Environmental and Experimental Biology (2013) 11: 91–98 *Original Paper*

Algal biomass and nutrient enrichment in the Angereb reservoir, Gondar, Ethiopia

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Abstract

Nutrient enrichment leads to eutrophication in various types of water bodies. This phenomenon is characterized by the presence of large biomass of algae and water weeds, which can decrease water quality in the domestic water supply system. Eutrophication is an anthropogenic factor, and is considered as a global aquatic pollution problem. The aim of this investigation was to assess the trophic status of water in the Angereb reservoir, which is source for domestic water supply in Gondar, Ethiopia. A systematic approach was used to select sampling sites from which sediment, soil and water samples were collected. The trophic status of Angereb reservoir water was mesotrophic (4.2 μg L^{-1} of chlorophyll *a*). Nitrogen and phosphorus were main factors causing eutrophication and algal blooms in the reservoir. Dissolved oxygen, pH and temperature of the reservoir were found at a level that was not harmful to aquatic biota. Additionally, the turbidity level was high. Sediments and soils of all selected sub watersheds contained significant amounts of total nitrogen and total phosphorus, leading to nutrient enrichment of the reservoir water. Particularly, the Angereb and Defecha sub watersheds were identified as the main sources of nutrient input to the reservoir. Appropriate soil and water conservation measures are required to reduce the input of nutrients to the Angereb reservoir. In addition, bio-manipulation techniques should be undertaken to impede further growth of algae.

Key words: chlorophyll *a*, eutrophication, nutrients, reservoir, trophic status, watersheds.
Abbreviations: ANOVA, analysis of variance; AR, Angereb River; ARS, Angereb River site; Chl *a*, chlorophyll *a*; DS, Defecha stream; DSS, Defecha stream site; GPS, global positioning system; GS, Gesite stream; GSS, Gesite stream site; LSD, least significant difference; LWE, lake water edge; NTU, nephlometric turbidity unit; SD, standard deviation; TKN, total Kjeldahl nitrogen; TN, total nitrogen; TP, total phosphorus.

Introduction

Eutrophication is gradual enrichment of reservoir water with nutrients. Its severity is increasing and is considered as one of the most vital environmental problems both in developed and developing countries (Ryding, Rast 1989; Harper 1992; Smith, Shindler 2009). About 30 – 40% of lakes and other reservoirs have been degraded by eutrophication all over the world (Young et al. 2008). Degradation of these water resources can be estimated as loss of natural systems, their component species, and the amenities they provide.

Rapid urbanization, industrialization, intensifying agricultural production and practices, and humans in the watershed areas have caused leaching of excessive nutrients to streams, rivers, lake, reservoirs and other water bodies (Anderson 1994; Ongley 1996; Carpenter et al. 1998; Wright 2008). These activities have caused cultural eutrophication, which has promoted growth rate of algae and caused blooms in a short period of time, leading to water quality impairment for use in the domestic water supply (O'Riordan 2000; Anderson et al. 2002; Smith, Shindler 2009). Moreover, anthropogenic factors directly or indirectly affect water quality in relation to the type and level of developmental activities within catchments. Anthropogenic activities in domestic water supply areas are considered as potential risks to water quality impairment. This is one of the most visible examples of human-caused changes in the biosphere (Smith 2003).

Considering the visible risk factors, the Angereb reservoir for Gondar, Ethiopia was chosen in this investigation. This reservoir is the main source of domestic water supply of Gondar town. It is surrounded by agricultural fields where fertilizers and pesticides are applied, creating a source of nutrient flows to the reservoir. The reservoir is suffering from sedimentation and eutrophication. Amare (2005) reported that on average 152.5 t ha^{-1} $year^{-1}$ of soil has been carried to the reservoir, which has affected the storage capacity of the reservoir, and resulted in shortage of domestic water supply. However, no information is available on factors causing eutrophication. Thus, the aim of this investigation was to assess the level of phosphorus and nitrogen in the water and sediments of Angereb reservoir, and in sediments of selected streams and soils of selected sub watersheds. In addition, level of algal biomass, trophic status and physico-chemical parameters were examined.

