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# Assessment of the influence of water quality on the primary productivity of the mtera dam, Tanzania

*[1,2]*PASCAL M., [1]KATONGE J H., [1]ANGELINA M*

[1]Department of Physics, The University of Dodoma, Dodoma, Tanzania
[2]The Ministry of Livestock and Fisheries, Itigi District Council, Fisheries Section, P. O. Box 70, Singida, Tanzania

***Corresponding Author**: michaelpaschal598@gmail.com

**Abstract**

Mtera Dam, the largest dam in Tanzania, was built primarily for hydroelectric power generation. It also serves other potential purposes, including fishing, irrigation, and community water supply. Despite government efforts, fish production in the dam has decreased, and pollution levels have increased due to disturbances caused by anthropogenic activities. This study investigated the influence of physical and chemical water quality parameters on Mtera Dam's primary productivity. Water samples were collected from three fish landing sites and each site was divided into strata I (shallower part) and strata II (Deeper part). Temperature (temp), dissolved oxygen (DO), pH, total dissolved solids (TDS), electrical conductivity (EC), turbidity (Turb), phosphate (PO43-), nitrate (NO3-), nitrite (NO2-), silicate (SiO2), and chlorophyll a (Chl-a) were measured. Most parameters fell within allowable limits, except for temperature, which exceeded them, and pH levels, which approached maximum standards (8.48±1.01) in the dry season. Measurements were as follows: pH (7.71±1.07), temp (30.64±4.17°C), DO (7.72±1.22 mg/L), TDS (120.23±11.10 mg/L), EC (239.68±22.87 µS/cm), Turb (165.37±22.59 NTU), PO43- (3.25±3.85 mg/L), NO3- (11.88±6.75 mg/L), NO2- (9.27±6.49 mg/L), SiO2 (7.72±4.09 mg/L), and Chl-a (8.08±7.03 mg/L). Physicochemical parameters exhibited significant variations across seasons and stations ($p < 0.01$) and showed a significant correlation with primary productivity ($p < 0.01$). Linear regression results indicated that physicochemical parameters positively influenced primary productivity ($p < 0.01$). Chl-a significantly varied between strata I and strata II in dry (4.34 ± 3.04 mg/L) and wet seasons (11.82 ± 5.04 mg/L) within a range of 1.4 mg/L to 24.42 mg/L. The study observed changes in primary productivity as water quality variables fluctuated. Therefore, implementing a more comprehensive and adaptive management approach that includes long-term, improved water quality monitoring programs is necessary.

**Keywords:** *Anthropogenic activities; Mtera Dam; Physicochemical parameters; Seasonal variation; Water quality*

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## Introduction

Mtera Dam covers 660 square kilometres and is located midway between the Dodoma and Iringa regions. Built in the 1980s, it is sourced from two Rivers, the Ruaha River and the Kisigo River (URT, 2014). Mtera is a freshwater resource that supports hydropower generation, agricultural activities, and fisheries (Semanini, 2010; Mgandu *et al.*, 2020). The primary productivity of such reservoirs is directly connected to their nutrient levels, such as phosphate and nitrate, which are the main factors for the health of the aquatic food web (Panikkare *et al.,*2022). Currently, the dam faces massive pollution from human activities conducted in and outside the water such as domestic uses, agricultural activities, livestock grazing and fishing activities. Massive increases in siltation in reservoirs, resulting from human activities, have degraded water quality in freshwater ecosystems (Kumar *et al.,*2022). Therefore, freshwater ecosystems should be properly monitored, managed, and conserved for sustainable productivity of fishery resources (Rajabu, 2007).

Physicochemical parameters of water such as temperature, dissolved oxygen, total dissolved solids, turbidity, electrical conductivity, silica, nitrate, and phosphate are essential variables in freshwater ecosystems since the overall health of aquatic ecosystems depends on these parameters, therefore proper conservation of fishery resources depends on the deep assessment of the physicochemical parameters (Venkatesharaju *et al.,* 2010; Mishra *et al.,* 2023). Massive increases in phosphorous and nitrogen from human activities are causing eutrophication in water bodies. This leads to excessive phytoplankton growth and harmful algal blooms (Akinnawo, 2023). This phenomenon destroys water quality, leading to a depletion of oxygen, which in turn impacts aquatic organisms in freshwater bodies (Bhateria and Jain, 2016; Oduor *et al*., 2023).

Chlorophyll-*a* content in lakes, reservoirs, or dams is used as the key determinant of primary productivity which is mostly affected by nutrient level (phosphorous and nitrogen) and sunlight availability in water (Hiroki *et al*., 2020). Chlorophyll- *a,* an essential molecule for photosynthetic organisms as a photoreceptor such organisms include diatoms, brown algae, red algae, and green algae which play a great role in absorbing and converting sunlight energy into the organic compound and thus serve as food and oxygen producing while reducing carbon in water during photosynthesis process (Walker *et al*., 2007; Nunez-Pons*et al*., 2018).

By following standard procedures, this study employed in-situ measurements and laboratory analysis to determine the physicochemical parameters of water in the Mtera dam (Riduan *et al*., 2009; Al-Fahdawi *et al*., 2015). Electrical conductivity, pH, temperature, and dissolved oxygen were measured using a multiprobe meter whereas phosphate, nitrite, nitrate, and chlorophyll-a were measured in the laboratory using a UV-visible spectrophotometer (Weber, 1980).

Conservation of these reservoirs can be controlled by managing all the human activities conducted across water sources such as lakes, dams, or rivers (Adjovu *et al*., 2023). It is important to consider the sustainability of nutrient dynamics in the Mtera dam to manage aquatic resources properly. Most studies recommend ecological restoration to conserve the exploited resources in inland waters (Kibanda, 2019; Sun *et al*., 2024).

The production of these organisms in dams forms the base of the aquatic food chain and food web, maintaining ecological balance, and promoting overall health, abundance, and diversity of the freshwater ecosystem. Therefore, studying chlorophyll-a level in lakes is very important because it is a key indicator of ecological health, dynamic, abundance, and diversity of aquatic species including fish.

Unfortunately, there remains a deficiency of comprehensive and up-to-date information regarding the current state of water quality and primary productivity of the Mtera dam. Given these obstacles and the crucial need to ensure the viability of the fishery resources, this study aims to bridge the current gaps in knowledge.

