

Spatiotemporal variations of water quality parameters in selected young reservoirs in Tigray, Northern Ethiopia

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ABSTRACT. The health status of aquatic ecosystem is depended on the physicochemical and biological characteristics of water which provides significant information about the available resources for supporting life. This study aims to assess spatiotemporal variation of water quality parameters in selected young reservoirs in Tigray. Depth-integrated water samples (surface, middle, and just above bottom) were collected bimonthly (two times during the wet, dry-cold and dry-hot seasons) at each sampling sites with a heart-valve sampler. Variation between the wet, dry-cold and dry-hot seasons was examined using one-way ANOVA but variation between littoral and pelagic sites were analyzed with the independent t-test. We showed a significant ($p < 0.05$) seasonal variation in temperature, pH and transparency in all the reservoirs investigated. Kalema reservoir was recorded with highest mean value of temperature, chlorophyll-*a* and conductivity. Mean value of pH has a spatially significant difference ($p < 0.05$) in all the study reservoirs except Kalema. None of the physicochemical water quality parameters in Kalema reservoir exhibited spatially significant ($p > 0.05$) variations. Dissolved oxygen and pH showed spatially significant variation ($p < 0.05$) in Mihtsab-Azmati and Seisa reservoirs. A significant correlation ($p < 0.01$) was recorded between temperature with turbidity, chlorophyll-*a*, transparency and conductivity. The physicochemical parameters of the reservoirs showed distinct temporal and spatial variations. The result obtained in this study is very important as baseline information to know the ecology of reservoirs for future reservoir management. Further detailed studies that include total phosphorus, total nitrogen, etc., are needed to suggest the trophic conditions of the reservoirs.

Keywords: Chlorophyll-*a*, Dissolved Oxygen, pH, Physicochemical, Temperature, Turbidity

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1. Introduction

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. Water quality assessment is the overall process of evaluating the physical, chemical and biological variables of water in relation to natural quality, human effects and intended uses of different substances, particularly uses that many affect human health and the health of aquatic species in general (Chapman, 1996). Water quality is affected by a wide range of natural and human influences. The quality of

water may be described in terms of the concentration of the organic and inorganic material present in the water, together with certain physical characteristics of the water (Sheela et al., 2012).

Limnology is the study of the structural and functional interrelationship of organisms of inland waters as their dynamic physical, chemical, and biotic environments affect them. It covers the attributes of all inland waters, both running as in rivers (lotic ecosystems) and standing as in lakes (lentic ecosystems) (Trenberth et al., 2007). Generally, water quality is connected with physical, chemical and biological (including bacteriological) characteristics (Nancy, 2009) and these char-

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acteristics determine the healthy status of any aquatic ecosystem (Venkatesharaju et al., 2010). Therefore, assessing the quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem.

Water is the major limiting factors for agriculture in Tigray, northern Ethiopia. To mitigate the water shortage and support subsistence agriculture of the dense population in north Ethiopia, several small reservoirs have been constructed in the past three decades for the purpose of irrigation and watering of cattle (Haregeweyn et al., 2006; Dejenie et al., 2008). This region is characterized by a tropical semi-arid climate with an extended dry period and a maximum effective rainy season of about two months, July-August (Nyssen et al., 2005). To alleviate these water shortage related problems, the regional state of Tigray decided to construct a large number of small man-made reservoirs (Haregeweyn et al., 2006).

Reservoirs are described as artificial lakes and separated from natural lakes with some of their characteristics, such as high water flow velocity, solid matter presence in influent suspend and short-term water exchange (Harper, 1999). Reservoirs may exhibit particularly variable nutrient and light availability, both temporally and spatially. Nevertheless, a closer relationship between the catchment area and the aquatic system is a particular characteristic of reservoirs. Furthermore, these artificial ecosystems have a higher potential for eutrophication because of the release of nutrients from decomposing organic matter driven from flooded land (Kalff, 2002). Reservoirs are constructed for the main purpose of storing water and other uses, such as water supply for agriculture, urban activity, flood control, power generation, irrigation, recreational use and fish farming (Haregeweyn et al., 2006).

Water must be tested for different physicochemical parameters. The selection of parameters for testing water depends upon the intended use. Physical parameters for which samples are tested include temperature, pH, turbidity, water transparency (secchi depth), total suspended solid (TSS), etc., while chemical tests are often performed for inorganic nutrients, dissolved oxygen, alkalinity, salinity (or conductivity), hardness and total dissolved solids (TDS) (Patil et al., 2012).

The water quality of freshwater habitats provides substantial information about existing resources, which depends on the influences of physicochemical parameters and biological features. Life in aquatic environments is largely governed by different physicochemical water quality characteristics and their stability. These characteristics have enabled biota to develop many adaptations that improve sustained productivity and regulate reservoir metabolism. The role of various factors, such as temperature, transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, ammonia, nitrite, primary productivity, biochemical oxygen demand (BOD), plankton population, etc., can't be overlooked for maintaining a healthy aquatic environment and for the production of sufficient fish food organisms in reservoirs for increasing fish production (Geneviève et al., 2008).

The quality of water resources is declining due to both natural (change in precipitation, erosion) and anthropogenic (industrial and agricultural activities) factors (Sheela et al., 2012). In addition, all reservoirs are subjected to periodic fluctuations in water levels due to rain, hydrological regimes that are influenced by irrigation of agricultural lands and temperature changes (Duncan and Kubečka, 1995). Moreover, the clearance of catchment land use and water extraction modifies the natural flow and associated water quality characteristics. The availability of water and its physical, chemical, and biological quality and quantity are altered, organisms are often adversely affected and ecosystem services may be lost (Reynolds, 2006).

