

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 coefficient of 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

I is the density of industrialization.
 s_0 is the 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,
 β_1 is the growth rate of cumulative density of human population effect of resources,
 β_2 is the corresponding depletion rate coefficient of the resource biomass density due to population.
 λ is the growth rate coefficient of population pressure,
 λ_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, π is the growth rate of industrialization effect of population pressure,
 θ_0 is the coefficient of control rate of industrialization (government control) and
 β_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:

$$\frac{dB}{dt} = s \left(1 - \frac{B}{L}\right) B - s_0 B - \beta_2 NB - s_1 IB - \beta_3 B^2 I \quad (1)$$

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

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

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

with the initial 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 from 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

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 5th month with a value of 97.07% which decreases to 61.38% at the 11th month and decreases monotonically to 0.1013% at the 132nd 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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