Assessing Physicochemical Parameters and Trophic Status of Lake Hayq, South Wollo, Ethiopia

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Research Article

Keywords: Eutrophication, Physicochemical Parameter, and Trophic Status

Posted Date: June 13th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1723597/v1

Abstract

Lakes are one of the most important resources for human like tourism, irrigation and drinking. Hence lake water quality should be regularly monitored for better management of the water resources. The aim of the study was to assess the current physicochemical property and the trophic status of lake Hayq which is located in the norther part of Ethiopia. Using non probability with judgmental sampling method, eighteen water samples at six sampling sites were collected in pre wet season (May), wet (July) and post wet (December) of 2020. Both on site and laboratory analyze of water quality parameters were conducted. Data analyses used descriptive statix10 to summarize and analyze of the data, T-test for temporal variation and, GIS (IDW) interpolation was used for analyzing of spatial variation. The result shows, the mean value of temperature 27.3C°, turbidity 7.8NTU, SD 1.3m, pH 8.5, EC 908.83µs/cm, TDS 464.8mg/L, TP1.3mg/L, TN 21.84mg/L, DO 7.69mg/l, COD 13.33mg/l, BOD 6.40 mg/L and chlorophyll a 35µg/L. The comparison of result with fresh water guideline (EPA/USEPA) T, DO, pH and EC with in permissible limits and TDS, Tur, TP, TN, COD, BOD and CH-a was above permissible limits. The temporal variation of pollutions was statistically significant ($p<0.05$) in average dry and wet. GIS IDW interpolation shows significant color difference in spatially variation of parameters along lake shore. Trophic State index was TSI 76.7 and TLI 67.5 that indicates higher eutrophic level. Therefore, providing terrace, buffer zone, and silt trap are needed to reduce the overflow of pollution.

1. Introduction

Water resources are vital for human beings and for all ecosystems. It is essential for agriculture, manufacturing and energy production.

However, surface water pollution that is caused by excessive loading of dissolved, particulate organic matter and inorganic nutrients (C, N, and P). it has a significant problem in the world by affecting water quality, public health and ecosystem sustainability. Severity of surface water body pollution in lakes, reservoirs, estuaries, and rivers is increasing worldwide, especially in the developing countries (Li, Sha, & Wang, 2017). As a result, human health is at risk due to poor quality of water (Tessema et.al., 2020) and poor water quality also contributed to shrinking or total disappearance of ponds, lakes and wetlands (Carlson, 1977). The lake water factors contributing for human and water resources health includes temperature, aquaculture development and agriculture practices (Teklay & Amare, 2015).

Ever-increasing population, urbanization and modernization are posing problems of sewage disposal and contamination of surface waters like lakes. Various types of problems in the lake that cause nutrient enrichment, land-use change, increasing the risk of eutrophication and loss of biodiversity. Lake is naturally tourism attraction place having the fresh water and serving for various activities such as fishing, boating and recreational activities. However, its water quality is likely affected by eutrophication. Lakes under natural conditions are influenced by topography, geology and inputs through rainwater, water/rock interactions and climate variability (Liu et.al, 2019). Due to human interference, there is a change on quality and size of natural lakes, there is a change of island to peninsula and size of water bodies of lake significantly decreasing due to poor watershed management, intensification of agriculture and expansions of recreation centers like lodge construction on the shore of Lakes.

Teklay & Amare, (2015), reported that it was not potable to drink water and recommend to held regular monitoring to use water safely. lake Hayq, among the lakes in the northern part of Ethiopia, is vital for the survival of surrounding community. The community use the water for multipurpose, which includes irrigation, drinking water, recreation and fishing. Gradually, there is an increasing trend of expansion of irrigation, construction of recreation places like lodge around the shore of lake, land use change on the upstream watershed, extraction of water for drinking, cattle rearing and fatting in the upstream watershed and around Lake Shore. As the result, there is growing of macrophytes around shore of the lake and rapid change of lake water quality pollution like odor, color, taste. However, for sustainable uses of water resources and effective management, regular assessment has high priority for determination of current condition and trend. So this study was to assessing the current physicochemical of the lake water quality and evaluating the tropic status of the lake are very important.

2. Methodology

2.1 Description of the study area

The study area, Lake Hayq found in south wollo zone Amhara region in the eastern part of Ethiopia. It is 430 km far from Addis Abeba which is the capital city of Ethiopia. It is a typical example of highland Lake of Ethiopia with volcanic origin.

Table 1. Lake profile

Location	A. Elevation m.s.l	1911m
	Total Watershed Area	77 km2
	Lake Hayq Area	22.8 km2
	Mean Depth	37 m
	Maximum Depth	81 m
	Latitude	1103' N to 11018' N
	Longitude	39041' E to 390 68' E
Climate	Average Annual Rainfall	1211.4 mm
	Mean Temperature	25.9c^{o}
Land use land cover, (1972-2010)		4 % - 66 % irrigation land
Socio-economic features		206 h irrigation land ,1130 household

Different sizes and types of bushes, trees and grass cover Lake Hayq watershed. In addition, poorly managed state and predominantly community eucalyptus plantation forest is the common land cover of the watershed. Lake Hayq is totally surrounded by agricultural land, grazing land and settlement area. The socio-economic activities of the watershed area community mainly practicing mixed farming systems; cereal cropping, livestock production irrigation practice around the lakeshore, around Hayq Estifanos church and logy practice.

2.2 Study design

Field observation and reconnaissance survey were carried out to identify the sampling sites. A systematic sampling technique with non-probability with judgmental sample method was employed for design study. A preliminary reconnaissance survey was conducted to assess the existing situations of the study area. From the land uses maps, 66% of the watershed area of Lake Hayq covered by agricultural land and 28% of the watershed slope is above 12%, which exposes to erosion. Due to the land degradation and to improve crop production, there is higher agricultural fertilizer application practices by the community.

2.2.1 Selection of sampling sites

The selection of sampling points is necessary for proper analysis of surface water pollution. To make the sample more representative with respect to pollutant space and time variation. Sample point selection focus on the human activity in the lake surrounding edge (shoreline) and exposed to more pollution. The lake edge is often a region of dynamic of physical processes, having high biodiversity and, productivity. The dry and wet season sample were taken, considering as pre wet season, wet season and post wet (2020). About 18 observations totally in three moth from six sampling points in the lakeshore were taken which symbolized as SP-1 to SP-6. The water samples were collected just from the surface of the lake up to 50cm depth.