Therefore, this study investigates the influence of physicochemical water parameters on the primary productivity of the Mtera Dam. The present study also investigates seasonal variation and spatial variations between water quality parameters. Moreover, this study provides the pathway to ensure the proper monitoring and appropriate management of the dam as well as the general ecological health of the Mtera dam ecosystem.

Furthermore, this study provides more detailed information on how water quality parameters determine the primary productivity of the Mtera dam. Hence this study will help to regulate the effects posed by pollution and degradation due to various anthropogenic activities that are conducted adjacent to the Dam.

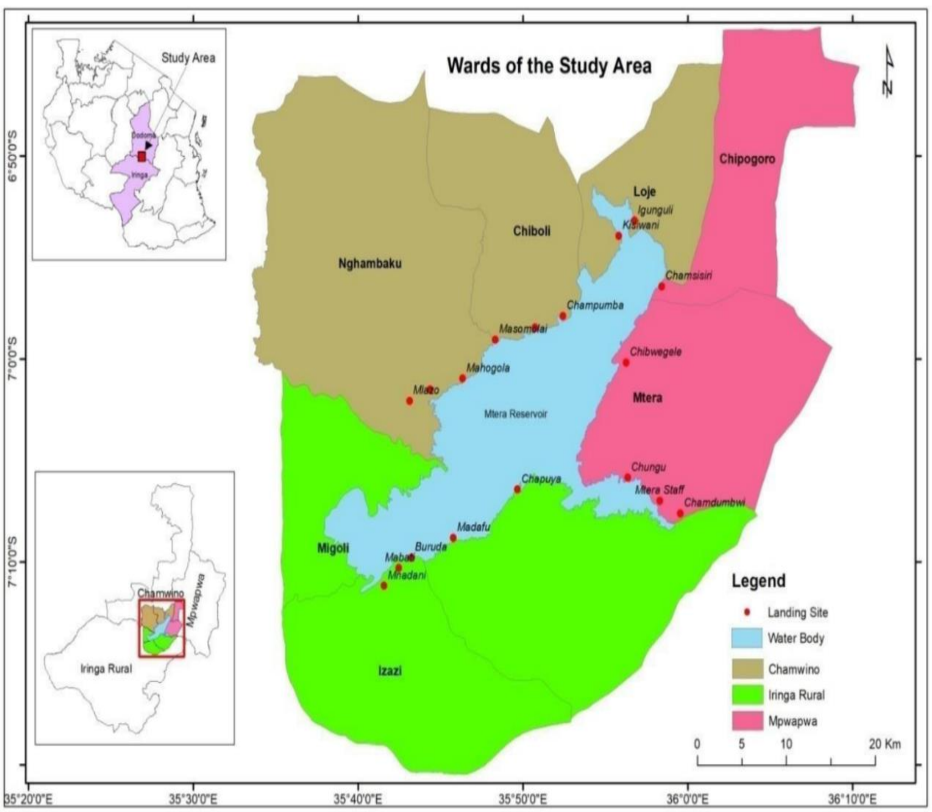
## Materials and Methods

### *Description of the Study Area*

Mtera Dam is the largest man-made dam in Tanzania which was built in 1979 mainly for hydroelectric power generation (Mwalyosi, 1986). Currently, the dam is used for other socio-economic activities including fishing, irrigation, and community water supply (Tortajada, 2015; Perera and North, 2021). It covers 660 square kilometres and is located midway between the Dodoma and Iringa regions (Kibanda, 2019). Mtera Dam is located within the boundaries of three districts: Mpwapwa, Iringa Rural, and Chamwino. It lies within the latitudes 7°09′10.4′′S and longitudes 35°58′12.5′′E (Figure 1). The Dam is 56 kilometres long and 15 kilometres wide. The main sources of water for this dam are the Great Ruaha River and the Kisigo River. The area has a mean temperature and average rainfall of 22.6 °C and 564mm/year respectively (URT, 2014; Bayo and Rija, 2021).

**Figure 1**

*The Map showing landing sites in Mtera Dam and its location between Iringa and Dodoma Regions*




### *The research design*

A longitudinal and experimental research design was employed which involved the collection of data over time and the testing of variables (independent and dependent variables). Two-level stratified random sampling was used, with strata defined by shallower and deeper parts within each landing site. Two landing sites were found in the Mpwapwa district (Mtera and Chamsisiri landing sites), one from the Iringa rural district (Madafu landing site), and two strata in depth for each site (shallower and deeper parts). Sampling spanned two seasons dry and wet in which water samples were collected every month from January to December (2022 to 2023).

***Sampling Procedures and Measurement***

Water samples were collected from six sampling stations ($S_1$, $S_2$, $S_3$, $S_4$, $S_5$, and $S_6$), in which three points represented shallower parts and another three represented deeper parts in both dry and wet seasons in the Mtera dam. Water samples were collected at 40 cm depth from each sampling point, a 1.5 Litre sterilized plastic bottle was used to store and then the samples were taken to the University of Dodoma-CNMS laboratory within 20 hours for more analysis.

Physicochemical parameters of water such as pH, temperature, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and turbidity were measured directly on the spot (in situ) by using hand-held Sigma Hanna Checker 1 pH meter, Multi probe meter, Hatch conductivity meter model 44600 and Turbid meter while other parameters like Phosphate, nitrate, nitrite, and silica were measured ex-situ by following procedure documented (Rice *et al*, 2012; APHA, 2012) and then concentration was measured by UV-Visible Spectrophotometer (UV 1601 – Shumadzu Cooperation, Tokyo, Japan). Chlorophyll-a was determined by employing standard methods described by (Rice *et al*, 2012; APHA, 2012). A 2-litre plastic container at 50 cm depth below was used to sample the water and was kept in a cool box then directly taken to the laboratory. A 0.45-micrometre membrane filter was used to filter the sample.The filtered samples were then treated with a 95% ethanol solution in water (aqueous solution) and refrigerated overnight for extraction. The chlorophyll-a content was then measured using a UV-visible spectrophotometer (UV 1601–Shumadzu Cooperation, Tokyo, Japan) at different wavelengths 664 nm, 647 nm, and 630 nm as according to Pearson *et al*. (1989) and APHA. (2012). Therefore, to compute the amount of chlorophyll-a in the samples, the standard formula and equation given below were used (APHA, 2012).

