

Impacts of land use on the water chemistry and physical parameters of tropical streams on the northeast shore of Lake Tanganyika

Student: Ramadhani Shineni

Mentor: Catherine O'Reilly

Introduction

Human beings, in their struggle to meet basic needs and to better their lives, through agriculture, lumbering wood for fuel, and in finding space for settlement, have depleted more of the environment than they replenish. Various land uses produce an increase in erosion of soil sediments, which are often deposited in water bodies, such as streams, and are then transported to a larger water body.

Stream flow and ecology are both affected by catchment conditions. Because the catchments and stream are integrated, a change in one part of the system will be felt elsewhere. The water chemistry of the streams can reflect changes in their watersheds, making streams good indicators of land use.

The natural and human modification of the streams or upland areas can have profound effects on the state of the streams. The composition of the stream substrates can be altered by sediment influx from upland erosion and channel modification. Vegetation influences the physical habitat of the streams by providing shade and altering the structure of channels.

The northeast shore of Lake Tanganyika provides an ideal study site for assessing the impact of human activities on the limnology of the streams because the area has two types of contrasting streams: forested and deforested. The forested streams are located in Gombe Stream National Park, whereas the deforested streams are located in the surrounding villages.

Studies by Nkotagu and Mbwambo (2000) and Lombardozi (2003) have shown higher concentration of various ions in the stream waters of a disturbed watershed than in the stream waters of an undisturbed site. Loss of vegetation loosens soil and exposes rocks for increased weathering; it also decreases the nutrient uptake in the soil, resulting in an increased rate of nutrient leaching from the soil.

Methods

Study sites

The study sites were located along the northeast shore of Lake Tanganyika providing an ideal comparison between forested and deforested watersheds. Seven contrasting streams were studied; four of these streams were located in forested watersheds within the Gombe Stream National Park. Vegetation in Gombe Stream National Park consists of semi-deciduous woodland, wetter canopy forests at lower elevations, and dry forest and open grassland at higher elevations.

The other three streams were located in deforested watersheds, where the vegetation is dominated by cultivated areas, particularly cassava on steep slopes, oil palm and bananas along valley bottoms, and disturbed (burned and grazed) grasslands. Relict patches of miombo woodland occur in part of the watershed, particularly at higher elevations. Villages are located in each of these watersheds.

Field sampling

Water samples from seven streams were collected and filtered in the field using a vacuum filtration method and a 0.7 μm pore size filters. Samples were stored in a cooler in the field and were frozen in the lab until analyzed for nutrients. Six filtered and six unfiltered water samples were collected in each stream, three of each type at one site near the mouth of stream and three at other site 100 m upstream.

In situ measurement of temperature, conductivity, percent dissolved oxygen and dissolved oxygen in mg/l was carried out in the field using a YSI 556 multi-probe.

Laboratory Analysis

Alkalinity and turbidity of unfiltered water were analyzed in the lab on the same day as sample collection; alkalinity was analyzed using a titration method while turbidity was measured using a turbidity meter.

Filtered and stored water was analyzed for nutrient concentrations in the lab using the Hach standard method, but unfortunately the Hach machine stopped working after only two stream samples were analyzed. A spectrophotometer method was alternatively used for nutrients analysis for the other five streams

Statistical analysis

Statistical differences in nutrient concentrations and physical parameters between forested and deforested watersheds were determined using t-tests.

Results

Field Sampling

Stream temperatures ranged from 18.76 to 25.17 degrees C. Average stream temperature in the impacted watersheds was 23.63, while the average stream temperature in non-impacted watersheds was 20.86 degrees C. Conductivity ranged from 11.5 to 62 $\mu\text{S}/\text{cm}$. Conductivity values were higher in Ngelwa and Kasekela, 62 and 52 $\mu\text{S}/\text{cm}$ respectively, than in any other watershed. Dissolved oxygen ranged from 8.32 to 11.09 mg/l, averaging 9.19 mg/l in deforested watersheds and 9.8 mg/l in forested watersheds. Average turbidity values were higher in deforested streams (10.14 NTU) than in forested streams (4.32 NTU)

Nutrients analysis

Reactive phosphorous, nitrate, silica and alkalinity were analyzed in the laboratory for all streams. The mean nutrients concentrations together with the physical parameters are presented in Table 1.

Status	Stream Name	PO4 (mg/L)	SiO2 (Mg/l)	NO3 (mg/l)	Temp (dec C)	Cond ($\mu\text{S}/\text{cm}$)	DO (%)	Turbidity (NTU)	Alkalinity (mg/l CaCO3)
D	Ngelwa	0.10	27.25	0.04	23.96	62.00	118.90	10.79	29.47
D	Ngonya	0.05	27.87	0.35	21.65	34.50	104.30	6.50	15.53
D	Mtanga	0.07	7.70	0.08	25.27	24.00	105.40	13.15	6.45
F	Kasekela	0.05	22.72	0.68	22.64	52.00	102.85	5.76	24.67
F	Rutanga	0.07	25.28	0.36	19.52	17.50	115.30	2.50	8.80
F	Kalande	0.02	10.33	0.01	22.34	11.25	110.55	4.14	5.13
F	Mkenke	0.05	20.14	0.04	18.96	15.50	110.95	4.89	7.40

Table 1. The values presented are an average of 6 samples taken in two sites, 3 from each site 100 m apart in each stream.

