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ORIGINAL ARTICLE

Evaluate the hydro-geochemical characteristics of Selamko farm reservoir water quality and its potential for multipurpose uses in Debre Tabor, Ethiopia using GIS-based water quality indices

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Abstract
Surface water pollution is a global problem and has been evident for a long period of time. Hence, the aim of the study was to evaluate the hydro-geochemical characteristics of Selamko farm reservoir water quality and its suitability for multipurpose uses using GIS-based water quality indices. The water sampling sites and parameters were selected systematically based on the land use, land cover, and anthropogenic activities around Selamko reservoir watershed in Debre Tabor, Ethiopia. Water samples were collected from 11 sampling stations from July 2019 to March 2020 using the composite sampling method and examined using standard procedures. The suitability of the reservoir's water quality for multipurpose use was investigated using drinking and irrigation water quality indices, and other tools. The spatial distribution maps of water quality parameters were prepared using the kriging method in ArcGIS 10.5. The results of the geospatial analysis indicated that the reservoir water quality parameters had spatial variation, which was caused by industrial and household wastewater inflow across the reservoir's watershed. Based on WHO and ES standards, the computed drinking water quality index results revealed that 81.81% and 18.18% of the reservoir's water quality fall into the poor to very poor classes, which indicates that the water in the reservoir is not fit for drinking. However, a Wilcox diagram, irrigation indices, and USEPA regulations revealed that the reservoir water quality is found to be safe and suitable for irrigation, fishing, and livestock purposes. The study concluded that Selamko reservoir's water quality is suitable for irrigation, fishing, and livestock watering with proper management accordingly.

Keywords Hydro-geochemical · Multipurpose uses · Surface water pollution · Water quality · Water quality index · Selamko reservoir

Introduction

Ethiopia is categorized as a developing country in sub-Saharan Africa. Agriculture is a major contributor to the country's economy, which in turn relies on the availability of seasonal rains (Yalew et al. 2018). Ethiopia is known as Africa's water tower, and it is home to a diverse range of aquatic habitats, including a number of lakes and man-made reservoirs that are both scientifically and economically important (Asres 2016; Yigezaw et al. 2019). Inland waterways cover 8,800 square kilometers in Ethiopia, making up about 0.72 percent of the country's total surface area (Berhane et al. 2016). The country has 124.4 billion cubic meters of surface water, 30 billion cubic meters of ground water, and 70 billion cubic meters of lake water (Berhanu et al. 2014). However, previous Ethiopian experiences sparked ideas for how to manage surface water resources in order to

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meet the growing demand for agricultural products (Aragaw and Gnanachandrasamy, 2021).

The population of the country is rapidly increasing, and infrastructure demands have grown in lockstep (Razack et al. 2020). According to several studies, the country's economy has grown by double digits over the last two decades, necessitating more surface water abstraction not only for agriculture but also for hydropower generation, water supply, fisheries, and recreation in order to provide adequate opportunity for the economy's long-term growth (Ahrens et al. 2016; Anteneh et al. 2018; van der Zwaan et al. 2018). Ethiopia has constructed many hydraulic structures in recent years and plans to construct many more in the future to accommodate the country's growing demand for electricity, water, and recreation (Desta and Belayneh 2021; Zeinalzadeh and Rezaei 2017). An increasing human population, unregulated urbanization, and inadequate sanitary infrastructure, on the other hand, are causing substantial quality deterioration of surface water in Ethiopia (Lasage et al. 2015). As a result, water quality is heavily influenced by various contaminant sources in practically every section of Ethiopia (Teklu et al. 2021).

These point sources of pollutants discharged by drainage pipes of industries, waste water treatment facilities, factories, and power plants are key contributors to the country's declining surface water quality (Awoke et al. 2016; Zinabu et al. 2018). Non-point sources such as those discharged by mining, forestry, and agriculture are also a source of pollution for surface water quality (Angello et al. 2020; Mekuria et al. 2021). In general, these point and non-point sources of pollution alter the physical, chemical, and biological composition of surface water quality, which has a negative impact on Ethiopia's decent water ecology (Hasan et al. 2019; Chen et al. 2019). Surface water pollution is a serious environmental concern around the globe today, rendering water unsuitable for various purposes and harming socioeconomic activities as well as the structural biodiversity of various water sources (Saha and Paul 2018).

Different evaluation methods were used to determine the suitability of surface water quality. Individual water quality parameters were compared to their specific guideline or standard values for assigned water applications in the classic water quality suitability evaluation technique. This type of evaluation is simple and thorough, but it is useless in producing a complete and understandable picture of water quality, particularly for managers and decision-makers who need quick access to information regarding water bodies (Gao et al. 2020). In such conditions, the water quality index (WQI) is a useful tool for determining the overall health of water resources. WQI uses mathematical techniques to convert water quality parameter values into a numerical score, which is then used to represent the overall state of water bodies (Ewaid and Abed 2020). The WQI is the most effective approach for assessing the quality of the surface or ground water and deciding whether or not to utilize the water resources.

The most acceptable and relevant approach for evaluating the contamination status of surface water quality is the weighted arithmetic water quality index (Noori et al. 2019; Dutta et al. 2018; Misaghi et al. 2017). It is most likely because it incorporates data from several water quality factors into a mathematical equation that assesses the health of water and represents the combined effect of various parameters (Bora and Goswami 2017; Ewaid and Abed 2017). The weight arithmetic index approach was used in this study to evaluate the water quality of a man-made reservoir by condensing complex scientific data regarding a number of water quality criteria into a single, dimensionless score.

Selamko Farm Dam is a man-made reservoir in Debre Tabor, Ethiopia that was developed for agricultural production. The reservoir has been used by the communities for a variety of purposes, including domestic use, fishing, and animal watering, due to its accessibility and the lack of other water supply sources in the district. These days, natural, climatic, and geological variables, in combination with human factors, may have a considerable impact on the reservoir's water quality (Wassie and Melese 2017; Shiferaw and Abebe 2021).

To date, only a few studies have been conducted to determine if the Selamko Farm Dam reservoir water quality is suitable for multipurpose use (Wassie and Melese 2017). As a result, the aim of the research is to offer basic data for establishing the reservoir's water quality pollution status and evaluating its suitability for drinking, irrigation, and aquatic life using drinking and irrigation water quality indices.

Materials and methods

Description of the area

Selamko reservoir is located (38° 05′ 43″ east latitude and 11° 53′ 24″ north longitude) in Farta Woreda, South Gondar Zone and 3 km from the Ethiopian town of Debre Tabor. In 2005, it was constructed across the Selamko River. The reservoir has a surface area of 0.116 km^2 and a total capacity of 1.03 Mm^3 of water storage (Moges et al. 2018). The location of the research area is depicted in Fig. 1. The reservoir was constructed to irrigate around 63 hectares of nearby farmland. There were 161 beneficiaries in the reservoir, 114 of whom were members, and 47 of whom were not, because they were ignorant of the association's responsibilities.

The mean total rainfall for the year was 1521 mm and the mean monthly rainfall varied from 0.6 (January) to 415 mm (July). The mean annual temperature of the study area is 16.23 °C (ranging from 9.2 to 23.26 °C in the wet and dry

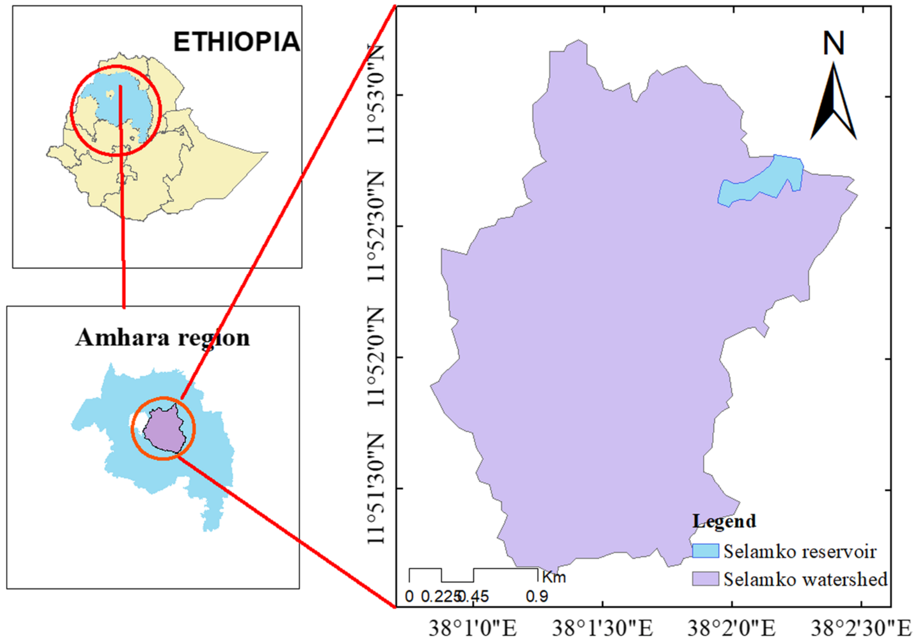

Fig. 1 Map of the study area

seasons, respectively). According to the climatological classification of Ethiopia, Debre Tabor is located inside the "Woina Degas agro-ecological zone (Wassie and Melese 2017). The research area's geography ranges from hilly to foot plains, with a height of 2513 m above sea level. The majority of the mountainous land is prone to erosion as a result of the destruction of the current plant cover for farming. Streams run through the research region, both seasonal and permanent. The Selamko watercourse is the reservoir's only perennial river. Waste from slaughterhouses, pig husbandry, solid waste dumping sites upstream of the reservoir and other sources is collected and diverted by the seasonal and permanent streams.

