International Scholars Journals

African Journal of Ecology and Ecosystems ISSN: 2756-3367 Vol. 10 (6), pp. 001-011, June, 2023. Available online at www.internationalscholarsjournals.org © International Scholars Journals

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Full Length Research Paper

Interactions between algal cells and water quality parameters with rainfall in riverine ecosystems: a case study of River Malewa, Kenya

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Accepted 08 June, 2023

Abstract

Algal biomass production and water quality are majorly affected by rainfall changes in all aquatic ecosystems. African rivers general experience changes in algae species and biomass during wet and dry seasons. Survey in River Malewa for twelve months from November 2020 was to explore responses in rainfall patterns and algal biomass. Rainfall data was obtained from Water resource Authority (WRA). Chlorophyll-*a* was determined using UV-1800 Shumadzu (UV spectrophotometer). Algal samples were analysed using a 30 µm2phytoplankton net. Identification and counting was done using Sedgewick-Rafter cell and a Binocular compound microscope. Rainfall recorded 0mm in August, September and October and highest in May (155.2mm). Two way ANOVA was used to test the significance of water quality and algal cells. Pearson's Correlations was used to test for relationship. Results show lowest and highest mean values of chlorophyll-*a* in June (25±0. 0005µg/l and May 47±0.0007µg/l) respectively. A total of 18 species of algae were identified during the sampling period. *Aphizomenon sp* had highest cells (276)*, Tabellaria flocculosa* (73), *Flagillaria biceps* (23), while *Gomphonema parvulum, Cymbella cistula* and *uroglena acus* had 14, 13and 12 respectively. The highest percentage composition of algal biomass was recorded in the month of January9.77%, February was represented by 9.38%. Two Way ANOVA test was significant with algal cells and water quality parameters and rainfall p<0.05 while insignificant with chlorophyll-*a*P<0.05). There was a significant correlation between algal cells and rainfall, similarly there was a strong correlation of algae and water quality parameters (p<0.05). Chlorophyll-a was strongly related with rainfall. This study outlines the role of rainfall and environmental factors in influencing algal community structure. Future such studies on algal community structure interactions to various environmental and biogeochemical cycles.

Keywords: Algal biomass; Chlorophyll-a; Water quality; Rainfall: River Malewa.

1.0 INTRODUCTION

Their distribution and abundance of algal vary greatly due to hydrodynamics, nutrients and chemical composition of the water body, other factors include tides, salinity, turbidity, and river flows (Jerling & Wooldridge, 2010). Algal community structure depends on species succession which is affected by environmental changes (Huisman et al., 1999). This can lead to dynamic interactions between biological processes and physico-chemical conditions of rivers. Algal community structure is influenced by rainfall can be reflected by major shifts in changes of environmental factors (Hubble et al., 2002;Huang et al., 2004; Reavia et al., 2010).

River Malewa is likely to or is experiencing effects of extreme climatic conditions causing fluctuations in the stream flow (Cheruiyot et al., 2018). Rainfall trends fluctuate depending on climate changes and global warming where seasonality and intensity of rainfall affects

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aquatic organisms. The trends in rainfall intensity and severe drought have adverse effects at both the upper, middle and lower catchments of the River Malewa and the Lake Naivasha basin. Rainfall trends coupled with stream flow affect River Malewa ecosystem (Kitaka et al., 2002). Land cover degradation and deforestation encourages soil erosion and increases runoff to the river channel. Consequently, the effects of rainfall, water abstraction, flow and discharges into River Malewa affect biomass and algal community structure. Rainfall discharges enters the river directly by wet deposition or indirectly by runoff, through surface, and subsurface flow and seepage respectively (Reichwaldt & Ghadouani, 2012).

The effect of wet deposition is immediate as water in the river channel directly influences ecological processes in it, and eventually at its river estuarine ecosystem. Therefore, there is a correlation between the amount of rainfall, algal biomass and water quality parameters (temperature, pH, DO and conductivity, TDS, salinity, ORP, secchi depth, TSS,) under nutrient-rich and stratified conditions.

Primary productivity is highest during high rainfall because enhanced enrichment with nutrients through runoff by loading nitrogen and phosphorous. A positive correlations are shown between total rainfall and TP concentration in rivers (Attayde et al., (2018;Everard et al., 2002;Liu et al., 2020); Yun and An, 2016). Excessive inflow of nutrients and other organic substances correlate well with the algal biomass production (Rojo et al., 1994).

