MODELLING CONTROL OF POLLUTANTS LOADS IN LAKE KIVU USING BINARY LOGISTIC REGRESSION METHODS

Jean Pierre IYAKAREMYE[1], Verdiana Grace MASANJA[2]

[1]Assistant Lecturer in Catholic University of Rwanda, Faculty of Science and Technology Computer Science Department, P.O.Box 49 BUTARE/HUYE.,iyajeanp@yahoo.fr,

Cell phone: (+250)788986233

High concentration of pollutants in water surfaces causes catastrophes which kill aquatic life, kill people and affect livelihoods of those living in the catchment of the polluted water surfaces. In this study, a logistic binary regression model was applied to existing data of pollutant concentrations in rivers in flowing into Lake Kivu to compute estimations of probabilities that the rivers pollute the Lake. Rivers that discharge large amounts of pollutants in the Lake were identified. The goodness-of-fit test statistic established that the formulated model could be used to predict the status of pollutants load in the Lakes. The amount of Total Suspended Solids, Soluble Reactive Phosphorus, Nitrates, and Dissolved Silica are determinant factors to be used to predict the status of pollutant loads in Lake Kivu. The model was then used to simulate scenarios to reduce and control pollutant loads using methods of Infiltration Basin, Terrace System, and Constructed Wetlands.

It is established that the use of any of the above control methods will drastically reduce the pollutants load to allowable levels in all of the five identified rivers on the Rwanda side and five out of the eight identified rivers on the DRC side. The constructed wetlands method is the best option to reduce the level of pollutants followed by the Terrace System. The least is the Infiltration Basin method. However, since the constructed wetlands method is expensive and has many limitations, the Terrace System could be used for all the rivers on Rwanda side and five on the DRC side. It fails for three rivers on DRC side. These results are in excellent agreement with former studies elsewhere.

Keywords: Logistic Binary Regression, modelling pollutants in lakes, Pollutant load control Pollutants in Lake Kivu, Logistic modelling of pollutants

1. INTRODUCTION

This paper seeks to use Logistic Regression modelling and simulation to investigate how to control the flow of six pollutants into Lake Kivu via eight rivers on the Rwanda side and thirteen rivers on the DRC sides of the Lake that discharge their water into the Lake. The 21 rivers were sampled and data on pollutant loads were collected by Muvunja and colleagues over a two year period 2006 - 2008, (Muvunja *et* al, 2009). The rivers (13 on DRC and 8 on Rwanda side) are: Nyabahanga, Musogora, Muregeya, Koko and Gisayo have been selected on Rwanda side and Kawa, Nyabaronga, Mubambiro, Binyabihira, Kihira, Mugaba, Murhundu and Kakumbu on DRC side of the Lake and Nyabahanga, Musogora, Muregeya, Koko, Gisayo, Buhari, Kiraro on the Rwanda side.

In this paper, the following pollutants have been considered: Total Suspended Solid (TSS), Nitrate, Ammonia, Soluble Reactive Phosphorus (SRP), Dissolved Silica (DSi) and the Total Phosphorus (TP).

2. LITERATURE REVIEW

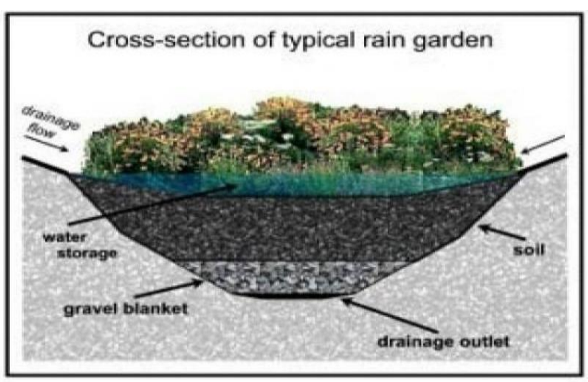
This section gives an overview of research studies conducted on the control of pollutants in lakes in general and Lake Kivu using physical methods and mathematical methods. Also, discussed are studies based on Logistic Regression models to predict and simulate scenarios to control pollution loading by rivers flowing in Lake Kivu.

2.1. **Overview of Research Studies conducted to Control Pollutants Loads in Lakes and Rivers.**

2.2.1.Site-specification Technologies control methods

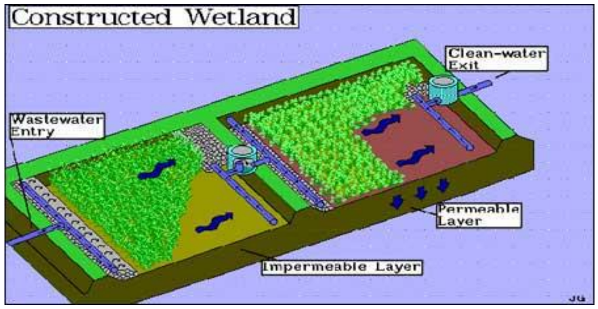
- **Infiltration Basin**

Infiltration Basin is practicable around a given river, it can remove 75% of TSS, 60% of Nitrogen, 90% of Metals, 90% of bacteria, 75% of DSi and 75% of SRP which would be transported by runoff to the river or Lake (USEPA, 1993).