Materials and methods

Description of the study area

Angereb watershed is located in the North central massif in Ethiopia, which is characterized by rugged mountains and valleys. The watershed is located on the eastern side of Gondar town between 328000 to 338000 m E and 1393500 to 1407000 m N and has an area of 7653.73 ha. It belongs to the Blue Nile basin and has an average altitude of 2125 m a.s.l. (Fig. 1).

Selection of sampling sites

Based on sediment deposition differences, sediment and soil samples were taken from Angereb River, Defecha and Gesite streams. On the Angereb River the first sampling site was located 100 m from the reservoir; the second and third sites were located at 200-m intervals for the upriver sample location. The sample location followed the same design for the Defecha and Gesite streams. Similarly, in the Angereb, three sampling sites namely, Lake Water Edge-1 (LWE-1); Lake Water Edge-2 (LWE-2); and Lake Water Edge-3 (LWE-3) were selected at the edges of the reservoir with 100-m intervals from each other (Fig. 2).

Sediment sampling

A total of 18 sediment samples were taken from the streams. Sediments in all sampling places were more or less similar in texture; mainly sand and silt were the main components of the sediments. In the Angereb River, and Gesite and Defecha streams, two sediment samples from each of the three sites were taken. In the reservoir, three replicate sediment samples were taken monthly from December 24, 2010 to February 17, 2011. Thus, a total of nine sediment samples were taken from the three sites of the reservoir. Surface sediments were collected using a scoop sampler to obtain the recent sediment deposition (Smodis et al. 2003). In the streams, sediments were taken in the middle, and at stream edges, samples were mixed (composite sample), and placed in clean plastic bags. Composite samples were duplicated for each of the sampling sites of the streams. The scoop was washed with distilled water after each sample to avoid contamination.

Soil sampling

Soil samples were collected from the top 20-cm depth. The samples were taken parallel to the sites where sediment samples are taken. A total of 18 composite soil samples were taken from all sites. From 20 × 20 m plots area, soil samples were taken at the corners and middle using a tube auger, and samples were made composite.

Water sampling

Water samples were taken monthly from December 24, 2010 to February 17, 2011 for the analysis of total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* (Chl *a*). For the analysis of TN and TP, grab water samples were taken monthly from the reservoir water sites where sediments were taken using 1 L polyethylene bottles. The samples were preserved using concentrated sulfuric acid ($pH < 2$) when they could not be analyzed immediately. For Chl *a* estimation, water samples were also taken from the same sites of the reservoir monthly, and transported to the laboratory and analyzed immediately. For measurement of turbidity, water samples at the same sites of the reservoir were used. In addition, dissolved oxygen, pH, and temperature were measured. Altitude and geographical positions were taken for each of the sampling sites using a Garmin etrix GPS (Table 1).

Analytical studies

Standard methods used to analyze water, soil and sediment samples are given in Table 2.

Statistical analysis

Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) Windows® software

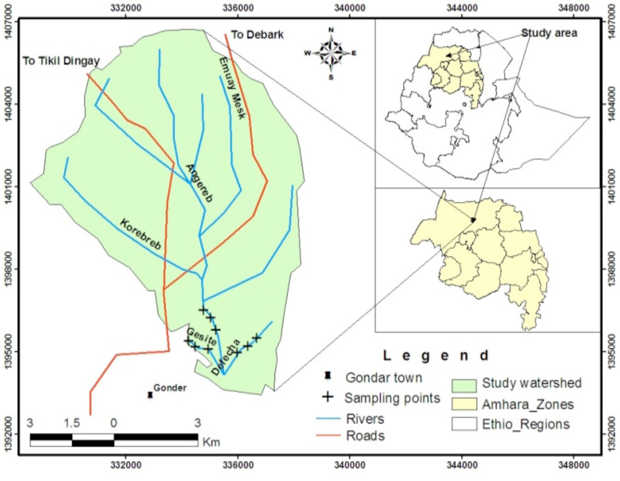

Fig. 1. Location map of the study area in Ethiopia and its catchments.