Reactive phosphorous ranged from 0 to 0.2 mg/l, averaging 0.074 mg/l in deforested watersheds and 0.047 mg/l in forested watersheds. Silica concentration ranged from 5.8 to 37.22 mg/l, the average silica values for deforested watersheds were 20.94 mg/l and 19.62 mg/l in forested watersheds. Nitrate values were greater in Kasekela, a forested but impacted stream, due to presence of settlements. Nitrate ranged from 0.03 to 1.35 mg/l, averaging 0.159 mg/l in deforested watersheds and 0.27 mg/l in forested watersheds. Total alkalinity, which is the total concentration of bases in water, expressed as mg/l of CaCO_3 , ranged from 4.6 mg/l to 36 mg/l, averaging 17.15 mg/l and 11.5 mg/l for deforested and forested streams, respectively.

Statistical Analysis

T-tests were performed to determine if nutrient concentrations and physical parameters in deforested watersheds were significantly different than those in forested watersheds. Reactive phosphorus was significantly higher in deforested watersheds than in forested watersheds ($p=0.03$). Excluding the silica concentration from two streams analyzed using the Hach standard method, silica concentration were significantly higher in deforested sites than forested sites ($p=0.0176$).

Deforested sites had significantly higher temperatures ($p=0.01$) and turbidities ($p=0.0001$) than forested sites. Total alkalinity was significantly higher in deforested site than in forested sites ($p=0.0466$). When Kasekela, a forested but impacted stream, was excluded nitrate concentrations were not significantly different between deforested and forested sites ($p=0.6189$). Conductivity and percent dissolved oxygen were not significantly different between forested and deforested sites ($p=0.1801$ and 0.1138 , respectively).

Discussion

Physical parameters

Land uses have a significant impact on the physical parameters in streams. It causes a reduction in water clarity due to increased suspended particles, which are usually inorganic and are derived from erosion of soil particles in the catchments and resuspension of bottom sediments. The particles both absorb and scatter light. Stream water temperatures increase with increasing vegetation loss; vegetation provides shade, which keeps water cool. Stream conductivity increases with an increase in ion concentration. Increased ion concentration in streams is attributed to erosion and leaching of micronutrients from the soil. Solubility of oxygen is affected nonlinearly by temperature, and increases considerably in cold water (Wetzel 1975). Since deforested streams have significantly higher temperatures, they have lower dissolved oxygen.

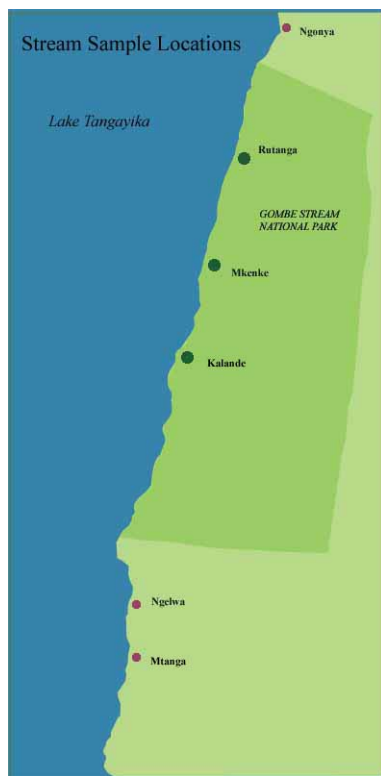
Nutrient concentration

Deforestation has a significant impact on a stream's phosphorus and silica concentrations. Both of these nutrients are geologically derived and are deposited in streams via erosion. The increase in both phosphate and silica concentrations in deforested watersheds are strong indicators of the anthropogenic impacts that land use causes. Influent loading of phosphorus to streams increases markedly as a result of man's accelerated use, inefficient recovery of phosphorus for agricultural nutrients, and detergent use. The slightly higher nitrate values in deforested streams are largely due to lack of vegetation that would use the nitrogen compounds for growth and production. Consequently, more nitrogen is leached from the soil and deposited in streams.

Conclusion

These streams in villages along the northeast shore of Lake Tanganyika have been significantly impacted by human activities. Nutrient concentrations are higher in these streams. Temperature, turbidity and conductivity are also higher in deforested streams. The eroded and leached sediments are discharged into Lake Tanganyika, where they have the potential to affect the lacustrine ecosystem in various ways. Such effects may occur over a long time span, such as long-term climatic change, as well as in the short-term, such as a decline in littoral and benthic productivity, decline in species richness, and changing trophic structures of fish, ostracodes and diatoms (Cohen et al. 2004).

Increased loading of nutrients into the streams has become one of the major environmental problems facing society today. Greater attention should be taken to determine a watershed's capacity to absorb these nutrients before its ecological integrity is threatened. Since my study, and previous studies by Nkotagu and Mbwambo (2000) and Lombardozzi (2003) have shown higher concentration of nutrients in disturbed streams, future studies should compare the water chemistry within the deforested streams from their sources, where there is no or low human activities, to the villages in order to come up with a reliable estimation of land use impact.



Study site: The northeast shore of Lake Tanganyika.

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