➢ Constructed Wetlands

If the method of Constructed Wetlands is well used, it can remove 93% of TP, 92% of TN, 88% of Ammonia, 90% of TSS and 90% of DS (USEPA, 1993).



➢ Bio-retention System

Bio-retention systems are a best management practice that is conventionally utilised to treat urban storm water runoff from commercial, residential and industrial areas (USEPA, 1999).

➢ Terrace System

Terraces are constructed across a slope and form a series of channels and earthen embankments. They reduce soil erosion by breaking a long slope into several short sections. This reduces the speed of runoff water, which reduces the amount of soil that can be transported. If the method of Terrace System is practicable in river catchment's area, this method can remove 85% of Dissolved Silica, 20% of Nitrogen, 70% of Total Phosphorus and 85% of TSS transported runoff into river or Lake (USEPA, 1993).

2.2. Overview of Mathematical Models used

We model the level of pollutants concentration in lakes using logistic regression model whose function is given as

$$P_i(X) = E(Y_i = 1/X_{i1}, X_{i2}, \ldots . X_{iN}) = \frac{1}{1 + e^{-\left(\beta_0 + \sum_{j=1}^{N} \beta_j X_{ij}\right)}}$$

Here $Y_i \backsim indep.bernoulli(P_i)$, β_0 and β_j are model parameters to be estimated using the maximum likelihood method; $P_i(X)$ denotes the Probability of event; Y_i denotes the level of pollutant concentration coded with 1 for high level and 0 otherwise; and X_{ij} denotes factors of pollutant concentration in Lakes.

After estimating the model parameters, one can estimate the probability of event by equation

$$\hat{P}_i(X) = \frac{1}{1 + e^{-(\hat{\beta}_0 + \sum_{j=1}^{N} \hat{\beta}_j X_{ij})}}$$

Comparison of the fitted model and the full model is given by equation

$$D = -2ln\left[\frac{likelihood\ of\ fitted\ model}{likelihood\ of\ full\ model}\right]$$

Where D is the deviance (MeCullagh and Nelder, 1983). The likelihood value is given by equation

$$G = -2ln\left[\frac{likelihood\ of\ constant\ model}{likelihood\ of\ model\ with\ variable}\right]$$

G follows the Chi-square distribution with $k - 1$ degrees of freedom, where k is the number of parameters in the model with variables. Using the P_value associated with the test, if $P(\chi^2(k-1) > G) < \alpha$, the variables in the model are significant.

In order to assess the performance of the logistic regression model, we use equation

$$\frac{loglikelihood\ of\ constant\ model - loglikelihood\ of\ fitted\ model}{loglikelihood\ of\ constant\ model}$$

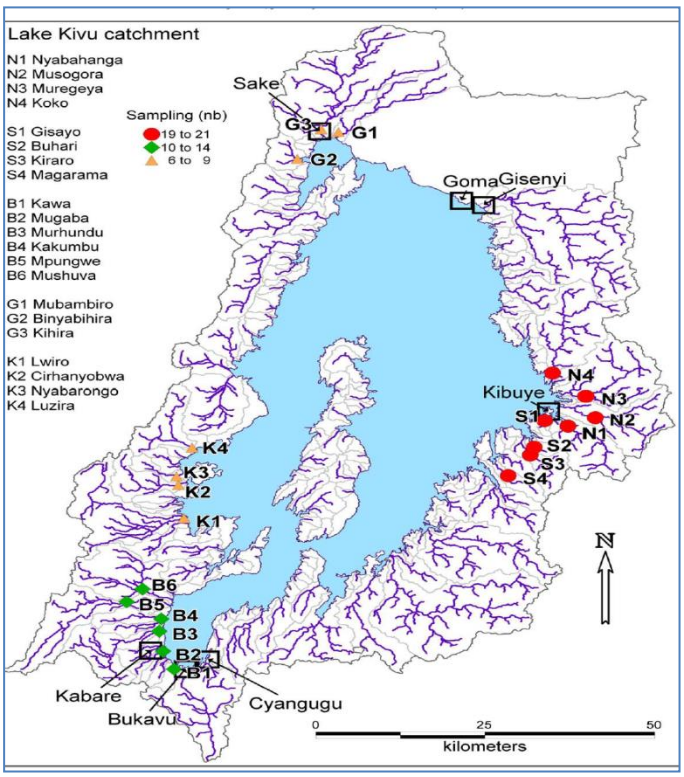
This is called the percent of the correct prediction

2.3. Methods used in this research

This research uses both analytic and computational methods to estimate the probabilities of given rivers to load large amounts of pollutants into Lake Kivu, do predictions for marginal effects and simulate scenarios for control of pollutants loads in the lake. The analytical methods are used in model building using logistic regression modelling.

A priori data by Muvunja et al (2009), which were collected on 21 rivers that discharge their waters in Lake Kivu on Rwanda and DRC sides, are used in the model building.