Land use land coverage characteristics of Selamko Watershed

Land use and land cover in the watershed are crucial for water quality. It was used to locate both point and non-point sources of pollution. Diverse types of land use and cover have an impact on the quality of water in various sources. The Selamko watershed's land use and cover classifications are shown in Fig. 2. The 2019 Landsat-8 imageries were used to create the land use/cover map, which can be downloaded from the USGS Earth Explorer website at http://earthexplore.usgs.gov. In the study, watersheds were predominantly categorized using the ERDAS Imagine tool. In this study, the watershed's land use/cover was divided into the following five categories: urban land, agricultural land, forest, marshy regions, rural villages, and grassland and water bodies. Table 1 lists the detailed land use land/cover classes and types of pollutants in the study area.

Water sampling points

The water sampling sites on the reservoir were chosen after considering the present land use/cover and human activities in the Selamko watershed. The current study chose water sample sites in the reservoir using a combination of purposive and random sampling procedures. Nine sample stations were chosen at random from a total of eleven depending on the pollution source in the reservoirs. The geographic location of the water sample locations in the reservoir is shown in Table 2. Near the reservoir's midpoint, the final two sample locations (S8) and (S9) were picked at random. The effect of pollutants was measured from the place of application to the reservoir's center using these locations. The location of sampling points was determined using a global positioning system (GPS) (Model: GPS map 76 CSx), and its geographical distribution is presented in Fig. 3.

Grab water samples were collected once a month during a four-month period with appropriate seasonal representation among all sites from July 2019 to March 2020. Specifically, surface water samples were taken in the months of July, August, December, and March because the reservoir was being utilized for irrigation at the time. Each point was sampled by holding the collecting container and lowering it to a depth of 30 cm in the surface reservoir water. The data was gathered using a checklist that had been developed ahead of time. The water quality analysis materials and accessories were calibrated according to the manufacturer's instructions and the required accessories. A high-quality polyethylene sample collecting bottle with a tight cap was extensively cleansed with nitric acid and then rinsed multiple times with distilled water. The collected water samples

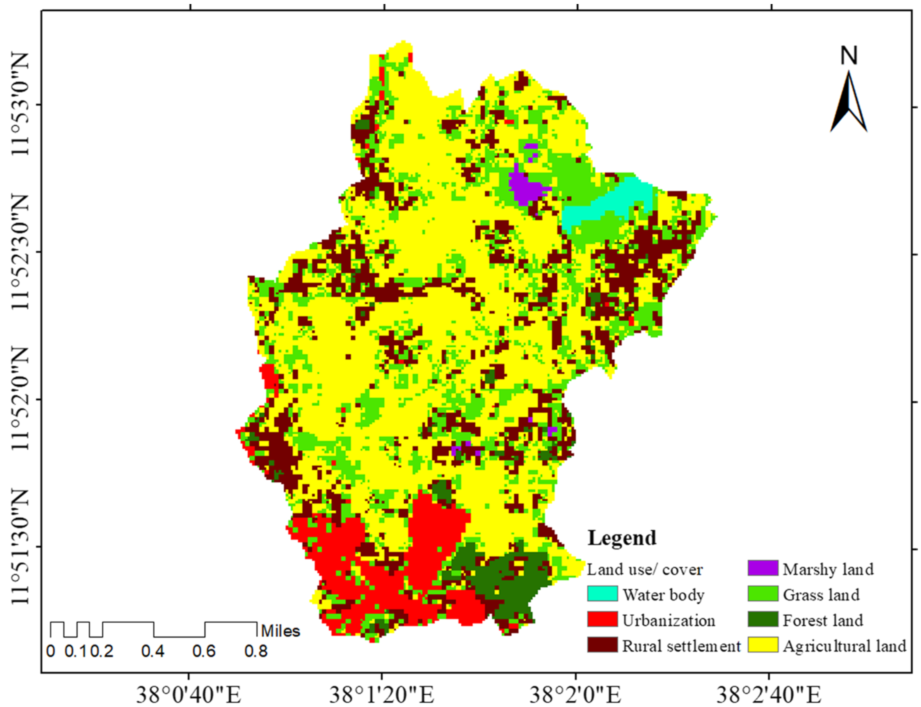

Fig. 2 Land use land cover map of Selamko watershed

Table 1 Current land use land cover classes and types of pollutant along the study area

LUC class	Description	Common pollutants
Agriculture	land covered with annual and perennial agricultural crops	Phosphate, nitrate, nitrite and ammonia, Residues, suspended solids and BOD
Rural settlement	Scattered rural settlements	Biochemical oxygen demand phosphorus, nitrogen etc
Grass land	dominated by native or introduced grasses and forbs, including grass-like plants such as sedges and small flowering and non-flowering plants occurring on upland and flat land areas	Fecal coliform, phosphate, nitrate etc
Marshy area	is an area where the water table is at the surface for a significant part of the year	Salinity, chloride, etc
Open water	land completely covered with water and includes mainly the reservoir water	_
Forest land	represents both the natural and enhanced plantation forest areas that are stocked with trees capable of producing timber or other wood products including bushes with open stands of short trees and shrubs	Total suspended solids
Urbanization	is a portion of land used for urban settlement	Biochemical oxygen demand, Fecal coliform, Chloride, sodium, etc

at each site were preserved at 4 °C in an ice-filled box and transported to the laboratory of the faculty of water supply and environmental engineering at Bahir Dar University for further physicochemical and biological composition analysis as per the methods prescribed in the American Public Health Association manual APHA (2005).

Water quality analysis

Between July 2019 and March 2020, 15 physicochemical and biological parameters were assessed at eleven sampling locations for this investigation. The pH, dissolved oxygen, total dissolved solids, and electric conductivity were all measured using onsite testing tools (Aqua Probe, AP 700). The methods and technologies used to collect data on water quality are listed in Table 3. The five-day biological oxygen demand (BOD_5) was determined using azide modification iodometric methods. A dual-channel flame photometer (model 2655–10) was used to measure the sodium and potassium concentrations.

The values of (magnesium, calcium, chloride, nitrate, ammonia, and phosphate) were measured using the plain test

Table 2 Geographic coordinates of water sampling points

Sampling point name	GPS coordinates	Location
S1	11°52′34.49″ N 38° 1′58.35″ E	Selamko river inlet
S2	11°52′39.48″N 38° 1′57.79″E	In marshy and agricultural land
S3	11°52′36.95″N 38° 2′4.17″E	In grazing land
S4	11°52′40.69″N 38° 2′3.12″E	Grazing land
S5	11°52′43.52″N 38° 2′7.72″E	In bush land
S6	11°52′36.98″N 38° 2′8.90″E	Farm land and rural settlement
S7	11°52′40.24″N 38° 2′15.82″E	Agricultural land
S8	11°52′40.15″N 38° 2′7.51″E	center of the reservoir
S9	11°52′42.28″N 38° 2′11.58″E	Center of the reservoir
S10	11°52′46.04″N 38° 2′9.77″E	The outlet of the canal
S11	11°52′44.91″N 38° 2′15.78″E	Outlet of spillway

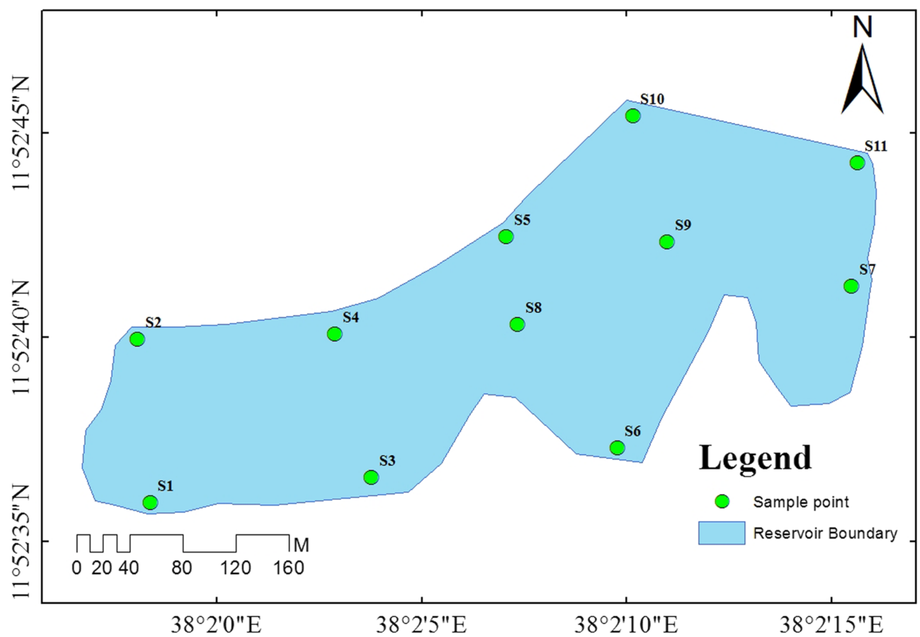

Fig. 3 Location of water sampling point in the Selamko reservoir

Table 3 Methods and instruments used for water quality parameters examination

Parameters	Determination methods	The instrument used and model
pH, Electric conductivity, Dissolved oxygen and Total dissolved solids	Onsite measurement	Aqua probe (AP 700)
Turbidity	Nephlometric method	Turbid meter (Hach 2100AN)
Biochemical oxygen demand (BOD5)	Titration method with 5 days' incubation at 20◦C	Incubator (MIR-153)
Nitrate, Phosphate, Ammonia, calcium, magnesium and chloride	Plain test Photometer	Photometer (PHOT 7500)
Sodium and potassium	Flame photometer	JENWAY PFP 7
Total coliform bacteria	MPN method	Incubator(POTALAB 03G030)

photometer (Photometer 7500). The bacteriological analyses were determined using the membrane filtration technique. After laboratory examination, the geographical distribution maps of quality parameters were prepared using ArcGIS 10.5's kriging interpolation method. Statistical, descriptive analysis, significance test, and correlation between the water quality index and parameters of water chemistry were done by IBM SPSS Statistics for Windows, version 26.0 (IBM 2019). Post hoc tests for significantly different parameters between stations were also carried out to find significantly different groups following an ANOVA analysis. All descriptive analysis and significance tests were done with 95% confidence interval statistics. The suitability of reservoir water for multipurpose uses is evaluated using a water quality index.