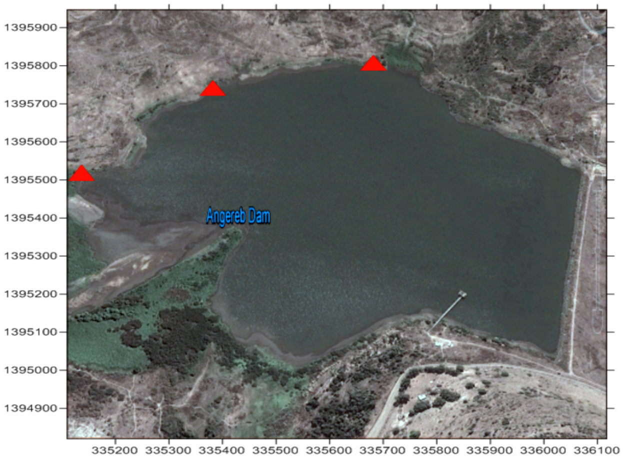

Fig. 2. Location map of the sampling points of Angereb reservoir (red triangles indicate sampling sites).

package. Descriptive, correlation and analysis of variance (ANOVA) tests were made. Descriptive statistics were used for mean computation. One way ANOVA was also used to determine spatial variations of physical, chemical and biological characteristics of the reservoir water. Means were compared by using the Tukey's test at significance level $P < 0.05$. In addition, correlation tests were carried out to assess the relations of physico-chemical characteristics of the reservoir water with its biological characteristics.

Results and discussion

Nutrient status of the Angereb reservoir

In the water of the Angereb reservoir, the concentration of total nitrogen (TN) and total phosphorus (TP) was significantly affected by the different water sources. In the Angereb reservoir TN was highest at LWE-1 in comparison to LWE-2 and LWE-3. N concentrations at LWE-1 and LWE-3 significantly differed, while they were similar for LWE-1 and LWE-2. Similarly, N concentrations at LWE-2 and LWE-3 did not significantly differ. TP concentration in the Angereb reservoir differed significantly between all sites. It was highest at LWE-1, in comparison to LWE-2 and LWE-3 (Table 3). The observed differences of TN and TP in the three sites might be due to the activity of zooplankton, microorganisms, macrophyte roots and other factors. At LWE-1, relatively high disturbance of sediments causes release of nutrients to the water column, resulting in high concentrations of TN and TP. Additionally, high concentrations of TN and TP in the Angereb reservoir water indicate management problems in the upland of the watershed. Pfafflin and Ziegler (2006) reported that growth of algae is inhibited if the concentration of TN is below 0.2 ppm. According to Khan and Ansari (2005), maximum growth of algae is attained when TN is less than 1.0 mg L^{-1}. Thus, the concentration of TN of the water in the Angereb reservoir was sufficient to support growth and development of algae and other aquatic plants. Similarly, the production of algae can be hindered if the concentration of TP is below 0.05 ppm (Pfafflin, Ziegler 2006), and accelerated when the concentration of TP is between 0.1 and 0.75 mg L^{-1}, and particularly when it is less than 1.0 mg L^{-1} (Khan, Ansari 2005). The concentrations of TP in the water of the Angereb reservoir were in the range of that promoting algal production. Regarding inorganic and organic nitrogen compounds, NO_3^- is a dominant species in Angereb reservoir, but NO_2^- was not recorded. However, total Kjeldahl nitrogen (TKN) was at a level less than inorganic nitrogen (Table 4), indicating the absence or low vegetation cover in the watershed. According to Kortelainen et al. (1997), in forested and pristine watersheds usually concentrations of organic nitrogen are higher in surface water than inorganic nitrogen. This can likely explain why the organic nitrogen concentration is low compared to inorganic nitrogen concentration in the Angereb reservoir.