Chl-a in (mg/L) $= (11.85 \times A_{664}) - (1.54 \times A_{647}) - (0.08 \times A_{630})$ (1)

Chl-*a* in (mg/L)$=\frac{V1 \times (11.85 \times A_{664} - 1.54 \times A_{647} - 0.08 \times A_{630})}{V2 \times L}$(2)

Where by

Chlorophyll-a (Chl-*a*) in equation (ii) is in milligrams per cubic meter (mg/L)

L=Length of the cuvette in Centimetre, cm

A is the absorbance at different wavelengths corrected by the value at 750 nm,

A664 = value of absorbance at a wavelength of 664nm, A647= value of absorbance at a wavelength of 647nm, A630= value of absorbance at a wavelength of 630nm

$V_1$ is the Volume of extract (90% acetone) in ml, $V_2$ is the Volume of filtered water sample in liter

***Data analysis***

The statistical analyses were conducted using IBM SPSS Statistics Version 27 (International Business

Machines Corporation, Armonk, New York, USA) and STATA 16. The sampled data were first subjected t

o the Shapiro-Wilk normality test to test for normality. One-way analysis of variance (ANOVA) was used

to test the significant difference between means values of physicochemical parameters and chlorophyll-a

concentration followed by Post hoc analysis. Multiple linear Regression models and Pearson correlation

tests were employed to establish the relationships between physicochemical water parameters and

hlorophyll-a in the Mtera dam and, were considered significant at 0.01 and 0.05 confidence levels. All

assumptions of regression analysis were tested before running linear regression analysis. The assumptions

and regression model followed the equations below:

Variance of Inflation Factor (VIF) = $\frac{1}{1-R^2}$(3)

Where $R^2$ is the value obtained from the regression model

$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon$(4)

Whereby; y is primary productivity (in terms of Chlorophyll-a), $\beta_0$ is the constant term, βj for (j=1…...10) are the regression coefficients relating the physicochemical variables to the Chlorophyll-*a* and $\varepsilon$ is an error term.

## Results

### *Seasonal variation of physicochemical parameters of water in the Mtera dam*

The results obtained in this study are presented in Table 1. There was a seasonal disparity of water quality parameters for the study period in the Mtera dam. Except for dissolved oxygen, which showed no significant difference ($p > 0.05$), all other parameters exhibited statistically significant variations between the dry and wet seasons ($p < 0.01$). During the dry season, pH levels ranged from 6.34 to 9.90, whereas dissolved oxygen levels ranged from 5 to 10.5 mg/l. Total dissolved solids ranged from 108 to 141 mg/l, and electrical conductivity varied from 127 to 202 µS/cm, with both parameters being higher in the dry season. Temperature ranged from 24.3°C to 37.5°C, while turbidity concentrations were higher during the wet season. The concentration of phosphate (4.79±5.89 mg/l), nitrate(17.59±4.08 mg/l) and chlorophyll-a (11.82±5.04 mg/l) were recorded high in the wet season. The concentration of Chlorophyll-a was ranging (1.4 -24.42) mg/l. Nutrient concentrations (phosphate, nitrate, nitrite, silica) were all significantly ($p<0.01$) higher in the wet season compared to the dry season. The chlorophyll-a concentrations were considerably higher during the wet season (11.82 ± 5.04 mg/l) compared to the dry season (4.34 ± 3.04 mg/l).

### *Spatial variation of water quality parameters*

The spatial variation of physicochemical parameters of the three study landing sites with six sampling stations has been tabulated (Table 2). The highest measured dissolved oxygen (DO) was (8.57 ± 0.81 mg/l) measured in the Chamsisiri site, followed by the Madafu site but the lowest Dissolved oxygen (6.86 ± 1.03 mg/l) was found in the Mtera landing site. The highest average pH value determined was (8.20± 1.25) at the Chamsisiri site followed by the Mtera site, whereas a low pH value was recorded in Madafu sites. The Mtera landing site had the lowest turbidity (144.7 ± 9.6 NTU), but the Madafu site had the highest turbidity followed by the Chamsisiri site. For the Chlorophyll-a level in the dam, the highest value (13.46 ± 3.35 mg/l) was recorded at the Mtera site followed by Chamsisiri whereby the lowest average concentration of chlorophyll-a (4.19±0.96 mg/l) was recorded at the Madafu landing site. The variation in physico-chemical parameters and chlorophyll-a was significant ($p > 0.05$) except for temperature.

**Table 1**

*Seasonal variation of water quality parameters (Mean ± SE, n=120) and range (Max-Min) measured at the Mtera dam*

| Parameters | SEASONS | | Total | Range | | *P* | Standard |
|---|---|---|---|---|---|---|---|
| | **Dry season** | **Wet season** | | | | | |
| | Mean ± SD | Mean ± SD | Mean ± SD | Min | Max | | **Limits** |
| pH(range) | 8.48± 1.01 | 6.94±0.23 | 7.71±1.07 | 6.34 | 9.90 | <0.01 | 6.5-8.5 |
| Temp ($^0$C) | 26.69±1.5 | 34.59±1.18 | 30.64±4.17 | 24.30 | 37.5 | <0.01 | 20-30 |
| DO (mg/L) | 7.86±1.57 | 7.57±0.703 | 7.72±1.22 | 5.0 | 10.5 | 0.186 | 3-12 |
| TDS (mg/L) | 129.85±7.8 | 110.62±1.14 | 120.23±11.10 | 108 | 141 | <0.01 | 1000 |
| EC (µS/cm) | 259.38±16.2 | 219.98±1.57 | 239.68±22.87 | 216 | 281 | <0.01 | 10 – 1000 |
| Turb (NTU) | 157.13±20.4 | 173.6±21.79 | 165.37±22.59 | 127 | 202 | <0.01 | 240 |
| $PO_4^{3-}$(mg/L) | 1.71±1.07 | 4.79±5.89 | 3.25±3.85 | 0.60 | 13.00 | <0.01 | < 60 |
| $NO^{3-}$(mg/L) | 6.18±3.02 | 17.59±4.08 | 11.88±6.75 | 2.00 | 23.50 | <0.01 | 50 |
| $NO_2^-$(mg/L) | 3.62±1.74 | 14.93±4.09 | 9.27±6.49 | 1.34 | 26.10 | <0.01 | < 0.0135 |
| $SiO_2$ (mg/L) | 5.68±0.60 | 9.76±4.81 | 7.72±4.09 | 2.38 | 21.31 | <0.01 | |
| Chl-a (mg/L) | 4.34±3.04 | 11.82±5.04 | 8.08±7.03 | 1.40 | 24.42 | <0.01 | <7 or 7-15 |