Drinking water quality index

A drinking water quality index is a numerical representation of a list of elements in a water sample along with their concentrations. It is a straightforward and practical means of describing the purity of water in terms of its quality. The weighted arithmetic index approach was used in this study, which is extensively used for water quality index in water quality analysis. It is a simple and modified index technique for determining the quality of surface water (Bora and Goswami 2017; Dutta et al. 2018). A total of fifteen factors were used to create the reservoir drinking water quality index (WQI) in this study. These variables are classified as physicochemical properties of water. The WHO (2017) criteria for drinking and domestic use were used to calculate the WQI. The calculation of WQI contains the following steps:

The first stage was to calculate a quality rating for a specific water quality parameter by dividing measured water quality parameters by standard permitted values in various parameters.

$$q_n = \frac{100|V_n - V_{10}|}{|S_n - V_{10}|} \quad (1)$$

where, q_n = quality rating for the nth water quality parameter, V_n = measured value of the nth parameter at a given sampler, S_n = standard permissible value of the nth parameter, V_{10} = Ideal value of nth parameter during a pure water; Ideal value in most cases $V_{10} = 0$ except in certain parameters like pH and dissolved oxygen. Calculation of quality rating for pH and DO ($V_{10} \neq 0$) is 7.0 and 14.6 mg/L, respectively.

The unit weight of the measured parameters was determined in the second phase. A worth inversely proportional to the suggested standard values Sn of the related parameters was used to determine unit weight.

$$W_n = \frac{K}{S_n} \quad (2)$$

where, W_n = unit weight for the nth parameter, S_n = standard value for nth parameter, K is the constant of proportionality which is determined from the condition, and $k = 1$ for sake of simplicity.

The total drinking water quality index is calculated in the third stage. The aggregated water quality index was generated by linearly combining the quality rating and unit weight.

$$\text{WQI} = \frac{\sum q_n W_n}{\sum W_n} \quad (3)$$

The WQI findings of Selamko reservoir were compared to Ewaid and Abed (2017) water quality index status after all relevant computations were done (Table 4).

Results and discussion

Hydro-geochemical and biological characteristics of Selamko farm reservoir water quality

The results of the hydro-geochemical and biological examinations are discussed based on the main findings of the study in detail herein. The descriptive statistical analysis of water quality parameters in the Selamko reservoir is presented in Table 5.

Physical water quality parameters

Turbidity, TDS and EC

Turbidity is a metric for water clarity or the optical quality of water that is determined by the intensity of the light reflected by suspended particles (WHO 2017). The Selamko reservoir water has turbidity ranging from 25.55 NTU (S9) to 32.99 NTU (S4), with an average of 30.3 NTU (Table 5). The tested levels were found to be higher than the WHO (2017) as well as ES (2003) permitted limit value of 5NTU for drinking and domestic use. The results of the ANOVA analysis indicated a significant difference in turbidity across the stations ($p < 0.05$). The post hoc test result indicates that significant variations were observed between stations at the center of the reservoir (S8 & S9) and other stations (S1, S2, S3, S4, S5, S6, S7, S10, and S11). Based on the analysis, turbidity levels were higher in the upstream of the reservoir, adjacent agricultural area, and edge of the reservoir relative to the center of the reservoir. According to the geographical distribution map of turbidity minimum values, observed at the center of the reservoir (Fig. 4a). The high turbidity may be due to sediment movement from neighboring agricultural

Table 4 Rating of water quality index status (Ewaid & Abed, 2017)

Range	Category
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
> 100	Highly polluted and unfit for drinking

Table 5 Descriptive statistical analysis results of water quality parameters in Selamko reservoir

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Average	Max	Min	S.D
pH	7.61	7.70	7.49	7.52	7.44	7.48	7.47	7.46	7.39	7.41	7.50	7.50	7.70	7.39	0.09
E.C	174	143	148	146	144	149	145	145	144	146	144	148.13	174	143	8.91
DO	5.15	5.66	5.58	5.69	5.73	5.75	5.47	5.70	5.93	5.76	5.84	5.66	5.93	5.15	0.21
BOD_5	10.6	8.82	7.88	6.28	6.07	7.07	5.81	6.59	5.86	5.90	6.28	7.01	10.6	5.81	1.52
Turbidity	30.4	30.7	32.2	32.9	30.5	30.4	31.5	26.7	25.6	29.5	28.9	30.30	32.9	25.6	2.35
TDS	109	87.0	90.6	90.7	90.7	92.8	89.7	86.9	87.5	89.3	87.7	91.12	109	86.9	6.35
NO_3-N	6.31	5.23	6.39	5.61	5.23	5.62	7.25	4.73	4.69	5.83	5.79	5.70	7.25	4.69	0.75
PO_4^{2-}-P	0.70	0.47	0.58	0.55	0.48	0.47	0.82	0.48	0.47	0.56	0.52	0.55	0.82	0.47	0.11
NH_3-N	0.16	0.12	0.13	0.15	0.31	0.28	0.34	0.32	0.28	0.26	0.18	0.23	0.34	0.12	0.08
Ca^{+2}	31.9	27.9	32.9	35.5	31.8	34.8	37.6	29.2	36.8	65.4	57.0	37.53	65.4	27.9	11.87
Mg^{+2}	18.3	15.8	14.9	15.5	15.9	16.7	18.9	16.2	16.6	16.3	15.7	16.43	18.9	14.9	1.19
Na^+	35.6	29.6	31.8	32.9	35.5	39.5	37.3	42.2	38.4	43.0	36.8	36.61	43.0	29.6	4.14
K^+	14.8	13.5	13.3	11.9	13.7	13.7	14.7	11.9	11.9	14.8	13.3	13.39	14.8	11.9	1.11
Cl^-	6.14	4.4	3.88	3.84	4.08	3.91	3.16	3.57	3.51	2.39	3.35	3.84	6.14	2.39	0.93
TCB	77.5	54	53.0	28.7	39.5	46.3	55.8	34.8	38.3	50.0	41.3	47.23	77.50	28.8	13.26

*all units are mg/L except pH (unit less), EC in μS/cm, Turbidity in NTU, TCB (total coliform) in CFU/100 ml

areas and runoff from the Selamko River during the wet season. In the reservoir, higher turbidity offers an excellent setting for microbial contaminants (Tomperi et al. 2020).

The availability of any minerals, salts, metals, cations, or anions dissolved in water is determined by total dissolved solids (TDS). TDS values in the reservoir range from 109.42 mg/l (S1) to 86.9 mg/l (S8), with a mean of 91.12 mg/l. TDS concentrations in freshwater are less than 500 mg/l; however, TDS concentrations in saline water range from 1000 to 10,000 mg/l, according to WHO (2017). The concentration of TDS in the reservoir is also below the maximum permissible limits of (1000 mg/l) ES (2003) for drinking purposes. During the whole research period, the ANOVA result revealed no significant variation in TDS across sample locations ($p > 0.05$). The geographical distribution map of TDS in the research region (Fig. 4b) showed that the higher TDS levels are found in the upstream section of the reservoir. It's most likely attributable to the reservoir's upstream regions having heavy human and land degradation activities. The TDS values in this study were found to be lower than those studied by Hishe et al. (2022) in the Abay River, which varied from 117 to 294 mg/l.

Electrical conductivity (EC) values ranged from 143 (S2) to 174.2 (S1) μs/cm, with an average value of 148.13 μs/cm. EC indicates water's capability to pass electrical flow. The electric conductivity concentration in the reservoir was determined to be below the permissible limit for drinking WHO (2017) values, which range from 400 to 1500 μs/cm. According to the ANOVA results ($p > 0.05$), there were no significant differences across the stations. A high EC concentration was detected on the upstream side of the reservoir due to the presence of extreme anthropogenic activities upstream of the reservoir and runoff and soil erosion from the surrounding region of the reservoir (Fig. 4c).

Chemical water quality parameters

pH, DO, and BOD_5

The degree of acidity and alkalinity of water is determined by its pH, which is a measure of hydrogen potential. The highest pH value was observed at S2 (7.7), while the lowest pH value was reported at S9 (7.39), with a mean value of 7.5 in Selamko reservoir (Table 5). During the sampling period, the ANOVA result revealed that there was no significant difference ($p > 0.05$) across the stations. The spatial distribution map (Fig. 5a) demonstrates that the upstream section of the reservoir has higher pH values than the downstream side. It is most likely due to increased runoff from agricultural and marshy terrain. All of the pH readings in these sample points are within the acceptable range for aquatic life (EEPA 2003). In general, pH values in the reservoir are found in the range of WHO (2017) and ES (2003) with threshold limits of 6.5 to 8.5 for drinking purposes.

