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# Modeling Intervention with Respect to Biodiversity Loss: A Case Study of Forest Resource Biomass Undergoing Changing Length of Growing Season

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***Abstract—*** *This paper examines the extent of a system interventions against the loss of biodiversity due to an increase in the length of the growing season. By using a computationally efficient numerical scheme, we have observed that a shorter length of the growing season dominantly predicts a biodiversity loss whereas a relatively increased length of the growing season has predicted a biodiversity gain which has sufficient implication for the availability of adequate ecological-forestry services which are capable to provide a useful insight for the management of the forestry conservation and sustainable development. The novel contributions of this pioneering research has not been seen elsewhere; it is fully presented and discussed in this paper.*
***Keywords— Forest resource biomass, intervention strategies, environmental perturbation, biodiversity, growing season, numerical simulation.***

## I. INTRODUCTION

It is a vital crop science ideology that the length of the growing season plays a significant role in the harvest of interacting legumes for a limited resource within an agricultural setting. In the same manner, the length of the growing season is equally an important model parameter in the distribution of the forest resource biomass over a specified duration of growth which we have considered to be in the unit of months and for our numerical simulation propose the length of the growing season to be twenty-five (25) months.

In our intervention strategy against biodiversity loss, we have measured the extent to which environment provides protection to prey species by proposing a longer length of growing season which allows premature tress to mature. This present paper is modeled after the Leslie-Gower functional response Chaudhary et al (2015), Gupta & Chandra (2013) Yue (2015). Optional control policy as applied to fishery management (Clark 2010), Kar and Ghorai (2011), Ghosh and Kar (2014).

From the theory of forest development and forest conservation, a relatively low environmental perturbation and a severe environmental perturbation have the potential to lead to early harvest for the forest resources biomass. There two (2) concepts were taken into consideration in our bid to provide a short term intervention strategy against the loss of biodiversity.

### Mathematical Formulations

In this paper, we have adopted the model in respect of the depletion of forestry resources due to human population and human population activities developed by Ramdhani et al 2015. This mathematical model on the depletion of forestry resources has the structure of a system of continuous nonlinear first order ordinary differential equations.

The model assumptions are specified follows:

(i) The growth of forest resources biomass and human population are governed by the logistic type equation.
(ii) The growth rate of population pressure is proportional to the density of human population
(iii) The depletion of forestry resources is due the human population and industrialization.

### Description of Model Parameters

B is the density of forestry resources biomass
s is the intrinsic growth rate coefficientof the forestry resource biomass
L is the carrying capacity of the forestry resource biomass
N is the density of human population,
P is the density of population pressure and

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I is the density of industrialization.
$s_0$ isthe coefficient of the natural depletion rate of resources biomass,
$r_0$ is the coefficient of the natural depletion rate of population,
r is the intrinsic growth rate of population density,
K is the carrying capacity of population density,
$\beta_1$ is the growth rate of cumulative density of human population effect of resources,
$\beta_2$ is the corresponding depletion rate coefficient of the resource biomass density due to population.
$\lambda$ is the growth rate coefficient of population pressure,
$\lambda_0$ is the natural depletion rate coefficient of population pressure,
θ is the depletion rate coefficient due to industrialization,
$s_1$ is the coefficient of the depletion rate of the biomass density caused by industrialization,
The coefficient $\pi_1 s_1$ is the growth rate of industrialization due to forestry resource, $\pi$ is the growth rate of industrialization effect of population pressure,
$\theta_0$ is the coefficient of control rate of industrialization (government control) and
$\beta_3$ is the depletion rate coefficient of forestry resources biomass due to crowding by industrialization.
Following the above, the governing equations of the model are:

$$\frac{dB}{dt} = s\left(1-\frac{B}{L}\right)B - s_0B - \beta_2NB - s_1IB - \beta_3B^2I \quad (1)$$

$$\frac{dN}{dt} = r\left(1-\frac{N}{K}\right)N - r_0N + \beta_1NB \quad - \quad (2)$$

$$\frac{dP}{dt} = \lambda N - \lambda_0P - \theta I \quad - \quad (3)$$

$$\frac{dI}{dt} = \pi\theta P + \pi_1s_1IB - \theta_0I \quad - \quad (4)$$

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

## II. METHOD OF ANALYSIS

Since the proposed model formulations do not have a close-form solution, we have proposed to analyze our model formulation using a computationally efficient ODE 45 numerical scheme. The result we have obtained will be presented and discussed in the next section of this paper.