Table 2. Sample selection reason

Name site	reason to select site
SP 1 @ Monastery	wastes from manure, drinking and irrigation
SP 2 @ Minimum Impact	low human population pressure
SP 3 @ Irrigation	community use for irrigation
SP 4 @ Anqrka river	supply runoff at rain season
SP 5 @ Rikum Logy	solid waste, wastewater from recreational place
SP 6 @ Drink water/bath	Drinking/bathing, washing clothes, cattle drinking

2.3 Data collocation

In order to know the main indicators of water pollution which comprising as pressure indicators (nutrient emissions and loads), state indicators (nutrient concentrations in the water) and impact indicators describing the health of aquatic ecosystems (such as biological indicators, oxygen, chlorophyll-a concentration, and Secchi depth. Selected physicochemical water quality parameters were measured pH, temperature, turbidity, secchi depth, dissolved oxygen, conductivity, total dissolved solid, total phosphorus (TP), total nitrogen (TN), chemical oxygen demand (COD), biological oxygen demand (BOD) and chlorophyll a (Ch-a).

For the measurement of turbidity, pH, conductivity, temperature and DO were measured on-site. Whereas the rest physiochemical parameters like TP, TN, BOD, COD, chlorophyll-a, the samples were preserved using cooler icebox and transporting to BDU water quality lab analyzed immediately.

2.3.1 Sampling protocol

I. Onsite measured parameters
Portable multimeter Hanna instrument (HI98194 model) was used for measurement of physicochemical parameters (Temperature, pH, electrical conductivity, total dissolved solid, and dissolved oxygen). Standard Secchi disk of 20 cm diameter with black and white quarters used to measure Secchi depth. The chemical analyses of water, samples were carried out in Bahir Dar University water quality laboratory for total nitrogen, total phosphorus, and also biological oxygen demand and carbonaceous oxygen demand chlorophyll-a was analyzed.

II. On lab measured parameters
The total nitrogen and total phosphorus water sample was analyzed using the N tube method model 819. Chlorophyll a was analyzed using spectrophotometer placed filtered containing the

concentrated algal sample in a centrifugal tube and Chemical oxygen demand was analyzed using the Tube test. Biological oxygen demand using the sensor method was analyzed.

2.4 Method of analysis and procedures

The computer program used for data interpretation and analysis like statistix 10.0, Microsoft excel, and ArcGIS V 10.4 software.

2.4.1 Characterizing physicochemical parameter of lake Hayq

The physicochemical parameter of the lake water analysis using Statistix 10.0 for descriptive mean, maximum and minimum computation. To show the lake water physicochemical parameter of temporal variation analysis used T- test at 95% confidence interval to check statistically significant difference. It is very essential to see the lake water physicochemical parameter varies in season. The lake water quality varied monthly considerably with time, during dry and wet season (Liu et al., 2019).

ArcGIS V 10.4 Spatial Interpolation Spatial variation of physic chemical parameter measured value varied in magnitude along the sample place. But it is small lake mostly affect by complete mixing of pollutant input to whole part, so in this study used the GIS statistical analyst tools and map the spatial variation physicochemical parameter from sample point to sample point in lake shore.

2.4.2 Trophic status assessment and classification

For assessing the trophic status of waters the most-popular and useful methods are (1) based on mean concentration nutrient, means that use direct mean calculation TP, TN, Ch-a and SD. (2) based on aggregated indicators called indexes of eutrophication. This study selects two types indices as describing in literature review Chap. 2, TSI indices by (Carlson, 1977), TLI indices by (Liu et al., 2019). The main assumption that the basic factors of eutrophication are nutrients (primarily nitrogen and phosphorus). The effect of eutrophication is increasing due to chlorophyll-a, which is the result of algae biomass production by nutrient; and strongly correlated with the corresponding deterioration of water transparency (SD) (Neverova-Dziopak & Kowalewski, 2018).

I. Based on calculations of trophic indices
In these studied the selected trophic indices was developed by TSI by Robert and Carlos and TLI) was formulated by N. Burns the best method to know exact status of lake according to (Liu et al., 2019). A Trophic State Index The index is based on the relationship between the transparency of the water and biomass of the algae. The TSI value is between 0 and 100 (up to 110 in some cases). When the mass of algae is doubled, the water transparency decreases, and the TSI index value increases by 10 (Carlson, 1977).

Equation 1 Carlson Trophic State Index

TSI = 60–14.41 ln Secchi disk (meters)

TSI = 9.81 ln Chlorophyll a (μg/L) + 30.6

TSI = 14.42 ln Total phosphorus (μg/L) + 4.15

where: TSI = Carlson trophic state index ln = natural logarithm

TSIave = (TSIsd + TSIch-a + TSItp) /3

TSI values Trophic status Attributes < 30 Oligotrophic ,it means that is Clear water and has oxygen throughout the year in the hypolimnion, 30–40 oligotrophic, it means the lake will still exhibit oligotrophic, but some shallower lakes will become anoxic 40–50, Mesotrophic ,it means that water moderately clear, but increasing probability of anoxia ,50–60 Eutrophic, it is lower boundary of classical eutrophic which decrease transparency, warm water fisheries live only,60–70, eutrophic which water show dominance of blue-green algae, algal scum probable and extensive macrophytes problems 70–80, eutrophic which means show heavy algal blooms possible > 80 hypereutrophic it means the water show algal scum, summer fish kills, few macrophytes.

3. Results And Discussion

3.1 Characterization of physicochemical parameter of lake Hayq

The physicochemical water quality parameter of a lake influenced by natural conditions and poor basin management. To characterize physicochemical water quality parameter, the discussion part includes a table. The first table states that comparing the present result with previous studied result.

