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# Numerical simulation of biodiversity: comparison of changing initial conditions and fixed length of growing season

Atsu, J. U.[1]; Ekaka-a, E.N.[2]

[1]Department of Mathematics/Statistics, Cross River University of Technology, Calabar, Nigeria
[2]Department of Mathematics, Rivers State University, Nkpolu, Port – Harcourt, Nigeria

***Abstract*— *This study examined the effect of varying the initial value of industrialization for a fixed length of growing season on the prediction of biodiversity loss. We have found that when the initial value of industrialization is 0.1 under a shorter length of growing season, a relative low due of biodiversity loss can be maintained. The biodiversity loss value can be further lowered by maintaining the same length of growing season but with a reduced initial value of industrialization to 0.01 or 0.02. We would expect this alternative result to provide a further insight into our fight against biodiversity loss which has both human and sustainable development devastating effects.*

***Keywords*— *varying initial data, industrialization, numerical simulation, growing season, quantitative technique, forestry resources biomass.***

## I. INTRODUCTION

The vulnerability of the forest resource biomass to the ecological risk of biodiversity loss is one of the major concerns for experts working on the mitigation measures of forest conservation and sustainable development. In order to circumvent this ongoing environmental problem, we have proposed to study the effect of the synergistic variation of the initial data value of industrialization and a fixed length of the growing season that has previously predicted a high volume of biodiversity loss. Atsu and Ekaka-a (2017) in modeling the intervention with respect to biodiversity loss, considered changing length of growing season for a forestry resource biomass. Their result showed that a longer length of growing season dominantly predicts a biodiversity gain and vice versa. Hooper et al (2012) examined a global synthesis which reveals biodiversity loss over time as a major driver of the accompanying ecosystem change. In their study, global environmental changes over time were considered with no consideration given to initial data of species resources biomass. In the same context, Isbell et al (2015) showed that biodiversity increases the resistance of ecosystem productivity to climate extremes. This was however without recourse to the underlying factors that sustain biodiversity and even quantitatively.

Tilman et al (2014) undertook a study which showed that species diversity is a major determinant of ecosystem productivity, stability, invasibility and nutrient dynamics. This paper did not consider a quantitative technique that can be used to maintain species diversity. Aerts and Honnay (2011) did research on forest restoration, biodiversity and ecosystem function. Their result qualitatively showed that restoring multiple forest functions requires multiple species.

Naeem et al (1999) did a biological essay that suggests that biodiversity and ecosystem functioning are necessary drivers of natural life support processes. It is pertinent to point out that in all these papers, quantitative examination of the factors responsible for biodiversity richness and ecosystem functioning was left out. Reich et al (2012) showed qualitatively that the impacts of biodiversity loss escalate through time as redundancy fades but without a quantitative technique.

This research idea is therefore expected to quantitatively select the relatively best-fit initial value of industrialization that will indicate a decrease in biodiversity loss. We will use a computationally efficient numerical scheme called Ruge-Kutta ordinary differential equation of order 4-5 (ODE 45) to tackle this challenging environmental problem when the length of the growing season is five (5) months with a varying trend.

## II. MATHEMATICAL FORMULATIONS

The method that we have proposed to analyse our research problem has considered the following simplifying assumptions:

i. The growth of forestry resources biomass and human population is governed by a logistic type equation.
ii. The growth rate of population pressure is proportional to the density of human population.
iii. The depletion of the forestry resources is due to human population and population related activities.

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Based on these simplifying assumptions the governing equations of the model according to Ramdhani, Jaharuddin & Nugrahani (2015) are defined by

$$\frac{dB}{dt} = s\left(1-\frac{B}{L}\right)B - s.B - \beta_2 NB - s_1 IB - \beta_3 B^2 I \quad (1)$$

$$\frac{dN}{dt} = r\left(1-\frac{N}{K}\right)N - r_0 N + \beta_1 NB \quad (2)$$

$$\frac{dP}{dt} = \lambda N - \lambda_0 P - \theta I \quad (3)$$

$$\frac{dI}{dt} = \pi\theta P + \pi_1 s_1 IB - \theta_0 I \quad (4)$$

With the initial condition $B(0) \geq 0, N(0) \geq 0, P(0) \geq 0, I(0) \geq 0$ and $0 < \pi \leq 1, 0 < \pi_1 \leq 1$

In this context, $B$ isthe density of forestry resources biomass with its intrinsic growth rate coefficient s and carrying capacity L, N represents the density of the human population, P is the population pressure density while I is the density of industrialization $s_0$ represents the coefficient of the natural depletion rate of resources biomass, $r_o$ is the coefficient of natural depletion rate of human population, r is the intrinsic growth rate of population density, K represents the carrying capacity of the population density, $\beta_1$ is the growth rate of cumulative density of human population effect of resources, $\beta_2$ is the depletion rate coefficient of the resource biomass density due to population. We recognize λ as the growth rate coefficient of population pressure while $\lambda_0$ is its natural depletion rate coefficient, θ is its depletion rate coefficient due to industrialization, $s_1$ is the coefficient of depletion rate of the biomass density as a result of industrialization, the combined effect of $\pi_1 s_1$ is the growth rate of industrialization due to forestry resources, $\pi$ is the growth rate of industrialization effect of population pressure, $\theta_0$ is the coefficient of control rate of industrialization which is an applied mitigation measure by government, while $\beta_3$ is the depletion rate coefficient of forestry resources biomass due to crowding by industrialization.