Previous studies were conducted on the ecology and related aspects of many manmade semiarid and arid reservoirs in Tigray (Asmelash et al., 2007; Dejenie et al., 2008; Teferi et al., 2014; Zebib and Teame, 2017). However, there are no scientific data on spatiotemporal water quality parameters for the selected young reservoirs. Therefore, the novelty of the present study is to generate scientific data on spatiotemporal water quality parameters, which have never been studied yet. We hypothesized that during the cold-dry and hot-dry seasons when the input of water is low, most water quality parameters would have higher concentrations (as compared to the wet season) for different reasons, such as re-suspension, absence of dilution, and increased evaporation.

2. Methodology

Description of the study site

This study was conducted in four selected man-made young reservoirs: Seisa, Mihtsab-Azmati, Mai-Dimu and Kalema. The study reservoirs are located in Tigray national regional state of Ethiopia. Tigray is found in northern Ethiopia with a rugged terrain ranging between 400 to almost 4000 masl, having a total surface area of 53,000 km² and lies between latitudes 12°15' and 14°57'N and longitudes 36°27' to 39°59'E (CSA, 2006). It is bounded in the north by Eritrea, to the west by the Sudan and to the east and south by the Afar and Amhara regions of Ethiopia, respectively (Fig. 1).

Seisa reservoir is found in Laelay Legomti Tabia (Tabia is the lowest administrative level in the Tigray national regional state of Ethiopia), Geter Adwa woreda (district) of central zone of Tigray. This site is found 27 km east of Adwa town. Seisa reservoir was constructed in 2014 with a capacity of 12 Mm³.

Mihtsab-Azmati reservoir is found in Baekel Tabia, Mereb Leak woreda, central zone of Tigray, which is found 9 km east of Rama town. This reservoir was constructed in 2014 with an actual water capacity of 34Mm³. Both reservoirs were constructed mainly for irrigation purposes.

Mai-Dimu reservoir is found in Mai-Dimu Tabia, Tahtay-Koraro woreda, northwestern zone of Tigray which is located 15 km west of Shire Endaselassie town. This reservoir was constructed in 2010, with 18Mm³ of water. The dam was mainly constructed for drinking

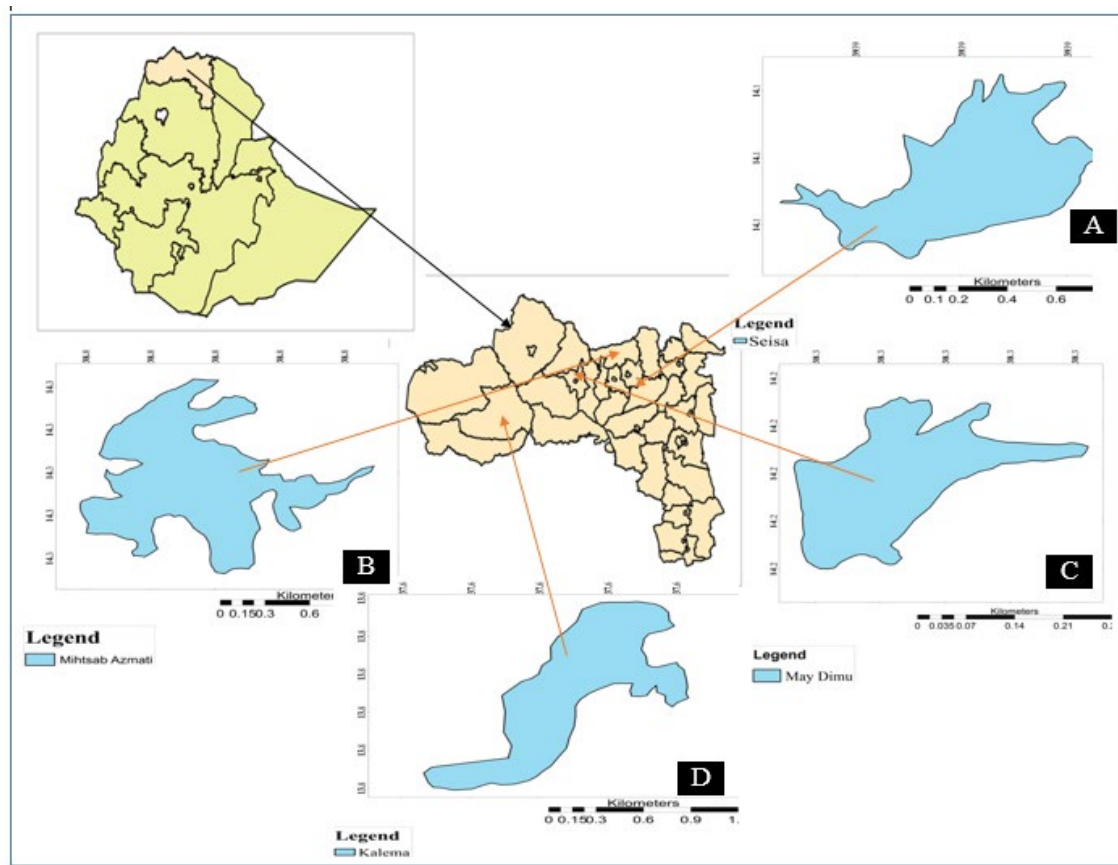


Fig.1. Map of Ethiopia (top left) and Tigray with districts (center). Inset map of the study sites: A=Seisa, B= Mihtsab Azmati, C= May Dimu and D= Kalema reservoirs.

purpose for the community of Shire Endasselassie town.