Table 3: - Mean ± SD result and comparison with pervious study

Descriptive Statistics at 95% CI of lake									
Parameter	Mean and range of lake Hayq wq in this studie				Previous studies				
	mean ± Std. Err	Range	Dry season Range	Wet season Range	Teklayand Amare2015	Tessema etal 2015	Tessema etal 2020	Fetahi 2010	Kebede etal 1992
T C°	27.3±2	23.54-28.9	23.8-30.4	23.0-27.8	22.84-29.5	22-27	21.8-24.7	¡	23
TUR NTU	7.77±5	2.8-18	2.1-12	4.25-29	1.26-66.1	3.95-6.9	4.5	¡	¡
SD m	1.29±0.3	0.86-1.7	0.86-1.8	0.61-1.28	-	-	3.5	2.7±0.49	1.2
pH	8.5±0.6	7.51-8.9	7.2-8.7	6.4-9.35	8.71-8.9	6.8-8.7	8.8	9.00±0.2	¡
ECμs/cm	908 ±15	889-933	867-923	907-975	916-924		420	910 ±3	¡
TDS mg/l	464±12	448-479	443-474	457-491	458-463	¡	¡	¡	¡
TP mg/l	1.26±+0.1	1-1.5	0.98-1.4	1.1-1.7	¡	¡	0.039	0.049±5.99	0.27
TN mg/l	21.84±+1.3	20.-23.9	18.-22	22-26	¡	¡	¡		¡
DO mg/l	7.7±1.1	6.-8.6	5.3-8.35	7.3-9.57	¡	¡	6.7-8	3-8.42 mg/1L	7.3-8.1
COD mg/l	13.33±1.1	12.-15	11.5-15	13.1-15.4	¡	¡	¡	¡	¡
BOD mg/l	6.4±0.7	5.5-7.5	5.5-7.6	5.6-7.5	¡	¡	¡	¡	¡
CH-a μg/l	35+20	10.6-60	8.5-51.9	14-99.97	¡	¡	4.03	12.9	13-22
wq water qulity ¡= not include in the research									

I. Temperature

In this study, the surface water temperature was measured a daytime between 6 and 9 hours. During average dry season (May, December) the temperature (C°) was maximum (30.4C°). The value in a different part of the lake and seasons are slightly changed in accordance with the interaction of the surrounding areas. To compare the result from above table with the previous study the temperature (C°) in dry range of Lake Hayq (23-30.4C°) similar with (Teklay & Amare, 2015). The mean temperature within permissible limit of fresh water guideline. The mean temperature (°C) of lake Hayq (27.28°C) was greater than other Ethiopian lake for examples mean temperature of lake Hawassa (23.5°C) and lake Chamo (26.5°C) (Abate et al., 2015). However, relatively near lake Tana 23–26°C. Factors contributing to lake Hayq high temperature value is probably lake basin expansion of deforestation activities and it is surrounded by mountains.

II. Turbidity

The highest value of turbidity during dry and wet season recorded to be 11.93,29.5 NTU respectively near to irrigation place(sp-3). It may related to the erosion loaded input to that shor line from the cultivation land, unpaved road like suspended material and nutrient, (Tibebe et.al., 2018). In cases of Rikum lodge (sp-5), it may be due to the wastewater from logy which increase the organic matter. The lowest value record on minimum impact (sp-2) because it has less disturbance and no pollutant input to that shoreline of lake. The overall mean turbidity of the lake water was 7.8NTU.

III. pH

pH of the lake Hayq water during the wet season was maximum 9.35 which is similar to Lake Tana wet season maximum 9.35. As the result show at the level of pH was not good conditions, which could be linked to the increasing of the base character. Minimum value recorded in dry season 7.2. It may be by mineral transport from the surrounding watersheds area, by rain season erosion accumulation of organic matters, from decay and decomposition forest plant, limestone, changed as carbonate and bicarbonate, calcium, magnesium, in the lake water content (Umerfaruq M, 2015). To compare result with other Ethiopian lake greater than pH 7.9 Tana, lower than lake Ziway 8.65, Hawassa 8.66 and Chamo were 8.84, as cited on (Tibebe et.al., 2018) respectively. lake Hayq water pH status can support the inhabitants of the water ecosystem the values between 4.5 and 9.5 are good to aquatic life.

IV. Electrical conductivity

Lake Hayq water EC increment was due to different source such as, increasing by the discharge of domestic and sewage wastewater enrichment of electrolytes, possibly due to the phenomenon of mineralization or weathering of sediments. Lake Hayq water may get EC from groundwater through large faults. The mean value of pH on the lake is 908µs/cm.

V. Total dissolved solid

The highest value of total dissolved solids recorded on Anqrka River in wet season was 491.5mg/l. These may be due to the surrounding watershed erosion, river input in rain season and discharge of domestic and sewage wastewater. Whereas the lower value of

TDS recorded at minimal impact was 433mg/l. It may be due to there is minimum human intervention activity and forest.

VI. Dissolved oxygen

In the lake Hayq the maximum value of dissolved oxygen was measured during wet season which is 9.57mg/L at Anqrka river (sp-4). Higher DO levels may be due to the reaeration of water from atmosphere river enter to lake, air diffusion to the water. Whereas minimum value was recorded around Rikum logy (sp-5). It may be due to the waste of organic pollution, sewage discharge, used as respiratory gas for aerobic aquatic life and in biological and chemical reactions these ideas supported by (Hailesilassie & Tegaye, 2019).

VII. Total nitrogen
According to the result at wet season highest value of TN was recorded from irrigational place (sp-3) which is 26.6mg/L. It may be due to the application of fertilizers on cultivation land and decomposition of organic matters washed off into the lake as source of nutrient loading, liv stock manure in monastery, surrounding farmer cattle fertilizer and sewage from logy. Whereas during the dry season minimum value recorded at sample point of minimum impact (sp-2) which is 18.6mg/L. It is due to nutrient enrichment of the littoral zone of the lake from anthropogenic impacts in the catchment area.

VIII. Total phosphorus
The highest value of phosphorus was recorded near site irrigation (sp-3) which is 1.7mg/l during the wet season. The concentration of phosphorus increase due to the use of fertilizer, from wastewater and detergent. It may be due to soaps to wash their clothes, for bathing as well as discharges of storm water and wastewater directly entering into the lake system supported by (Dessie, 2019).