In the sampling period, S1 at the town's run-off entry had the lowest DO (5.15 mg/l), whereas S9 in the reservoir's center had the highest (5.93 mg/l). During the sample period, the ANOVA result revealed no significant differences across the stations ($p > 0.05$). Figure 5b displays the dissolved oxygen (DO) spatial distribution map, which demonstrates that more dissolved oxygen was recorded in the downstream section of the reservoir due to the comparatively lower volume of organic pollutants entering than in the upstream region. Wassie and Melese (2017) reported

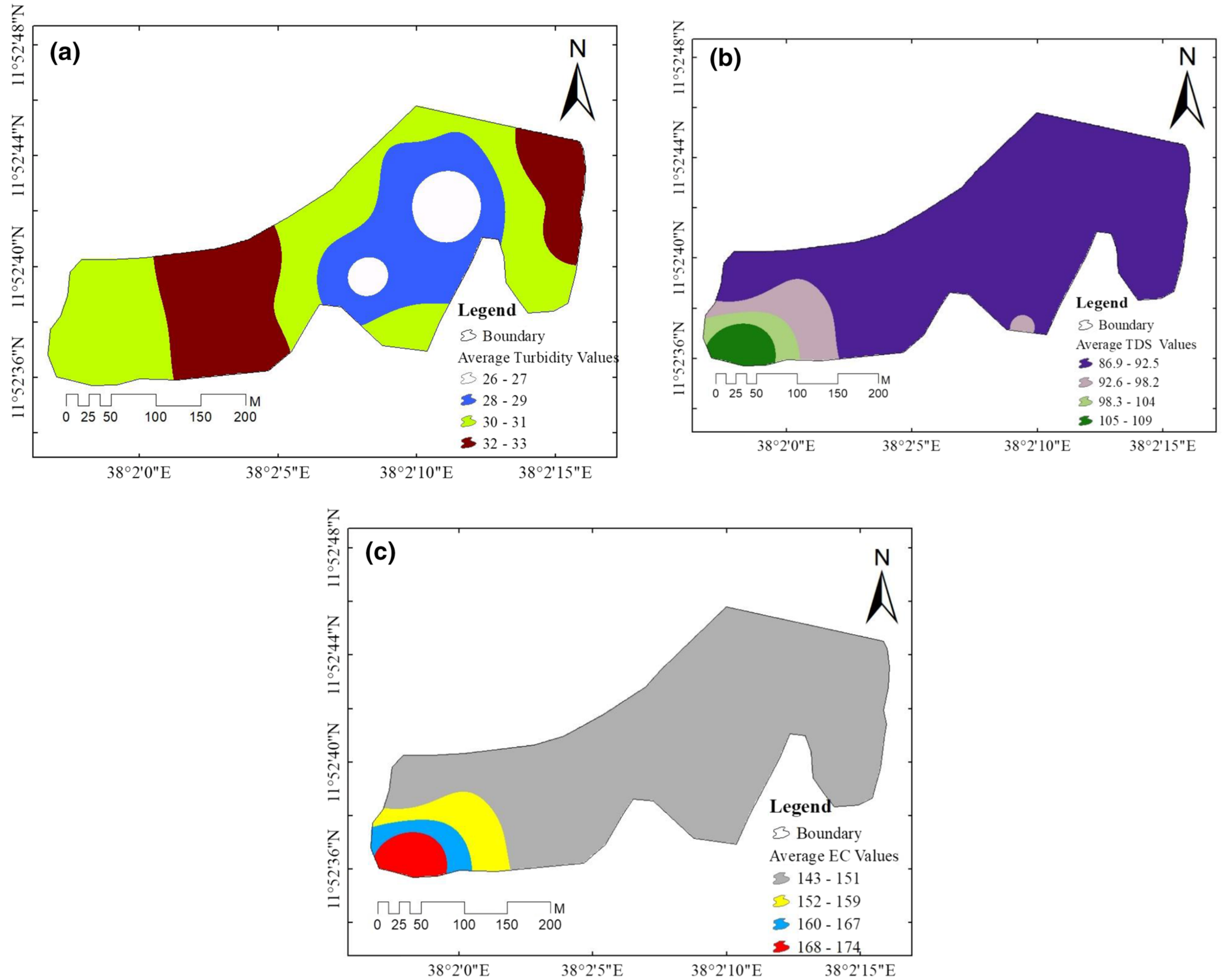

Fig. 4 Spatial distribution map of **a** turbidity, **b** TDS, and **c** EC in Selamko reservoir

a DO level of above 5.0 mg/L in the same reservoir during their investigation. Selamko reservoir had a higher DO content than other man-made reservoirs in the country, namely Gilgelgibie, which ranged from 3.85 to 5.28 mg/l (Woldeab et al. 2018). The DO levels reported at all sites are adequate for aquatic creatures and plankton to live and conduct a variety of physiological functions (USEPA 2017).

The quantity of organic matter in the water is measured by the biochemical oxygen demand (BOD_5). During the sample period, the BOD_5 of the reservoir water varied from 5.81 (S7) to 10.63 mg/l (S1), with a mean value of 7.01 mg/l across the whole reservoir (Table 5). The concentration of BOD_5 in the reservoir was found to be above the maximum permissible values of WHO (2017). During the sample period, the ANOVA result revealed no significant differences across the stations ($p > 0.05$). Figure 5c indicates the biochemical BOD_5 spatial distribution map, which demonstrates that greater dissolved oxygen levels are found in the reservoir's upstream region, while the lowest levels are found near agricultural fields. The BOD_5 concentration in water bodies continues to rise as a result of natural plant degradation and other contributors such as fertilizer, construction effluent, animal farm, solid waste, slaughterhouses, and pig husbandry that raise the overall nutrient level. In this investigation on Selamko reservoir, the biochemical oxygen demand was lower than the Abay River and Gilgelgibie reservoir (Hishe et al. 2022; Woldeab et al. 2018).

Phosphate, nitrate, ammonia and chloride

During the sample period, phosphate (PO_4^{-2}) concentrations varied from 0.47 (S3) to 0.82 (S7) mg/l, with an average of 0.55 mg/l (Table 5). The reservoir's phosphate content was below WHO (2017) and ES (2003) maximum permissible limits of 1 mg/l for drinking purposes. There was no significant difference across the stations over the sample period

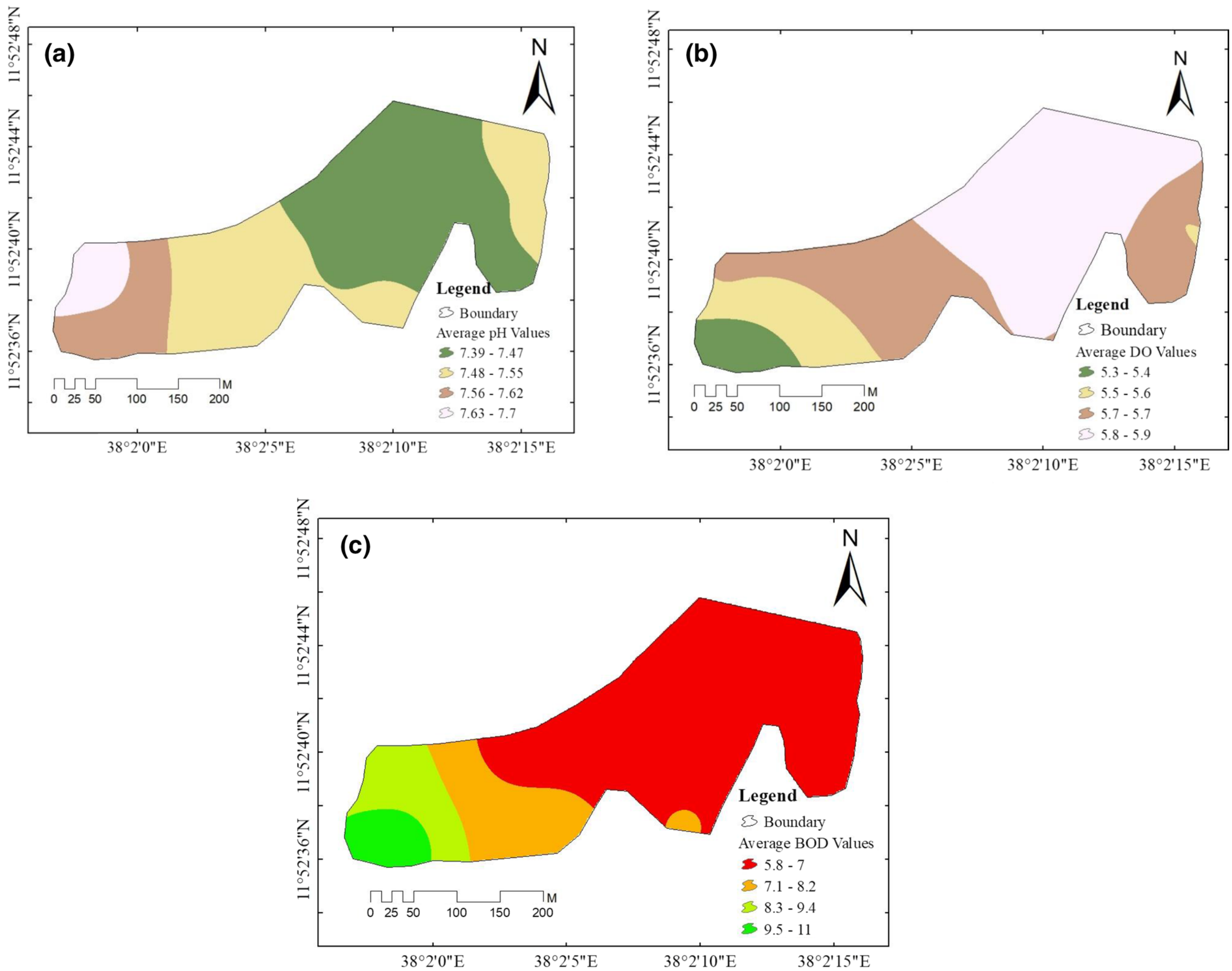

Fig. 5 Spatial distribution map of **a** pH, **b** DO, and **c** BOD in Selamko reservoir

($p > 0.05$). Excess phosphate can cause algae and aquatic plants to flourish, reducing dissolved oxygen levels. When compared to previously conducted studies on the same reservoir (0.45 to 0.73 mg/l), the current study's phosphate concentrations were determined to be substantially higher. However, the phosphate concentrations in the present study were found to be lower than those previously measured in other dams, such as Koga reservoir, which varied from 0.135 to 1.4 mg/l (Densaw et al. 2016). The spatial distribution map of phosphate (Fig. 6a), which demonstrates that phosphate levels are found to be greater on the side of agricultural land at station seven. Phosphate levels in this reservoir were greater due to fertilizer run-off from nearby agricultural regions (Hoorman et al. 2008).