Kalema reservoir is found in Kalema Tabia, Wolkait woreda, located in western zone of Tigray, approximately 11 km west of Mai-Gaba town. The reservoir is constructed in Kalema River in 2013 for irrigation purpose for Wolkait sugar cane project. The Kalema reservoir is with a capacity to hold as much as 11Mm³ of water. Currently, the reservoir is irrigating over 3,000 hectares of land (Tigray Water Resources, Mines and Energy Bureau, 2017). Though these reservoirs were recently constructed to harvest water for irrigation and livestock and human drinking they may also have potential for fish production to provide additional sources of animal protein to the local community.

Sampling design and methodology

To select sampling sites characteristics of each reservoir were observed. Mihtsab-Azmati and Mai-Dimu reservoirs are relatively protected from direct human and animal contact. The waste from domestic animals and household disposals and other related agricultural byproducts may not easily reach the center of the reservoir, especially in the dry season when no flood carries waste matter from the watershed.

Kalema reservoirs situated on the Kalema river (a tributary of the Tekeze river) having a continuous year-round water flow but with low human and animal interference. Seisa reservoir was surrounded by agricultural land and human settlements. Hence, the site has a relatively high anthropogenic impact.

Water samples were collected bimonthly from October 2018 – September 2019 (two times in the dry-cold season (November/2018 and January/2019); two

times in the dry-hot season: (March and May/2019 and two times in the wet season (July and September/2019). Taking the surface area of the study reservoirs in to consideration, three littoral and two pelagic from Seisa, four littoral and two pelagic from Mihtsab Azmati, two littoral and two pelagic from Mai-Dimu and two littoral and two pelagic from Kalema reservoirs were selected. Spatial variables include geographical coordinates (altitude, latitude and longitude) and average depth was taken. A boat was used to take depth-integrated water samples (surface, middle, and just above bottom) at each site with a heart-valve sampler (volume: 3 L content). Temperature, dissolved oxygen, conductivity and pH of the water were measured in situ at three different depths (surface, middle, near-bottom) with a portable meter WTW Multi 340 I electrodes. We used calibrated fluorometer readings (Turner Aquafluor; an average of three measurements) on the pooled water sample to measure turbidity and chlorophyll-a concentration (as a proxy of phytoplankton biomass). Water transparency was measured using both a cylindrical Snell's tube (length: 0.6 m; diameter: 60 mm; disc diameter: 55 mm) and a secchi-disc (diameter: 30 cm). In shallow systems, the measurement of Snell's depth is often the preferable method to quantify water transparency because it avoids missing data in cases when reservoir sediments are visible.

Data analysis

Except pH, all variables were log transformed prior to statistical analysis. We studied patterns of association between the investigated variable with principal component analysis (PCA). Differences for each water

quality variables among the wet, cold-dry and hot-dry seasons were examined using one-way ANOVA but the independent t-test was used to analyze the littoral and pelagic variations at a significance level of $p < 0.05$. The degree of association between the water quality parameters were analyzed using the Pearson correlation coefficient r . The significance of these coefficients was tested at different probability levels ($p < 0.05^*$ and $p < 0.05^{**}$) (Beguin, 1979). The reservoir water quality variables were also subjected to multivariate statistical techniques using principal component analysis (PCA), which is one of the most commonly used multivariate statistical techniques (Quinn and Keough, 2002).

3. Result

Physicochemical characteristics

Average water quality parameters is presented in (Table 1). The highest and lowest pH mean values were recorded in the Seisa and Mai-Dimu reservoirs, respectively. The highest mean values of temperature (27.66 ± 0.15), chlorophyll *a* (108.81 ± 6.55) and conductivity (369.72 ± 10.2) were recorded in Kalema reservoir. However, lowest mean turbidity (4.07 ± 0.28) and secchi disc transparency (cm) (193.55 ± 3.53) were recorded in Seisa and Mihtsab-Azmati reservoirs during the study period. Mai-Dimu and Kalema reservoirs had the highest and lowest mean dissolved oxygen contents (6.23 ± 0.09 mg/l and 5.82 ± 0.13 mg/l), respectively.

Spatial variation in water quality parameters

Spatial variations in water quality parameters are presented in (Table 2). Overall littoral regions of the reservoirs showed statistically significant different values for pH, dissolved oxygen (mg/l) and transparency (cm) (Table 2). However, the values for most of the other water quality parameters did not show significant difference in spatial variation during the study period. The littoral and pelagic habitats of Mihtsab-Azmati reservoir had the highest (6.53 mg/l) and lowest (5.52 mg/l) mean values of dissolved oxygen, respectively, compared with the other selected reservoirs during the study period (Table 2). The highest and the lowest water temperatures were recorded in the pelagic habitat of Kalema and Seisa reservoirs, respectively. Only the mean values of pH and dissolved oxygen (mg/l) were significantly different ($p < 0.05$) in Mihtsab-Azmati and Seisa reservoirs. Furthermore, the

mean value of pH has a spatially significant difference ($p < 0.05$) in Mai-Dimu reservoir. None of the physico-chemical water quality parameters in Kalema reservoir exhibited spatially significant ($p > 0.05$) variations. Similarly, other water quality parameters such as temperature, chlorophyll *a*, turbidity, secchi disc transparency and conductivity in all the four study reservoirs were also not significant ($p > 0.05$) spatially.

