and underestimations of certain values. Furthermore, the low resolution of the far-flung sensing pictures hindered accurate class (Karimi and Talebi 2023).

In conclusion, over the period from 1990 to 2022, the expansion of cultivated land and settlements significantly reduced wetlands and flooded vegetation. The DPSIR model was used to assess the condition of the wetland ecosystem. Scientific research and local perspectives have confirmed the changes in land use and land cover change within the basin. The net land use changes have impacted ecosystem services associated with wetlands and other land covers, driven largely by population growth and demand for agricultural land. Major drivers are the conversion of natural habitats into agricultural land as well as over-harvesting activities in wetlands that both reduce habitat availability and biodiversity levels and degrade soil quality. Overgrazing of edaphic factors, their dry season wetland drainage, and alterations in hydrology sedimentation augment the challenges. These problems are compounded when local farmers drain wetland water to both increase arable land and facilitate crop irrigation. Another major threat involves the construction of a large irrigation dam on the Ribb River, which will block waters from entering the wetlands and its connection to nearby Lake Tana, which is crucial for wetland sustainability within this part of the floodplain. The degraded and overgrazed forage of the particular landscape also indicates planting native vegetation to help improve grazing fields surrounding wetlands like *Phalaris paradoxa*. We also need to replant *Papyrus* and *Typha* around wetlands, lakes, and riverbanks. Mitigation of further degradation can be achieved by the restoration of degraded wetland ecosystems surrounding Lake Tana and sustainable land use practices; enhancing the wetlands biodiversity through restoration of native vegetation and control of invasive species. Directly planting native plants and other forms of active restoration is one way to speed up these natural processes. Similarly, the monitoring and management of water resources during dry seasons will ensure that the wetlands continue to perform their hydrological functions. Engaging and raising awareness in the community is essential for long-term success. One way to address this issue is to promote local involvement in conservation efforts and raise awareness among communities about the value of wetlands. These will be further complemented by public outreach programs aligned with and incorporated into proposals for government policies and conservation incentives.

ACKNOWLEDGEMENTS

The authors extend our gratitude to the household respondents and land use and land administration experts in the study area for their invaluable collaboration and support during the survey interviews. We also wish to express our appreciation to Bahir Dar University, Ethiopia and the Ethiopia Environment and Forest Research Institute for financing field activities.

REFERENCES

Anteneh W, Dejen E, Getahun A. 2012. Shesher and Welala floodplain wetlands (Lake Tana, Ethiopia): Are they important breeding habitats for Clarias gariepinus and the migratory Labeobarbus fish species? Sci World J 2012 (6): 298742. DOI: 10.1100/2012/298742.

Assefa WW, Eneyew BG, Wondie A. 2021. The impacts of land-use and land-cover change on wetland ecosystem service values in peri-urban and urban area of Bahir Dar City, Upper Blue Nile Basin, Northwestern Ethiopia. Ecol Process 10: 39. DOI: 10.1186/s13717-021-00310-8.

Assefa WW, Eneyew BG, Wondie A. 2023. Macroinvertebrate assemblages along a gradient of physicochemical characteristics in four riverine wetlands, Upper Blue Nile basin, Northwestern Ethiopia. Environ Monit Assess 195: 643. DOI: 10.1007/s10661-023-11243-4.

Bradley P, Yee S. 2016. Using the DPSIR Framework to Develop a Conceptual Model: Technical Support Document. US Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett. DOI: 10.13140/RG.2.1.1870.7608.

Carnohan SA, Trier X, Liu S, Clausen LP, Clifford-Holmes JK, Hansen SF, Benini L, McKnight US. 2023. Current Research in Environmental Sustainability Next generation application of DPSIR for sustainable policy implementation. Curr Res Environ Sustain 5: 100201. DOI: 10.1016/j.crsust.2022.100201.

Chaaban F, El Khattabi J, Darwishe H. 2022. Accuracy assessment of ESA WorldCover 2020 and ESRI 2020 land cover maps for a region in Syria. J Geovisualization Spat Anal 6 (2): 31. DOI: 10.1007/s41651-022-00126-w.

Cochran WG. 1977. “Sampling Techniques” 3rd eds. Wiley, New York.