The reservoir water's nitrate (NO_3–N) content fluctuates between 4.69 (S8) and 7.25 mg/l (S7), with an average of 5.70 mg/l across the sample period. During the sample period ($p > 0.05$), there was no significant variation in nitrate concentration between the stations. The nitrate spatial distribution map (Fig. 6b), which demonstrates that at S7, greater nitrate was reported on the side of agricultural land. It's mostly due to agricultural practises surrounding the reservoir, which supply nutrients to the reservoir directly. The nitrate content in this research was greater than that reported in the same reservoir by Wassie and Melese (2017), which varied from 1.85 to 2 mg/l. The current study's nitrate content was greater than that of Lake Tana, which was measured at a maximum of 1.03 mg/l (Tibebe et al. 2019). The nitrate content in this study falls within the permissible limit for drinking water as per ES (2003) and WHO (2017) with a value of 50 and 10 mg/l, respectively.

NH_3-N concentrations in water samples varied from 0.12 mg/l (S2) to 0.34 (S7) mg/l during the course of the monitoring period, with an average of 0.23 mg/l. The ANOVA test revealed that there was no significant difference in ammonia–nitrogen levels between the sites ($p > 0.05$).

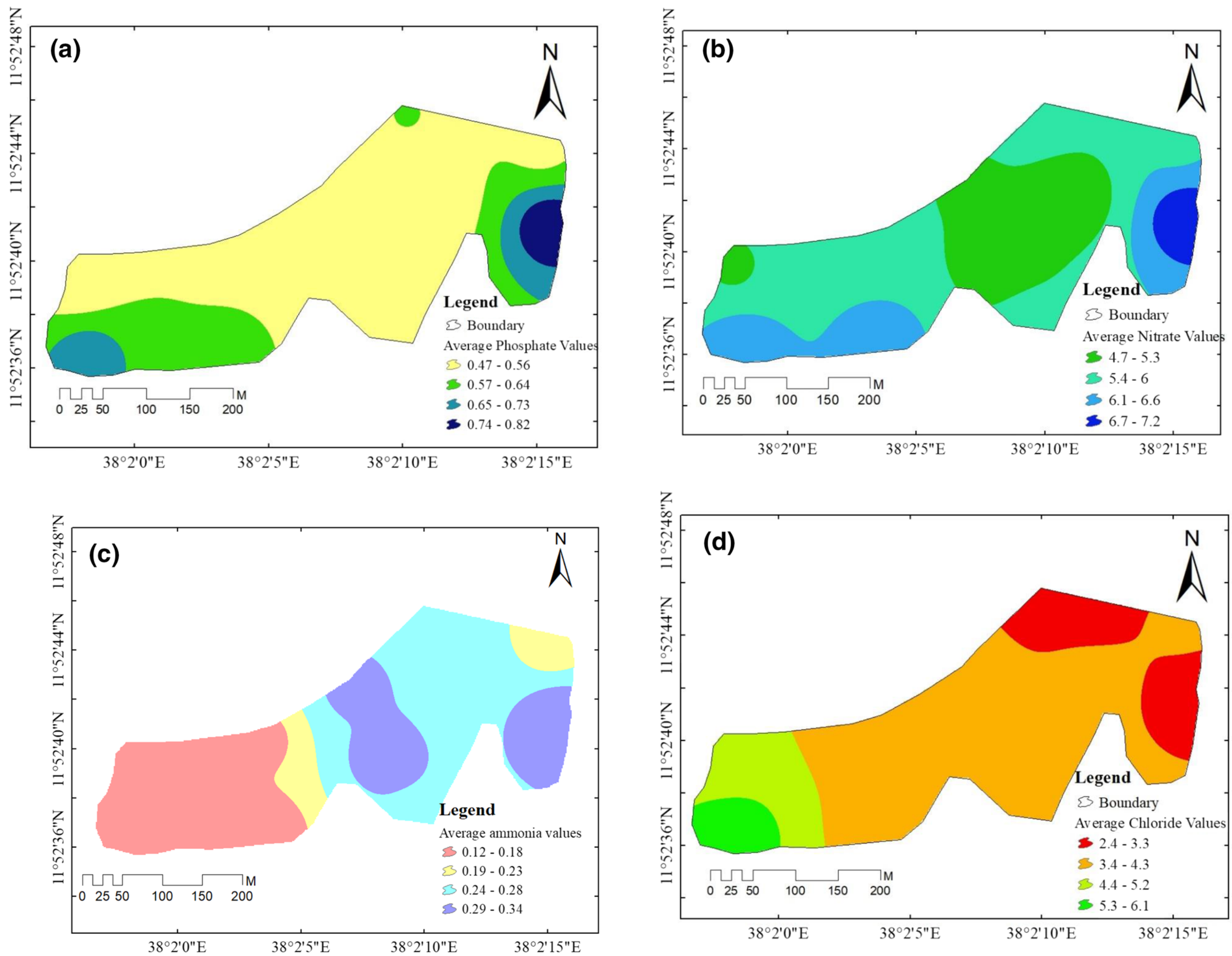

Fig. 6 Spatial distribution map of **a** PO_4^{-2} and **b** NO_3^-, **c** NH_3-N, and **d** Cl^- in Selamko reservoir

The spatial distribution map of NH_3-N concentrations is illustrated in Fig. 6c. The maximal NH_3-N concentration required to support aquatic life is 0.025 mg/l (USEPA 2017). However, the current study's NH_3-N content was over this limit, which may be harmful to aquatic animals (fish).

Water samples had total chloride concentrations ranging from 2.39 to 6.14 mg/l, with an average of 3.84 mg/l across the measurement period (Table 5). Chloride concentrations in the water make it unsafe to drink or use for animal watering, as per WHO (2017). Selamko reservoir's chloride value was discovered to be less than 10 mg/l, indicating that the reservoir's water quality is adequate for multipurpose usage. During the sample period, the ANOVA result revealed no significant differences across the stations ($p > 0.05$). The geographical distribution of chloride in the reservoir (Fig. 6d) indicates that upstream has more chloride contamination than downstream due to more human activity in the reservoir. The most significant sources of chlorine in water were domestic wastes and industrial effluents.

Ca^{+2}, Mg^{+2}, Na^+ and K^+

The calcium salts, together with magnesium, are responsible for the hardness of water. Maximum calcium concentrations in the Selamko reservoir were measured at S10 (65.3 mg/l), while the lowest concentration (27.9 mg/l) was measured at S2, with an average of 37.53 mg/l over the entire sampling period (Table 5). In the whole sample period, the ANOVA result revealed no significant difference ($p > 0.05$) in calcium across the stations. Calcium concentrations in Selamko reservoir were greater than in Koga reservoir, which ranged from 12 to 18.5 mg/l (Densaw et al. 2016). Calcium values in the present reservoir fall within the maximum permissible values of ES (2003) with a value of 75 mg/l for drinking purposes.

The highest magnesium content (18.9 mg/l) was found at S7, while the lowest (14.9 mg/l) was found at S3, for a mean value of 16.43 mg/l for the sampling period (Table 5). According to the ANOVA results, there is no significant difference in calcium and magnesium between the stations ($p > 0.05$). Ca^{+2} and Mg^{+2} levels in the Selamko artificial reservoir were below FAO (2010) for irrigation applications. The spatial distribution map (Fig. 7a and b) shows that the upstream region of the reservoir has more calcium and magnesium than the downstream. On the upstream side, it is most likely owing to heavy human activity and weathering of basaltic rocks. The calcium and magnesium values in the Selamko reservoir were found to be lower than Koga reservoir concentrations, which ranged from 11 to 42.5 mg/l (Densaw et al. 2016).

When water is to be utilized for drinking or agricultural purposes, sodium (Na^{+}) is frequently tested. Water samples had sodium levels ranging from 29.62 mg/l at S2 to 43 mg/l at S10, with an average of 36.61 mg/l across the study period (Table 5). The salt value obtained in the present study was within the range of 0 to 40 meq/l for irrigation application (Ayers & West, 1985). The ANOVA result revealed a significant difference in sodium between the stations ($p > 0.05$). The sodium content in Selamko reservoir was found to be greater than that in Koga reservoir in previous research, which ranged from 3.5 to 3.7 mg/l (Densaw et al. 2016). The geographical distribution of sodium in the reservoir is illustrated in Fig. 7d. The sodium content is lower than the Ayers and Westcot (1985) norm, however owing to the weathering of luvisols and basaltic rocks around the reservoir, a greater value is recorded upstream.