Seasonal variation in water quality parameters

Seasonal variation in water quality parameters is described in (Table 3). In Mihtsab-Azmati reservoir, highest values pH mean value (8.51), dissolved oxygen (6.69 mg/l), chlorophyll *a* ($45.87 \mu\text{g l}^{-1}$) and turbidity (3.66 NTU) were recorded during the wet season. However, highest values of temperature (26.38°C) and transparency (207.5 cm) were recorded during the dry-hot season. All the water quality variables were seasonally (among wet, dry-cold and dry-hot) significant ($p < 0.05$) (Table 3). Highest values of dissolved oxygen (6.73 mg/l), chlorophyll-*a* ($62.13 \mu\text{g l}^{-1}$), transparency (127.50 cm) and conductivity ($80.19 \mu\text{S/cm}$) were measured during the dry-cold season in Mai-Dimu reservoir. Whereas, pH (7.88) and transparency (92.61 cm) were measured with lowest values during the wet season. Except turbidity all the water quality variables were shown significant variation seasonally ($p < 0.05$). In Seisa reservoir highest values of pH (8.36), dissolved oxygen (6.16 mg/l), chlorophyll-*a* ($77.71 \mu\text{g l}^{-1}$) and turbidity (4.60 NTU) during the wet season but temperature (23.48°C) and conductivity ($211.47 \mu\text{S/cm}$) were measured during the dry-hot season. Among the water quality parameters only chlorophyll-*a*, temperature and conductivity showed significant variation ($p < 0.05$) seasonally. In Kalema reservoir temperature (28.25°C), conductivity ($463.10 \mu\text{S/cm}$) and chlorophyll-*a* ($130.34 \mu\text{g l}^{-1}$) were recorded with the highest value during the dry-hot season (Table 3).

Correlation analysis between physicochemical water quality parameters

The degree of association between any two of the water quality parameters as measured by the simple correlation coefficient (r) is presented in (Table 4). Accordingly, pH has a significant negative correlation with chlorophyll-*a* ($\mu\text{g/l}$) and conductivity ($\mu\text{S/cm}$), with correlation values of $r = -0.195$ and $r = -0.100$, respectively, with significance at $p < 0.01$.

Table 1. Annual average water quality parameters (mean $\pm$ SE) of the four study reservoirs

Reservoir	Altitude (masl)	Av/Depth (m)	pH	Dissolved Oxygen (mg/l)	Temperature ($^\circ\text{C}$)	Chlorophyll <i>a</i> ($\mu\text{g l}^{-1}$)	Turbidity (NTU)	Secchi disc-transparency (cm)	Conductivity ($\mu\text{S/cm}$)
MA	1512	21.5	8.22 ± 0.02	6.19 ± 1.10	24.78 ± 0.15	38.88 ± 1.17	2.43 ± 0.19	193.55 ± 3.53	182.73 ± 5.64
MD	1642	17	7.97 ± 0.03	6.23 ± 0.09	22.77 ± 0.17	50.85 ± 1.77	3.10 ± 0.80	113.87 ± 2.55	67.95 ± 2.38
SE	1941	17	8.23 ± 0.04	6.10 ± 1.10	22.29 ± 1.14	67.16 ± 2.16	4.07 ± 0.28	93.06 ± 2.74	159.96 ± 4.88
KA	827	10.5	7.98 ± 0.06	5.82 ± 0.13	27.66 ± 0.15	108.81 ± 6.55	1.69 ± 0.13	103.65 ± 5.94	369.72 ± 10.2

Note: MA – Mihtsab Azmati, MD – Mai-Dimu, SE – Seisa and KA – Kalema reservoirs

Table 2. Spatial variation in physicochemical parameters with in the reservoirs (mean during the study period)

Physico-chemical parameters	Reservoirs											
	Mihtsab Azmati			Mai-Dimu			Seisa			Kalema		
	Littoral	Pelagic	P value	Littoral	Pelagic	P value	Littoral	Pelagic	P value	Littoral	Pelagic	P value
pH	8.27	8.12	0.00	7.89	8.06	0.00	8.34	8.06	0.00	8.10	7.87	0.07
DO (mg/l)	6.53	5.52	0.00	6.37	6.22	0.44	6.36	5.70	0.00	5.72	5.93	0.45
Temp (°C)	25.01	24.49	0.13	22.72	22.82	0.79	22.46	22.02	0.13	27.48	27.85	0.22
Chl a (µg l ⁻¹)	40.24	36.18	0.10	50.98	50.73	0.94	70.04	62.84	0.10	115.75	101.86	0.29
Turb (NTU)	2.54	2.88	0.65	3.61	2.59	0.53	3.84	4.41	0.32	1.53	1.85	0.22
Trans (cm)	193.45	193.75	0.97	112.08	115.66	0.48	87.88	100.83	0.02	101.40	105.90	0.70
Cond (µScm ⁻¹)	184.35	179.49	0.68	69.66	66.25	0.47	161.59	157.51	0.68	359.04	380.39	0.29

Note: $p < 0.05$ (significant) and $p > 0.05$ (not significant)

and $p < 0.05$, respectively. However, a positive correlation was observed between pH and secchi disc transparency (cm), pH and turbidity (NTU), pH and water temperature (°C) and pH and dissolved oxygen (mg/l), with correlation values of $r = 0.135$, $r = 0.007$, $r = 0.07$ and $r = 0.267$, respectively, with significance at $p < 0.05$, $p < 0.05$, $p > 0.05$ and $p < 0.01$, respectively. Dissolved oxygen (mg/l) was positively correlated with turbidity ($r = 0.080$), but it was negatively correlated with secchi disc transparency, water temperature (°C), chlorophyll-*a* (µg/l) and conductivity (µS/cm), with correlation values of $r = 0.049$, $r = -0.095^*$, -0.088 and -0.136^{**} , respectively. A highly significant negative correlation ($r = -0.212$, $p < 0.01$) was recorded between water temperature (°C) and turbidity (NTU), but a highly significant positive correlation ($r = 0.260$,