2.3.1. Sampling site



2.3.2 Computational methods

MATLAB software package is used for computation. The maximum likelihood method is used to fit the model to the proposed determinant factors of pollutants loads in Lake Kivu using

MATLAB codes. Significance of parameter estimates is tested at 5% confidence intervals, and the significance of the model is tested using the likelihood ratio Chi-Square test. Reduction of variables to significant variables is attained using step by step elimination of insignificant variable at 5% level of significance.

The number of samples taken on each river to quantify the amounts of pollutant that river i discharge into Lake Kivu at different times was denoted by N_i. The number of cases found in N_i samples where river i discharges large amounts of pollutants were denoted by n_i. MATLAB function *glmfit* was used as follows:

$$[\beta, dev, stats] = glmfit(X, [Y_i \;\; N_i], 'binomial', 'link', 'probit')$$

Where β are parameter estimates, dev is deviance of the fit at solution vector, the dependent variable Y_i is the vector of n_i $i = 1, . . ,23$ since the model seeks to find the probability that river i discharges large amounts of pollutants in the Lake, and X is a matrix of the form: $X = \begin{bmatrix} X_{1,1} & X_{1,2} & \dots & X_{1,6} \\ X_{2,1} & X_{2,2} & \dots & X_{2,6} \\ \vdots & \vdots & \vdots & \vdots \\ X_{23,1} & X_{23,2} & \dots & X_{23,6} \end{bmatrix}$, with X_{ij} the average concentration of pollutant j discharged by river i, $i = 1, . . ,23$ $j = 1, \dots ,6$.

3 Results

3.1. Parameter estimates

Table1 shows the results of parameter estimates and their corresponding confidence interval at 5% level of significance. Using the step by step elimination of insignificant variable at 5% level of significance, the variables are reduced to four significant variables: Nitrates, Si, TSS and SRP. It is established that the amounts of specific loads of Dissolved Silica, Total Suspended Solids and Soluble Reactive Phosphorus in Lake Kivu are high. This confirms the findings of former researchers (Olapade, 2012; Muvunja *et al*, 2009; Pasche *et al*, 2009 etc) that Lake Kivu has lost its transparency due to large amounts of Dissolved Solid. As it can be seen from Table1, the amounts of Nitrates, Si, TSS and SRP are positively and significantly related to the level of pollutants concentration in Lake Kivu.

Table 1: Parameter Estimates of the Logistic Regression

Variables	Coefficient (95% Confidence Interval)	Standard Error	P-value
Constant	-2.0949 (-2.8653 1.3245)	0.3931	0.0000
Average concentration of Nitrate	0.0007 (0.00002 0.0014)	0.0003	0.0430
Average concentration of Ammonia	-0.0001 (-0.0005 0.0003)	0.0002	0.5554
Average concentration of DSi	0.0726 (0.0209 0.1244)	0.0264	0.0059
Average concentration of TSS	0.0044 (0.0026 0.0063)	0.0009	0.0000
Average concentration of TP	-0.0003 (-0.0007 0.00013)	0.0002	0.1845
Average concentration of SRP	0.0074 (0.00018 0.0147)	0.0037	0.0446

The log likelihood values are computed using determinant factors. In Table 2 we see that the log likelihood value is 1264.7 with P<0.001. This indicates that at least one of the parameters of the determinant factors of pollutants concentration in Lake Kivu is significant.

Table2: Significance and Efficient

	Value	P-value
Log likelihood Value	1264.7	<0.001
Percent of correct prediction	0.9580	

3.2. Marginal effects and Interpretation

Table 3 gives the computed marginal effects (i.e. the decrease in the probability that river i discharges large amounts of pollutants in Lake Kivu) given a unit change in the amount of a given determinant factor, computed at sample mean of holding size.

Table 3: Marginal Effect for significant determinants

Determinants	Marginal Effect
Amounts of Nitrate (μg/l)	-0.00014
Amounts of DSi (mg/l)	-0.014
Amounts of TSS (g/l)	-0.0008
Amounts of SRP ($\mu g/l$)	-0.0006

From Table 3, we discuss the marginal effects for each of the four significant determinant factors:

Nitrates: the probability that river i will discharge large amounts of Nitrates into Lake Kivu will decrease by 0.0001333 by the removal of one microgram per litre from the amount of Nitrates that are transported by runoff to a given river or into the lake.

Dissolved Silica: the probability that river i will discharge large amounts of DSi into Lake Kivu will decrease by 0.013 by the removal of one milligram per litre from the amount of DSi that are transported by runoff to a given river or into the lake.

Total Suspended Solids: the probability that river i will discharge large amounts of TSS into Lake Kivu will decrease by 0.0008 by the removal of one gram per litre from the amount of TSS that are transported by runoff to a given river or into the lake.

Soluble Reactive Phosphorus: the probability that river i will discharge large amounts of SRP into Lake Kivu will decrease by 0.0006 by the removal of one microgram per litre from the amount of SRP that are transported by runoff to a given river or into the lake.