SD= Standard Deviation Significant at *P-value*<0.01

Temp ($^0$C) =Temperature, DO (mg/L) = Dissolved Oxygen, TDS (mg/l) = Total Dissolved Solid, EC (µS/cm) = Electrical conductivity, Turb (NTU) = Turbidity, $PO_4^{3-}$(mg/L) = Phosphate, $NO^{3-}$(mg/L) = Nitrate, $NO_2^-$ (mg/L) = Nitrite, $SiO_2$ (mg/l) = Silica, Chl-a (mg/L) = Chlorophyll-a.

**Table 2**

*Spatial variation of water quality parameters across the strata in the studying landing sites (Mean ± SE, n=120)*

| | **STRATA** | | | | | | **ANOVA** |
|---|---|---|---|---|---|---|---|
| | **Shallower Part (**Means ± SD) | | | **Deeper Part (**Means ± SD) | | | |
| **Parameters** | **$S_1$** | **$S_2$** | **$S_3$** | **$S_4$** | **$S_5$** | **$S_6$** | ***P-value*** |
| pH (range) | 7.86± 1.19 | 8.20± 1.25 | 7.26± 0.03 | 8.14± 1.13 | 7.85± 1.19 | 6.69± 0.26 | <0.01 |
| Temp ($^0$C) | 30.4± 5.24 | 30.97± 4.5 | 30.9± 1.01 | 29.9± 5.27 | 31.1± 3.35 | 30.6± 3.43 | 0.947 |
| DO (mg/l) | 6.86±1.03 | 7.61±1.01 | 8.17±1.12 | 7.22±0.89 | 7.88±1.56 | 8.57±0.81 | <0.01 |
| TDS (ppm) | 116.9±7.2 | 117.1±6.76 | 125.7±14.4 | 117.5±6.63 | 119.9±11.1 | 124.6±14.8 | 0.023 |
| EC (µS/cm) | 232.3±13.9 | 234.1±13.4 | 249.5±30.9 | 233.1±14.7 | 239.5±23.1 | 249.7±29.3 | 0.026 |
| Turb (NTU) | 144.7±9.6 | 159.1±22.4 | 185.9±10.2 | 140.5±10.9 | 182.2±14.8 | 179.95±7.6 | <0.01 |
| $PO_4^{3-}$ (mg/l) | 5.74±5.56 | 4.65±5.13 | 2.54±3.56 | 2.35±2.66 | 2.89±4.07 | 1.32±5.6 | 0.005 |
| $NO^{3-}$(mg/l) | 16.32±5.10 | 12.74±7.73 | 11.78±7.72 | 10.55±4.81 | 11.16±7.28 | 8.7±5.31 | 0.011 |
| $NO^{2-}$(mg/l) | 12.23±8.1 | 10.66±7.39 | 7.85±5.70 | 10.42±5.01 | 6.72±4.96 | 7.75±5.92 | 0.05 |
| $SiO_2$ (mg/l) | 12.20±4.79 | 9.38±4.31 | 5.85±2.19 | 6.89±3.95 | 5.58±1.86 | 5.85±2.19 | <0.01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Chl-a (mg/l) | 13.46±3.35 | 10.51±6.26 | 6.34±3.66 | 6.18±3.39 | 4.19±0.96 | 4.49±1.94 | <0.01 |

**Table 3**

Association between physicochemical parameters and primary productivity in the Mtera dam during the dry season (n=60)

| | Ph | Temp | DO | TDS | EC | Turb | $PO_4^{3-}$ | $NO_3^-$ | $NO_2^-$ | $SiO_2$ | Ch-*a* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | | -0.336** | -0.301* | -0.945** | -0.938** | -0.446** | 0.215 | 0.352** | 0.544** | 0.429** | 0.252 |
| Temp | -0.336** | | 0.717** | 0.499** | 0.506** | 0.870** | -0.265* | -0.560** | -0.676** | -0.577** | -0.553** |
| DO | -0.301* | 0.717** | | 0.416** | 0.418** | 0.796** | -0.330* | -0.553** | -0.593** | -0.558** | -0.492** |
| TDS | -0.945** | 0.499** | 0.416** | | 0.987** | 0.584** | -0.239 | -0.499** | -0.623** | -0.569** | -0.421** |
| EC | -0.938** | 0.506** | 0.418** | 0.987** | | 0.601** | -0.223 | -0.523** | -0.604** | -0.587** | -0.444** |
| Turb | -0.446** | 0.870** | 0.796** | 0.584** | 0.601** | | -0.199 | -0.555** | -0.697** | -0.585** | -0.522** |
| $PO_4^{3-}$ | 0.215 | -0.265* | -0.330* | -0.239 | -0.223 | -0.199 | | .553** | 0.277* | 0.376** | 0.444** |
| $NO_3^-$ | 0.352** | -0.560** | -0.553** | -0.499** | -0.523** | -0.555** | 0.553** | | 0.446** | 0.794** | 0.806** |
| $NO_2^-$ | 0.544** | -0.676** | -0.593** | -0.623** | -0.604** | -0.697** | 0.277* | .0446** | | 0.537** | 0.404** |
| $SiO_2$ | 0.429** | -0.577** | -0.558** | -0.569** | -0.587** | -0.585** | 0.376** | 0.794** | -.537** | | 0.911** |
| Chl-*a* | 0.252 | -0.553** | -0.492** | -0.421** | -0.444** | -0.522** | 0.444** | 0.806** | 0.404** | 0.911** | |