$p < 0.01$), ($r = 0.187$, $p < 0.01$) ($r = 0.472$, $p < 0.01$) was observed between water temperature (°C) and chlorophyll-*a* (µg/l), water temperature (°C) and secchi disc transparency (cm) and water temperature (°C) and conductivity (µS/cm). The value of chlorophyll-*a* (µg/l) was negatively correlated and highly significantly negatively correlated with turbidity (NTU) and secchi disc transparency (cm) ($r = -0.59$, $p > 0.05$ and $r = -0.300$, $p < 0.01$) but highly positively correlated with conductivity (µS/cm) ($r = 0.506$, $p < 0.01$). Significant negative correlation analysis values ($r = -0.143$, $p < 0.01$), ($r = -0.123$, $p < 0.05$) and ($r = -0.006$, $p < 0.05$) were recorded between turbidity (NTU) and secchi disc transparency (cm), turbidity (NTU) and conductivity (µS/cm) and between secchi disc transparency (cm) and conductivity (µS/cm), respectively.

Table 3. Seasonal water quality parameters of four reservoirs 2018/19

Reservoirs	Spatio-temporal variations		Altitude (masl)	Depth (m)	pH	DO (mg/l)	Temp (°C)	Chl a (µg l ⁻¹)	Turb (NTU)	Transp (cm)	Cond (µS/cm)
Mihtsab-Azmati	Season	Wet	1512	15.20	8.51	6.69	25.50	45.87	3.66	193.17	119.10
		Dry-cold		11.46	8.12	6.08	22.51	39.96	1.91	180.25	267.29
		Dry-hot		7.29	8.10	5.75	26.38	30.84	1.61	207.25	160.60
		p-value			0.00	0.00	0.00	0.00	0.00	0.02	0.00
Mai-Dimu	Season	Wet	1642	16.96	8.17	5.60	23.84	48.94	5.03	92.61	62.42
		Dry-cold		13.13	7.88	6.73	21.08	62.13	2.79	127.50	80.19
		Dry-hot		7.75	7.96	6.43	23.39	41.14	1.66	122.88	59.35
		p-value			0.00	0.00	0.00	0.00	0.23	0.00	0.00
Seisa	Season	Wet	1941	14.45	8.36	6.16	23.06	77.71	4.60	85.50	126.27
		Dry-cold		9.78	8.20	5.86	20.33	65.08	4.29	96.90	140.71
		Dry-hot		5.90	8.23	6.13	23.48	58.71	3.32	96.80	211.47
		p-value			0.28	0.63	0.00	0.00	0.16	0.24	0.00
Kalema	Season	Wet	827	4.50	8.40	5.37	27.55	43.93	2.11	174.39	207.13
		Dry-cold		8.75	7.78	6.14	26.92	119.72	2.06	69.88	335.70
		Dry-hot		5.81	7.97	5.55	28.25	130.34	1.37	155.75	463.10
		p-value			0.00	0.17	0.00	0.00	0.10	0.00	0.00

Note: $p < 0.05$ (significant difference) and $p > 0.05$ (no significant difference)

Table 4. Correlation matrix between different physicochemical water quality parameters of the selected reservoirs. All parameters were analyzed using Pearson correlation

	pH	DO	Temp	Chl a	Turb	Transp	Condu
pH	1						
DO	0.267**	1					
Temp	0.007	-0.095*	1				
Chl a	-0.196**	-0.088	0.260**	1			
Turb	0.135*	0.080	-0.183**	-0.59	1		
Transp	0.007	-0.049	0.187**	-0.300**	-0.143**	1	
Condu	-0.100*	-0.136**	0.472**	0.506**	-0.123*	-0.006	1

Note: + = Positive Correlation, - = Negative Correlation, * = Correlation is significant at $p < 0.05$ level, ** = Correlation is significant at $p < 0.01$ level

Data are the mean value of bimonthly collected samples; 1. pH 2. DO-Dissolved Oxygen (mg/l) 3. Temp-Water temperature ($^{\circ}\text{C}$) 4. Chl a- chlorophyll-a ($\mu\text{g l}^{-1}$) 5. Turb-Turbidity (NTU) 6. Transp-Secchi disc transparency (cm) 7. Condu-Conductivity ($\mu\text{S/cm}$)

Principal component analysis

More than 77% of the variation in environmental variables of the reservoirs is explained by two PCA axes, and axis 1 is highly loaded by chlorophyll-a, conductivity, temperature and transparency. The Principal Component Analysis (PCA) showed that the first principal components (Axis 1) represented approximately 50.9% of the total variation in the entire data set. However, Axis 2 contains pH, turbidity and dissolved oxygen. This graph showed that turbidity and transparency had negatively co-related. Dissolved oxygen and pH were also showed strong positive correlation with the littoral site. Temperature also showed reverse co-relation with altitude. The principal components (PCs) helped to classify the water quality factor loadings as strong, moderate, or weak in correspondence

with their absolute loading strengths of > 0.75 , $0.75-0.50$, and $0.50-0.30$, respectively (Fig. 2).

4. Discussion

We have detected seasonal variation among the measured water quality parameters, with values for chlorophyll-a, pH and turbidity being higher during the wet season in most reservoirs while the values for water temperature was higher during the dry-hot season. During the study period a narrow spatial variation of mean pH value was recorded among the reservoirs, with minimum value (7.78) in Kalema and maximum value (8.51) in Mihtsab Azmati. The mean pH values of young reservoirs studied here indicate that the reservoirs are relatively alkaline system. The pH range of these young reservoirs fall within the pH value accepted as good water quality (6.5 to 8.5) for drainage basins across the globe (Carr and Neary, 2008). The pH values reported here are similar to other young reservoirs previously reported by other researchers (Teferi et al., 2013; Tadesse et al., 2015).