Removal of nutrients (effluents and organic acids) by algae sustains aquatic life (Huang, Liu, and Qian, 2004; Radchenko et al., 2019). Water quality in urban rivers and lake basin's dynamics are poorly understood and although nutrients and chlorophyll *a.* (Chl-*a*) are commonly limiting factors of primary productivity in rivers and lakes, rainfall is also key in the production of algal biomass and water quality improvement (Ferreira et al., 2020); Ndebele-Marisa, 2016); Pan et al., 2018). Chlorophyll-*a* responses to TP with rainfall in aquatic systems may differ and nutrient manipulations by rainfall through runoff greatly affect eutrophic rivers and lakes, whereby TP are likely to limit productivity (Terer et al., 2014). Algal biomass may commonly be limited by multiple nutrients in more productive rivers over shorter temporal scales (Billy, 2005). Rivers primary production is strongly controlled by rainfall intensity and nutrient inputs (Otero et al, 2020). Excessive nutrient input from anthropogenic activities, rainfall intensity and hydrological modification have an effect on aquatic biodiversity (Hamka & Kurnia, 2019).Changes in temperature and insolation may cause eutrophication which is enhanced by accumulation of organic matter from algal overgrowth and aquatic macrophytes (Domis et al., 2013). Algal overgrowth leads to formation of blooms that are unaesthetic, and in some cases, produce harmful toxins and noxious odors (Yisa & Jimoh, 2010). These conditions can lead to occurrence of anoxia that often results in a reduction of aquatic biodiversity. Studies by (Bastaraud et al., 2020) demonstrated that storm water runoff caused by heavy rainfall intensity can reduce water quality by increasing water turbidity and microbial contamination which lead to occurrence of water borne disease. Rainfall in tropical ecosystems affects nutrient input through runoff from adjacent watersheds enhancing the trophic state of the water. Runoff influenced by rainfall plays a crucial role by transferring nutrients and other organic matter into rivers. During wet seasons increased nutrients through runoff cause eutrophication. Consequently, during heavy rains disruption of algal blooms due to flushing in the occurrence of large storms (Liu et al., 2020 ;Pan et al., 2018). While in absence of rainfall and storms proliferation of algal may occur, as they can rapidly use nutrients that are added during rainfall events especially if there are no storms. Wet seasons leads to favorable conditions for the growth of algal species. Environmental parameters favoring growth are; water temperature, light intensity, and nutrient (Obegi et al., 2021;Hamka & Kurnia, 2019). The river morphology, discharge, and water residence time, can also influence algal growth and distribution. Environmental factors in lotic systems are obvious, however hydrological cycle to avail nutrients such as phosphorous and nitrogen concentrations into solution for algal growth and distribution in rivers (Lewis, Saunders, & McCutchan, 2008). Low-lying rivers and streams show characteristics different from lentic systems such as hydraulic gradients, and shallow ground. Most studies have indicated that algal responds well in wet seasons when environmental conditions are favorable (Kitaka et al., 2002).The safe drinking water and favorable conditions of aquatic life is related to biological stability and functioning of rives. Algal community structure can be reflected by major shifts in changes of environmental factors (Larned et al., 2010; Hubble et al., 2002; Huang et al., 2004).

This paper investigates the responses of some selected species ofalgal growth to rainfall and land use. Obegi et al., 2022) reported similar work on spatial-temporal composition, abundance and diversity of algal communities in River Malewa. The objectives of the study were to: (1). Establish rainfall patterns of river Malewa from 2020-2021, (2)To calculate the abundance and percentage composition in River Malewa (3) To describe the correlation of rainfall distribution with chlorophyll-a biomass and some selected algal species.

2.0 METHODS AND METHODOLOGY

2.1 Study area

The Malewa River is located at a longitude of $0^{0}43'29.2''$S, $36^{0}21'11.84'$E and it is elevated at 1885m

(6184ft It rises in the western slopes of the Aberdare range in Kenya (Fig. 1) and flows south and west into Lake Naivasha in the Great Rift Valley (Figure 1). The Malewa River catchment of 1,730 square kilometers (670 sq mi) provides about 90% of the water flowing into Lake Naivasha, with most of the remainder coming from the Gilgil River. River Malewa annual flow is estimated at 153 million cubic meter. Major land cover types include agriculture, grassland, bush/scrub land and forest.

2.2 Sampling Design

Sampling was carried monthly from November 2020 to December 2021.

Water samples for phytoplankton were collected for identification and analysis by filtering 40Lwater through a phytoplankton net of 30 μm^2, and the filtrate was fixed stored in a 200mL bottle transported in the laboratory for further analysis. A total of ten sampling points was established and triplicate samples of each chlorophyll-a and algal were collected in well double rinsed sampling bottles pre-soaked overnight with0.5% of hydrochloric acid and rinsed with double distilled de-ionized water.

