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The Logistic Multiple Regression Flow Model- A Tool for Aquatic Macrophyte Prediction and Management in Kolo Creek, Niger Delta

A. E. Gobo, Etiga, G.E and Abam, T.K.S

Institute of Geosciences and Space Technology, (IGST), Rivers State University of Science and Technology P.M.B. 5080, Port Harcourt, Nigeria

Abstract- Flow reduction has been identified as the major predisposing factor that promotes the exuberation of most aquatic macrophytes in open channels. This study , therefore examines various flow variables such as Velocity (v), Cross Sectional Area (CSA), Discharge (Q) as well as Depth (D) from which a data base is generated. The least square multiple regression approach was adopted (to design a logistic flow model) to predict the spread of water hyacinth in Kolo creek in the Niger Delta. The flow variables obtained are used against percentage macrophyte area covered. Results from the model gives R^2 values of 0.62 and 0.9887 for dry and wet seasons respectively. All the flow variable studied negatively correlated with the area covered by macrophyte for both seasons. Velocity (-0.6844), CSA (-0.6974, discharge (-0.6986) and depth (-0.7566) during dry season and velocity (-0.990), CSA (-0.978) and discharge (-0.980) and Depth (-0.9902). This indicates and inverse relationship between the flow variables and the macrophyte area covered for both seasons.

Index Terms- Flow model, Water hyacinth, Aquatic ecosystem, Macrophyte , Kolo Creek.

I. Introduction

The survival of the river ecosystem is largely dependent on its flow dynamics. This stems from the fact that the migration, growth and distribution of aquatic magroplytes such as water hyacinth Eichhornia crassipes and other Aquatic exotic species is principally dictated by flow (Haslam, 1989).

Robertson *et al*., (2001) however opined that the survival of ecological communities relies on the maintenance of ecological processes, species life cycles and their interactions. Alteration to natural flow regimes of rivers and streams may distrupt these processes.

Walker (1985) also confirm that the alteration to natural flow regimes of rivers and streams is recognized as a major factor contributing to loss of biological diversity and ecological functions in aquatic ecosystem.

Alteration to natural flow regimes of rivers and streams and their flood plains and wetlands could cause a large number of other species populations and other ecological communities that rely on river flow for their short term and long term survival to become threatened (Kingsford , 1999; Leslie, 2001).

Goodrick and Wilson (1974) added that, although channelisation and the hydrological manipulations provided flood protection for the region, the ecological integrity of the river/floodplain ecosystem was degraded, and altering vegetative communities and associated founa.

The International River network in their argument against large dams, also posited that; down stream from dams, disruption of natural flow, sediment and energy dynamics destroys the integrity of many ecosystems.

In the same vein, Obot, (2002) opined that hydropower is not a "clean energy". By altering the chemical and thermal regimes, reservoirs effectively pollute rivers and destroy downstream ecosystems.

From the foregoing, it becomes clearly evident that the flow reduction in the lower River Niger due to the Kainji dam (Commissioned in 1968) must have influenced the luxuriant macrophyte vegetation in Kolo creek and other streams in the Niger Delta (Etiga, 2008).

This study therefore, attempts to design a macrophyte spread prediction model using the flow variables such as velocity, discharge, cross sectional area and depth against macrophyte area covered as database and the logistic multiple regression approach.

This is with the view of ascertaining the level of prevalence of water hyacinth which has constituted great biophysical and socio-economic impasse in the region and to proffer plausible solutions as to curb the menace.

II. STUDY AREA

The Niger Delta in which the Kolo creek is located is the Africa's largest and World's third largest mangrove forest; the most expansive fresh water swamp in Western and Central Africa and Nigeria's major forest concentration of high biodiversity (Okaba, 2005).

The study area is the entire Kolo creek as well as one of its major tributary – the Esoghoni creek which are all located in the Ogbia local government area of Bayelsa State; Nigeria.