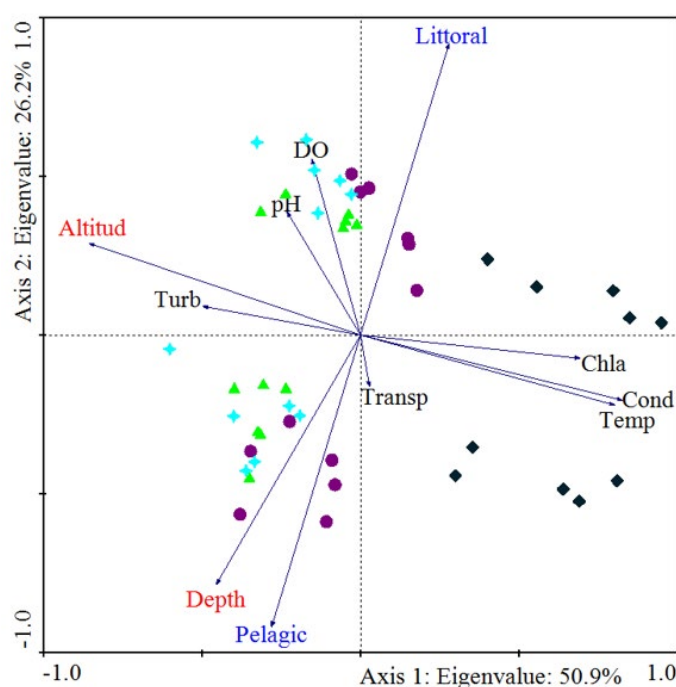


Fig.2. Biplot of Principal Component Analysis (PCA), results showing the association between water quality variables of the four study reservoirs. Seisa reservoir (◆), Mihtsab-Azmati reservoir (●), Mai-Dimu reservoir (▲) and Kalema reservoir (◆). The abbreviations in the PCA graph is: Altitud = altitude, Temp = temperature, cond = electrical conductivity, Turbidit, Turbidity, DO = dissolved oxygen, Chla = chlorophyll-a, Transp = water transparency).

A previous study in Funil reservoir by Francisco et al. (2011) reported higher mean values of pH during the wet season (8.6) and lower mean values during the dry season (7.2), with no significant seasonal differences, which agrees with the current finding. Shallow tropical reservoirs critically exhibit longitudinal gradients in turbidity, nutrient concentration, mixing depth, euphotic depth, with sufficient light for photosynthesis, flushing rates, chlorophyll concentration, plankton productivity, fish standing stocks, macrophytes abundance, benthic community structure and other limnological and biological variables. The highest pH was due to having much increased photosynthesis activity by phytoplankton than the respiratory activity (Atobatele and Ugwumba, 2008; Meesukko et al., 2007) and presence of high turbulence. However, low pH was recorded due to reduced photosynthetic activity (Rafique et al., 2002); the absence of rain (Atobatele and Ugwumba, 2008) and the decomposition of organic matter by microbial activity which was enhanced by high temperature, causing excessive production of carbon dioxide and reduced pH (Moundiotiya et al., 2004). According to Gupta and Gupta (2006), accumulation of free carbon dioxide due to little photosynthetic activities of phytoplankton (during rainy season) will lower pH values of waterbody while intense photosynthesis by phytoplankton (during dry season) will increase pH values. pH is a very important factor of water body for the fish culture as it controls the amount of soluble ions in the water. An acidic pH of water reduces the growth rate, metabolic rate and other physiological activities of fishes (Mollah et al., 2015), thus suggested that pH values varying from 6.5 to 9.0 as suitable for the normal growth of fishes.

Dissolved oxygen is one of the most important water quality parameters, and its correlation with water bodies provides direct and indirect information, e.g., bacterial activity, photosynthesis, availability of nutrients, and stratification (Premlata, 2009). A similar study by Thirupathaiah et al. (2012) and Hussain et al. (2013) reported minimum and maximum values of dissolved oxygen (5.60 to 8.395 mg/l and 5.0 to 9.46 mg/l, respectively), which is a narrow range but higher value compared with the present finding. The variation in dissolved oxygen in different reservoirs may be due to the high metabolic rate of organisms and low atmospheric temperature. The mean dissolved oxygen in all reservoirs of the current finding was higher than previous finding (Zebib and Teame, 2017) with mean dissolved oxygen value (4.77 and 4.85 mg/l) but lower than Tadesse et al. (2015) reported higher average dissolved oxygen value 7.03 mg/l from five tropical small dams (Korrir, Laelay Wukro, Mai Nigus, Mai Sessea and Mai Seye dams) and Berihun and Dejenie (2012) reported 7.19 mg/l average dissolved oxygen value for Korrir and Laelay Wukro dams. Sources of dissolved oxygen in the aquatic environment include the atmosphere and photosynthesis. This depends on its solubility, while a loss of oxygen includes respiration, decay by aerobic bacteria and decomposition of dead decaying sediments (Gupta and Gupta, 2006).