2.3 Sample Analysis

Algal species were identified using Olympus binocular microscope at X40 resolution after pipetting 0.5ml of the concentrated sample in one liter. Individual species were identified and counted using Sedgewick-Rafter cell and using the formula below, the total number of algae was calculated in liter. No. of cell counts was divided by 0.5 ml and further extrapolated to a unit volume of water sampled (formula 1).

$$K = \frac{No.of\ cell\ count}{0.5ml} X100$$ ……………………………………………………………(1)

Chlorophyll-a was determined by extracting a sample with 90% acetone after filtering200 ml volume of water sample using Whatman filter paper of 0.47 μm diameter. Extraction was done by incubating the soaked sample in 15 ml of 90%acetone, calculations were reported as μg/l using (formula 2). The absorbance was then recorded by a double beam spectrophotometer at 630 nm, 647 nm, 664 nm and 750 nm which was used as a blank.Rainfall data was collected by Water Resource Authority (WRA).Ca=11.85E664-1.54E647-0.08E630

$$Chlorophyll - a\ (\mu g/L) = 11.85E664 - 1.54E647 - 0.08E630$$ ………………………(2)

3.3 Data analyses

Data was analysed using non-parametric (Kruscal-Wallies tests and regression) models in testing the hypothesis and correlations by SPSS software was used to construct charts and figures of relationships between algal and chlorophyll-*a* biomass with rainfall. Bar charts, line charts and central tendency descriptions were used in this study.

3.0 RESULTS AND DISCUSSION

3.1 Rainfall Distribution From 2019-2021

The calculated stream velocity recorded as a stream flow of0.069 m^3/s with a stream flow of 171.9m^3/s. The discharge volume varied across the years, 2020 had the highest volume discharge of 154,49300m^3/yr (Table 1)

3.1.1 Daily Rainfall distribution from 2019 to 2021 in River Malewa

The mean daily rainfall description was 2.326 and standard deviation of 6.367 with and range of 70.9 (Fig.2). The minimum range was 0 and maximum 70.9ml. The model exhibited a positive correlation with R^2=0.027, F=21.675, P< 0.000. The distribution of rainfall across categories was the same and the results exhibited positive insignificance of P<0.493.

3.1.2 The Monthly rainfall distribution from 2019-2020 in River Malewa

The mean distribution of rainfall in 2019 was 70.75±28.114, with a median of 327ml, standard deviation of 97.39ml and a range of 317.7ml (Fig.3). The mean distribution of rainfall in 2020 was 49.34±15.04, with a median of 30.05, standard deviation of 52.12ml, and a range of 156.9ml. The mean distribution of rainfall in 2021 was 39.07±14.23, with a median of13.9ml, standard deviation of 51.02 and a range of 155.2ml. Kolmogorove-Smirnov test was significant R^2 =0.804, P< 0.0005 N=14.

3.2 Water Quality Parameters Variations with Rainfall in River Malewa

The means of water quality parameters are presented in (Table 2); dissolved oxygen 8.26±0.088(mgL^{-1}) with lowest and highest7.54 (mgL^{-1}) and 8.94 (mgL^{-1}), ammonia 0.0625±0.002 (mgL^{-1}) with lowest and highest 0.053 (mgL^{-1})and 0.08 (mgL^{-1}), total nitrates 0.115±0.009 (mgL^{-1}) with lowest and highest 0.06 (mgL^{-1}) and 0.18 (mgL^{-1}), total phosphates 0.0419±0.0.003 (mgL^{-1})with lowest and highest 0.04 (mgL^{-1}) and 0.045 (mgL^{-1})total suspended solids 0.022±0.001(mgL^{-1}) with lowest and highest -0.017(mgL^{-1}) and 0.038(mgL^{-1}), secchi depth 19.55 ±2.90 cm with lowest and highest 9.4cm and 42.6cm.

The distribution across categories of months was significant p<0.05. There was a strong relationship between the water quality parameters (DO, ammonium, TN, TP, chlorophyll-a TSS and SD with rainfall = p=0.000