Table 1. Location of sampling sites (LWE, Lake Water Edge; ARS, Angereb River Site; DSS, Defecha Stream Site; GSS, Gesite Stream Site)

Sampling site	Location	Altitude (m)
LWE-1	1395520N, 0335137E	2139
LWE-2	1395741N, 0335380E	2130
LWE-3	1395808N, 0335682E	2129
ARS-1	1396229N, 0335042E	2131
ARS-2	1396400N, 0334931E	2139
ARS-3	1396527N, 0334784E	2149
DSS-1	1395111N, 0336161E	2131
DSS-2	1395219N, 0336364E	2156
DSS-3	1395394N, 0336581E	2177
GSS-1	1395161N, 0334530E	2156
GSS-2	1395291N, 0334426E	2166
GSS-3	1395395N, 0334239E	2181

TN and TP concentrations in the sediments of Angereb reservoir is significantly affected by the different water sources. TN was observed maximum at LWE-3 site in comparison to LWE-2 and LWE-1; and these variations among all the sites were significant. TP also recorded more at LWE-3 followed by LWE-1 and LWE-2 (Table 5). The highest concentration of TN and TP in the sediment of LWE-3 as compared to the remaining sites could be associated with the low disturbance of sediments by aquatic organisms. Sediments are internal storage pools of nutrients and cause nutrient dynamics in the water column. Therefore, sediments in the Angereb reservoir can be the long-term potential source for the nutrients even if the discharging of nutrients from the external source can be decreased.

Algal biomass and trophic status of the Angereb reservoir

Although, the Gondar town water supply and sanitation department regularly adds copper sulphate ($CuSO_4$) to water of the Angereb reservoir to combat algae growth;

Fig. 3. Macrophytes around the edge of the Angereb reservoir at LWE-3.

Table 2. Analytical methods used for measurement of physical, chemical and biological parameters of the water, soil and sediment samples. NTU, Nephelometric Turbidity Units

Parameter	Unit	Analytical method
Chlorophyll *a*	μg L^{-1}	Acetone extraction spectrophotometric method (APHA, AWWA 1995)
Total Kjeldahl nitrogen (in water)	mg L^{-1}	USEPA method No.351.3 (EPA-600/4-79-020) (Csuros 1997)
NO^{3-} (in water)	mg L^{-1}	UV spectrophotometric method (APHA, AWWA 1995)
NO^{2-} (in water)	mg L^{-1}	UV spectrophotometric method (APHA, AWWA 1995)
Total nitrogen (in soil and sediments)	%	Modified Kjeldahl method (Jaiswal 2003)
Total phosphorus (in water)	mg L^{-1}	Digestion and ascorbic acid spectrophotometric method (APHA, AWWA 1995)
Total phosphorus (in soil and sediments)	%	AOAC (Association of Official Agricultural Chemists) of USA (Jaiswal 2003)
Dissolved oxygen	mg L^{-1}	Hana model H1-9143 DO meter
pH	–	Digital pH meter (Model H1-8314)
Turbidity	NTU	Nephlometric method (APHA, AWWA 1995)
Temperature	°C	Hana model H1-9143 DO meter

the algal biomass at the three study sites of the Angereb reservoir water was significant (Table 6). The highest amount of chlorophyll *a* concentration was observed at LWE-2 sites followed by LWE-1 and LWE-3. However, Chl *a* concentration did not significantly differ between LWE-1 and LWE-2. Interestingly, floating macrophytes were observed only at the LWE-3 site, which could be a reason for the differences in Chl *a* concentration and algal biomass (Fig. 3). At the LWE-3 site, the available N and P in the water column may be consumed by macrophytes at a higher rate than algae. Furthermore, macrophytes may also release toxic substances that hinder the growth and production of algae (Osomon 2008).