** Correction is significant at the 0.01 *Correction is significant at the 0.05

**Table 4**

*Association between physicochemical parameters of water and primary productivity in the Mtera dam during the wet season (n=60)*

| | pH | Temp | DO | TDS | EC | Turb | $PO_4^{3-}$ | $NO_3^-$ | $NO_2^-$ | $SiO_2$ | Ch-*a* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH(range) | | -.140 | -.080 | .372** | -.086 | .225 | .135 | .215 | -.331** | -.128 | -.057 |
| Temp | -.140 | | -.066 | -.059 | -.195 | -.465** | .157 | .135 | .420** | .230 | .424** |
| DO | -.080 | -.066 | | -.088 | .112 | -.213 | -.207 | -.175 | .218 | -.004 | -.201 |
| TDS | .372** | -.059 | -.088 | | -.089 | .153 | .063 | -.037 | -.158 | -.264* | -.066 |
| EC | -.086 | -.195 | .112 | -.089 | | .214 | -.007 | -.091 | -.090 | -.087 | -.045 |
| Turb | .225 | -.465** | -.213 | .153 | .214 | | -.250 | -.041 | -.659** | -.409** | -.483** |
| $PO_4^{3-}$ | .135 | .157 | -.207 | .063 | -.007 | -.250 | | .441** | .195 | .271* | .411** |
| $NO_3^-$ | .215 | .135 | -.175 | -.037 | -.091 | -.041 | .441** | | .184 | .245 | .444** |
| $NO_2^-$ | -.331** | .420** | .218 | -.158 | -.090 | -.659** | .195 | .184 | | .373** | .483** |
| $SiO_2$ | -.128 | .230 | -.004 | -.264* | -.087 | -.409** | .271* | .245 | .373** | | .579** |
| Chl-*a* | -.057 | .424** | -.201 | -.066 | -.045 | -.483** | .411** | .444** | .483** | .579** | |

** Correction is significant at the 0.01(2-tailed) 0o* Correction is significant at the 0.05(2-tailed)

SD=Standard Deviation $S_1$ is the Shallower part of Mtera landing site, $S_2$ is the Shallower part of Chamsisiri landing site, $S_3$ is the Shallower part of Madafu landing site, $S_4$ = Deeper part of Mtera landing site, $S_5$ is the deeper part of Chamsisiri landing site, $S_6$ is the deeper part of Madafu landing site.

**Table 5**

*Shows the results of regression coefficients for physicochemical variables influencing primary productivity in the Mtera dam during wet season (n=60)*

| Mode | Unstandardized Coefficients | | Std. Coefficients | *t-value* | *P-value* | *VIF* | *DW test* |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | | | | |
| (Constant) | -164.983 | 145.314 | | -1.135 | 0.262 | | |
| pH(range) | 0.288 | 4.386 | 0.008 | 0.066 | 0.948 | 2.028 | |
| Temperature | 0.616 | 0.755 | 0.091 | 0.815 | 0.419 | 1.553 | |
| DO | -3.105 | 1.128 | -0.277 | -2.754 | 0.008 | 1.257 | |
| TDS | 0.723 | 0.712 | 0.104 | 1.016 | 0.315 | 1.308 | 1.594 |
| Turbidity | 0.073 | 0.087 | 0.201 | 0.835 | 0.408 | 7.200 | |
| Conductivity | 0.334 | 0.521 | 0.066 | 0.640 | 0.525 | 1.333 | |
| Phosphate | 0.837 | 0.366 | 0.626 | 2.287 | 0.027 | 9.308 | |
| Nitrate | -0.343 | 0.342 | -0.188 | -1.002 | 0.321 | 4.373 | |
| Nitrite | 0.522 | 0.250 | 0.271 | 2.086 | 0.042 | 2.104 | |
| Silica | 0.554 | 0.186 | 0.338 | 2.978 | 0.005 | 1.600 | |

Dependent variable is chlorophyll-a, Significant at $P<0.05$, DW- Durbin-Watson test

Acceptable range ($1.5 < DW < 2.5$) Acceptable VIF ranging (1 to 10)

**Table 6**

*Shows the results of regression coefficients for physicochemical variables influencing primary productivity in the Mtera dam during dry season (n=60))*

| Mode | Unstandardized Coefficients | | Std. Coefficients | t-value | *P-value* | *VIF* | *DW-test* |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | | | | |
| (Constant) | -57.328 | 6.778 | | -8.458 | <0.01 | | |
| pH(range) | 0.189 | 0.131 | 0.063 | 1.445 | 0.155 | 2.555 | |
| Temperature | -0.347 | 0.134 | -0.162 | -2.580 | 0.013 | 5.358 | |
| DO | 0.015 | 0.092 | 0.008 | 0.161 | 0.872 | 3.023 | |
| Turbidity | 0.004 | 0.010 | 0.025 | 0.367 | 0.715 | 6.425 | 1.542 |
| Phosphate | 38.498 | 4.365 | 0.637 | 8.819 | <0.01 | 7.047 | |
| Nitrate | 0.493 | 0.067 | 0.513 | 7.374 | <0.01 | 6.543 | |
| Nitrite | 0.037 | 0.080 | 0.021 | 0.469 | 0.641 | 2.784 | |
| Silica | 1.634 | 0.114 | 0.809 | 14.356 | <0.01 | 4.298 | |

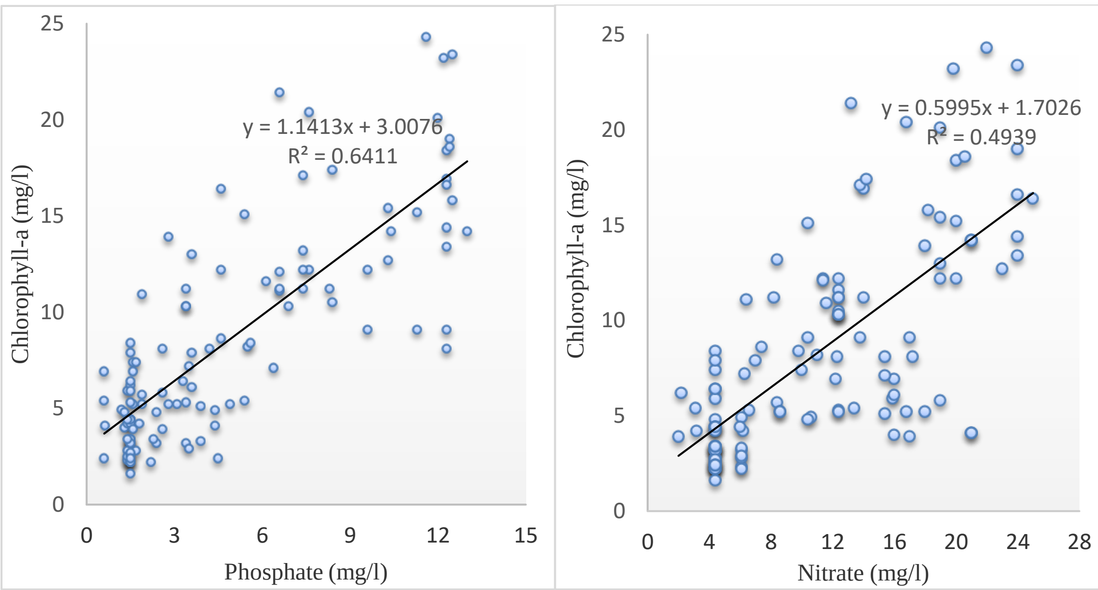
Dependent variable is chlorophyll-a, Significant at $P<0.05$, DW- Durbin-Watson test