3.3. Impact of major determinant factors on pollutants loads in Lake Kivu

The following average concentrations for each of the significant factors are used as reference to predict conditional probabilities: 477.2857 $\mu g/l$ Nitrate, 9.7952 mg/l DSi, 127.9048 g/l TSS and 74.6190 $\mu g/l$ SRP. The impact of significant factors is assessed through levels of change in the predicted conditional probability of river i to discharge large amounts of pollutants in Lake Kivu following the reduction of a significant factor of pollutant concentration in Lakes. Predictions are done with reference to the probability that river i discharges large amounts of pollutants in Lake Kivu given that the above specified average concentrations are discharged by river i into the Lake. This is the base group of rivers which pollute Lake Kivu with above concentrations of significant factors. The results are presented in Table 4.

From table 4, the conditional probability of a given river to discharge large amounts of pollutants in Lake Kivu for the base group is about 0.4308.This means that, out of 100 unit measures of the significant factors transported runoff, at least 43 unit measures enter the river and are discharged into the Lake Kivu.

Table 4: Impact of Determinants on the probability that river i discharge large amounts of pollutants

Variables	Predicted Probability
Base	0.4308
If we remove one $\mu g/l$of Nitrate_Nitrogen	0.4306
If we remove one mg/l of DSi	0.3241
If we remove one g/l of TSS	0.4300

If we remove one μg/l of SRP	0.4302

If we remove one μg/l of Nitrate the probability that a given river discharges large amounts of pollutants in Lake Kivu will decrease from 0.4308 to 0.4306. Meaning that if ten thousand micrograms of Nitrates per litre are stopped from entering runoffs which are pouring into the base group and into Lake Kivu, the amount of nitrates discharged into the lake will decrease by 2 micrograms per litre, from 4,308 to 4,306. The removal of ten thousand milligrams of DSi per litre from run-offs, results in a decrease of 1,067 grams per litre (from 4,308 to 3,241) of the amount of DSi discharged into the lake. Reduction of ten thousand grams of TSS per litre from run-offs causes a decrease of 8 grams of TSS flowing into the Lake, while the removal of ten thousand micrograms of SRP per litre from runoffs results in a decrease of 6 micrograms by per litre of SRP flowing into the lake.

3.4. Rivers that discharge large amounts of Pollutants in Lake Kivu

In this study 21 rivers which discharge their waters into Lake Kivu have been considered, 13 on DRC and 8 on Rwanda side. The rivers are: Nyabahanga, Musogora, Muregeya, Koko and Gisayo have been selected on Rwanda side and Kawa, Nyabaronga, Mubambiro, Binyabihira, Kihira, Mugaba, Murhundu and Kakumbu on DRC side of the Lake and Nyabahanga, Musogora, Muregeya, Koko, Gisayo, Buhari, Kira78yuijkoro on the Rwanda side. In section 3.3 we have established that four of the six pollutants are significantly related to the level of pollutants load in Lake Kivu through these rivers. The four pollutants are: Nitrates, TSS, DSi and SRP. At this point it is necessary to determine which of these rivers contribute large amounts of pollutants loads in Lake Kivu. We determine such rivers by using Equation (3.6) and computing the probabilities. Rivers whose probability exceeds 0.35 are categorised as discharging large amounts of pollutants in the lake.

Table 5: Probability $\widehat{P}_i$ that river i discharges large amounts of pollutants in Lake Kivu

River i on Rwanda Side	$\widehat{P}_i$	River i on DRC Side	$\widehat{P}_i$
Nyabahanga	0.3731	Kawa	0.8514
Musogora	0.4151	Mugaba	0.6175
Muregeya	0.3770	Murhundu	0.7043
Koko	0.3940	Kakumbu	0.5095
Gisayo	0.4087	Mpungwe	0.2784
Buhari	0.3354	Mushuva	0.3215

Kiraro	0.3071	Lwiro	0.3493
Magarama	0.3192	Cihanyobwa	0.3484
		Nyabarongo	0.3659
		Luzira	0.2885
		Mubambiro	0.4761
		Binyabihira	0.5190
		Kihira	0.4867

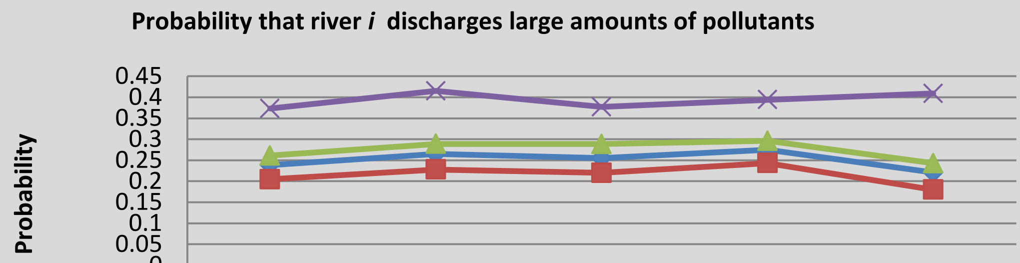
Table 5 gives the computed probability $\hat{P}_i$ that river i discharges large amounts of pollutants in Lake Kivu. As it can be seen from Table 5, only three rivers Buhari (0.3354), Kiraro (0.3071) and Magarama (0.3192) on the Rwanda side have probabilities below 0.35. In brackets are the probabilities. Meaning that five rivers are likely to discharge large amounts of pollutants into the Lake. On the DRC side, five rivers Mpungwe (0.2784), Luzira (0.2885), Mushuva (0.3215), Cihanyobwa (0.3484) and Lwiro (0.3493) have probabilities below 0.35. The remaining eight rivers are likely to discharge large amounts of pollutants into the lake. The range of probabilities is [0.4151, 0.3071] on Rwanda side and [0.8514, 0.2784] on the DRC side. The situation is very alarming and requires immediate interventions. However, for efficient and cost effectiveness of the meagre resources available to mitigate pollution, use of mathematical methods is imminent.