In the present study, higher mean values of dissolved oxygen (5.37 mg/l and 6.73 mg/l) were

recorded in Kalema and Mai-Dimu reservoirs in the wet and dry-cold seasons, which is in agreement with previous findings by Francisco et al. (2011) in the Funil Reservoir. This may be due to the addition of varieties of biodegradable pollutants from domestic sewage, municipal wastes, run-off from agricultural land, etc, that stimulate the growth of microorganisms that consume dissolved oxygen from decomposition. Long days and intense sunlight seems to accelerate photosynthesis by phytoplankton, utilizing carbon dioxide and giving off oxygen, possibly for greater qualities of oxygen recorded during the dry season (Krishnamurthy, 1990). The dissolved oxygen concentration in the aquatic ecosystem is regulated by the process of diffusion of oxygen from the atmosphere, photosynthetic activity, respiration and decomposition of aquatic organisms (Mollah et al., 2015).

The mean water temperature of the study sites has showed spatial variation with 22.51 to 26.38 °C in Mihtsab Azmati, 21.08 to 23.84 °C in Mai-Dimu, 20.33 to 23.48 °C in Seisa and 26.92 to 28.25 °C in Kalema reservoirs, which is supported by Thirupathaiah et al. (2012). The water temperature of the lower Manair reservoir of the Karimnagar district ranged from 24.75 °C to 28.5 °C in different seasons. The fluctuation in water temperature was high, which may be due to the low water level, high air temperature and clean atmosphere. The present finding was showed higher values compared to previous study by Zebib and Teame (2017) in Korrir (20.07 °C) and Laelay Wukro (21.98 °C) reservoirs. Berihun and Dejenie (2012) also found an 18.88 °C average temperature value for Korrir and Laelay Wukro reservoirs for one year of data, which is lower than the present finding. The variation in water temperature among the reservoirs might be depend on altitude because as altitude increases, water temperature decreases. Water temperature affects the activity, growth and reproduction of all organisms, including fish (Wetzel, 1983). In the present study, we found that there was a distinct seasonal pattern in water temperature, which was higher in the dry-hot season in most of the investigated reservoirs. The current finding was in disagreed with (Francisco et al., 2011). Senthil and Prabakaran (2012) reported that higher average temperatures were recorded during the wet season. However, in line with the present finding, Woldeab et al. (2018) reported higher water temperatures (22.49 to 25 °C) in the dry season from the Gilgel Gibe reservoir. Similar findings in the Eleyele reservoir (Olanrewaju et al., 2017), Ado-Ekiti reservoir (Idowu et al., 2013), Oyun reservoir (Mustapha, 2009) and Ero reservoir (Oso and Fagbuaro, 2008) also reported higher temperatures during the dry season. The low temperature observed during the rains could be due to high humidity and moderate or less sunlight in this period of the year.

Secchi disc depth is a good indicator of environmental health and ecological productivity. In the present study, spatiotemporal variation of secchi disc-water transparency was observed among reservoirs with higher mean value during the dry season. Zebib and Teame (2017) reported higher mean value of secchi disc-water transparency (29.55cm) in Laelay Wukro

reservoir. Secchi disc-water transparency in Gereb Awso reservoir (0.15m), in Tsinkanet reservoir (0.7m) and in Mai Gassa I reservoir (0.3m) were also reported by Teferi et al. (2013). In 32 reservoirs found in Tigray also reported a mean value of secchi disc-water transparency (0.46m) by Dejenie et al. (2008). However, all these previous findings were lower than the current finding with 69.88 cm and 207.25 cm mean value of secchi disc-water transparency in Kalema and Mihtsab-Azmati reservoirs, respectively. Therefore, these values reflect that the depth of light penetration is good in the present finding, which is worthy of a shallow reservoir as plankton grow, thus making food available to fish. The present finding agrees with similar previous findings of Syarifah et al. (2018) in the Sembrong reservoir, Olanrewaju et al. (2017) in the Eleyele reservoir, Francisco et al. (2011) in the Funil reservoir and Thirupathaiah et al. (2012) in the lower Manair reservoir. This seasonal variation was due to erosion from the upper catchment that created a sediment load on reservoirs because most of the catchment of the reservoirs was not well protected. The main reason for lower Secchi disc-water transparency in the wet season may be due to high concentrations of dissolved and particulate substances (eroded soils and nutrients) that were transported from the surrounding catchment into the reservoir after rainfall reduced light transmission and water clarity. On the other hand, Khan and Chowdhury (1994) reported that higher water transparency occurred during the dry season, which may be due to the absence of rain, runoff and flood water as well as the gradual settling of suspended particles.

We found that there was a distinct seasonal pattern with a higher mean value of electrical conductivity in the dry-cold and dry-hot seasons. This difference may be due to the difference in geological characteristics of these watersheds. Similar findings were also reported by Woldeab et al. (2018) in the Gilgel Gibe reservoir, Fasil et al. (2011) in Koka reservoir but highly lower than the previous finding of Tessema et al. (2014) (569 $\mu\text{S}/\text{cm}$) in the Tendaho. During the dry season, the increased concentration of electrical conductivity may be associated with evaporation and the absence of a dilution effect, while the lower values during the wet season are hypothesized to be due to the effect of dilution arising from the tributaries. The higher conductivity values measured during the dry season in the sampling period, indicating the apparent correlation between conductivity and water level.