The trophic status of water bodies is mainly determined by the level of algal biomass. TN and TP are also commonly used to classify trophy. According to the trophic classification system, the concentrations of TN and TP (Mackie 2004) (Table 3) in the Angereb reservoir can be classified as eutrophic. However, according to the algal biomass level (4.20 μg L^{-1}; Table 6), the reservoir corresponds to a mesotrophic level. Using concentration of Chl *a* to determine the trophic status of the water, based on the classification of Ryding and Rast (1989), Novotny and Olem (1994), and Wetzel (2001), the trophic status of the Angereb reservoir is mesotrophic.

Addition of $CuSO_4$ to the Angereb reservoir by the Gondar town water supply and sanitation department may explain why, despite high concentrations of phosphorus and nitrogen in the water (Table 3), excessive blooms of algae did not occur. P and N concentration might not be limiting for algae (Cloern 1999). Eutrophication is not simply a matter of nutrient loading; but the pathways through which nutrients have impact on productivity are numerous and varied, and governed by other physical and biological processes. The N/P ratio plays also significant role on the growth of phytoplankton. A N/P ratio less than 10 indicates N limitation, and above 17 indicates P limitation; values between 10 and 17 indicate that either N or P may be limiting (Forsberg, Ryding 1980; Hellstrom 1996). The N/P ratio of Angereb reservoir is 7, indicating that N is the limiting nutrient for phytoplankton. Moreover, Ugo (2008) also found that algal blooms did not occur even when concentration of P was high. The transformation of nutrients to algal biomass requires solar radiation which can be blocked by turbidity, which in the Angereb reservoir was 18.55 ± 2.068 NTU (Table 7), and sufficient to block (attenuate) incoming radiation. As reported earlier, water bodies with turbidity more than 10 NTU have a low level of water quality and provide risk to aquatic life (ENSR 2002). In addition, the proliferation of algae in the water

Table 3. Total nitrogen and total phosphorus concentrations in water in the Angereb reservoir (LWE-1, Lake Water Edge-1; LWE-2, Lake Water Edge-2; LWE-3, Lake Water Edge-3). Values followed by the same letter indicate no significant differences at $P < 0.05$ level according to the Tukey's test. Each value represents mean ± SD of three replicates

Parameter (mg L^{-1})	Site			Mean
	LWE-1	LWE-2	LWE-3	
Total nitrogen	0.905 ± 0.132a	0.802 ± 0.127ab	0.708 ± 0.084b	0.805 ± 0.137
Total phosphorus	0.178 ± 0.024a	0.103 ± 0.021b	0.050 ± 0.013c	0.110 ± 0.057

Table 4. Concentration of nitrate, nitrite and total Kjeldahl nitrogen in the Angereb reservoir. Each value represents mean ± SD of three replicates

Parameter (mg L^{-1})	Mean value
Nitrate	0.489 ± 0.081
Nitrite	0.000 ± 0.000
Total Kjeldahl nitrogen	0.314 ± 0.073

of Angereb reservoir might be limited by grazing activities of zooplankton. According to Walker et al. (2006), grazing by snails, caddisfly larvae, mayfly larvae, filter feeding organisms, and other aquatic organisms, can control algal growth and production even under high levels of nutrients.