This study aimed to propose ways of reducing loading of pollutants by rivers and run-offs into Lake Kivu. We want to simulate scenarios to reduce the pollutant loading into the lake. For this purpose, we have selected three physical methods that are commonly used by governments and other stakeholders to control pollutants loading in water surfaces. These methods are Infiltration Basin, Constructed Wetland and Terrace System. Previous studies have established that if the methods are used well in rivers' catchment areas, they may significantly reduce the level at which rivers discharge large amount of pollutants into the Lake. For example, previous researchers established that the method of **Infiltration basin** if used well, it can remove 75% of TSS, 60% of Nitrogen, 90% of Metals and 90% of bacteria, 75% of Si and 75% of SRP transported by runoff into the river or Lake (USEPA, 1993). Also the same study established that **Constructed Wetlands**, if used properly, can remove 93% of TP, 92% of TN, 88% of Ammonia, 90% of TSS and 90% of Si (USEPA, 1993). Furthermore, the study established that good use of the **Terrace System** can remove 85% of DSi, 20% of Nitrogen, 70% TP and 85% of TSS transported runoff into rivers or Lakes (USEPA, 1993).

This study has simulated scenarios to determine the extent to which these methods can contribute to reduce pollutants loading if used on the rivers' catchment areas. Considered are only the rivers most likely to discharge large amounts of pollutants in the lake. The results are given in Figure 2 and Figure 3.

Figure 2 illustrates the comparison of the methods for the five rivers on the Rwanda side. It can be seen that the Constructed Wetlands method is sufficient to reduce the pollutants load by all the rivers than other methods, from the range [0.4151, 0.3731] of the probability that river *i* discharges large amounts of pollutants into the lake to the range [0.2431, 0.1801].

Figure 1: Probability that river i on Rwanda Side discharges large amounts of pollutants after and before use of control measures

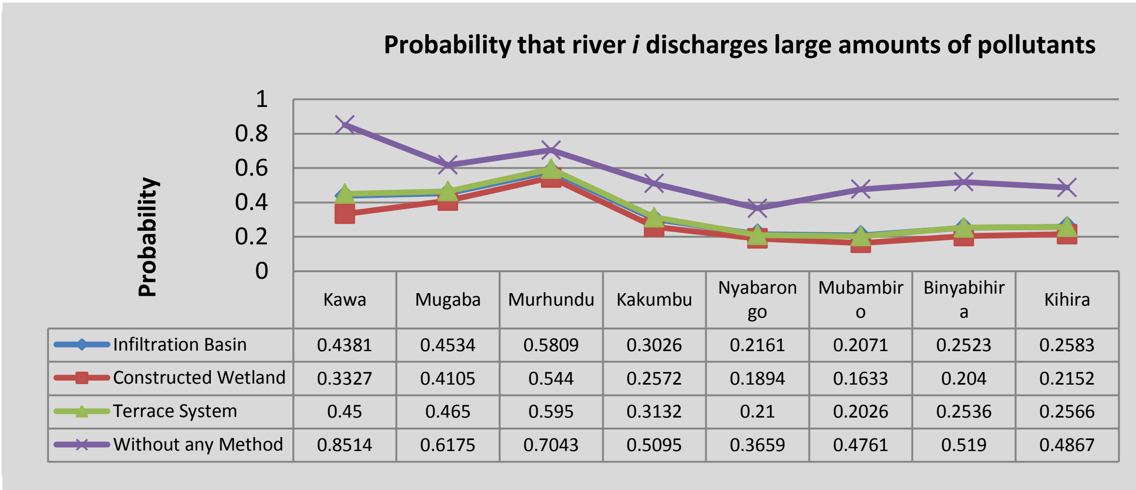


	Nyabahanga	Musogora	Muregeya	Koko	Gisayo
Infiltration Basin	0.2385	0.265	0.2551	0.2748	0.2209
Constructed Wetland	0.2049	0.2279	0.2201	0.2431	0.1801
Terrace System	0.2611	0.289	0.2884	0.296	0.2428
Without any Method	0.3731	0.4151	0.377	0.394	0.4087

From Figure1, we see that the Constructed Wetland method yields the best result overall. However the method fails for two rivers Mugaba (0.4105) and Murhundu (0.5440), in brackets are probabilities. For these rivers, a combination of methods can be used.