IX. Biological oxygen demand
The highest biological demand of oxygen in the water was recorded during wet season which is 7.6mg/l on Rikum logy (sp-5). These high demand of oxygen in the water was due to the input of high amount of organic waste added in the lake by human activities which responsible for the increase in BOD. The highest biochemical oxygen which can be due to the high bacterial activity and heavy input of organic matter in the lake waterbody. As result of this study, BOD increase from the logy (sp5), and monastery (sp6) and surrounding watershed due to wastewater, dead plants and, manure. But high levels of BOD can cause severe dissolved oxygen depletion and the fish did not get enough dissolved oxygen. The overall of mean BOD lake water was 6.4mg/L.

X. Chemical oxygen demand

COD is the amount of oxygen demand to oxidant organic matter in water. During the wet season on Rikum logy (sp5) COD was recorded 15.42mg/L. it may be due to the waste water was enter to lake in the rain season. The highest value of mean COD may be due to prolong accumulation organic compounds leachates into the aquifers. The overall mean value of water COD 13.33mg/L. Comparatively very small than COD (48.73mg/L), Hawassa (Worako, 2015).

XI. Chlorophyll –a

The highest value in wet season was 99.9mg/L on irrigation place(sp-3). It might be due to the use of Nitrogen fertilizers in the agricultural fields along the shore, the upper watershed poor conservation work and effluents discharged from domestic wastes. Rikum logy, monastery deliver the wastewater effluent to lake. During the dry season, lowest value recorded on minimum impact (sp-2) which is 6.55mg/L. The overall result of the mean Cha of water samples is 35μg/l. Lake Hayq water Chlorophyll –a above the permissible level for lake both standards (0.3mg/l) (Trodd & O'Boyle, 2021).

3.2 Temporal variation of the physicochemical parameter of lake Hayq.

The lake Hayq water mean value of physicochemical parameter in May and December with July and average dry and wet season were analyzed to show the overall interaction water quality problem and aggravate trophic status lake problem. The result shows that, in December (Dry Season) Vs July (wet season) p value was less than 0.05 ($p < 0.05$). So it has statistical significant difference in all parameter. This implies there were a difference in source of pollution in July and December. In December there is no rainfall cause for runoff load to lake. So there is no external input loaded to the lake from the surrounding watershed. It shows that all physicochemical parameter temporally in in July and December. In the above table May Vs July physicochemical parameter p value is less than 0.05 ($p < 0.05$) in some parameters such as Temperature, EC, TDS, DO, TN and BOD. It implies that lake Hayq water was statistically significant difference in May and July. It implies that the physicochemical parameter varies temporally in in dry and wet season. Due to the major source of pollutant was run off load to lake from the surrounding watershed.

3.3 Spatial variation of the physicochemical parameter of Lake Hayq.

Spatial analyses are done by GIS interpolation (IDW technique) using a raster surface from CSV comma delineated excel format measured value points. As sown the figure below in wet season the highest magnitude of turbidity has been recorded on irrigation place (sp-3) and Anqrka river (sp-4). Whereas the lowest magnitude of turbidity has been recorded in minimum impact (sp-2). This implies that in sp-4 and sp-3 there was a high accumulation of nutrients, suspended material, solid waste and manure.

As shown in the map below, in dry season the results show high total nitrogen value on irrigation land area (sp-3) and the monastery (sp-1). Where as in the wet season high total nitrogen value recorded on irrigation land (sp-3) and Anqrka river (sp-4). It is due to addition of fertilizer, manure and sheet erosion input of non-point source from above watershed. To decrease TN decreasing the external load and biological activities in the lake ecosystem should have to consider.

As shown in the map below dry season result shows high total phosphorus value between irrigation land area (sp-3) and logy (sp-5). Whereas wet season result irrigation land and drinking/bathing (sp-6) sample point, it may be the distribution varied across shoreline input from detergent detergents, like (conditioner, shampoo, hand soap, body soap, solid soap) and forest leaves, fertilize and manure.

3.4 Trophic status assessment and classification of lake Hayq

The trophic status classification of water bodies is mainly determined by the level of algal biomass, total nitrogen. total phosphorus and secchi dich.

I. Trophic State Index of lake Hayq

According to Carlson, 1977, the trophic state index(TSI) of Carlson was calculated using the following formulae and Based on table 5 above mean concentration of parameter.

1. TSI for Chlorophyll-a (CA)TSI = 9.81In Ch-a (µg/L) + 30.6 = 65.5
2. TSI for Secchi depth (SD)TSI = 60-14.41In SD (m) = 57.1
3. TSI for Total phosphorus(TP) = 14.42 In TP (µg/l) + 4.15 = 107.43

TSIave, = (TSIsd + TSIch-a + TSItp)/3

CTSI may Ch-a, SD, TP, = [65.5 + 57.1 + 107.43)/3 = 76.67

The lake Hayq water pollution trophic state index using (TP), (Chl-a), and (SD) were in Eutrophic (high productivity) 70 > 76.67 < 80 The analytical results of the TSI may aggravated at irrigation place(sp-3) and Rikum logy(sp-5). It may due to the run off that comes from agricultural land and the waste water from the logy (sp-5), monastery (sp-1) and Anqerka River (sp-4) supplied pollutant to lake. TSI values indicate that Lake Hayq is found in higher eutrophic stage.

To generalize assessment of trophic level of lake Hayq water in this study using trophic indices and mean concentration results show with range eutrophic level up to hypereutrophic level .so the lake has indicator of very high amount of nutrient, and algal blooms which face water quality problem turbidity, odor, taste, growth macrophytes. It may be due to lake external pollutant loading and nature of surface outlet.

4. Conclusion

The current study evaluates the physiochemical water quality and trophic status of Lake Hayq. The parameters of water quality analyzed and examine from six sampling sites from lake surface along shoreline to shows pollution spatiotemporal variation using selected water quality lab. As This study has indicated that by comparing result with fresh water guideline T (C°), DO (mg/L), pH, EC(µs/cm) with in permissible limits and TDS (mg/L), Tur (NTU), TP (mg/L), TN (mg/L), COD (mg/L), BOD (mg/L), CH-a (µg/L) was above permissible limits. This study indicates that pollution varied temporally which was statistically significant in average dry and wet season. That indicate during wet season all sampling site has more pollution due to the runoff was loaded to the lake. The spatial variation of pollutant (GIS) indicates high in dry at Rikum logy (sp-5) and monastery (sp-1).