***Association between physicochemical parameters of water and primary productivity in the dry and wet seasons***

Pearson's correlation coefficients for physicochemical parameters and chlorophyll-a presented in Table 3 showed a significant positive relationship ($p < 0.01$) between chlorophyll-a and four nutrients studied (silica, phosphate, nitrate, and nitrite). In contrast, chlorophyll-a had a moderately significant negative relationship ($p<0.01$) with five water parameters measured (total dissolved solids, electric]al conductivity, turbidity, dissolved oxygen, and temperature). It was also evidenced that some parameters such as pH had a weak correlation with chlorophyll-a but on the other hand temperature, DO, TDS, EC, turbidity, nitrite, and phosphate had a moderate correlation. Nitrate and silica were highly correlated with chlorophyll-a during the dry season

**Figure 2**

*Scatter plots of phosphate, nitrate versus chlorophyll-a concentrations in the Mtera dam*




***Association between physicochemical parameters and primary productivity in the wet season***

Pearson correlation test was (Table 4) used in this study to determine the connection between chlorophyll-*a* and physicochemical variables of water whereby temperature, nitrate, nitrite, phosphate, and silica showed significant positive correlation ($p < 0.01$). The pH, dissolved oxygen, total dissolved solids, turbidity, and electrical conductivity showed a negative correlation with chlorophyll-*a*, but only turbidity was significant ($p < 0.01$).

***Multiple linear regression analysis between physicochemical parameters and primary productivity in Mtera dam***

The result (Table 5 and 6) of assumptions of linear regression was observed and met, before testing the relationships between variables, whereby Durbin-Watson were 1.542 in dry and 1.594 in wet seasons means errors were independent and Variance inflation factor (VIF) was ranging between 1 to 10 means no symptoms of multicollinearity. A significant relationship between chlorophyll-a content and physicochemical water parameters was obtained in the dam ($p < 0.01$) (Table 7) and the model was appropriate to predict primary productivity in the Mtera dam.

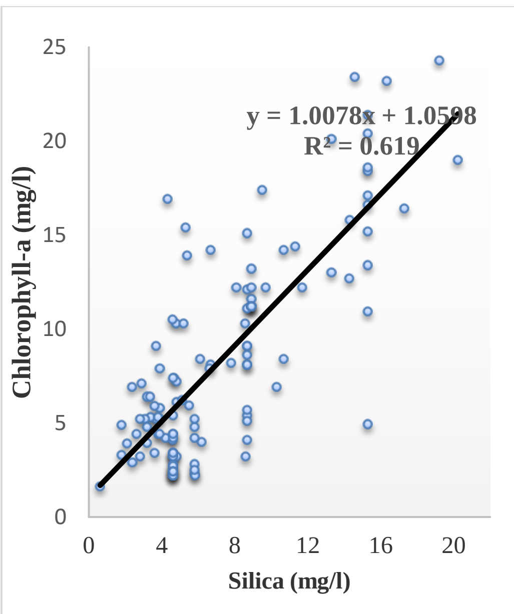
**Table 7**

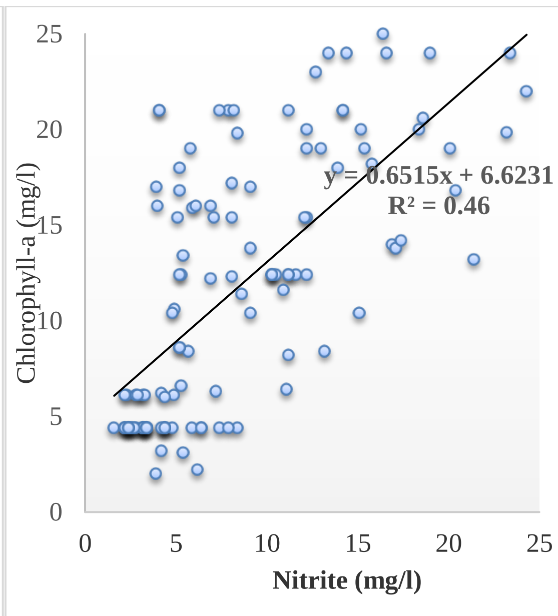
*Shows the analysis of variance for the test of goodness of fit of the regression model in wet and dry seasons (120)*

| **Wet season** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Model. 1** | Sum of Squares | df | Mean Square | F-Test | P-value | R | R-Square | Adjusted $\hat{R}^2$ |
| Regression | 2224.751 | 10 | 222.475 | 7.538 | <0.01 | 0.778 | 0.606 | 0.526 |
| Residual | 1446.261 | 49 | 29.516 | | | | | |
| Total | 3671.012 | 59 | | | | | | |
| **Dry seasons** | | | | | | | | |
| **Model 2.** | Sum of Squares | df | Mean Square | F-Test | P-value | R | R-Square | Adjusted $\hat{R}^2$ |
| Regression | 527.792 | 8 | 65.974 | 162.64 | <0.01 | 0.981 | 0.962 | 0.956 |
| Residual | 20.688 | 51 | 0.406 | | | | | |
| Total | 548.479 | 59 | | | | | | |