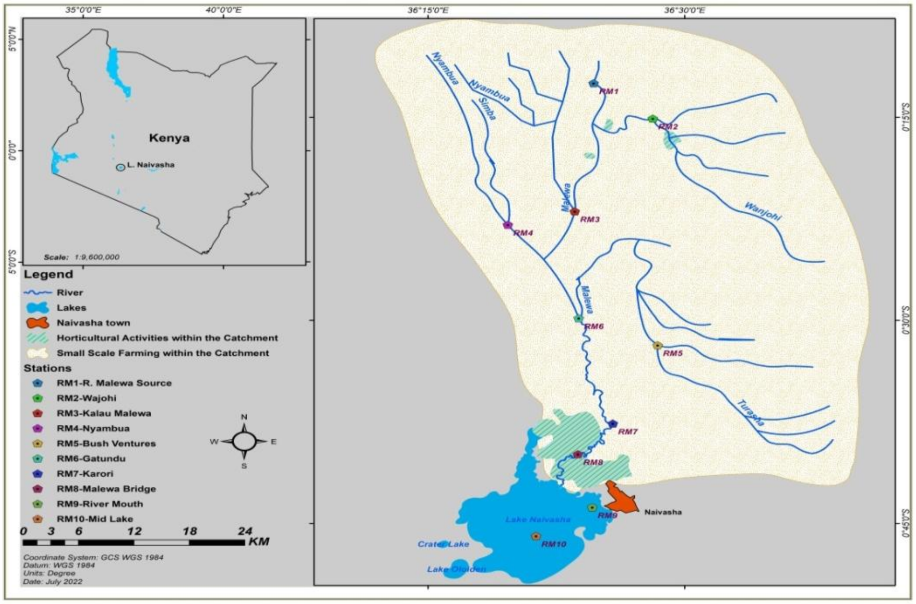

Figure 1. Description of sampling sites in River Malewa.

Table 1. Showing River Malewa velocity, stream flow, and river discharge.

River Characteristics		2019	2020	2021
Velocity	$0.069m^3/s$			
Stream Flow	$171.9m^3/s$			
Discharge (volume)		$84,121,250m^3/yr$	$154,49300m^3/yr$	$53,370500m^3/yr$

at P<0.01 (Figure 4 and 5).

3.2 Distribution of algal cells and chlorophyll-a biomass in River Malewa

3.2.1 Algal frequency and Composition in River Malewa

The descriptive study recorded *Ankistrodesmus* sp 58.75%,*Tabellaria sp*. 15.7%, *Gamphomenasp*4.50% *Anabeana sp* 4.50%*Cymbella sp*. 2.95%, *Meridion sp, 2.68% Diatom sp*. 2.27%, *Uroglena sp 2.21%* (Table 2). While the rest of the species presented 1% and below.

3.2.2 Distribution of chlorophyll-a biomass in River Malewa

The study revealed a mean of 35µg/l, with a standard deviation of 10.95 µg/l with a range of 4 µg/l 4.Chl-*a* was highest in May 2021 & lowest in June 2021. The findings presented a decreasing trend from December 2020 to March 2021 while an increasing trend from June 2021 to August 2021. General variations were noted throughout the months during the study.
The distribution of Chl-*a* across months was not significantly different **(p> 0.05).**
Distribution across categories of months was insignificant normal p= 0.312.

3.3 Relationship between algal cells and rainfall

3.3.1 The relationship of rainfall algal cells

The result show lowest values in November 2021 (1548) and highest value in July 2021 (2901) with a mean of 2337±42.The study showed an increasing trend in the month of March, April, May, and June 2021while a decreasing trend in July, August, and September but increased in October and November. The month of December 2020 and December 2021 recorded lowest biomass of algal cells. The results presented increased rainfall in December 2020, February, April, and May 2021, while a slight increase in July 2021.The findings also noted a decreasing trend in the month of January,

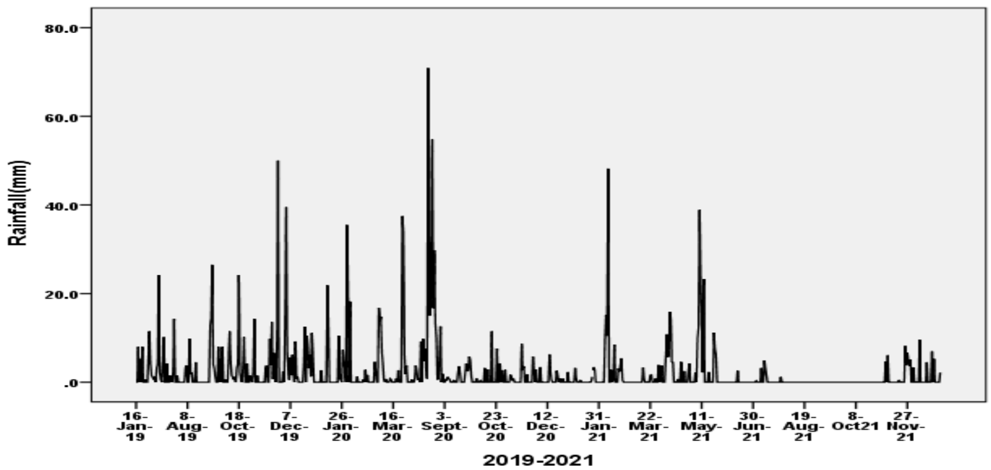

Figure 2. Daily rainfall variations from January 2019-2021 in River Malewa.