**Analysis**

Since these system of equations does not have a closed form solution, we have proposed to use an efficient numerical simulation scheme called ODE 45 numerical scheme. The parameters used in the analysis are as follows $L = 40, k = 50, \pi = 0.001, \theta = 8, \lambda = 5, \beta_1 = 0.01, \beta_2 = 7, s_0 = 1, s_1 = 4, \pi_1 = 0.005, \lambda_0 = 4, s = 34, \theta_0 = 1, r = 11, r_0 = 10$and$\beta_3 = 2$

## III. RESULTS AND DISCUSSION

*Table.1: Quantifying the impact of changing initial industrial condition data on the biodiversity when the length of the growing season is 5 months.*

| Example | LGS(months) | I(O) | $FRB_{old}$(kg) | $FRB_{new}$(kg) | Estimated effect (%) |
|---|---|---|---|---|---|
| 1 | 5 | 0.1 | 38.8263 | 36.9474 | 4.84 |
| 2 | 5 | 0.2 | 38.8263 | 35.9823 | 7.34 |
| 3 | 5 | 0.3 | 38.8263 | 35.3065 | 9.07 |
| 4 | 5 | 0.4 | 38.8263 | 34.7867 | 10.41 |
| 5 | 5 | 0.5 | 38.8263 | 34.3616 | 11.51 |
| 6 | 5 | 0.6 | 38.8263 | 33.9965 | 12.44 |
| 7 | 5 | 0.7 | 38.8263 | 33.6797 | 13.26 |
| 8 | 5 | 0.8 | 38.8263 | 33.3942 | 13.99 |
| 9 | 5 | 0.9 | 38.8263 | 33.1372 | 14.65 |
| 10 | 5 | 0.95 | 38.8263 | 33.0202 | 14.95 |
| 11 | 5 | 1.10 | 38.8261 | 32.6851 | 15.82 |
| 12 | 5 | 1.20 | 38.8311 | 32.4863 | 16.34 |
| 13 | 5 | 1.30 | 38.8305 | 32.2957 | 16.83 |
| 14 | 5 | 1.80 | 38.8306 | 31.4797 | 18.93 |
| 15 | 5 | 2.40 | 38.8258 | 30.6902 | 20.95 |
| 16 | 5 | 3.40 | 38.8316 | 29.6636 | 23.61 |
| 17 | 5 | 4.40 | 38.8263 | 28.8117 | 25.79 |
| 18 | 5 | 5.40 | 38.8262 | 28.0727 | 27.65 |
| 19 | 5 | 8.40 | 38.8258 | 26.3744 | 32.07 |
| 20 | 5 | 18.40 | 38.8267 | 22.8112 | 41.25 |

What do we empirically deduce from Table 1?

We can deduce that when the initial condition value of industrialization I(0) is 0.1 biodiversity loss is 4.84 percent. When the initial condition value of industrialization is increased monotonically from 0.1 to 1.10, this predicts a corresponding increase in biodiversity loss value monotonically from 4.84 percent to 15.82 percent. Furthermore, an increase in the initial condition value of industrialization to a value of 18.40 dominantly predicts a high percentage of biodiversity loss (41.25%). The following mitigation measure against biodiversity loss is suggestive.

**Mitigation measures**

*Table.2: Quantifying the impact on biodiversity loss of decreasing the initial condition value of industrialization I(0) and its implication for biodiversity control.*

| Example | LGS(months) | I(O) | $FRB_{old}$(kg) | $FRB_{new}$(kg) | Estimated effect (%) |
|---|---|---|---|---|---|
| 1 | 5 | 0.01 | 38.8190 | 38.4158 | 1.04 |
| 2 | 5 | 0.02 | 38.8196 | 38.1999 | 1.60 |
| 3 | 5 | 0.03 | 38.8043 | 38.0053 | 2.06 |
| 4 | 5 | 0.04 | 38.7840 | 37.8206 | 2.48 |
| 5 | 5 | 0.05 | 38.8357 | 37.6515 | 3.05 |
| 6 | 5 | 0.08 | 38.8317 | 37.2056 | 4.19 |

What do we learn from Table 2?

A relatively decreased initial condition value of industrialization has predicted a relatively weak biodiversity loss. This can be sustained by maintaining a relatively low initial condition value of industrialization which would inturn dominantly predict a high biodiversity gain. This mitigation strategy would ensure high levels of biodiversity gain.

## IV. CONCLUSION

We have used the technique of a numerical simulation to quantify the impact on biodiversity of maintaining a sustainable level of industrialization. This level of industrialization if properly managed can lead to a high biodiversity gain scenario.

## V. RECOMMENDATIONS

i. For sustainable development to occur, proper levels of industrialization should be maintained relative to biodiversity requirements.

ii. Proper monitoring of industrialization pressures should be conducted in order to maintain a proper functioning of the ecosystem which results into improved ecosystem services.

iii. Data on industrialization, biodiversity and ecosystem services must be updated continually to keep tract of ecosystem functioning.

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