**Figure 3**

*Scatter plots of silica, nitrite versus chlorophyll-a concentrations in the Mtera dam*




The results tabulated in (Table 5) for the wet season showed the association between dissolved oxygen, phosphate, nitrite, silica, and chlorophyll-a content was statistically significant ($p < 0.05$) while except for pH, temperature, total dissolved solids, turbidity, and electrical conductivity. Whereby, during the dry season (Table 6) a significant association was revealed between temperature, phosphate, nitrate, and silica. During wet season (Table 7), a significantly positive impact on the chlorophyll-a level in a dam was revealed, this means for each unit increase in phosphate, nitrite, and silica concentration was associated with the increases in 0.837 mg/l, 0.343 mg/l, and 0.554 mg/l respectively in Chlorophyll-*a* concentration whereas in dry season (Table 7) significant positive impact observed in phosphate (38.49 mg/l), nitrate (0.493 mg/l), silica (1.634 mg/l). Also, dissolved oxygen (B=-3.105, p<0.05) and temperature (B=-0.347, $p<0.05$) were significantly negatively impacting Chlorophyll-*a* content in the dam. Figures (2 and 3) showed the linear relationship between phosphate, nitrate, nitrite, and silica with chlorophyll-a.

The results (Table 7) of the analysis of variance for the test of goodness of fit of the regression models used, showed that adjusted R squared in the dry and wet seasons, $\hat{R}^2=0.956$ and $\hat{R}^2 = 0.526$ respectively implying that 95.6% and 52.6% of variation of Chlorophyll-a described by the regression models used. R square, $R^2 = 0.962$ in dry and $R^2 = 0.606$ in wet seasons indicates that 96.2% and 60.6% of the variation in chlorophyll-a content in the dam can be explained by physicochemical parameters.

The unstandardized coefficients obtained in (Table 5) are the βj's and have been inserted in equation (5) to produce the following regression model:

$$\textbf{Chlorophyll-a} = -164.98+0.837PO_4^{3-}-0.343NO_3^{-}+0.522NO_2^{-}+0.554SiO_2+0.288pH-0.616Temp-3.105DO+0.073Turb+0.334EC \quad (5)$$

The unstandardized coefficients obtained in (Table 6) are the βj's and have been inserted in equation (ii) to produce the following regression model:

$$\textbf{Chlorophyll-a} = -57.33+38.5PO_4^{3-}+0.49NO_3^{-}+0.037NO_2^{-}+1.63SiO_2+0.189pH-0.35Temp-0.015DO+0.004Turb \quad (6)$$

**Discussion**

The results in this study revealed statistically significant differences between the water quality parameters as well as chlorophyll-a concentration which signifies remarkable variations in the water quality and chlorophyll-a content between the studied seasons as well as between the strata (shallow depth and deep depth), there was the direct impact of phosphate and nitrate on dam productivity observed in the site during investigation. Physical and chemical parameters of water measured greatly varies seas only and also between one site (lower depth) to another site (high depth) due to climate change and human-induced pressures as was also reported in the study conducted by Xu *et al.* (2019); Abdul *et al.*, (2021) and Wang *et al.*, (2023). Mostly nutrient concentration was found higher at shallower water depths which can be due to high nutrient loading from agricultural run-off, the same results obtained by Vase *et al.*, (2018).

The pH ranges (8.48) measured at some points in the dam were very close to the maximum limit as the acceptable range for pH is (6.5-8.5) according to FAO for fish health and growth (Svobodova, 1993; APHA, 2012; Alabaster and Lloyd, 2013; Demir *et al.*, 2021). Therefore, this level found in the dam was in an alkaline range which may cause abnormal growth performance in some species that grow and reproduce well in certain ranges below a pH of 8 in dam water (Ramolobeng, 2015; Abeba, 2018). The results obtained in this study showed a higher pH range to low chlorophyll-a level in the dry season compared to the wet season. Also, the study conducted by Li *et al*. (2021), reported that chlorophyll-a concentration in the dam is affected by pH fluctuation. The pH was higher in the dry season than in the wet season, with similar results documented by Teame and Zebib, (2016).

Oxygen is an important parameter for the health and survival of the entire aquatic ecosystem, the dam needs to be conserved and monitored for the sustainability of fishery resources. During the dry season, dissolved oxygen in the Mtera Dam was high while the chlorophyll-a concentration was low in the water, this signifies a negative relationship between DO and primary productivity during dry seasons (Hirsch & Medine, 1987). This can be attributed to the changing of climate from season to season which may vary in different locations in the dam (Regier *et al.*, 2023). During the wet season, the temperature was positively correlated with the chlorophyll-a concentration in the dam (Jeong *et al.*, 2020). Therefore, temperature is the limiting factor for primary productivity in the Mtera Dam as was also reported by the study conducted by Studies. (2020).

The average concentration of key nutrients such as Phosphate ($PO_4^{3-}$) and nitrate ($NO^{3-}$) in the dam was below the acceptable standard limit for the fish health, physiological process, and proper growth of aquatic organisms. The results revealed a positive association between nutrients and primary productivity in the Mtera Dam in dry and wet seasons. Similar results were obtained by Ogbuagu *et al*. (2019), who reported a significant association between the primary productivity and predictor variables. The higher nutrient level during the wet season specifically in shallow water depths in the Mtera Dam may be attributed to anthropogenic activities. Such activities include run-off of fertilizer such NPK from agricultural activities, grazing of animals, and pollution from domestic water uses conducted adjacent to the dam. According to Lake *et al*., (2000); Huang *et al*., (2013), and Yona *et al*., (2023), dams are extremely susceptible to several anthropogenic activities that modify the quantity of nutrients in the water. Silica, nitrite, nitrate, and phosphate levels were below the standard limit for fish survival and growth set by WHO and FAO in all six of the sampling points studied (Andrabi *et al*., 2024).

A Pearson correlation test revealed a significant relationship between water quality parameters in both seasons, similar to the results obtained by Bhat *et al.,* (2024). Also, the findings of this study showed significant associations between physicochemical water variables and primary productivity in the Mtera dam. This implies that during dry and wet seasons, water parameters are associated positively and negatively hence this means the variation in one parameter influences variation in the other parameters (Modi and Chintalacheruvu, 2024). Primary productivity in Mtera dam has been positively impacted by Silica, phosphate ($PO_4^{3-}$), and nitrate ($NO^{3-}$) in both dry and wet seasons which means these nutrients are the determinant of the health of the aquatic ecosystem as they tend to rise also cause an increase in the chlorophyll-a concentration in water, the similar results was also reported by Vase *et al*. (2018).

