Research article

Input of Pollutants by the Tributaries of Lake Yojoa, Honduras

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Abstract Lake Yojoa is the only freshwater lake in Honduras. Its principal water sources are Yure and Varsovia Rivers and Cianuro Creek. There are three principal contaminants of the Lake Yojoa: agrochemical contaminants, microbiological pathogens and heavy metals. So, the main objective of this study is to evaluate and quantify the amounts of pollutants that each water source deposits in the Lake Yojoa. Based on the historical data of precipitation over the watersheds, water samples taken from each water source were analyzed for calculating specific load in each watershed. The specific load was calculated by multiplying the water flow with the concentration and then divided by the area of each watershed. In addition, statistical analysis was conducted employing “SPSS 15”. As a result, there was no statistical difference in the amounts of monthly rainfalls among watersheds. The water flow, concentration as well as load and specific load differed among water sources. The results indicated that there was a tendency for Cianuro Creek to be the highest in specific load of organic matter and the only one in nitrogen as nitrite among water sources. The highest in specific load of potassium and chlorine was observed in Yure River. In addition, the quantity of pollutants discharged into the Lake Yojoa from water sources presents a threat of water degradation, especially eutrophication. A need of mitigating and reducing the amounts of pollutants is a reality. The high load of sulfate released by Cianuro Creek and Yure River present a threat not only for wild life, but also for humans that live near the lake. It was proposed that a filtering system should be prepared specifically to extract the pollutants carried by water sources that can be easily applied.

Keywords pollutants, eutrophication, specific load, Lake Yojoa

INTRODUCTION

Lake Yojoa is the only freshwater lake in Honduras and was designated as Protected Area Number 5 in the category of multiple uses according to the 71st decree of 8th of December 1971 by the government of Honduras. It is located 75km to the south of San Pedro Sula in the area where the departments of Comayagua, Santa Bárbara and Cortés converge. It is a monomictic lake, that is, the water mixes once a year.

The lake is surrounded by the National parks Meámbar and Cerro Azul and the mountain Santa Barbara from where 100% of the water is provided to the lake. Its principal water sources are Yure and Varsovia rivers. These two are artificially diverted to the lake, and the Cianuro Creek that has the higher water flow comparing to the other creeks,such as Horconcitos, La Jutosa, Balas, and La Pita creeks.

Table 1 General information of Lake Yojoa

Altitude (masl)	Length (km)	Width (km)	Perimeter (km)	Surface (km^2)	Average depth (m)	Average temp. (^oC)
632	16.2	4	88	54	28	24