The trophic status of the lake water was found at the level of both in (mean concentration and trophic index method) which indicate the lake is eutrophic zone. In mean concentration, it indicates the lake was lower eutrophic. In trophic index, TLI indicate the lake is upper eutrophic and TSI indicated the Lake is hypereutrophic condition which is an indication of the presence of pollution by algae.

Finally, this research shows the lake water pollution is very high in wet and relatively low in dry season. High pollutant in wet season due to non-point source trough runoff load Anqrka river, irrigation and surrounding watershed. In dry season pollute in logy and monastery due to domestic and other human waste enter to lake. So it need controlling of non-point sources along the Lake basin and this could be done by encouraging farmers to use soil and water conservation measures like terracing, growing tree, use of organic fertilizer and apply inorganic fertilizer after the crop cover land to protect soil erosion. Unless the lake water may be dead in recent decade with non-point load siltation in all direction even if it has high depth.

Declarations

Author Contributions: M.A conceived and developed the research framework. M. A., M.A, and T.D undertook the data processing and analysis. T.D., G.M., and S.E. wrote and revised the manuscript. T.D. supervised and revised the manuscript. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The author declares no conflict of interest.

Availability of data and material

All data generated and analyzed during this study are included in this published article.

Funding statement: -There is no funding Agency

Acknowledgments: The research was implemented under a collaborative partnership with the Bahir Dar University so the authors are would like to thank to these organizations for the financial and other support during this work. We also acknowledge the anonymous reviewers, whose comments greatly improved the paper.