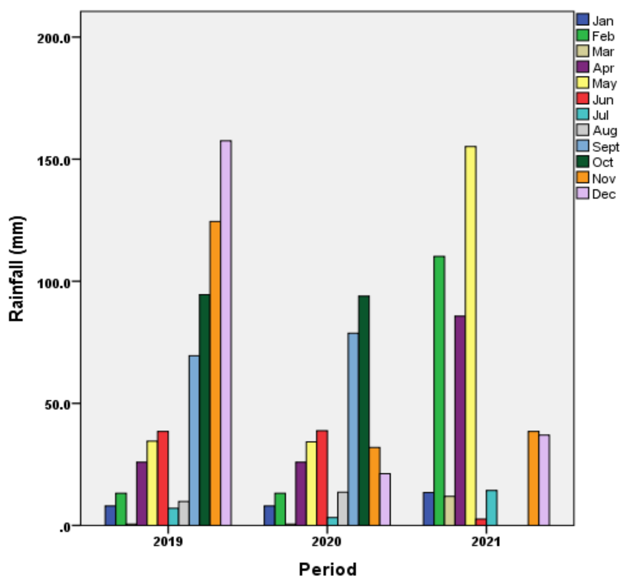

Figure 3. monthly rainfall variations from 2019-2021 of River Malewa.

March and June 2021.The rainfall and algal cells data was significantly normal with Kolmogorov-Smirnov test R^2 =0.889 p=0.002 N= 14 and R^2 =0.889 p=0.002 N=14 respectively.

There was a strong relationship between the algal biomass and rainfall (R^2=0.285, P= 0. 000)

3.3.2 The relationship of rainfall and chlorophyll-a biomass

The study revealed a mean of 36.5 and median of 35.5 with a standard deviation of 6.248.The range of 22, minimum value of 25 and maximum47.The findings presented a decreasing trend from December 2020 to March 2021 while an increasing trend from June 2021 to August 2021. General variations were noted throughout the months during the study.

There was no rainfall in the months of August 2021 to October 2021. The findings presented a decreasing trend from December 2020 to March 2021 while an increasing trend from June 2021 to August 2021. General variations were noted throughout the months during the study. The rainfall and chlorophyll-a data was significantly normal

Table 2. Mean values of water quality parameters in River Malewa.

Months	DO (MgL-1)	NH 4+(MgL-1)	TN(MgL-1)	TP(MgL-1)	TSS(MgL-1)	SD(cm)
Nov-20	7.543	0.053	0.06	0.041	0.038	12.9
Dec-20	8.338	0.06	0.09	0.043	0.035	11.3
Jan-21	8.635	0.057	0.07	0.04	0.017	15.4
Feb-21	8.308	0.075	0.11	0.043	0.021	10.6
Mar-21	8.106	0.055	0.13	0.041	0.018	9.4
Apr-21	7.985	0.08	0.14	0.04	0.021	16.9
May-21	8.165	0.056	0.14	0.045	0.021	18.3
Jun-21	8.183	0.07	0.16	0.041	0.021	15.8
Jul-21	8.214	0.055	0.18	0.042	0.021	19.2
Aug-21	8.94	0.067	0.11	0.041	0.018	16.2
Sep-21	8.093	0.057	0.07	0.044	0.018	11.9
Oct-21	8.631	0.056	0.08	0.041	0.018	33.5
Nov-21	8.351	0.08	0.13	0.043	0.021	39.8
Dec-21	8.165	0.054	0.14	0.042	0.021	42.6

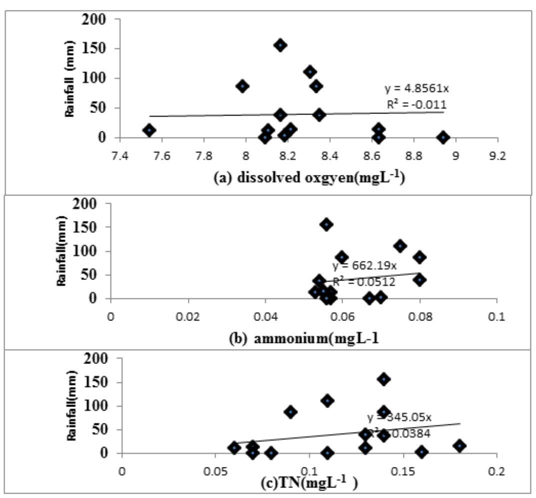

Figure 4. Correlation of Rainfall and water quality parameters (DO-TM).

with Kolmogorov-Smirnov test(R^2 =0.804 p=0.005 N=14 R^2 =0.952 p=0.167, N= 14) respectively.