When taking the cost into consideration, other options can be explored. For example, the Constructed Wetlands method is most expensive and has many limitations. The Terrace system is the least expensive, it has been in practice for decades and it is acceptable by many farmers. Probabilities based on the Terrace system are at most 0.3 on all the five rivers on Rwanda side and on five (out of eight) rivers on the DRC side. This method can be used to yield cost effective results on such rivers.

Figure 2: Comparison of methods to be used to control pollutants load in Lake Kivu on the DRC side



	Kawa	Mugaba	Murhundu	Kakumbu	Nyabarongo	Mubambiro	Binyabihira	Kihira
Infiltration Basin	0.4381	0.4534	0.5809	0.3026	0.2161	0.2071	0.2523	0.2583
Constructed Wetland	0.3327	0.4105	0.544	0.2572	0.1894	0.1633	0.204	0.2152
Terrace System	0.45	0.465	0.595	0.3132	0.21	0.2026	0.2536	0.2566
Without any Method	0.8514	0.6175	0.7043	0.5095	0.3659	0.4761	0.519	0.4867

Comparing the method of Infiltration Basin and the Terrace System, we see that they have almost the same result but the method of Terrace system is less expensive than the method of Infiltration Basin and also it is easy to put in practice in hilly locations like those of Rwanda side. Where possible, it is better to use Terrace System with the probability of at least 70% of reducing the pollutant load of all the 5 rivers on the Rwanda side and 5 of the 8 rivers on DRC side.

Figure3: Comparison of combined methods to control pollutants load on Rwanda side

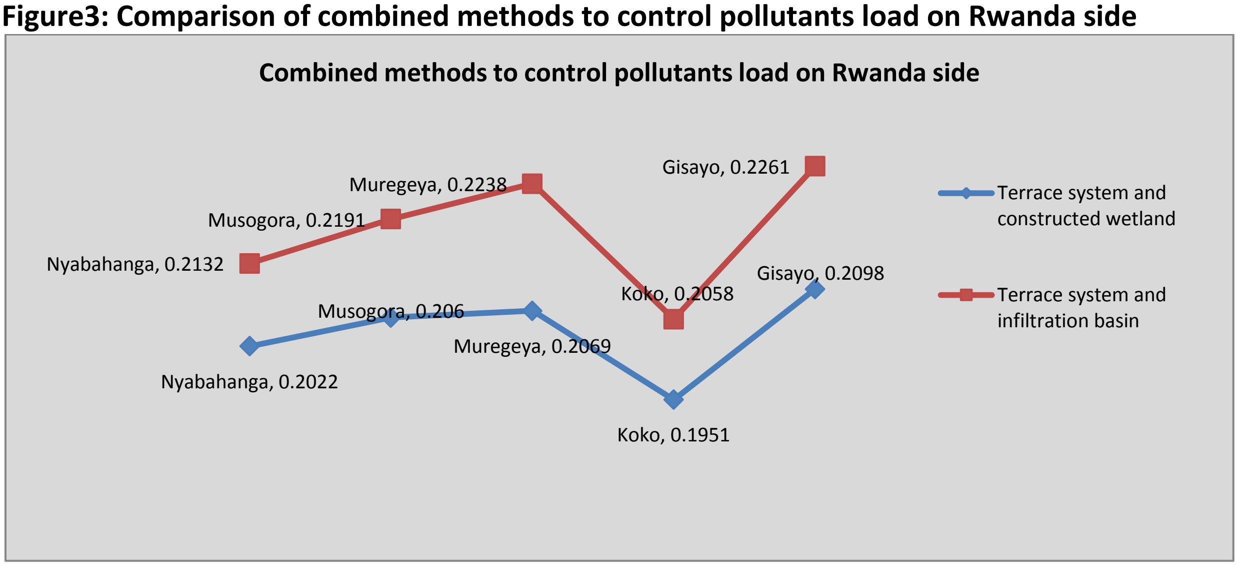
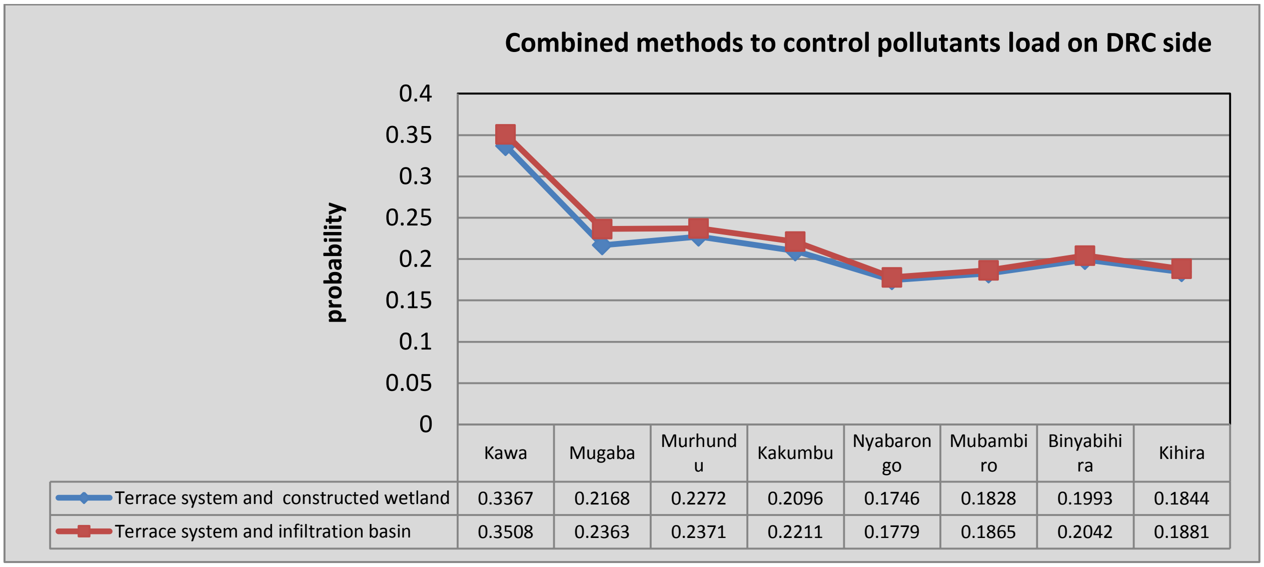