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Figures

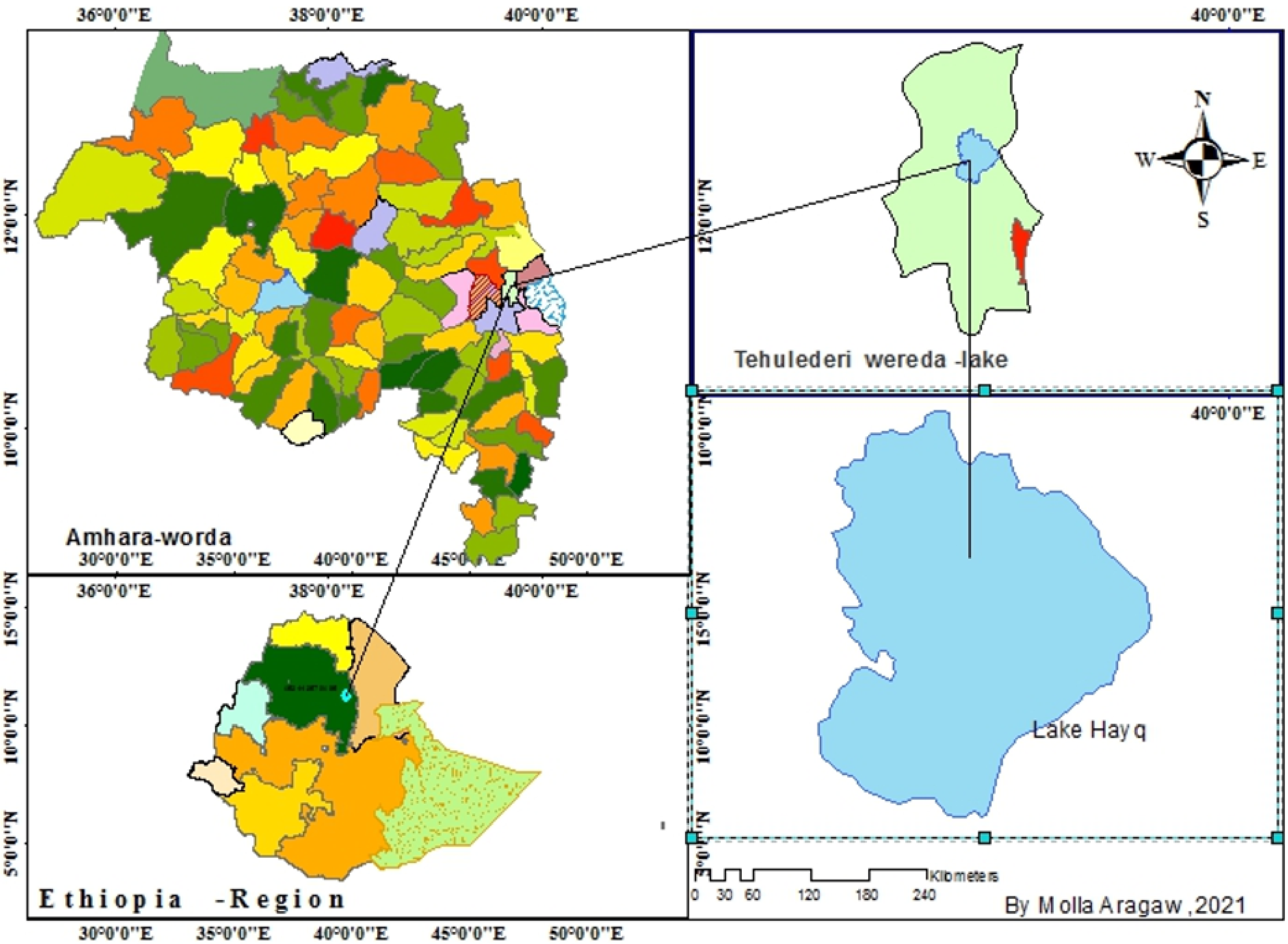

Figure 1

Location Map of the Study Area

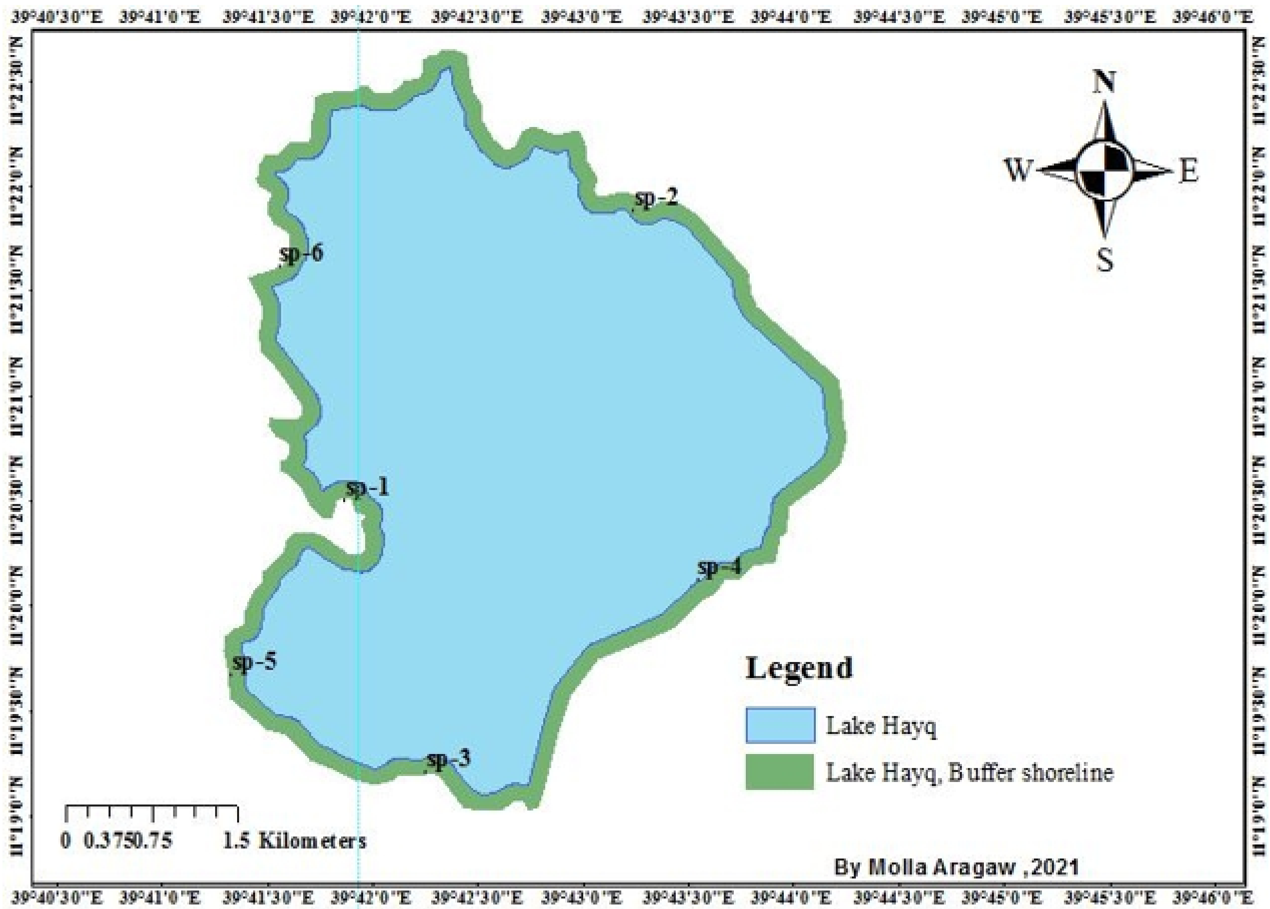