A negative correlation obtained in this study indicates that the pH, temperature, and turbidity during the wet season influence primary productivity negatively, consistent with findings by Chaudhuri *et al*., (2012). Similarly, dissolved oxygen, total dissolved solids, electrical conductivity, turbidity, and temperature in the dry season negatively influenced primary productivity (Jia et al., 2020; Halima *et al.*, 2023). Similarly, the study conducted by Adeosun *et al*. (2014), documented that low dissolved oxygen, high temperature, and high turbidity, have a corresponding low primary productivity. Dissimilar results reported in the study conducted by Vase *et al*. (2018) showed that dissolved oxygen was positively correlated with primary productivity in freshwater.

Total dissolved solids and turbidity experienced a negative correlation with chlorophyll-a which showed potential impacts on algal growth since this parameter acts as a limiting factor for phytoplankton growth. Therefore, excess turbidity causes a decrease in primary productivity (Mamun., 2020; Nunes *et al*., 2022). When TDS and turbidity are in excess in water signify the presence of pollution like industrial or domestic sewage discharge or runoff from agriculture in the dam (Liang, 2018). Excess nutrients or harmful heavy metals in water can impair the general growth performance of biomass and may block sunlight penetration for algal growth, the same fact was reported by Munye, (2020).

The results in (Tables 5 and 6), revealed assumptions of the linear regression model were satisfied and all water quality parameters measured were within acceptable ranges whereby Durbin-Watson statistics was (1.542 in the dry season and 1.594 in the wet season) and, Variance of Inflation Factor (VIF) of all parameters used in the model was between acceptable range (1 to 10). Therefore, this range of VIF means errors were independent of one another and no multicollinearity between physicochemical parameters so that the effects of one explanatory variable are not explained by another (Mgandu *et al*., 2020; Yohandoko and Supriyanto, 2023). The results of the linear regression model (Tables 5 and 6) were statistically significant at a 95% level of significance (Maqbool *et al.*, 2012) and, the results

(Table 7) of the analysis of variance for the test of goodness of fit of the regression models used, showed that adjusted R squared in the dry and wet season, $\hat{R}^2$=0.956 and $\hat{R}^2$ = 0.526 respectively implying that 95.6% and 52.6% of the variation of chlorophyll-a described by the regression models used (Shrestha and Basnet, 2018). R square, $R^2$ = 0.962 in dry and $R^2$ = 0.606 in wet seasons indicates that 96.2% and 60.6% of the variation in chlorophyll-a content in the dam can be explained by physicochemical parameters. The fluctuation percentage of chlorophyll-a concentration remained is described by other factors. The analysis showed a significant positive and negative relationship between the physicochemical parameters and primary productivity.

This present study revealed statistically positive impacts of phosphate, nitrate, nitrite, silica, turbidity, and pH on chlorophyll-a concentration within the Mtera dam (Vase *et al*., 2018; Zao *et al*., 2023). This signifies that each unit increase in the concentration of phosphate, nitrate, nitrite, silica, turbidity, and pH was connected with the rise in Chlorophyll-a concentrations in the Mtera dam. Balali *et al.* (2013) previously reported similar results, except for silica, which showed a negative association with primary productivity in the dam. Also, a similar impact was explained by Studies, (2020), Positive correlations indicate a linear relationship in which monthly fish yield increases with an increase in total phosphorus, hence, this variable can have a positive impact on dam primary productivity.

Also, similar results were reported by Perez-Ruzafa *et al*. (2019), which indicated that nitrate, phosphate, and silica showed a positive coefficient, suggesting that primary productivity tends to increase with these nutrients. These important nutrients such as phosphate and nitrate directly affect the amount of chlorophyll-a in water which determines the dam's primary productivity, therefore nutrients are limiting factors for the growth of phytoplankton within the dam (Omondi *et al*., 2016; Sun *et al*., 2022). The main cause of the massive increase in these nutrients is runoff from agricultural activities involving fertilizer and agricultural input applications, livestock grazing near the dam and other anthropogenic activities that pollute (Kumar *et al*., 2021). Therefore, silica, nitrite, nitrate, and phosphate concentrations in Mtera Dam were higher due to anthropogenic activities conducted adjacent to the dam. This finding contradicts previous research by Chapman. (1999) and Mbanaga *et al.* (2024), which indicated that nitrate concentrations exceeding 5 mg/L typically indicate pollution from human sources like industrial activities. Therefore, most studies conducted revealed, that there is a direct influence of phosphate and nitrate on primary productivity in the freshwater ecosystem (Maslukah *et al*., 2019; Maslukah *et al*., 2020).

**Conclusion**

Generally, water quality parameters in Mtera dam for both dry and wet seasons were within the maximum acceptable limit for fish growth and survival, however, several parameters such as temperature and pH measured in different locations are likely to approach the standard limit. Turbidity and total dissolved solids showed a negative association with primary productivity so it may limit algal growth in the Mtera dam. This may be due to pollution from fertilizer run-off, and animal waste from grazing near the dam. Phosphate and nitrate are important nutrients for primary productivity in the Mtera dam ecosystem and showed a direct positive relationship with chlorophyll-a. Furthermore, physicochemical parameters are directly impacting the primary productivity status of Mtera Dam. The results of this study provide a basis for further future studies as the source of monitoring, mitigation strategies, and establishment of management plans for water quality and fishery resources in the Mtera Dam. Therefore, the present study recommends continued analysis and monitoring of water quality over a long period using adaptive management approaches.

## Recommendation

The study suggests that further research should be implemented to examine the factors influencing water quality in the Mtera Dam and to understand the effects of climate change on primary productivity and fishery resources over a long period. This will help to capture the range of impacts that may occur to the entire Mtera dam ecosystem. Furthermore, continuous monitoring and best management practices of human activities, including agriculture and livestock grazing, should be implemented near the dam. This suggestion will help to prevent eutrophication in the dam caused by pollution from anthropogenic activities.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