Potassium concentrations varied from 11.9 to 14.8 mg/l in the rainy season, with an average value of 13.39 mg/l (Table 5). According to the ANOVA results, there is no significant difference ($p > 0.05$) between the stations. Potassium concentrations in natural surface waters fluctuate greatly based on local geological factors, wastewater discharges, and road salt use over the season. When comparing sodium concentrations ($Na^{+} > > K^{+}$), the lower concentration of K^{+} is seen. Figure 7e indicates the spatial distribution map of K^{+}. This is to be expected, given that K^{+} minerals have limited

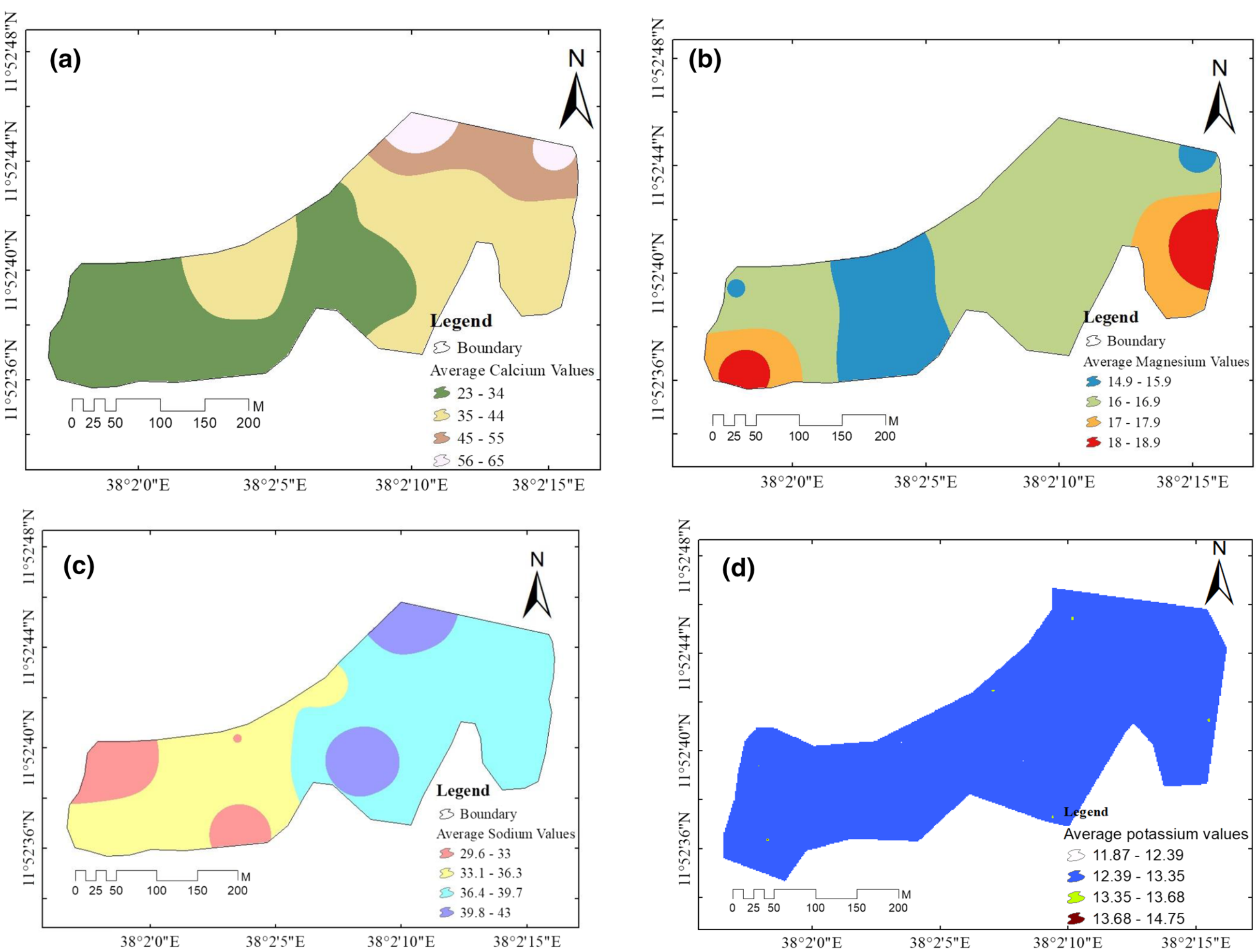

Fig. 7 Spatial distribution map of **a** Ca^{+2}, **b** Mg^{+2}, **c** Na^{+}, and **d** K^{+} in Selamko reservoir

migratory ability and are resistant to weathering breakdown (Egbueri 2019).

Biological water quality parameters

Throughout the sample period, total coliform bacteria (TCB) concentrations varied from 29 (S1) to 78 (S5) CFU/100 ml with an average value of 47.23 CFU/100 ml. During the sample period, the ANOVA test result revealed that there was no significant difference across the stations ($p > 0.05$). In addition, total coliform was steadily raised, but it was dramatically increased at S1 (Fig. 8), which gets large volumes of effluents from animal farms, slaughterhouses, and solid waste on the reservoir's upstream side. The total coliform content in this study was determined to be above the WHO (2017) permitted limit values for drinking water guidelines which should not be detectable in any 100 ml sample.

Drinking water quality index (WQI)

The WQI varied from 61.59 to 94.61, with a mean of 70.96 in the research region. The computed value of WQI is presented in Table 6. The greater water quality index at station one might be explained by human influences upstream of the reservoir, such as waste from slaughterhouses, pig husbandry, or illegal dumping of solid waste along the river (94.61). The Selamko reservoir's WQI rating indicates that the reservoir's water quality is often threatened or impaired by situations that frequently differ from natural or acceptable values. Table 7 shows the reservoir water quality index status at different sampling points. According to the estimated WQI values (Table 7), the reservoir water in the study area was categorized into two water quality statuses: extremely poor and poor for drinking and domestic use. Thus, the proportion of WQI categories in all reservoir water samples was extremely poor (18.18%) during the whole sampling period, but the proportion of WQI categories in all sampling stations for drinking and domestic purposes was poor (81.81 percent).

Suitability of Selamko reservoir water for multipurpose usage

Suitability of reservoir water for irrigation use

Salinity hazard (EC and TDS) When salts begin to collect inside the crop root zone, the amount of water accessible to the roots is reduced, posing a salinity threat. The ability of water to carry an electric current can be used to determine the degree of the salinity threat. Because conductance is a function of the total dissolved ionic solids, either an electrical conductivity (EC) or a total dissolved solids (TDS) measurement is possible. Electrical conductivity (EC) and total dissolved solids (TDS) in this investigation varied from 143 to 174.42 s/cm and 86.89 to 109.42 mg/l, respectively, falling short of the standards of (500 mg/l for TDS and 700 s/cm for EC). As a result, the Selamko reservoir water poses no salinity risk. Wilcox (1955) classified irrigation water electric conductivity as excellent (less than 250), well (250–750), permissible (750–2250), doubtful (2250–5000),

Fig. 8 Spatial distribution map of TCB in in Selamko reservoir

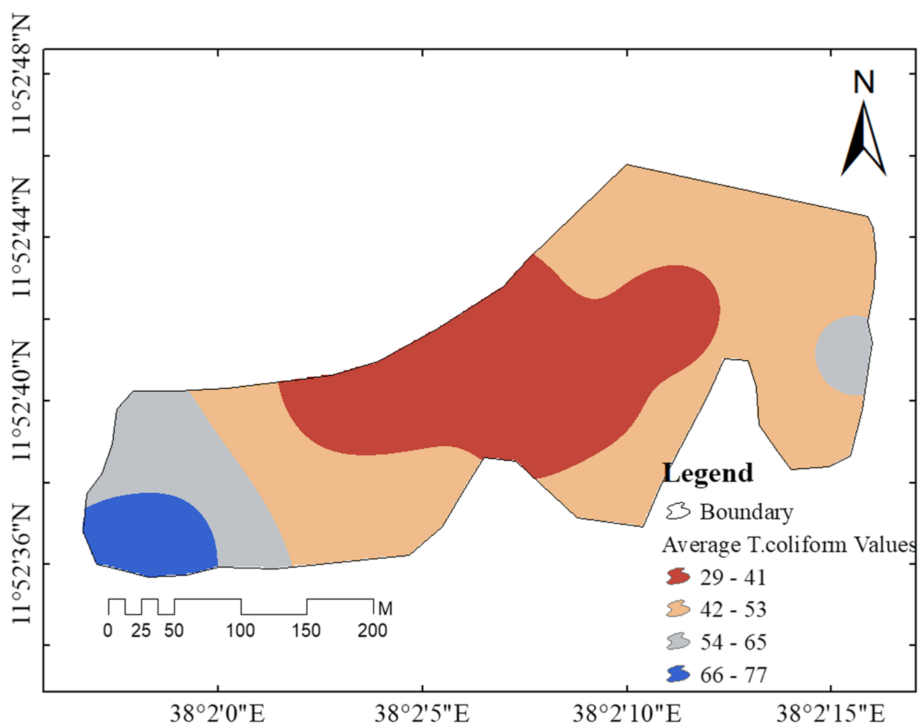

Table 6 Average WQI value in the reservoir

Parameters	Estimated Value (Vn)	Standard Value (Sn)	Ideal value (Vio)	Unit Weight (Wn)	Quality Rating (qn)	Multiple Value (Wn qn)
pH	7.50	7	7	0.15	− 99.09	− 15.24
E.C	148.13	400	0	0.00	37.03	0.09
DO	5.66	5	14	0.20	92.67	18.53
BOD	7.01	5	0	0.20	140.29	28.06
Turbidity	30.30	10	0	0.10	303.03	30.30
TDS	91.12	500	0	0.00	18.22	0.04
NO3-N	5.70	10	0	0.10	56.98	5.70
PO4-P	0.55	1	0	1.67	92.21	153.68
NH3-N	0.23	1	0	1.00	23.02	23.02
Ca^{+2}	37.53	75	0	0.00	50.03	0.17
Mg^{+2}	16.43	150	0	0.00	10.95	0.04
Cl-	3.84	250	0	0.00	1.54	0.01
Na^{+1}	36.61	200	0	0.01	18.30	0.09
K^{+1}	13.39	12	0	0.08	111.6	9.3
Sum				3.58	1406.50	253.81
WQI						**70.96**

All units are in mg/l except for turbidity (NTU), conductivity (μs/cm) and pH (non- dimensional)

and unsuitable (> 5000). According to this classification, the reservoir's water quality is outstanding, with the reservoir's electric conductivity ranging from 143 to 174.42 s/cm.