Source: AMUPROLAGO, 2010

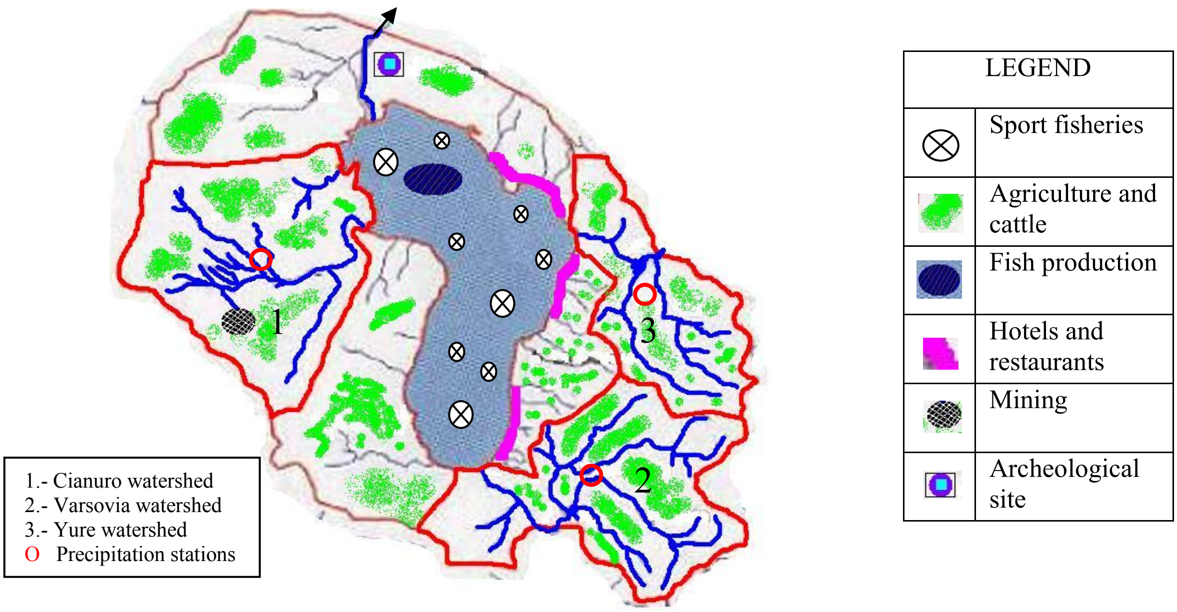

Fig. 1 Land use map of Lake Yojoa

In the world, different water management techniques have been developed (de Vries et al., 2008; UNDP, 1999; Pebbles, 2003; Lee, 2005). Most of the treatments are focused on reservoirs rather than on their water sources. Another approach is the management of water usage of the reservoir and other zones for reduction of water degradation (Queen's printer, 1999; British Land Company, 2008; Georgia Water Council, 2008). And the last is the maintenance of storm water to improve the water quality of a reservoir (Heiker, 2005).

There are three principal contaminants of the watersheds of the Lake Yojoa: agrochemical contaminants, mostly nitrogen, phosphorus and potassium (N P K), microbiological pathogens, mostly from coli forms, and finally heavy metals. There is nearly no information on agrochemical contaminants in the lake or the water sources, little on the microbiological pathogens and certain quantity of information on heavy metals. Most of the investigations done are focused on the lake (House, 2002; Studer et al., 2007; Figueroa, 1976) although (Borjas et al., 1999) water quality data taken from the top part of the Meámbar zone resulted in no contamination from the highest parts.

Data presented by Vaux et al. (1993) showed coli form level in the lake to be higher than those permitted in public beaches in USA (200 cfu/100 ml); but showed that the samples taken were very different from site to site. Samples varied from 1 cfu up to 240,000 cfu per 100ml.

Currently, water pollution in Lake Yojoa has become a big concern in Honduras. So, attention has been paid to the amounts of pollutants discharged into the Lake Yojoa. So, the main objective of this study is to evaluate and quantify the amounts of pollutants that each water source deposits in the Lake Yojoa. Also a secondary objective is to determine the need for a pollution mitigation plan to be set up and carried out.

METHODOLOGY

Research site

The watershed of Cianuro Creek is located to the west of Lake Yojoa and has an extension of 6,212.89 ha, where Las Vegas municipality represents 84% of the total extension. Las Vegas is the biggest human settlement in the region.

The Varsovia River watershed is located to the south east of Lake Yojoa. It has an extension of 5,379.17 ha. This river does not drain directly to the Lake Yojoa but is connected to it by a man made earth channel.

Yure River watershed is located to the south east of the Lake Yojoa, north to Varsovia watershed. It has a territorial extension of 3,558.41 ha. Although this river does not drain directly to the lake, it's connected through a concrete channel.