## III. RESULTS AND DISCUSSION

Our five (5) phases of results are presented as follows:

**Scenario one results**

Here we present the impact of varying the length of the growing season by ten percent (10%).

*Table.1: Predicting biodiversity loss when the length of the growing season is 2.5 months using ODE 45 numerical scheme indexed by the initial data (1, 1, 2, 1)*

| Example | LGS(months) | B(LGS) | $B_m$ (LGS) | BL (%) |
|---|---|---|---|---|
| 1 | 0.1 | 1 | 1 | 0 (no effect) |
| 2 | 0.2 | 17.1929 | 5.4386 | 68.3671 |
| 3 | 0.3 | 23.3727 | 10.2585 | 56.1091 |
| 4 | 0.4 | 27.8615 | 11.8724 | 57.3879 |
| 5 | 0.5 | 30.9432 | 12.7940 | 58.6531 |
| 6 | 0.6 | 33.0698 | 13.5859 | 58.9175 |
| 7 | 0.7 | 34.5667 | 14.3361 | 58.5262 |
| 8 | 0.8 | 35.6383 | 15.0674 | 57.7214 |
| 9 | 0.9 | 36.4142 | 15.7868 | 56.6468 |
| 10 | 1.0 | 36.9812 | 16.4950 | 55.3962 |
| 11 | 1.1 | 37.4022 | 17.1929 | 54.0326 |
| 12 | 1.2 | 37.7195 | 17.8826 | 52.5905 |
| 13 | 1.3 | 37.9618 | 18.5567 | 51.1176 |
| 14 | 1.4 | 38.1486 | 19.2139 | 49.6343 |

| | | | | |
|---|---|---|---|---|
| 15 | 1.5 | 38.2937 | 19.8565 | 48.1470 |
| 16 | 1.6 | 38.4072 | 20.4852 | 46.6632 |
| 17 | 1.7 | 38.4968 | 21.0983 | 45.1945 |
| 18 | 1.8 | 38.5680 | 21.6936 | 43.7522 |
| 19 | 1.9 | 38.6251 | 22.2707 | 42.3414 |
| 20 | 2.0 | 38.6713 | 22.8302 | 40.9635 |
| 21 | 2.1 | 38.7092 | 23.3727 | 39.6198 |
| 22 | 2.2 | 38.7398 | 23.8978 | 38.3121 |
| 23 | 2.3 | 38.7632 | 24.4049 | 37.0410 |
| 24 | 2.4 | 38.7800 | 24.8943 | 35.8064 |
| 25 | 2.5 | 38.7867 | 25.3626 | 34.6100 |

***LGS = length of growing season**

What can we learn and deduce form Table 1 results?
From this empirical numerically simulated results we have observed that a shorter duration of the length of the growing season in the magnitude of 2.5 months dominantly predicts biodiversity loss for which 3 days length of growing season is more vulnerable to biodiversity loss value of 68.4 percent (approx.) compared with a 34.6 percent loss of biodiversity when the length of the growing season is 72 days. Therefore, the vulnerability of the forest resource biomass to biodiversity loss tends to decrease from 3 days to 72 days.