Physical and chemical characteristics of the Angereb reservoir

In the Angereb reservoir, the level of dissolved oxygen was at a level that can support most aquatic organisms (Table 7), as most aquatic ecosystems require minimum dissolved oxygen in the range of 5 to 6 mg L^{-1} to support living organisms (Pennington, Cech 2010). Warm water fish can survive at a level of dissolved oxygen from 5 to 9 mg L^{-1}, and cold water fish require a minimum amount of 6.5 mg L^{-1} to a maximum of 9.5 mg L^{-1} (Alabaster, Liyod 1982). The pH of the reservoir water was basic, which might be due to the photosynthetic activity of producers. The temperature of water in the reservoir was favorable for fishery activities, as it was in the recommended range (22 to 31 °C) for growth of fish (Korai et al. 2008). However, the temperature of the reservoir might not be favorable for maximum growth of algae, as blooms occur when the temperature is 30 °C (Shen 2002; Khan, Ansari 2005). According to ENSR (2002), water bodies having turbidity above 10 NTU have a low level of water quality and can be a risk to aquatic life. Hence, the quality of the Angereb reservoir with respect to turbidity was low and could be detrimental to biota, especially to fish. However, the Gondar town water supply and sanitation department adds 400 kg and 150 kg $Al_2(SO_4)_3$ per day during rainy and winter seasons, respectively, to reduce the turbidity of the water.

Correlation studies between algal biomass and physico-chemical characteristics of the Angereb reservoir

Algal biomass is one of the principal biological responses to physical and chemical factors, but which causes fluctuation of other physical and chemical characteristics in aquatic ecosystems. Temperature is the other most important environmental factors that can regulate the growth of aquatic organisms. There was s significant positive correlation between temperature and algae production (Fig. 4).

Sources of nutrients to the Angereb reservoir

There were high amounts of TN and TP in the sediments of the selected streams indicating the absence of suitable soil and water conservation practices in the watershed (Table 9). The absence of stream buffer zones, and tillage of stream banks particularly accelerate stream bank erosion and result in the immediate erosion and deposition of soil on the bed of streams.

There was a significant difference between the streams in TN level (Table 9). High concentration of TN was found in the Defecha stream (DS) and lower in Gesite stream (GS) and Angereb River (AR). Since AR flows throughout the year, and there were evident algae blooms in this river. Subsequently, the low amount of TN in AR could be attributed to the consumption of it by phytoplankton, compared to the other two streams. On the other hand, in the other two streams, there was no water during the sampling period in the dry season, and as a result, the accumulated nutrients in the sediments had not been disturbed and consumed by algae. This most probably is the reason why the streams had high concentration of N and P than AR. Figures 5 and 6 indicate that the concentrations of TN and TP in the sediments decreased from the lower part of AR and DS to the upper parts. In the case of GS (Fig. 7) the concentration of nutrients in the sediment increased from the lower part to its upper part. This difference might be due to slope differences that allowed fine sediments to reach the lower parts of the streams. Fine sediments are more easily carried and to down streams than coarse sediments, and for this reason, large deposition of fine sediments occurs. Fine sediments tend to absorb nutrients more readily than coarse sediments (Smodis et al. 2003). As a result, in AR and DS, due to large deposition of fine sediments, higher amounts of TN and TP were found in the lower parts of the streams. In contrast, the concentrations of TN and TP in GS increased from downstream to upper parts. This may be due to gabions that have been constructed along the stream, as they might prevent the transport of sediments downstream, thus resulting in higher concentrations of TN

Table 5. Total nitrogen and total phosphorus concentrations of reservoir sediments (LWE-1, Lake Water Edge-1; LWE-2, Lake Water Edge-2; LWE-3, Lake Water Edge-3). Values followed by the same letter indicate no significant differences at $P < 0.05$ level according to the Tukey's test. Each value represents mean ± SD of three replicates

Parameter (mg L^{-1})	Site			Mean
	LWE-1	LWE-2	LWE-3	
Total nitrogen	198 ± 0.009a	300 ± 0.008c	600 ± 0.033b	370 ± 0.026
Total phosphorus	3170 ± 0.045a	2180 ± 0.035b	10130 ± 0.120c	5160 ± 0.371

Table 6. Potential algal biomass of the water in the Reservoir (LWE-1, Lake Water Edge-1; LWE-2, Lake Water Edge-2; LWE-3, Lake Water Edge-3) as estimated by chlorophyll a concentration. Values followed by the same letter indicate no significant differences at $P < 0.05$ level according to the Tukey's test. Each value represents mean ± SD of three replicates