Figure 2

Sample point on map

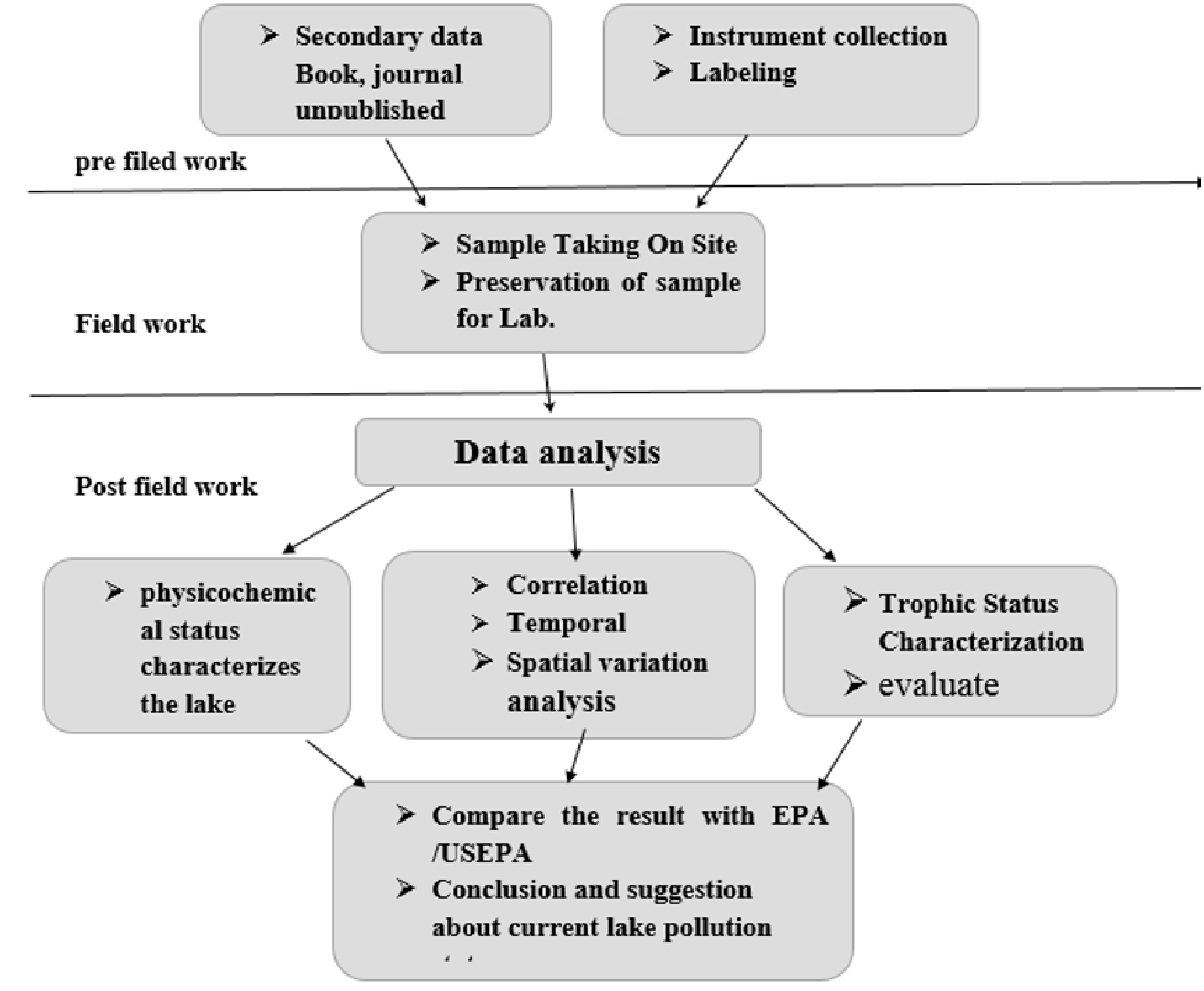

Figure 3

General framework of the study

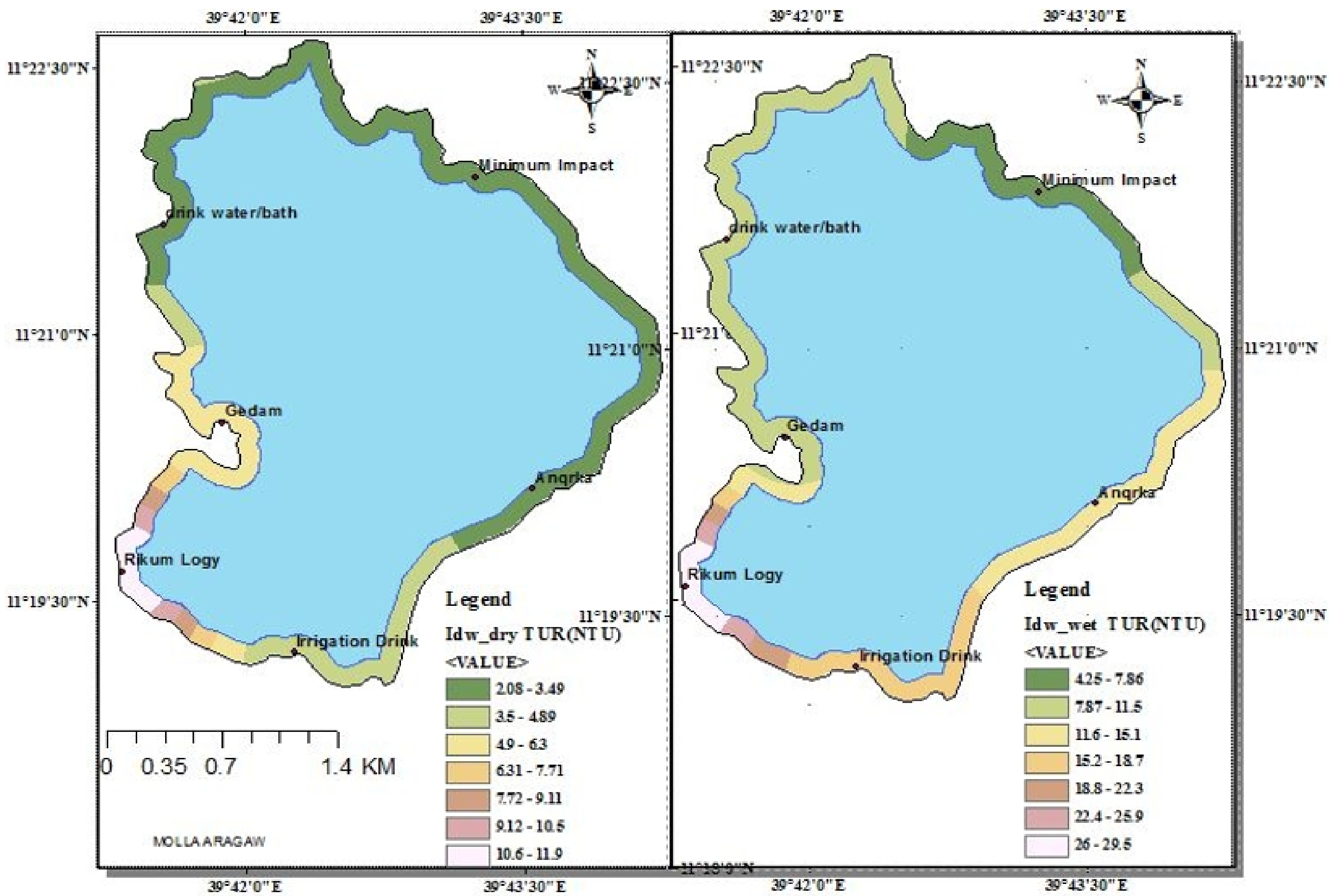

Figure 4