**Scenario two results**

*Table.2: Predicting biodiversity loss when the length of the growing season is 9.6 months using ODE 45 numerical scheme indexed by the initial data (1,1,2,1)*

| **Example** | **LGS(month)** | **B(LGS)** | **$B_m$ (LGS)** | **BL (%)** |
|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 (no effect) |
| 2 | 0.40 | 17.1929 | 12.7940 | 25.5852 |
| 3 | 0.8 | 23.3727 | 15.7868 | 32.4565 |
| 4 | 1.2 | 27.8615 | 18.5567 | 33.3968 |
| 5 | 1.6 | 30.9432 | 21.0983 | 31.8158 |
| 6 | 2.0 | 33.0678 | 23.3727 | 29.3232 |
| 7 | 2.4 | 34.5667 | 25.3665 | 26.6157 |
| 8 | 2.8 | 35.6383 | 27.0915 | 23.9821 |
| 9 | 3.2 | 36.4142 | 28.5747 | 21.5288 |
| 10 | 3.6 | 36.9812 | 29.8484 | 19.2878 |
| 11 | 4.0 | 37.4022 | 30.9432 | 17.2692 |
| 12 | 4.4 | 37.7195 | 31.8867 | 15.4636 |
| 13 | 4.8 | 38.9618 | 32.7030 | 13.8528 |
| 14 | 5.26 | 38.1486 | 33.4116 | 12.4174 |
| 15 | 5.6 | 38.2937 | 34.0284 | 11.1385 |
| 16 | 6.0 | 38.4072 | 34.5667 | 9.9996 |
| 17 | 6.4 | 38.4968 | 35.0375 | 8.9857 |
| 18 | 6.8 | 38.5680 | 35.4510 | 8.0818 |
| 19 | 7.2 | 38.6251 | 35.8145 | 7.2765 |
| 20 | 7.6 | 38.6713 | 36.1336 | 6.5623 |
| 21 | 8.0 | 38.7092 | 36.4142 | 5.9288 |
| 22 | 8.4 | 38.7398 | 36.6621 | 5.5633 |

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|---|---|---|---|---|
| 23 | 8.8 | 38.7632 | 36.8812 | 4.8550 |
| 24 | 9.2 | 38.7800 | 37.0756 | 4.3951 |
| 25 | 9.6 | 38.7867 | 37.2464 | 3.9714 |

What can we learn and deduce form Table 2 results?
Without loss of generality, for this every twelve (12) day prediction on the loss of biodiversity, we have observed that a relatively bigger volume of biodiversity loss has occurred when the length of the growing season is approximately 33 days whereas a lower volume of biodiversity loss has occurred when the length of the growing season is two hundred and eighty-eight (288) days. It is interesting to observe that the average of the vulnerability to biodiversity loss is estimated to be 15.1821. On the basis of a statistical analysis we have observed that the extent of biodiversity loss that is below this average ranges from the value of 3.9714 to 13.8528. On the other hand, the extent of biodiversity loss that is above the average ranges from the value of 15.4636 to 33.3968.

**Scenario three results**

*Table.3: Predicting biodiversity loss when the length of the growing season is 19.2 months using ODE 45 numerical scheme indexed by the initial data (1,1,2,1)*

| **Example** | **LGS(month)** | **B(LGS)** | **$B_m$ (LGS)** | **BL (%)** |
|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 (no effect) |
| 2 | 0.8 | 17.1929 | 15.7868 | 8.1784 |
| 3 | 1.6 | 23.3727 | 21.0983 | 9.7308 |
| 4 | 2.4 | 27.8615 | 25.3665 | 8.9549 |
| 5 | 3.2 | 30.9432 | 28.5747 | 7.6543 |
| 6 | 4.0 | 33.0698 | 30.9432 | 6.4309 |
| 7 | 4.8 | 34.5667 | 32.7030 | 5.3915 |
| 8 | 5.6 | 35.6383 | 34.0284 | 4.5274 |
| 9 | 6.4 | 36.4142 | 35.0375 | 3.7806 |
| 10 | 7.2 | 36.9812 | 35.8145 | 3.1548 |
| 11 | 8.0 | 37.4022 | 36.4142 | 2.6416 |
| 12 | 8.8 | 37.7195 | 36.8812 | 2.2225 |
| 13 | 9.6 | 37.9618 | 37.2484 | 1.8792 |
| 14 | 10.4 | 38.1486 | 37.5398 | 1.5959 |
| 15 | 11.2 | 38.2937 | 37.7736 | 1.3582 |
| 16 | 12.0 | 38.4072 | 37.9618 | 1.1598 |
| 17 | 12.8 | 38.4968 | 38.1148 | 0.9921 |
| 18 | 13.6 | 38.5680 | 38.2397 | 0.8513 |
| 19 | 14.4 | 38.6251 | 38.3421 | 0.7327 |
| 20 | 15.2 | 38.6713 | 38.4267 | 0.6325 |
| 21 | 16.0 | 38.7092 | 38.4968 | 0.5489 |
| 22 | 16.8 | 38.7398 | 38.5553 | 0.4763 |
| 23 | 17.6 | 38.7632 | 38.6041 | 0.4103 |
| 24 | 18.4 | 38.7800 | 38.6453 | 0.3473 |
| 25 | 19.2 | 38.7867 | 38.6864 | 0.2588 |