Figure4: Comparison of combined methods to control pollutants load on DRC side



	Kawa	Mugaba	Murhundu	Kakumbu	Nyabarongo	Mubambiro	Binyabihira	Kihira
Terrace system and constructed wetland	0.3367	0.2168	0.2272	0.2096	0.1746	0.1828	0.1993	0.1844
Terrace system and infiltration basin	0.3508	0.2363	0.2371	0.2211	0.1779	0.1865	0.2042	0.1881

Some methods may not be suitable to reduce the load of pollutants due to the limitations on the site where they are used. In such cases, the most effective way to control the pollutants loading would be to combine some of these methods. Figure 4 and Figure 5 illustrate simulations of two combinations: Terrace System with Constructed Wetlands and the Terrace System with Infiltration Basin. We see that both on Rwanda side and DRC side the combined methods yield much better results. However the combined Terrace System and Constructed Wetlands give better results than the combined Terrace System with Infiltration Basin.

It is also important to observe the allowable range of nutrients in the water. Nutrients are essential for plants, however if in excess or in shortfall they can cause significant water quality problems. In 1993 USEPA produced the acceptable range of the concentration of nutrients in drinking water as follows: Maximum contaminant level goal (MCLG) for nitrate is 10mg/l, the low level of nitrate in drinking water is between 0.4 and 0.6 mg/l. For dissolved silica, the standard concentration allowable in drinking water is between 0.5 and 5 mg/l. For TSS the allowable concentration in drinking water is between 35 and 90mg/l and for SRP the allowable concentration in drinking water is less that 0.02mg/l(USEPA,1993).

On average the five rivers on the Rwanda side that are likely to discharge large amount of pollutants in Lake Kivu have the following concentrations of the four pollutants, (Muvunja *et al*, 2009): 0.722mg/l of Nitrate, 7.1mg/l of dissolved Silica, 127.2mg/l of TSS and 0.037mg/l of SRP. All the concentrations are way out of the acceptable range. If the proposed methods are well used, the level of pollutants concentrations in the rivers on the Rwanda side could be reduced.

In general, introduction of physical methods to control pollutant loading can be effective except for Nitrates which would be reduced below the minimum required level for the quality of drinking water. Inspection by river catchment area could be used to determine how to handle this challenge.

These findings are in good agreement with finds from former studies. For example, in 1993, the USEPA studies established that when used well the methods of Infiltration Basin, Constructed Wetland and Terrace System, respectively, can remove at least 60%, 88% and 70% (except for Nitrates which is 20%) of pollutants transported by runoff into rivers or Lakes (USEPA, 1993).

4. Conclusion and Recommendation

Data collected by Muvunja *et al* (2009) on 21 rivers flowing into Lake Kivu have been used with the Logistic Regression Model to predict the level of pollutants loads in Lake Kivu. Significant Factors of pollutants loads in Lake Kivu have been determined. These Factors are amounts of Nitrates, Total Suspended Solids, Dissolved Silica and Soluble Reactive Phosphorus.

Estimates of marginal effects, computed at sample means using the significant factors, show that a unit change in reduction of pollutants discharged by river i can reduce the level of pollutants loads in Lake Kivu. This is in good agreement with previous studies. For example, in 2009 Mauna and colleagues (Mauna *et al*, 2009) conducted an impact assessment and established that a decrease in the amounts of TSS, SRP, Si and Nitrate transported by runoff into a river or Lake, has a potential to decrease the level at which the river discharges large amounts of pollutants in Lake Kivu and thus the reduction in the level of pollutants concentration in the lake.

We have simulated scenarios on how to control the level of pollutants loading in the Lake by 5 rivers on Rwanda side and 8 rivers on DRC side using three methods: Terrace System, Constructed Wetland and Infiltration Basin which are commonly applied to physically reduce amounts of pollutants in water surfaces. Simulations show that all the three methods can significantly reduce the pollutants loading in all the 5 rivers on Rwanda side and 5 of the 8 rivers on the DRC side. However, the Constructed Wetland methods yields the best result followed by the Terrace System and the least effective is the Infiltration methods.