Chlorophyll-*a* had a strong relationship with rainfall R^2=0.603, P= 0. 00003 (Fig. 8).

4.0 DISCUSSION

The water quality parameters showed variations during the sampling months. Pearson's correlation had significant relationship with dissolved oxygen, ammonium, total nitrogen, total phosphates, total suspended solids and secchi depth (p<0.01).Similar study in River Njoro by (Mokaya et al., 2004) concurred with the current studies.

Algal cells showed variations cannot be separated from responses to other larger environment changes occurring at the same time such as climate change.

High concentrations of chlorophyll-a recorded in November 2020, April 2021, May 21, September 21, were associated with long and short rains in April - May and September and October respectively. Small variations

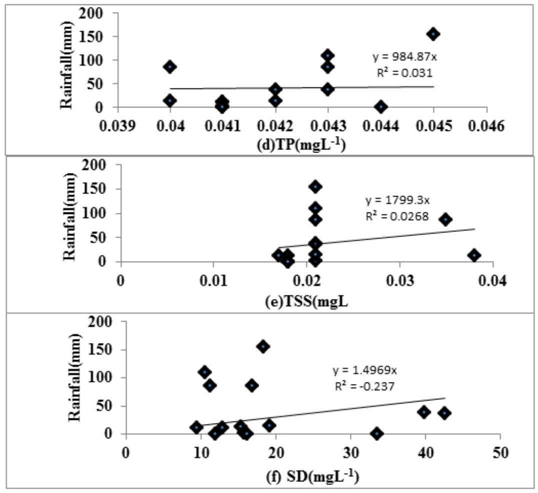

Figure 5. Correlation of Rainfall and water quality parameters(TP-SD).

Table 3. Showing the Means of Some Selected algal Species of River Malewa.

Algal cells	Frequency	%composition
Aphanizomenonsp	7746	58.75
Tabellariasp	2070	15.70
Anabeanasp	594	4.51
Gamphomenasp	594	4.51
Cymbellasp	390	2.96
Meridionsp	354	2.69
Diatomasp	300	2.28
uroglenasp	292	2.21
Akistrodesmussp	184	1.40
cocconeissp	135	1.02
Trachelomonassp	126	0.96
Flagilariasp	120	0.91
surillera	80	0.61
Euglena sp	60	0.46
synura	46	0.35
Naviculasp	46	0.35
Nitzstchia	28	0.21
synedra	19	0.14

in spatial- temporal concentration of chlorophyll-a in the in River Malewa was observed.

The algal 18 species were identified of River Malewa. *Aphanizomeno and Tabellaria* spcies were highest in the current study. Similar studies in River Moiben by (Masese et al., 2009) and (Chebet et al., 2020) in River Njoro reported the water quality.

The long-term trends of algae provide an indication of the change in the trophic status of the river basin, as well as a foundation for further studies of the distributions of upper-catchment, middle catchment and lower catchment.

Algal frequency were highest in May and rainfall in May. The linear correlation was all positively significant.

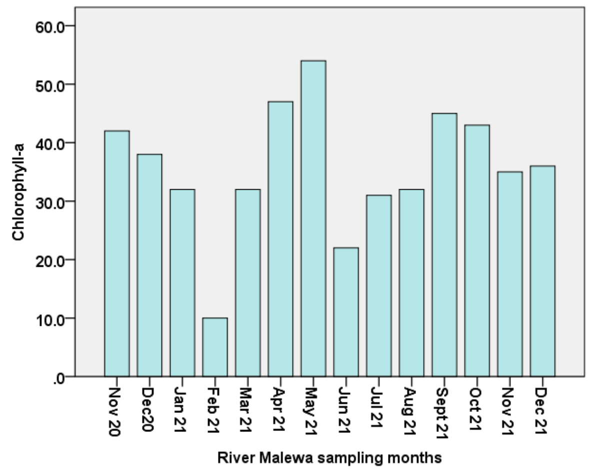

Figure 6. monthly chl-a variations of River Malewa.