Parameter	Site			Mean
	LWE-1	LWE-2	LWE-3	
Chlorophyll *a* (µg L^{-1})	4.34 ± 0.842a	4.95 ± 0.67a	3.31 ± 0.387b	4.20 ± 0.918

Table 7. Physico-chemical characteristics of the Angreb reservoir water. Each value represents mean ± SD of three replicates. NTU, Nephelometric Turbidity Units

Parameter (unit)	Mean value
Dissolved oxygen (mg L^{-1})	6.654 ± 0.521
pH	8.402 ± 0.147
Temperature (°C)	22.57 ± 0.384
Turbidity (NTU)	18.55 ± 2.068

and TP in the upper part of the stream.

The soils of all sub watersheds had high concentrations of TN and TP, and might be the source of nutrients to the reservoir (Table 9). In addition, Fig. 5, 6 and 7 indicated the reduction of TN and TP concentrations in the soil from downstream to upper parts in all of the selected sub watersheds. This might indicate erosion, which most probably has resulted from the absence of proper conservation measures. The high erosion rate in the watershed was also noted by Amare (2005). Based on his study, there was gross annual erosion of 269 586 and 36 871.1 t in the Angereb and Gesite sub watersheds respectively. The Defecha sub watershed had a gross soil erosion of 20 841 t. The deposition of sediments in the streams also indicates high removal rate of soil from the watershed.

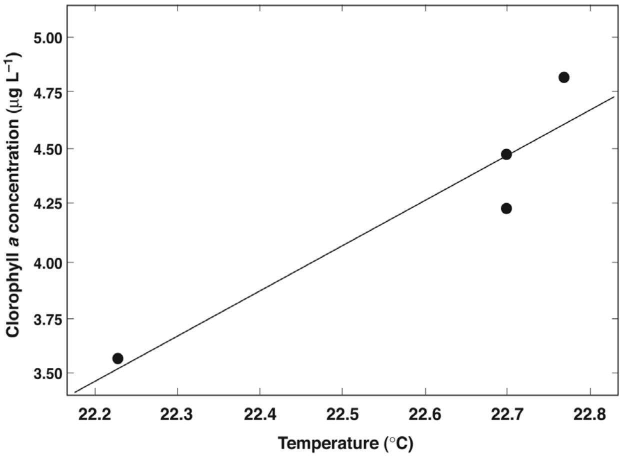

Fig. 4. Relationship between potential algal biomass (measured as chlorophyll *a* concentration) and temperature.

Conclusions

Eutrophication has a considerable impact on raw water quality, which affects water treatment technology and finally the quality of water. This study indicated that the Angereb reservoir had high amounts of TN and TP in water, sediment, and soil of sub watersheds, which are the principal sources of nutrients to the water in the reservoir. This indicates that there is no or poor soil and water conservation practices in the watershed. The trophic status of the reservoir was found at the level of a mesotrophic condition, which can be transformed to eutrophic condition unless measures are taken. The level of dissolved oxygen and the pH of the water of the reservoir were found to be at a level that can support aquatic organisms, but the turbidity status might present risk to zooplankton, and raises treatment costs

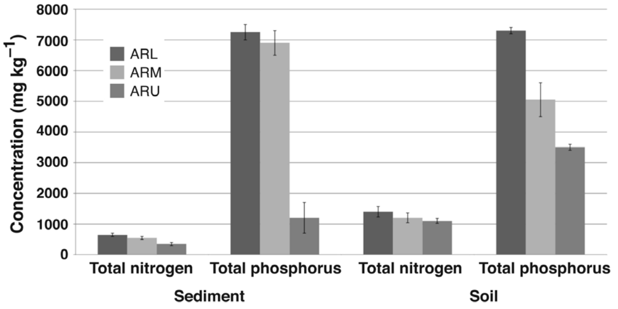

Fig. 5. Total nitrogen and phosphorus in sediment and soil of Angereb sub watershed at different positions (ARL, Angereb River Lower; ARM, Angereb River Middle; ARU, Angereb River Upper). Each value represents mean ± SD of three replicates.