Table 2 Land coverage

River watershed	Total area (ha)	Human settlement (ha)	Farmland (ha)	Woodland (ha)	Pasture (ha)	Water bodies (ha)	Wetland (ha)	Naked land (ha)
Cianuro	6,212.89 (100%)	252.32 (4.06%)	1,082.82 (17.43%)	2,792.76 (44.95%)	1,965.11 (31.63%)	0.03 (0.0004%)	15.50 (0.25%)	104.35 (1.68%)
Varsovia	5,379.17 (100%)	35.48 (0.66%)	268.61 (4.99%)	3,747.45 (69.67%)	1,280.68 (23.80%)	0.90 (0.02%)	12.23 (0.23%)	33.82 (0.63%)
Yure	3,558.41 (100%)	34.59 (0.97%)	66.95 (1.88%)	2,503.62 (70.36%)	882.62 (24.80%)	45.27 (1.28%)	15.44 (0.43%)	9.92 (0.28%)

Source: AMUPROLAGO, 2010

The land considered as overused is represented by the percentage of farmland and pasture that does not have a resting period. Mining is the main income source for the population in Cianuro watershed. Overused land is 43.26%. Agriculture and cattle husbandry are the main income sources for the population in Varsovia watershed. The overused land in Varsovia watershed is 22.68%. Cattle production is the main income for the population in Yure watershed. The 23.59% of the land is in overuse.

Research methods

Historical data recorded by the Honduran National Electric Energy Company (ENEE) on precipitation over the watersheds of the main rivers and creek that discharge to the Lake Yojoa was acquired. Precipitation data comprised the monthly precipitation from 1988 to 2010. Collecting stations are placed strategically in sites representing the three main watersheds to Lake Yojoa (Fig. 1). Due to the high percentage of woodland in all the sites, calculations for pollutants were made from water collected before the effect of human activities during the day to avoid alterations in the quality.

Six water samples were taken from the water sources on July 21st 2011. The samples were taken as follows.

Two samples were taken from each river at the same time; the samples were taken at 6:30 am and 7:30 am as to avoid human activities of that day. Each sample site was marked by a GPS. At the same time span, the water flow of each river was observed in sites.

Water samples were analyzed for organic matter (OM), pH, electric conductivity (EC), phosphorus (P), potassium (K), chlorine (Cl^-), nitrogen as nitrite (NO_3^-), and sulfate (SO_4^{2-}).

Samples taken from each water source were analyzed for calculating specific load in each watershed. All the data were introduced to "SPSS 15 for Windows" program for the statistical analysis (α=0.05). The specific load was calculated as follows.

$$SL = (Q \times C) / A \tag{1}$$

where SL (kg/s/km^2) is specific load, Q (l/s) is water flow, C (kg/l) is concentration and A (km^2) is area of the watershed.

RESULTS AND DISCUSSION

Precipitation and water flow

The rainfall data collected showed that there was no statistical difference in the amounts of monthly rainfall among watersheds. The water flow showed statistical differences among water sources although precipitation did not show statistical difference. Table 3 shows the mean of the water flow of each water source during the sampling period.

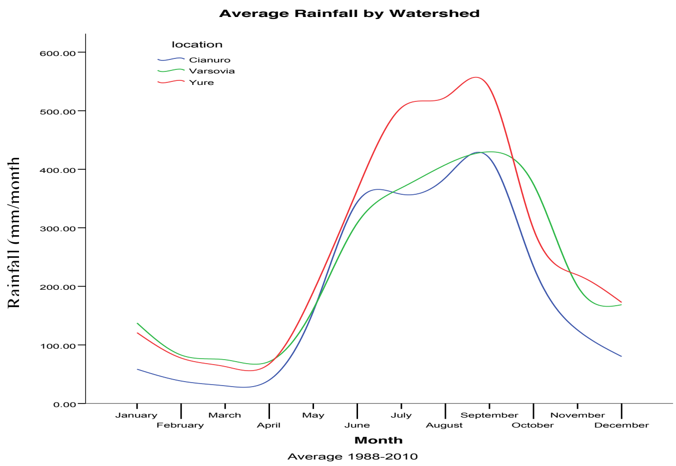

Fig. 2 Average monthly rainfall by watershed 1988-2010

Table 3 Average water flow towards the Lake (July, 2011)

Water source	Cianuro (m^3/s)	Varsovia (m^3/s)	Yure (m^3/s)
Water Flow	2.48^c±0.16	3.65^b±0.04	5.66^a±0.13

Different super indexes indicate statistical difference at 99% between columns

Input of pollutants to Lake Yojoa

The analyzed water samples showed that none of the three rivers transported phosphorus. In almost all of the analyzed nutrients there were statistical differences, placing the Cianuro Creek as the highest NO_3 carrier. In spite of this difference, to determine which river transports more amount of pollutants to the lake, the specific load was used. In Table 4, the specific loads of each water source were summarized.