The Kolo creek is one of the creeks in the Niger Delta that discharges the waters of the River Niger.

The climate of the area is characterised by dry season of about four months (November - February) and wet season of eight months (March - October). The annual rainfall varies from 2500 – 3000mm in Port Harcourt to Warri axis. Mean temperature are as high as 24-32^{o}C with humidity of about 81% between January – March and about 92% in the month of July-August. (NDES, 1999).

The Kainji dam, from where secondary data were generated, is about the first large capacity hydropower dam across the River

Niger. (Iloje, 2003). It is presently located in Borgu local government area of Niger State, North-western Nigeria. It was commissioned in 1968 and since then, the hydrology of the River Niger (both upsteam and down stream) has undoubtedly been interfered with. It has a reservoir capacity of 15,600 x 10^6 cubic metres and a spill way design of about 7900m2/s (Abam, 1999).

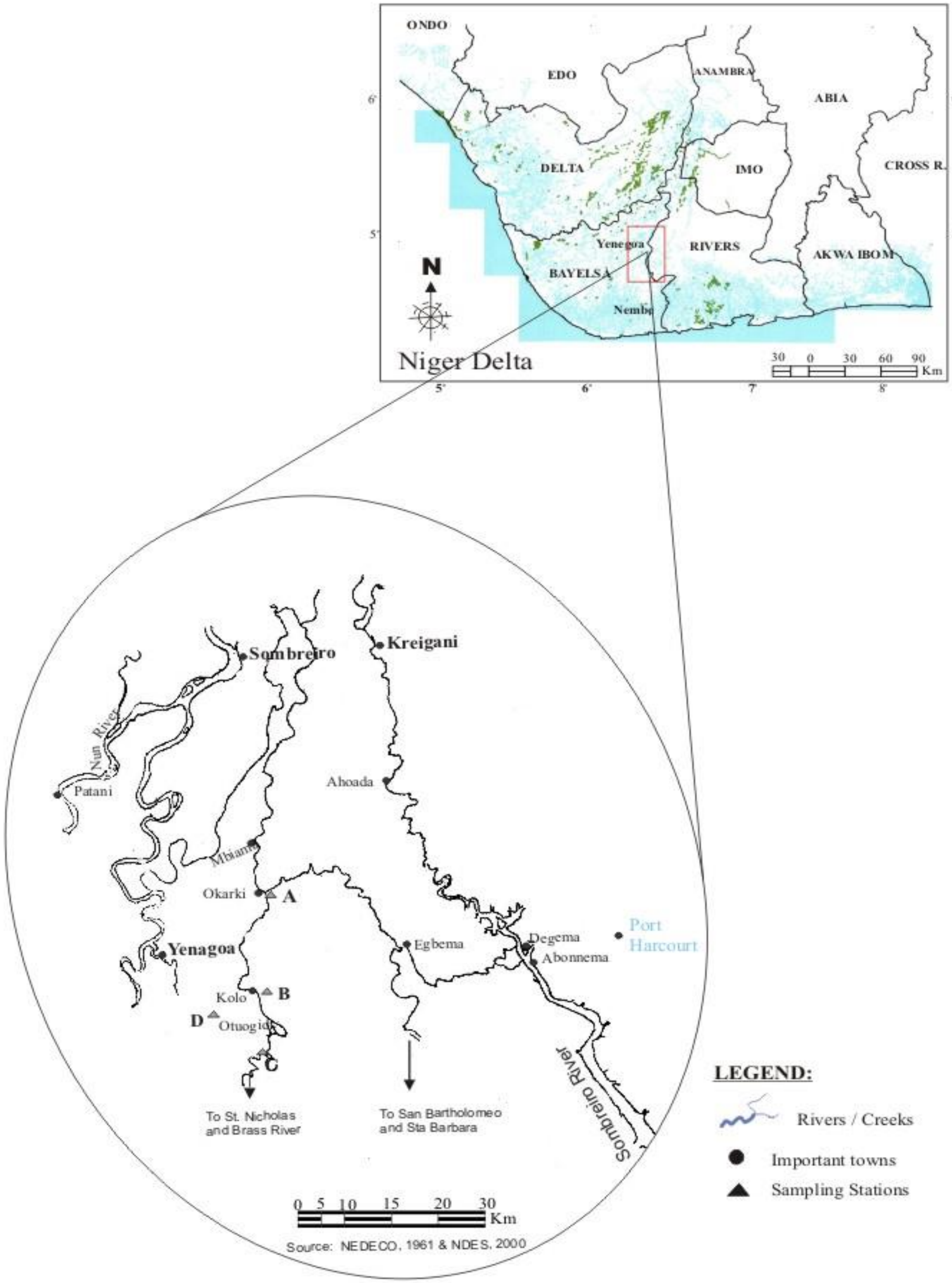

Fig. 1: Map of Nigr Delta showing sampling stations in Kolo Crek

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III. METHODOLOGY

Four sampling stations were established (at intervals of about 3 kilometres) along the River system. These include Okarki, Kolo, Otuogidi and the tributary of Esoghoni which are represented by A, B, C and D respectively fig (1). Each or these station were further divided into twelve (12) units out of which three (3) were randomly selected.

The float gauge technique was used to generate data for flow velocity (v) and discharge (Q) of the channels.

$V = \partial x/\partial t$ ……….. (1)
$Q = VA$ …………. (2)

Where A is the cross-sectional area of the channel given by

$A = I_a^b \partial x,\ ydx = fdx$ ……… (3)