From table 3, we observe that for this every twenty-four (24) day prediction of biodiversity loss, there is a 9 relatively bigger volume of biodiversity loss in the next 96 days which decreases after the first 48 days monotonically from 8.9549 to 0.2588 in last days of the growing season. The average vulnerability is 2.96 (approx.). On the basis of this analysis, the below average ranges from the value of 0.2588 to 2.6416.On the other hand the higher vulnerability ranges from the value of 3.1548 to 9.7308.

**Scenario four results**

*Table.4: Predicting biodiversity loss when the length of the growing season is 22.8 months using ODE 45 numerical scheme indexed by the initial data (1,1,2,1)*

| Example | LGS(months) | B(LGS) | $B_m$ (LGS) | BL (%) |
|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 (no effect) |
| 2 | 0.95 | 17.1929 | 16.8390 | 2.0582 |
| 3 | 1.90 | 23.3727 | 22.8302 | 2.3211 |
| 4 | 2.85 | 27.8615 | 27.2794 | 2.0891 |
| 5 | 3.80 | 30.9432 | 30.4159 | 1.7038 |
| 6 | 4.75 | 33.0698 | 32.6285 | 1.3345 |
| 7 | 5.70 | 34.5667 | 34.1697 | 1.1484 |
| 8 | 6.65 | 35.6383 | 35.2872 | 0.9854 |
| 9 | 7.60 | 36.4142 | 36.1336 | 0.7706 |
| 10 | 8.55 | 36.9812 | 36.7246 | 0.6938 |
| 11 | 9.50 | 37.4022 | 37.2069 | 0.5222 |
| 12 | 10.45 | 37.7195 | 37.5546 | 0.4371 |
| 13 | 11.40 | 37.9818 | 37.8245 | 0.3616 |
| 14 | 12.35 | 38.1486 | 38.0512 | 0.2554 |
| 15 | 13.30 | 38.2937 | 38.1956 | 0.2564 |
| 16 | 14.25 | 38.4072 | 38.3517 | 0.1446 |
| 17 | 15.20 | 38.4968 | 38.4267 | 0.1819 |
| 18 | 16.15 | 38.5680 | 38.5287 | 0.1018 |
| 19 | 17.10 | 38.6261 | 38.5748 | 0.1302 |
| 20 | 18.05 | 38.6713 | 38.6338 | 0.0970 |
| 21 | 19.0 | 38.7092 | 38.6713 | 0.0979 |
| 22 | 19.95 | 38.7398 | 38.6965 | 0.1117 |
| 23 | 20.90 | 38.7632 | 38.7367 | 0.0682 |
| 24 | 21.85 | 38.7800 | 38.7364 | 0.1123 |
| 25 | 22.8 | 38.7867 | 38.7753 | 0.0294 |

From table 4, we observe that the average vulnerability is 0.6405 which is much lower than the previous scenarios. The below average vulnerability value ranges from 0.0294 to 0.5222 whereas the above average vulnerability ranges from 0.6938 to 2.3211. Efforts at the mitigation of biodiversity loss should be concentration in reducing above average vulnerability.