The analysis showed that there was a statistical difference between Yure and the other two water sources and no difference between Cianuro and Varsovia water sources regarding pH, organic matter and chlorine. Yure River had the highest specific load of potassium, chlorine and sulfate. No difference in the potassium load among the sources. Cianuro Creek indicated the highest specific load of nitrogen in the form of nitrate that may create an environment for the super population of water plants. This super population of plants in the lake can cause the decrease in dissolved oxygen at night causing problems to the lake's water life. These nitrogen components may be derived from fertilizers applied to the farmlands in the watersheds.

Table 4 Mean separation of specific loads of each river (July, 2011)

Water source	pH	EC (mS/cm)	OM ($kg/s/km^2$)	K ($kg/s/km^2$)	Cl ($kg/s/km^2$)	NO_3 ($kg/s/km^2$)	SO_4 ($kg/s/km^2$)
Cianuro	7.72^a	28.50^a	0.13^a	0.11^a	0.42^b	0.38^a	1.29^a
Varsovia	7.68^a	41.00^a	0.15^a	0.26^a	0.49^b	0.00^b	0.37^b
Yure	7.10^b	19.00^a	0.03^b	0.66^a	1.13^a	0.00^b	1.51^a

Means in the same column with different letters are statistically different at a significance of 0.05

Vevey (1990) took samples of the sediments inside the Lake Yojoa and found high levels of contamination of heavy metals, the highest point near the outflow of Cianuro Creek. Although these high levels were found, they were not bio-available as the concentrations in fish and wildlife are very low.

Table 5 Land use versus specific loads of pollutant by Pearson correlation

Correlations	pH	EC	OM	K	Cl	NO_3	SO_4
Human settlement	0.470	-0.093	0.270	-0.558	-0.500	0.933**	0.408
Farmland	0.682	0.064	0.509	-0.716	-0.714	0.919**	0.148
Woodland	-0.558	0.032	-0.367	0.625	0.589	-0.936**	-0.309
Pasture	0.440	-0.113	0.238	-0.534	-0.469	0.930**	0.439
Water bodies	-0.970**	-0.473	-0.948**	0.842*	0.996**	-0.479	0.636
Wetland	-0.959**	-0.505	-0.959**	0.816*	0.984**	-0.393	0.712
Naked land	0.717	0.095	0.551	-0.741	-0.750	0.909*	0.097

** Correlation is significant at the 0.05 (2-tailed)*
***Ccorrelation is significant at the 0.01 (2-tailed)*

Nitrate is affected by human settlement, farmland and pasture creating an increase in the load as the extension of land use increases. Woodland affects negatively the NO_3 specific load due to the high amount of absorption by trees concerning water and nutrients. Cianuro Creek was the only water source that presented NO_3. This is due to the amount of farmland, pastures and naked land located in the watershed.

CONCLUSIONS AND RECOMMENDATIONS

Lake Yojoa, the only freshwater lake in Honduras, needs to be protected. The amount of pollutants carried by the water sources has to be evaluated in order to further protect the Lake Yojoa from eutrophication and other types of contamination.

Nitrate concentration was affected heavily by the land usage and that effect in time can easily be the same for all of the other pollutants.

The high load of sulfate released by Cianuro Creek and Yure River presents a threat not only to wild life but also to humans that live near the lake.

As a recommendation, a filtering system should be prepared specifically to cover all of the pollutants carried by rivers that can be easily applied to all the water sources of the Lake Yojoa. This system has to remove organic materials and nutrients directly from the water.

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