Dang KB, Phan TT, Nguyen TT, Pham TP, Nguyen MH, Hoang TT. 2022. Economic valuation of wetland ecosystem services in northeastern part of Vietnam. Knowledge Manag Aquat Ecosyst (423): 12. DOI: 10.1051/kmae/2022010.

Dixon A, Wood A, Hailu A. 2021. Wetlands in Ethiopia: Lessons from 20 years of research, policy and practice. Wetlands 41: 20 DOI: 10.1007/s13157-021-01420-x.

Elo M, Alahuhta J, Kanninen A, Meissner KK, Seppälä K, Mönkkönen M. 2018. Environmental characteristics and anthropogenic impact jointly modify aquatic macrophyte species diversity. Front Plant Sci 9: 01001. DOI: 10.3389/fpls.2018.01001.

Fetene A, Teshager MA. 2020. Watershed characteristics and physico-chemical analysis of lakes and reservoirs in North Western, Ethiopia. Sustain Water Resour Manag 6 (6): 98. DOI: 10.1007/s40899-020-00457-w.

García-álvarez D, Teresa M, Olmedo C. 2022. Land Use Cover Datasets and Validation Tools. SIDALC, Cham, Switzerland.

Gebresllassie H, Gashaw T, Mehari A. 2014. Wetland degradation in Ethiopia: Causes, consequences and remedies. J Environ Earth Sci 4 (11): 40-48.

Gedefaw AA, Atzberger C, Bauer T, Agegnehu SK, Mansberger R. 2020. Analysis of land cover change detection in Gozamin District, Ethiopia: From remote sensing and DPSIR perspectives. Sustainability 12 (11): 4534. DOI: 10.3390/su12114534.

Guelmami A, Arslan D, Ernoul L 2020. Assessing the impacts of land use and land cover changes 1984-2020 on wetland habitats in the Gediz Delta (Turkey). In: Salem AB, Rhazi L, Karmaoui A (eds.). Climatic and Environmental Significance of Wetlands: Case Studies from Eurasia and North Africa. IGI Global Scientific Publishing, Hershey, PA, USA. DOI: 10.4018/978-1-7998-9289-2.ch002.

Heckwolf MJ, Peterson A, Jänes H, Horne P, Künne J, Liversage K, Sajeva M, Reusch TBH, Kotta J. 2021. Science of the total environment from ecosystems to socio-economic benefits : A systematic review of coastal ecosystem services in the Baltic Sea. Sci Total Environ 755: 142565. DOI: 10.1016/j.scitotenv.2020.142565.

Heide F. 2012. Feasibility Study for a Lake Tana Biosphere Reserve, Ethiopia. Bundesamt für Naturschutz, Bonn.

Jamal R, Kristiansen P, Kabir J, Lobry de Bruyn L. 2023. Challenges and adaptations for resilient rice production under changing environments in Bangladesh. Land 12 (6): 1217. DOI: 10.3390/land12061217.

Karimi Z, Talebi A. 2023. An integration of remote sensing and the DPSIR framework to analyze the land-use changes in the future (Case study: Eskandari Watershed). ECOPERSIA 11 (4): 319-336.

Kingsford RT, Bino G, Finlayson CM, Falster D, Fitzsimons JA, Gawlik DE, Murray NJ, Grillas P, Gardner RC, Regan TJ, Roux DJ. 2021. Ramsar wetlands of international importance-improving conservation outcomes. Front Environ Sci 9 (March): 1-6. DOI: 10.3389/fenvs.2021.643367.

Mabidi A, Bird MS, Perissinotto R. 2017. Distribution and diversity of aquatic macroinvertebrate assemblages in a semi-arid region earmarked for shale gas exploration (Eastern Cape Karoo, South Africa). PLoS One 12 (6): e0178559. DOI: 10.1371/journal.pone.0178559.

Mereta ST, De Meester L, Lemmens P, Legesse W, Goethals PLM, Boets P. 2020. Sediment and nutrient retention capacity of natural riverine wetlands in Southwest Ethiopia. Front Environ Sci 8: 00122. DOI: 10.3389/fenvs.2020.00122.