**Scenario five results**

*Table.5: Predicting biodiversity loss when the length of the growing season is 132 months using ODE 45 numerical scheme indexed by the initial data (1,1,2,1)*

| Example | LGS(months) | B(LGS) | $B_m$ (LGS) | BL (%) |
|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 (no effect) |
| 2 | 5.5 | 17.1929 | 33.8820 | 97.0701 |
| 3 | 11.0 | 23.3727 | 37.7195 | 61.3828 |
| 4 | 16.5 | 27.8615 | 38.5344 | 38.3069 |
| 5 | 22.0 | 30.9432 | 38.7632 | 25.2722 |
| 6 | 27.5 | 33.0698 | 38.8068 | 17.3481 |
| 7 | 33.0 | 34.5667 | 38.8038 | 12.2578 |
| 8 | 39.5 | 35.6383 | 38.8213 | 8.9312 |

| | | | | |
|---|---|---|---|---|
| 9 | 44.0 | 36.4142 | 38.8387 | 6.6581 |
| 10 | 49.5 | 36.9812 | 38.8121 | 4.9508 |
| 11 | 55.0 | 37.4022 | 38.8083 | 3.7592 |
| 12 | 60.5 | 37.7195 | 38.8362 | 2.9605 |
| 13 | 66.0 | 37.9618 | 38.8167 | 2.2519 |
| 14 | 71.5 | 38.1486 | 38.8168 | 1.7514 |
| 15 | 77.0 | 38.2937 | 38.8293 | 1.9985 |
| 16 | 82.5 | 38.4072 | 38.8183 | 1.0704 |
| 17 | 88.0 | 38.4968 | 38.8322 | 0.8714 |
| 18 | 93.5 | 38.5680 | 38.8196 | 0.6526 |
| 19 | 99.0 | 38.6251 | 38.8396 | 0.5553 |
| 20 | 104.5 | 38.6713 | 38.8166 | 0.3757 |
| 21 | 110.0 | 38.7092 | 38.8266 | 0.3032 |
| 22 | 115.5 | 38.7398 | 38.8421 | 0.2640 |
| 23 | 121.0 | 38.7632 | 38.7923 | 0.0751 |
| 24 | 126.5 | 38.7800 | 38.8326 | 0.1357 |
| 25 | 132.0 | 38.7867 | 38.8260 | 0.1013 |

What can we deduce from table 5?

It is clear that an increase in the length of the growing season for every 165 days indicates the extinction of biodiversity loss. This bifurcation behavior of biodiversity has predicted a relatively lower volume of biodiversity gain in which its average value is 11.55 (approximately). In this scenario the below average implication of a biodiversity gain ranges from the value of 0.1013 to 8.9312 whereas its above average value ranges from 12.2578 for one hundred and ninety (190) days to 97.0701 for one hundred and sixty-five (165) days.

On the whole, we observe that biodiversity loss is highest at the $5^{th}$ month with a value of 97.07% which decreases to 61.38% at the $11^{th}$ month and decreases monotonically to 0.1013% at the $132^{nd}$ month. A biodiversity loss of 0.1013% dominantly predicts a biodiversity gain of over 99%, it is therefore clear that while biodiversity loss cannot be completely eradicated, maintaining a longer length of growing season is a powerful mitigation factor against biodiversity loss and a sustainable development strategy.

## IV. CONCLUSION

It is interesting to note that while biodiversity is being lost at an alarming rate and the intensity of environmental pressures behind the decline show no sign of abating, with many limitations of biodiversity indicators shared, models relate the response of biodiversity components to mechanisms of climate change. These mechanisms of change are often data deficient and assign qualitative classifications to intensities of change. We have by utilizing the ODE 45 numerical simulation scheme provided an insight into data associated with biodiversity loss due to climate change effects.

With data on biodiversity and environmental change made available we have measured the response to biodiversity.

## RECOMMENDATIONS

(i) The length of the growing season should be good and appropriate enough to avoid harvesting pre-mature species.

(ii) There should be deliberate efforts to measure relationship between biodiversity and intensity of mechanisms for environmental change.

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