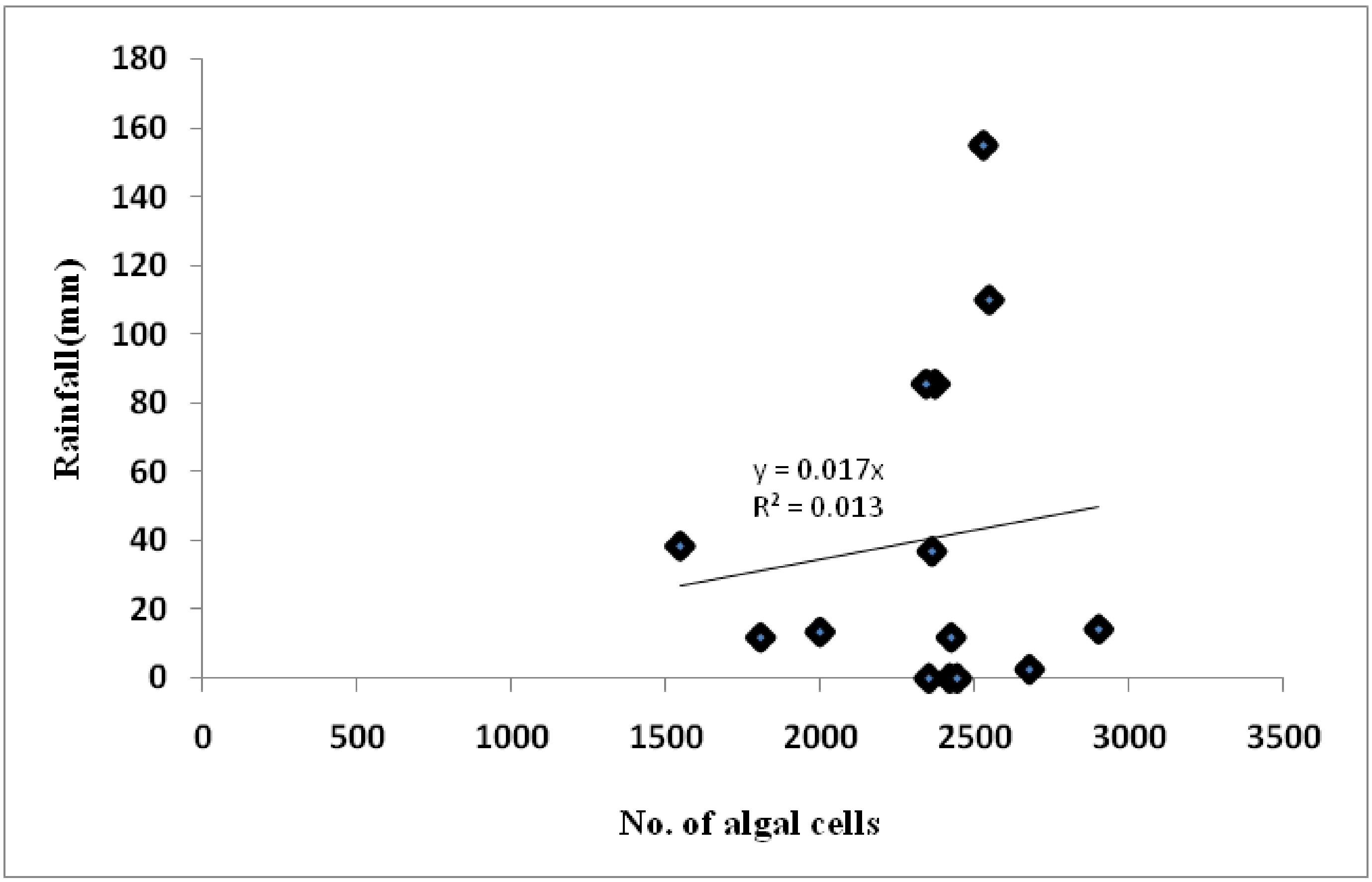

Figure 7. Showing relationship between algae cells and rainfall.

Increased rainfall can cause reduction of algal biomass due to flushing but later increases. This is well articulated by (Reichwald et al., 2011) that high volumes of inflow of water during rainfall events can lead to reduction of algal blooms due high flushing rate. It could take a few days for the biomass to reappear.

Increased biomass of some algae species *(Aphanizomenon sp pand Anabeana sp)* in this study during dry periods is likely to be due to non-mixing. Studies by Paerl et al.,(2011), Paerl et al., (2020) and by Lobo et al.,(2015) also noted the same.