The area of stream covered by macrophyte was obtained by dividing the surface areas into strips. The percentage macrophyte covered was determined by either the Simpson's rule given by

$A = S/3\ [(F+L) + 4E+2R]$ ………………. (4)

Or the Trapezoidal rule given by

$A = d/2\ [h_1 + hn + 2\ (h_2 + h_3 + h_4 + h_5 + hn)]$ …. (5)

Depending on whether the number of strips are odd or even numbered respectively.

IV. RESULTS AND DISCUSSION

For this study to be desirable and relevant it becomes very necessary to design a least square deterministic multiple regression flow model. This would account for the effect of all the flow variables considered; velocity (X1), Area of cross-section (X2) discharge (X3) and depth (X4) on the macroplyte area covered (y) for the dry and wet seasons respectively.

Table 1: Dry season flow data for all stations

Station	Y	X1	X2	X3	X4
Okarki	63.2	2.0	210.4	42.3	162.3
Kolo	70.8	2.03	21.4	43.6	154.2
Otuogidi	81	2.03	22.1	43.4	156.3
Esoghoni	86.3	1.46	6.9	10.3	93.6

Table 2: Wet season flow data in all stations

Station	Y	X1	X2	X3	X4
Okarki	28	19.08	102.6	1948	338.8
Kolo	28.3	1946	100.1	2033	346.0
Otuogidi	31.0	18.96	102.8	1956	330.8
Esoghni	43.5	17.78	37.9	674.2	168.3

The proposed model is given by

$Y = a_0 + a_1x_1 + a_2\,x_2 + a_3\,x_3 + a_4x_4 + E$……………………

Where

A_0, a_1, a_2, a_3, a_4, are constant; E is the random error component, Y is the dependent variable, while x1, x_2, x_3, and x_4 are the independent variables.

DRY SEASON REGRESSION MODEL

Table 3: Dry season flow variables on macrophyte cover.

Variables	**Mean**	**r**	**Coeff.**	**R^2**	**Y**
V	**1.89**	**-0.756**	**5.496**		
CSA	**17.75**	**-0.987**	**-0.410**	**0.62**	**318.35**
Q	**35**	**-0.989**	**5.580**		
D	**141.6**	**-0.988**	**-3.150**		

From the results in Table (3), the dry season least square model is given by:

$Y = 318.35 + 5.5x1 – 0.4103x2 + 5.58x3 – 3.15x4$ with a R^2 value of 0.62.