Mereta ST. 2013. Water quality and ecological assessment of natural wetlands in Southwest Ethiopia. [PhD Thesis]. Ghent University, Gent, Belgium.

Mulatu K, Hundera K, Senbeta F. 2024. Heliyon Analysis of land use/land cover changes and landscape fragmentation in the Baro-Akobo Basin, Southwestern Ethiopia. Heliyon 10 (7): e28378. DOI: 10.1016/j.heliyon.2024.e28378.

Ndue K, Baylie MM, Goda P. 2023. Determinants of rural households’ intensity of flood adaptation in the Fogera Rice Plain, Ethiopia: Evidence from Generalised Poisson Regression. Sustainability 15 (14): 11025. DOI: 10.3390/su151411025.

Obubu JP, Odong R, Alamerew T, Fetahi T, Mengistou S. 2022. Application of DPSIR model to identify the drivers and impacts of land use and land cover changes and climate change on land, water, and livelihoods in the L. Kyoga basin: Implications for sustainable management. Environ Syst Res 11: 11. DOI: 10.1186/s40068-022-00254-8.

Plain S, Chen H, Zhang W, Gao H, Nie N. 2018. Climate change and anthropogenic impacts on wetland and agriculture in the Songnen and Sanjiang Plain, Northeast China. Remote Sens 10 (3): 356. DOI: 10.3390/rs10030356.

Rahmawaty, Rauf A, Harahap MM, Kurniwan H. 2022. Land cover change impact analysis: an integration of remote sensing, GIS and DPSIR framework to deal with degraded land in Lepan Watershed, North Sumatra, Indonesia. Biodiversitas 23: 3000-3011. DOI: 10.13057/biodiv/d230627.

Rauf A, Harahap MM, Kurniawan H. 2022. Land cover change impact analysis: an integration of remote sensing, GIS and DPSIR framework to deal with degraded land in Lepan Watershed, North Sumatra, Indonesia. Biodiversitas 23 (6): 3000-3011. DOI: 10.13057/biodiv/d230627.

Reis V, Hermoso V, Hamilton SK, Ward D, Fluet-chouinard E, Lehner B, Linke S. 2017. A global assessment of inland wetland conservation status. BioScience 67 (6): 523-533. DOI: 10.1093/biosci/bix045.

Tewabe D, Fentahun T. 2020. Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. Cogent Environ Sci 6 (1): 1778998. DOI: 10.1080/23311843.2020.1778998.

Winn NA, Thu T. 2021. Effect of seasonal variation in fish species composition, abundance and diversity of Sunye Lake, Mandalay Region, Myanmar. Iran J Ichthyol 8 (3): 204-222. DOI: 10.22034/iji.v8i3.583.

Wondie A. 2018. Ecohydrology and hydrobiology ecological conditions and ecosystem services of wetlands in the Lake Tana Area, Ethiopia. Integr Med Res 18 (2): 231-244. DOI: 10.1016/j.ecohyd.2018.02.002.

Worku G. 2014. Assessment on the shrinkage and ecological importance of wetlands of Fogera Plain, North West Ethiopia. J Environ Earth Sci 4 (11): 25-32.

Zekarias T, Gelaw A. 2023. Impacts of land use/land cover change on wetland ecosystem services of Lake Abaya-Chamo Wetland, Rift Valley of Ethiopia. Geol Ecol Landsc 2023: 2202436. DOI: 10.1080/24749508.2023.2202436.

Zhang Y, Ye E, Liu F, Lai N, You X, Dong J, Dong J. 2023. The relationship between landscape construction and bird diversity: A bibliometric analysis. Intl J Environ Res Public Health 20 (5): 4551. DOI: 10.3390/ijerph20054551.

Zhang Y, Ye E, Liu F, Lai N, You X, Dong J, Dong J. 2023. The relationship between landscape construction and bird diversity: A bibliometric analysis. Intl J Environ Res Public Health 20 (5): 4551. DOI: 10.3390/ijerph20054551.

Zhu X, Jiao L, Wu X, Du D, Wu J, Zhang P. 2023. Ecosystem health assessment and comparison of natural and constructed wetlands in the arid zone of northwest China. Ecol Indicators 154 (967): 110576. DOI: 10.1016/j.ecolind.2023.110576.