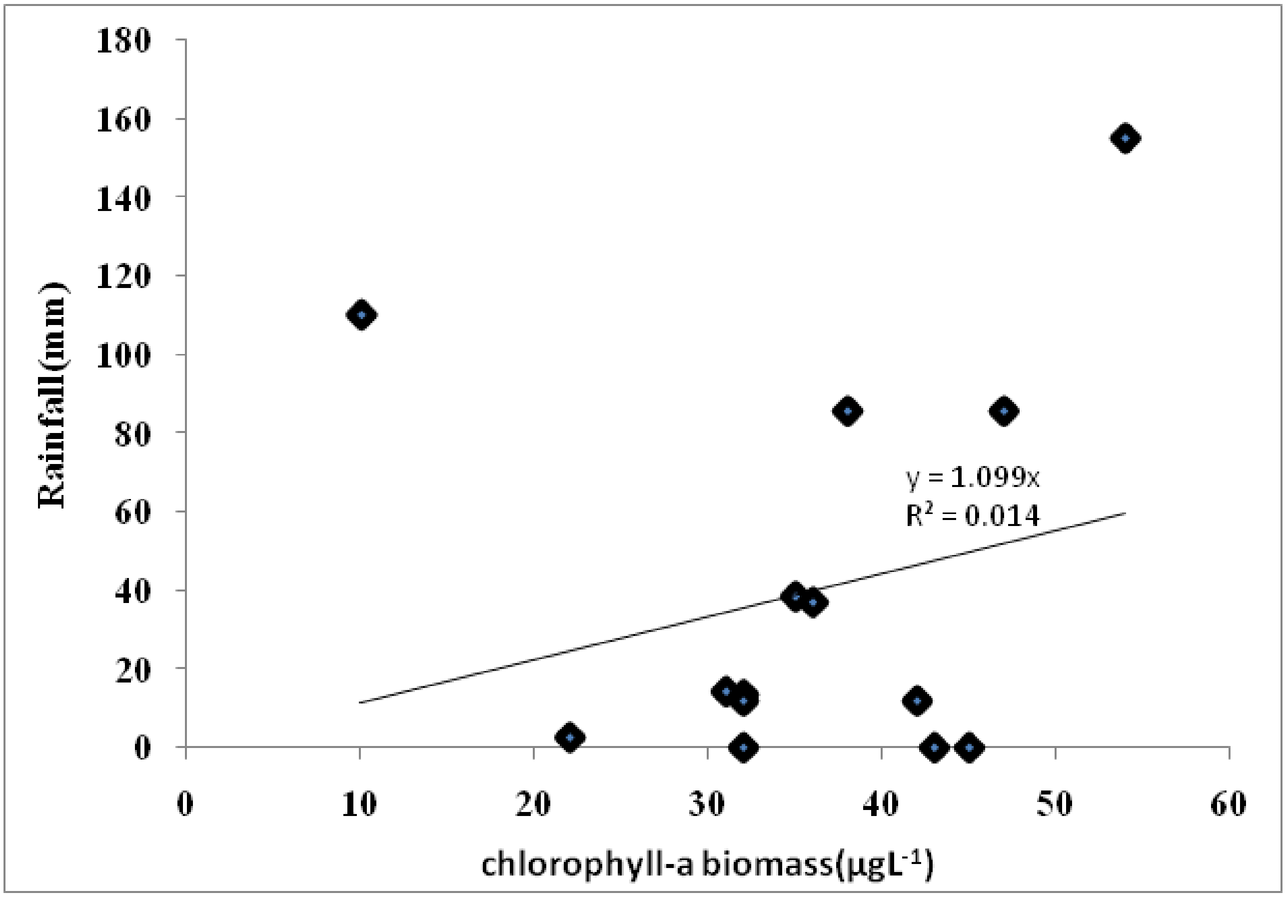

Figure 8. Showing relationship of chl-a and rainfall of River Malewa.

5.0 CONCLUSION

Rainfall had a strong significant relationship with water quality, algal and chlorophyll-*a* Heavy rainfalls (≥50 mm) significantly decreased pH, conductivity, transparency, chlorophyll- *a* concentration while nitrate remarkably increased. During dry periods proliferation of macrophytes affects water quality.

6.0 RECOMMENDATIONS

- In understanding the effect of changes in water quality and rainfall on rivers ,more studies are required River Malewa,
- The Government should develop more efficient management plans for River Malewa especially on issues of deforestation, siltation, pollution (use of fertilizers and pesticides from agricultural activities) as well as controlling increases water abstraction and diversion.
- More monitoring programs and mitigation measurements put in place consequently start aquaculture on well suited sites along River Malewa, in order to produce more fish for the growing population.

ACKNOWLEDGEMENTS

We appreciate the Water Resource Authority for Rainfall data. The authors are highly indebted the Kenya Marine and Fisheries Research Institute for allowing the usage of the Laboratory. We also acknowledge the technical team for the tireless. We also appreciate all those who had a hand on this precious work.

CONFLICT OF INTEREST

The authors have that they have no conflict of interest.

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