WET SEASON REGRESSION MODEL

Table 4: Wet season flow variables on macrophyte cover

Variables	Mean	r	Coeff.	R^2	Y
V	18.75	-0.990	47.690		
CSA	85.68	-0.999	0.338	0.98	-701.51
Q	1653.3	-0.993	0.018		
D	294.64	-0.995	-0.715		

From the result as shown in Table 4, the least square regression model for wet season is given by:

Y = -709.51 + 47.7x1 + 0.3382x2 + 0.0187x3
-0.7157x4

To see how well the model predicts the macropyte area covered during the wet season period, we have R2 = 0.9887.

V. MODELLING SCENARIOS

Considering the annual flow variations of the rivers and creeks in the Niger Delta it becomes imperative to model some scenarios as to test the usefulness of the least square multiple regression models for both seasons.

Case 1:

In the dry season months of January – March of a particular year, the mean flow indices of the system are measured as: velocity(x1) = 1.49cm/S, CSA (x2) = 6.7m^2, Discharge (x3) = 10.3cm^3/s, and Depth (x4) = 93.6cm. Estimate the percentage area of the system that would be covered by water hyacinth within the period.

Solution

Y = 318.35 + 55x1 – 0.4103x2 + 5.58x3 – 3.15x4
= 318.35 + 5.5 (1.49) – 0.4103 (6.7) + 5.58 (10.3) – 315 (93.6)
= 318.35 + 8.95 – 2.749 + 57.47 – 294.84 = 86.42

This implies that about 86.43% of the system would be covered by water hyacinth during the dry season period.

Case 2:

During the wet season period of a particular year, the flow variables of the Kolo creek were measured as:

X_1 =17.78cm/s, X_2 =37.9m^2, X_3 = 674.2cm3/s and X_4 = 168.3cm.

Estimate the percentage area of the system that would be covered by water hyacinth.

Solution

Y = -709.58 + 47.78x1 + 0.3382x2 + 0.0187x3 – 0.7157x4
= 709.38 + 47.7 (17.78) + 0.3382 (37.9) + 0.0187 (674.2) – 0.7157 (168.3).
= -709.5 + 847.93 + 12.82 + 12.61 – 120.45 = 43.63

This implies that about 43.63% of the system would be covered by water hyacinth within the period.

VI. CONCLUSION AND RECOMMENDATIONS

The Logistic Multiple Regression Flow Model described in this study could be quite valuable in predicting the state of spread and distribution of water hyacinth or other fresh water aquatic macrophytus. Undermine the fact that other environmental factors such as turbidity. Chemical composition of water body eutrophication; light penetration (Harvey et at, 1978) as well as temperature of water body (Haslem, 1978) could also influence aquatic macrophyte growth. The inclusion of some or all of these varieties could further enhance the efficacy of the flow model. This is however dependent on the environmental characteristics of the system. It is also worthy of note that all other environmental variables (turbidity, chemical composition, light penetration and temperature) are dependent on the flow dynamics of the system (Haslam, 1978).

Thus, when the rate of spread of water hyacinth of a system is ascertained possibly through the logistic multiple regression flow model. The choice of the management or mitigation option for the weed becomes more feasible and plausible.

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AUTHORS

First Author – A. E. Gobo, Institute of Geosciences and Space Technology, (IGST), Rivers State University of Science and Technology P.M.B. 5080, Port Harcourt, Nigeria
Second Author – Etiga, G.E, Institute of Geosciences and Space Technology, (IGST), Rivers State University of Science and Technology P.M.B. 5080, Port Harcourt, Nigeria
Third Author – Abam, T.K.S,
Institute of Geosciences and Space Technology, (IGST), Rivers State University of Science and Technology P.M.B. 5080, Port Harcourt, Nigeria