When salts begin to collect inside the crop root zone, the amount of water accessible to the roots is reduced, posing a salinity threat. The ability of water to carry an electric current can be used to determine the degree of the salinity threat. Because conductance is a function of the total dissolved ionic solids, either an electrical conductivity (EC) or a total dissolved solids (TDS) measurement is possible. Electrical conductivity (EC) and total dissolved solids (TDS) in this investigation varied from 143 to 174.42 s/cm and 86.89 to 109.42 mg/l, respectively, falling short of the standards of (500 mg/l for TDS and 700 s/cm for EC). As a result, the Selamko reservoir water poses no salinity risk. Wilcox (1955) classified irrigation water electric conductivity as excellent (less than 250), well (250–750), permissible (750–2250), doubtful (2250–5000), and unsuitable (> 5000). According to this classification, the reservoir's water quality is outstanding, with the reservoir's electric conductivity ranging from 143 to 174.42 s/cm.

Table 7 Reservoir water quality index status according to Ewaid & Abed (2017)

Sampling point	Average WQI	Reservoir water status
S1	83.94	Very poor
S2	61.59	Poor
S3	72.27	Poor
S4	68.05	Poor
S5	66.92	Poor
S6	65.76	Poor
S7	94.61	Very poor
S8	65.76	Poor
S9	63.24	Poor
S10	71.73	Poor
S11	66.73	Poor

Sodium absorption ratio The sodium adsorption ratio (SAR), which is affected by major cations like sodium, magnesium, and calcium ions, is a water quality factor that governs the rate at which water penetrates. It forecasts the magnitude of the Na–Ca/Mg exchange process between water and soil fine particles, in which adsorbed Mg^{+2} and Ca^{+2} ions are replaced by Na ions. This cation-exchange process lowers soil permeability and causes drainage problems (soil hardening). The SAR advised by the US Department of Agriculture's salinity laboratory (USSL 1954) is computed using Eq. (4).

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}}\text{(expressed in milliequivalents per liter)} \tag{4}$$

A SAR value of more than 18 suggests a sodium hazard in general. SAR values varied from 1.11 to 1.6 across all study locations, with an average of 1.26 in the reservoir. SAR readings of less than 10 are considered excellent condition according to Richard (1954). The sodium adsorption ratio and conductivity were used by Wilcox to classify irrigation water as illustrated in Fig. 9. In terms of conductivity and sodium adsorption ratio, the Wilcox categorization ranges from acceptable (C1-S1) to extremely unsatisfactory (C4-S4). According to the Wilcox log diagram categorization, the reservoir water quality ranged from good (C1-S1) to medium good (C2-S1) (Fig. 9).

Exchangeable sodium ratio or Kelly's ratio Another measure for determining the irrigation appropriateness of reservoir water is the exchangeable sodium ratio. The measure was determined by comparing sodium ion levels in meq/l to magnesium and calcium ion levels in reservoir water. Statistical analysis indicated that the exchangeable sodium ratio in the reservoir ranged from 0.39 to 0.7. Selamko reservoir water samples, according to Kelley (1963) categorization, fall within the acceptable group and are suitable for irrigation. A greater sodium ratio might result in a poor tilt of the soil as well as permeability issues.

Magnesium hazard Higher magnesium levels in reservoir water have a detrimental influence on soil quality, which affects agricultural output (Todd and Mays 2004). Magnesium hazard is denoted by MH, calculated using Eq. (5).

$$MH = \left(\frac{Mg^{+2}}{Ca^{+2} + Mg^{+2}} \right) \times 100 \tag{5}$$

(where the concentrations are in meq/l)

Magnesium hazard levels greater than 50 meq/l are considered unsuitable for irrigation. In the present study, the magnesium ratio was estimated to range from 29.18 to 48.57% (Table 8). According to the Raghunath (1987) categorization, the tested reservoir water samples are suitable for irrigation throughout the sampling period (Table 8).

Sodium percentage Wilcox (1955) proposed the percentage sodium, which is an essential measure in evaluating irrigation water quality and can be written as follows:

$$Na\% = \frac{Na^{+} + K^{+}}{\sqrt{Na^{+} + K^{+} + Ca^{+2} + Mg^{+2}}} \times 100 \tag{6}$$

(expressed in milliequivalents per liter)

Fig. 9 Classification of irrigation waters based on Wilcox diagram

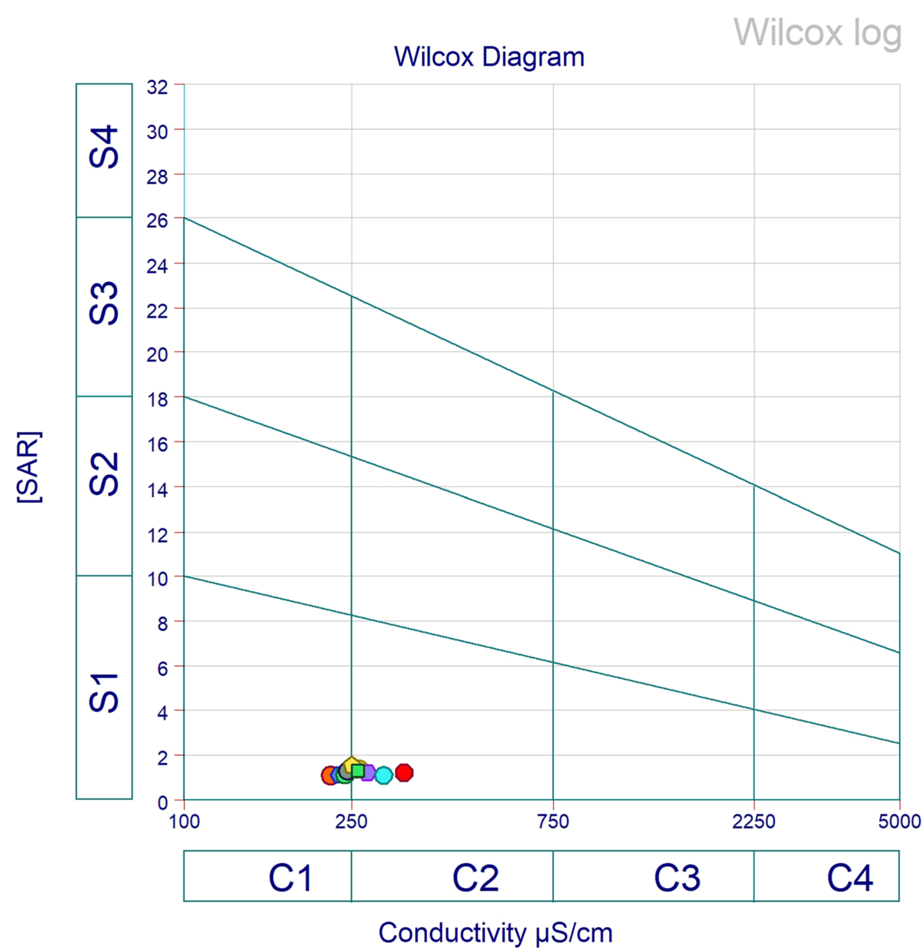

Table 8 Classification of reservoir water quality for irrigation use

Classification items (meq/l)	Categories	Ranges	Statistics values of samples	Selamko reservoir water conditions		
			Min	Max	Average	
Salinity hazard based on electrical conductivity (Richard, 1954)	Low Medium High Very high	< 250 250–750 750–2250 2250–5000	143	174.42	148.13	Low salinity
Sodium adsorption ratio $SAR=\frac{Na+}{\sqrt{(Ca+Mg)/2}}$ (USSL, 1954)	Excellent Good Fair Poor	0–10 10–18 18–26 > 26	1.11	1.55	1.25	Excellent
Kelly's ratio or sodium exchangeable ratio (Kelly's, 1953) $KL=\frac{Na+}{Ca+2+Mg+2}$	Safe Unsuitable	< 1 > 1	0.39	0.66	0.5	Safe
Sodium percentage (Wilcox 1955) $SP=\frac{Na+}{Ca+Mg+Na+K}*100$	Excellent Good Permissible Doubtful Unsuitable	< 20% 20–40% 40–60% 60–80% > 80%	26.34	37.24	30.83	Excellent
Magnesium Hazard (Raghunath 1987) $MH=\frac{Mg}{Ca+Mg}*100$	Suitable Harmful	< 50% > 50%	29.18	48.57	42.45	Suitable