Turbidity is a measure of how particles suspended in water affect water clarity. Turbidity results in a decrease in the intensity of light that passes through cloudiness or turbidity water due to light, absorption, and reflection of light, it also increases sharply during and after rainfall, which causes sediment to be carried into the water body (Higham et al., 2015). In the present finding, higher values of turbidity were recorded during the wet season and pelagic habitat in the studied reservoirs, and Mai-Dimu reservoir had the highest mean turbidity value of 5.03 NTU compared with the others. This finding is in line with previous research reports in Ajiwa reservoir Usman et al. (2017), Tono reservoir Akongyuure and Alhassan (2021), Gilgel Gibe

reservoir Woldeab et al. (2018). This might be because the watershed of the reservoirs is surrounded by agricultural farmlands and eroded silt particles by floods. Similar findings by Dagaonkar and Saksena (1992), Thirupathaiah et al. (2012) and Garg et al. (2006b) have also reported that high turbidity during the rainy season may be due to higher incoming flows or run-offs which cause re-suspension of dissolved materials. During the rainy season, silt, clay and other suspended particles contribute to the turbidity values, while during the dry season, the settlement of silt and clay results in low turbidity. Turbidity is also able to increase the water temperature because the particles in the water to the surface absorb more heat. These factors lead to the reduction of dissolved oxygen (Léziart et al., 2019). Turbidity measurement is an important test when trying to determine water quality.

Chlorophyll is a measure of the number of algae growing in a water body and is also used to classify the trophic condition of a water body. During the study period temporal variation in chlorophyll-*a* concentration was observed among the reservoirs with highest mean value (130.34 $\mu\text{g}/\text{l}$) recorded in Kalema reservoir. Teferi et al. (2013) also reported highest mean value of chlorophyll-*a* (65.64 $\mu\text{g}/\text{l}$) in Tsinkanet reservoir which is lower than the current finding. Dejenie et al. (2008) also reported similar finding in the 32 reservoirs in Tigray. Largest concentrations of chlorophyll-*a* in the transition zone can be due to the theoretical relationship between light and phosphorous, with a higher concentration in this area, increasing the primary productivity. In this relationship, the possibility of resuspension of forms of phosphorus trapped in the sediment that, associated with light availability, may cause elevated concentrations of chlorophyll-*a* and phytoplankton in the shoreline of reservoirs.

Moreover, the present study also analyzed the correlation coefficient (*r*) between every water quality parameter pair computed by taking the average values of the studied sites. Accordingly, pH with water temperature, turbidity, Secchi disc-water transparency and dissolved oxygen has been found to show positive correlations. The present finding disagrees with similar previous findings by Thirupathaiah et al. (2012); Atique and Kwang-Guk (2019) also reported a negative correlation between pH and dissolved oxygen, which is different from the present finding. However, a positive correlation of pH with electrical conductivity, pH with chlorophyll-*a* and dissolved oxygen with chlorophyll-*a* was also reported, which disagrees with the present finding. As indicated, the negative correlation of dissolved oxygen with numerous other water quality parameters (water temperature, electrical conductivity and chlorophyll-*a*) in the present study revealed the persistence of organic pollution in reservoirs, which can be reflected as one of the main roots of chemical, ecological, and environmental degradation. The present finding reported a highly significant positive relationship between water temperature and Secchi disc-water transparency and was in line with previous findings from the Awab reservoir by Anago et al. (2013). This could be possible because light heats the surface of the water before penetrating into other depths.

Negative correlation between turbidity and chlorophyll-*a* was observed during the present finding. This is agreed with the finding of Bacroume et al. (2015) studied in the Mansour Eddahbi reservoir, Morocco. This might be due to high water depth because in present finding the minimum average depth of the reservoirs is above ten meter. This means the fish species found in the reservoirs is less impact of increase turbidity by re-suspended the bottom layer. The reservoirs were newly established and less effect of agricultural activity so they are not affected by algal bloom. Alternatively, the turbidity has a negative effect on algal photosynthesis. It influences the degree of light penetration in the water column; also the turbidity adsorbs phosphates (nutrient) by silt (Zhang et al., 2010). This may explain the interaction of the turbidity and chlorophyll-*a*. However, Dejenie et al. (2008) reported positive correlation between chlorophyll-*a* and turbidity which was conducted in 32 manmade tropical highland reservoirs.

The maximum depths of the reservoirs were 11 meter which much shallow compared with the presently studied reservoirs. Often, water quality in such reservoirs is poor and is characterized by high nutrient levels, high turbidity and phytoplankton blooms. In addition the dominance Garra in the reservoirs can potentially have an impact on important ecosystem characteristics of the reservoirs (water transparency, nutrient availability, phytoplankton primary productivity).

5. Conclusion and Recommendations

This study persuasively contributes to assessing spatiotemporal water quality dynamics to provide valuable insight into the general health status of the selected young reservoirs. The physicochemical parameters of Mihtsab Azmati, Mai-Dimu, Seisa and Kalema reservoirs showed distinct temporal and spatial variations throughout the study period. Most physicochemical water quality variables (pH, dissolved oxygen, electrical conductivity and chlorophyll-*a*) were also spatially higher in the littoral site. pH was significantly positively correlated with water transparency, turbidity and temperature. However, dissolved oxygen showed a negative correlation with transparency, turbidity, temperature, chlorophyll-*a* and electrical conductivity. Turbidity also had a significantly negative correlation with water transparency and temperature. In this study, we tried to analyze some physicochemical water quality variables, but further detailed studies that include total phosphorus, total nitrogen, etc., are needed to suggest the trophic conditions of the reservoirs.

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Data availability declaration

We declare that whatever data have been used in the manuscript will remain intact. These data can be made available to anyone who desires to see them from the corresponding author on request.

Competing interest declaration

The authors declare that they have no competing interests.

Authors' contribution

Kalayu Mesn, Mekonen Teferi, Tsehaye Asmelash and Tsegazeabe Hadush collected the field data. Tsehaye Asmelash prepared the tables and figures. Tsegazeabe Hadush and Mekonen Teferi analyzed the collected data. All authors' interpreted the results, wrote the document and approved the final manuscript.

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