The Terrace System is the least expensive and it is easy to put it in practice, and hence should be the most favourable. Comparing the Constructed Wetlands and Terrace System, simulation results show the following differences at which the methods remove the pollutants loads: Constructed Wetland method removes more than the Terrace System 0.0435mg/l of Nitrates, 0.4277mg/l of Dissolved Silica, 7.6625 mg/l of TSS and 0.0022 mg/l of SRP.

Based on these differences in the amounts of pollutants removed by the two methods, we recommend the use of the Terrace System where possible for cost effectiveness. This method is most suited on Rwanda side because the rivers found to discharge large amounts of pollutants are located in the north of Kibuye where rivers are surrounded by hills. It is easy to construct terraces on the hills. On DRC side Rivers found to discharge large amounts of pollutants in lake Kivu are near the cities of Goma and Bukavu, it is recommended to use the combined method of Terrace system and Infiltration Basin to filter waste water from these cities

References

[1] David Pimental;C.Harvey;P.Resosudarmo;K.Sinclaire;D.Kurz;M.Mc Nair;S.Crist;L.Shpritz;L.Fihon;R.Saffouri;R.Blair. *Environmental and economic cost of soil Erosion and conservation Benefits, 1995.*

[2] J.G M.Majaliwa, S. Bashwira, M. Tenywa, F. Kansiine. *An overview of pollution loading into Lake Kivu Basin*, 2009.

[3] D. W.Hosmerr, S. Lemshow. *Applied Logistic Regression /Second Edition*, 2000.

[4] J.N.Namugize. *External Nutrient Inputs into Lake Kivu; Rivers and Atmospheric Depositions Measured in Kibuye*, 2009.

[5] F.Muvunja, N.Pasche, F.W.B.Bugenyi, M.Isumbiro, B.Muller, J.N.Namugize, R.Stiel, A.Wuest. *Balancing nutrient inputs to Lake Kivu Submitted to Journal of Great Lakes Research*, 2009.

[6] L.S.Ryan, *Biorentation System for control of Non point sources of Nitrogen*, 2007.

[7] Federal Environmental Protection Agency (FEPA). *Guidelines and Standards for Environmental Pollution Control in Nigeria, Federal Environmental Protection Agency Regulation 1991 on pollution abatement in industries and facilities generated wastes*, 2006.

[8] World Health Organization (WHO). *Guidelines for Drinking Water Quality*, 1993.

[9] H.J.Dumont, *The Tanganyika sardine in Lake Kivu: Another ecodisaster for Africa Environ*, 1986.

[10] M. Halbwachs, K.Tietze, A. Lorke, C. Mudaheranwa. *Investigations in Lake Kivu (East Central Africa) after the Nyiragongo eruption of January 2002,* 2002.

[11] R.E.Hecky, H.A. Bootsma, M.L. Kingdom. *Impact of land use on sediment and nutrient yields to Lake Malawi/Nyasa*, 2003.

[12] H.E.Hecky, *The eutrophication of Lake Victoria*, 1993.

[13] G.W.Kling, S.MacIntyre, J.S. Steenfelt, F.Hirslund, *Lake Kivu gas extraction —Report on Lake Stability*, 2006.

[14] E.Paschal, A. Sherwood. *Relation of Sediment and nutrient loads to watershed characteristics and Land use in the Otisco Lake Basin, Onondaga Country, New York*, 1987.

[15] B.Joachim. *Modelling non-point source pollution in Lake Victoria*, 2007.

[16] A.J.Dobson. *An Introduction to Generalized* Environmental Engineering *Linear Models*, 1990.

[17] T.Schueler. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*, 1987.

[18] United States Environment Protection Agency (USEPA). *Notes on the Agriculture Environment*, 1996.
http://www.epa.gov/OWOW/info/NewsNotes/issue44/nps44agr.html

[19] USEPA. *Guidance Specifying Management Measures for Sources of Non-Point Pollution in Coastal Waters*, 1993.
http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/index.html

[20] USEPA. *Notes on the Agriculture Environment*, 1995.
http://www.epa.gov/OWOW/info/NewsNotes/issue40/nps40agr.html

[21] R. Cestti, J. Srivastava, S.Jung. *Agriculture Non-Point source pollution control good management practices*.2003.

[22] Government of Rwanda (GoR).*Rwanda Vision 2020*, 2000.

[23] GoR.*Poverty Reduction Strategy 2002 – 2006,* 2002.

[24] GoR. *Development and Poverty Reduction Strategy (EDPRS) 2008-2012*, 2007.

[25] GoR. *Shaping Our development*, 2012.

[26] USEPA. *Water Quality trading policy*, 2003

[27] Sindayiheba. *Master plan for Fisheries and farming in Rwanda submitted to the Ministry of Agriculture and animal Resources*, 2012.

[28] Natural resources Conservation Service. *Environmental Engineering*, 2002

[29] P.M.N. Mwita, R.O. Odhiambo, V.G.Masanja, C.Muyanja. *Prediction of the Likelihood of Households Food Security in the Lake Victoria Region of Kenya*