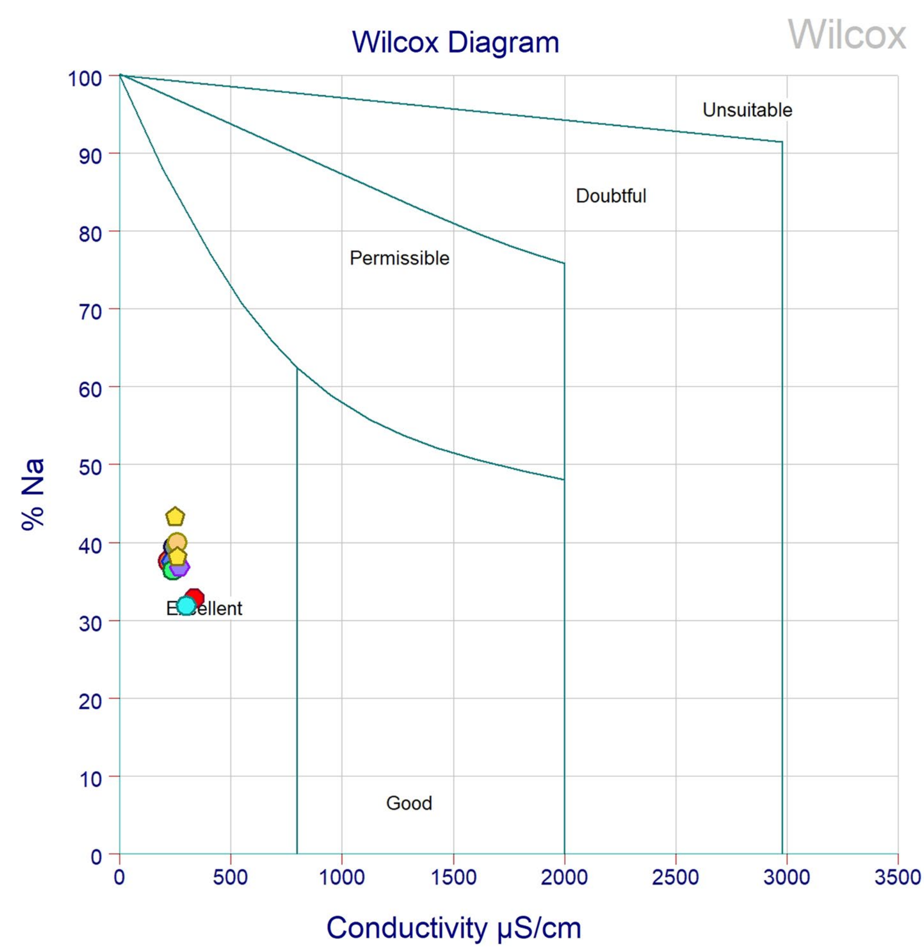

Fig. 10 USSL diagram for irrigation water quality classification (USSL Diagram 1954)

The present sodium percentage in the Selamko reservoir ranged from 26.34% (at S11) to 37.24% (at S8), with an average of 30.83 percent (Fig. 10). Water with Na% level of less than 35 meq/l is appropriate for irrigation. The result was below the permissible limits for irrigation water consumption (Wilcox 1955). By enhancing soil permeability, a lower salt content in irrigation water may be necessary for plant development.

Major cat-ions in reservoir water The reservoir water sodium content varied from 1.29 meq/l at S2 to 1.87 meq/l at S10, with an average of 1.59 meq/l (Figs. 11a &b). According to Ayers and West (1985), the obtained value was within the range. Furthermore, according to Ayers and Westcott (1985), if the Na^{+}: Ca^{+2} ratio surpasses 3:1, the soil will have an infiltration problem. Ca^{+2} levels in the lake varied between 1.4 meq/l at S2 and 3.26 meq/l at S10. The reservoir water was below the acceptable limit for irrigation usage, according to Ayers and Westcott (1985). The amount of Ca^{+2} ions used to neutralize the sodium content-related impacts of the infiltration problem was extremely small because Ca^{+2} ions are the best neutralized ions of sodium concentration. At stations three and ten, respectively, the magnesium concentration varied from 1.22 meq/l to 1.55 meq/l, with an average value of 1.35 meq/l, which was below the maximum limits of the research area (Ayers and Westcott 1985). The reservoir potassium content varied from 0.3 meq/l at station nine to 0.38 meq/l at station one, with an average of 0.34 meq/l. The potassium content was less than the FAO's suggested limit of 2 meq/l.

Suitability of reservoir water for fisheries and livestock

The appropriateness of fish breeding in Selamko reservoir was assessed using fishing criteria for streams, lakes, and ponds (USEPA 2017). The dissolved oxygen level (5.15–5.93 mg/l) is higher than the minimal amount necessary to keep fish in good health (5 mg/l at 20 °C). Because of the current turbulence conditions, the reservoir's appropriate dissolved oxygen concentration was maintained. The average pH of 7.5 is also within the permissible range (6.5.0–8.5). pH values below 6.5 for long periods of time can impair fish reproductive ability and are linked to fish death. The toxicity of ammonia in the water is also increased by a high pH. Surpasses the acceptable value (0.025 mg/l) at the appropriate temperature (0.12–0.34 mg/l). As a result, with some great care and restoration effort, the reservoir's water quality may be enhanced (by reducing the pollution load on the reservoir, by applying watershed management techniques

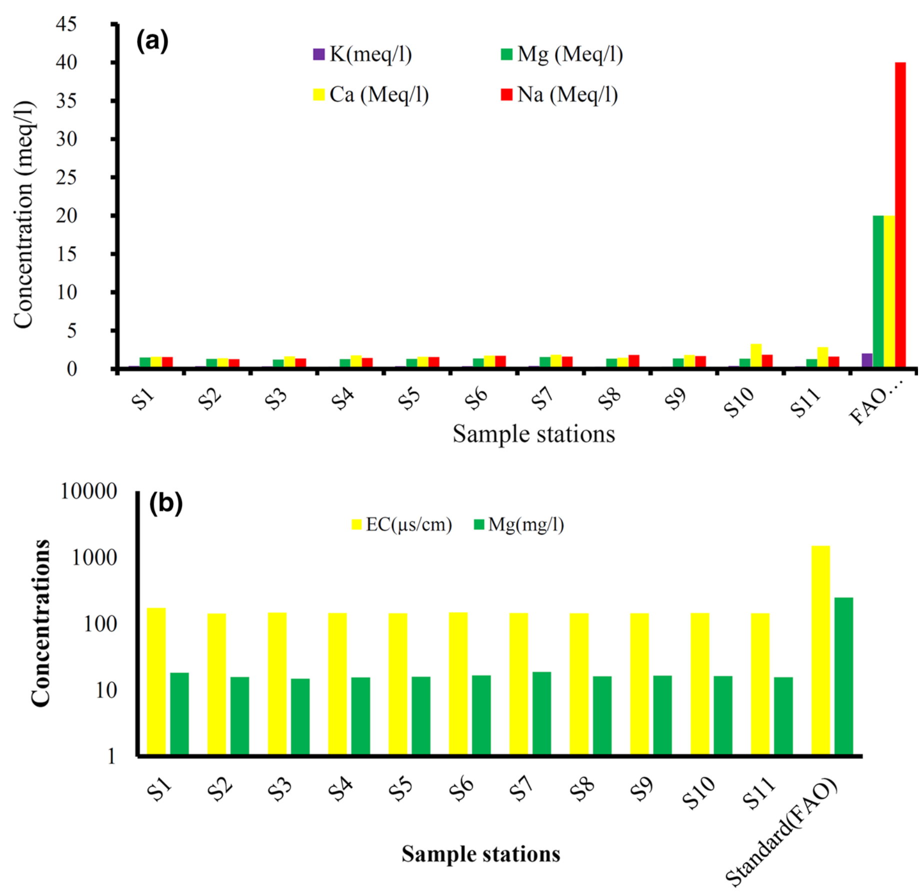

Fig. 11 Graphical comparison of major cat ions with FAO standard for irrigation use (**a**) and comparison of EC and Mg with FAO standard for livestock watering (**b**)

and improving agricultural farming methods). The reservoir water might be beneficial to aquatic life.

Livestock suitability Reservoir water might be used to supply cattle with water. According to Ayers and Westcott (1985), EC of 1500 s/cm and Mg^{+2} of 250 mg/l are acceptable for drinking by most cattle, hence Selamko reservoir water satisfies these requirements.

Conclusion

The quality of farm reservoir water and its suitability for multipurpose uses were assessed using GIS-based water quality indices in this study. The physicochemical and biological characteristics of farm reservoir water quality were studied in both the field and the laboratory. The concentrations of turbidity, phosphate, nitrate, ammonia, DO, and BOD_5 in the farm reservoir exceeded the acceptable limits as defined by ES (2003) and WHO (2017) guidelines for drinking and domestic uses, according to the descriptive statistical analysis. The presence of unregulated waste disposal and increased human activity near the Selamko farm reservoirs could cause certain water quality parameters to be exceeded, thereby compromising drinking water quality. The reservoir's geospatial distribution maps of water quality indicated that nutrient, phosphate, and nitrate concentrations were higher in the upper reaches, possibly due to increased irrigation and anthropological activities in the upstream catchment of the dam. The farm reservoir's QWI values were found to vary from 83.94 to 94.61. The computed WQI showed very poor (18.18%) to poor (81.81%) classes of water pollution in the reservoir water quality for drinking and domestic purposes, according to these findings. Irrigation water quality indices such as SAR, % Na, and EC values, on the other hand, show that the water quality in the farm reservoir is acceptable for irrigation. According to the USEPA's (2017) water quality requirements for fish reproduction, the water quality of Selamko reservoir meets the necessary water quality parameters to keep fish healthy. The oxygen level (5.15–5.93 mg/l), pH of 7.5, and other water quality criteria showed that the water quality in the Selamko farm reservoir is appropriate for cattle watering. In general, the study concluded that the Selamko farm reservoir's water quality is suitable for multipurpose uses, namely, irrigation, fishing, and livestock, except for drinking and domestic uses. Land use and practises in the basin watershed must be maintained in such a way that nutrients seeping into the dam are minimized if Selamko farm reservoir water is to continue to sustain its designated usage.

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Declaration

Conflict of interest The authors declare that they have no conflict of interest.

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