Table 8. Correlation of potential algal biomass (chlorophyll *a* concentration) with dissolved oxygen, pH and turbidity. * and ** significant at $P< 0.05$ and $P< 0.05$, respectively

	Chl *a*	Dissolved oxygen	pH	Turbidity
Chl *a*	1.000			
Dissolved oxygen	0.919**	1.000		
pH	0.824**	0.935**	1.000	
Turbidity	0.692*	0.861**	0.865**	1.000

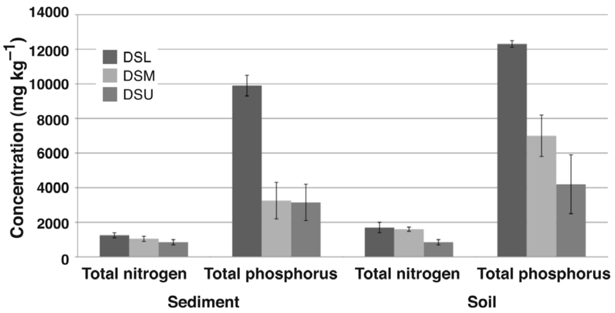

Fig. 6. Total nitrogen and phosphorus in sediment and soil of Defecha sub watershed at different positions (DSL, Defecha Stream Lower; DSM, Defecha Stream Middle; DSU, Defecha Stream Upper). Each value represents mean ± SD of three replicates.

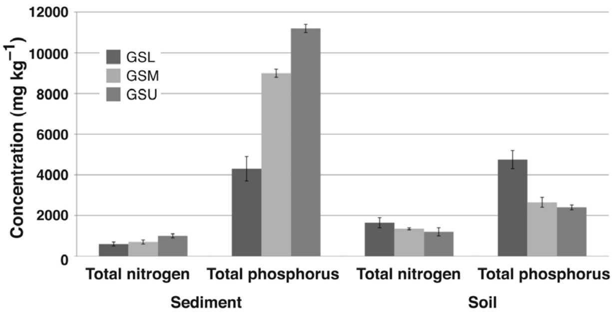

Fig. 7. Total nitrogen and phosphorus in sediment and soil of Gesite sub watershed at different positions (GSL, Gesite Stream Lower; GSM, Gesite Stream Middle; GSU, Gesite Stream Upper). Each value represents mean ± SD of three replicates.

Table 9. Total nitrogen (TN) and total phosphorus (TP) in the sediments of the streams and soils of the selected sub watersheds (AR, Angereb River; DS, Defecha Stream; GS, Gesite Stream). Each value represents mean ± SD of three replicates

Parameter	Sites	Sediment	Soil
TN (mg kg^{-1})	Angereb	520 ± 0.015	1230 ± 0.014
	Defecha	1050 ± 0.024	1380 ± 0.047
	Gesite	770 ± 0.021	1400 ± 0.029
TP (mg kg^{-1})	Angereb	5120 ± 0.307	5280 ± 0.175
	Defecha	5430 ± 0.361	7830± 0.391
	Gesite	8170 ± 0.318	3270 ± 0.194

for purification. Hence, in order to reduce sediment and nutrient delivery to the reservoir, immediate soil and water conservation measures are required. Additionally, agroforestry practices should be introduced into the watershed; and bio-manipulation techniques such as planting of macrophytes around and in the water of the reservoir, and introducing of algae-eating fish will be advantageous in reducing further growth and production of algae.

Acknowledgements

Asefa Mengesha is thankful to Department of Biology, University of Gondar; and Gondar Soil and Water Laboratory for providing lab facilities. This work was supported by Addis Ababa University, Addis Ababa, Ethiopia.

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Received 28 March 2013; received in revised form 22 May 2013; accepted 1 June 2013