Turbidity spatial map

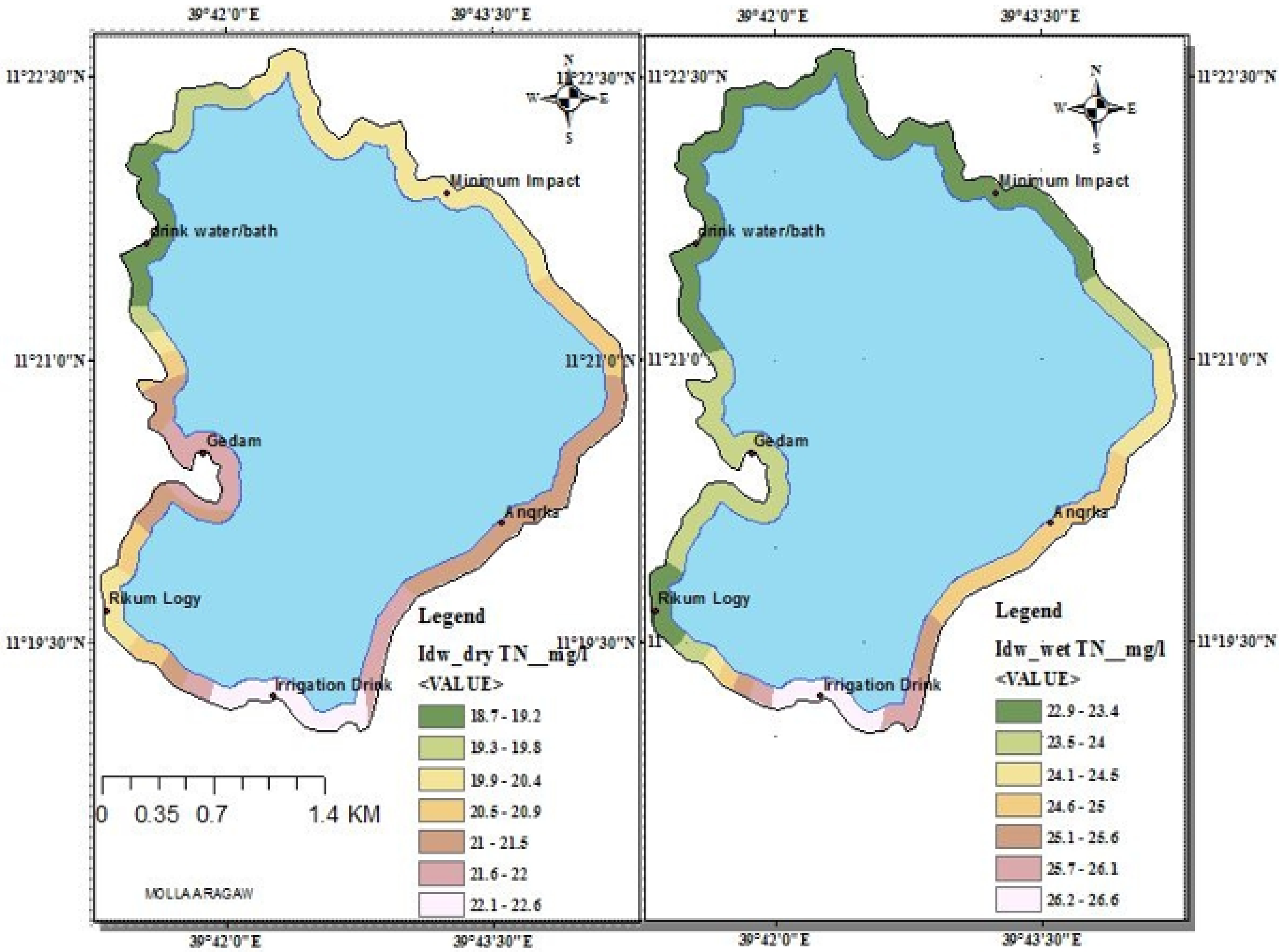

Figure 5

Total nitrogen spatial map

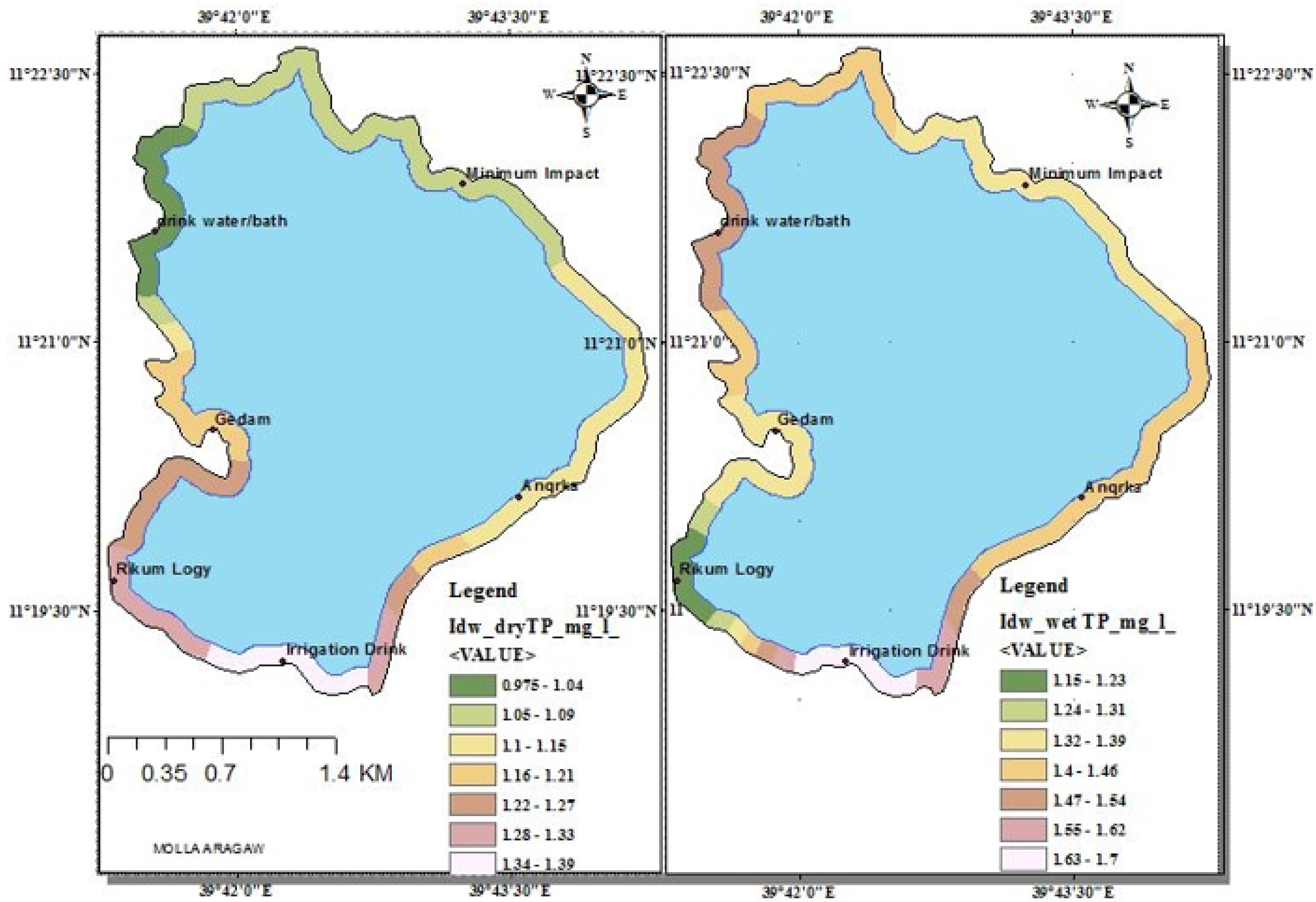

Figure 6

Legend not included with this version