Simulation for Mathematical Modelling of the Effects of a Random Disturbance on Biodiversity of Forestry Biomass

Bazuaye Frank Etin-Osa[*], **Musa Alex, Ezeora Jeremiah**

Department of Mathematics and Statistics, University of Port Harcourt, Port Harcourt, Nigeria

Email address:

febazuaye@yahoo.com (Bazuaye Frank Etin-Osa)

[*]Corresponding author

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Abstract: Mathematical modelling and simulation of dynamical system have drawn attention in recent times. In addition, there has been so much interest in dynamical characteristics of population model. Forest biomass system happens to play an important role in population dynamics. The study of forests and forestry preservation has gained tremendous attention in government, among individuals and researchers. The ecological dynamical system is highly vulnerable to random perturbation which can be attributed to the other environmental and climatic factors and other characteristics of the ecosystem. However, there are two factors that may have a high potential to influence the performance of biodiversity gain or loss. Therefore, this study focusses on the effect of a random disturbance of five different degrees on the forestry biomass, the density of the wood-based industry and the density of the synthetic based industry. The ODE 45 solver have been used to tackle this problem. We have utilized the technique of a numerical simulation to predict that a higher random noise perturbation has the potential to predict higher degree of biodiversity gain than a lower random noise. The result indicates that not all random noise driven factors do predict biodiversity loss. These are presented and fully discussed. quantitatively.

Keywords: Biomass, Random Noise, Biodiversity, Density, Numerical Scheme

1. Introduction

In recent years, the depletion of forest, bio-diversity loss and changes in climate are closely linked to high rate of deforestation. This has made the environment not to be eco-friendly. One of the primary reasons for this deforestation is to harness timber products (wood) which serve diverse functions to human need. Wood is used for making furniture, houses, cooking, baskets, papers, etc. However, the negative impact of deforestation outweighs its benefits of preserving forestry resources for mankind. There is an urgent need to ensure the continuity and services rendered by forests to humanity, and to address this threatening problem of the universe, and reduce the excruciating effects of wood industry on forestry biomass, provision of synthetics would serve as suitable alternative to reduce the impact of wood industry on forest biomass. In addition, choosing a specific level of deforestation, increasing the density of forest resources through planting, and subjecting

the wood based industries under control either by the action of government agencies or human awareness, could help in conserving our forest biomass.

An ecological dynamical system is inherently highly vulnerable to random disturbance which can be attributed to the other environmental and climatic factors and other characteristics of the ecosystem However, there are two factors that may have a high potential to influence the performance of biodiversity gain. One of these factors could be a conducive steady environment and healthy government agricultural policies. These two factors have the potential of improving the performance of biodiversity gain. In other words, a random noise disturbance in terms of these mentioned factors may not necessarily bring about biodiversity loss but are capable to increase the magnitude of biodiversity gain.

Different researchers have used different approaches and analysis to the mathematical models for the interaction between forest biomass, wood densities and synthetic industries. Some have used the analytical methods and others

have used computational methods to predict the behavior of dynamics of the system. Agarwal *et al* [1] studied the depletion of forestry resources biomass due to industrialization pressure while Chaudhary and Dhar [2] investigated a mathematical model for forestry biomass with a maturation delay. But Rachana [3] proposed and analyzed a non-linear mathematical model. In a similar study, Jyotsna and Tandon [4] investigated a non-linear mathematical model to check the impact of mining activities and pollution on forest resources and wildlife populations. They applied numerical simulations and element of stability theory to analyze their model. Misra and Lata [5] proposed a mathematical model to analyze the depletion and conservation of forestry resources in the presence of industrialization. Also, Lata *etal* [6]. Considered the modelling the effects of wood and non-wood based industries of forestry resources. Their model showed that the increase in the carrying capacity of forest biomass due to technological efforts has destabilizing effect. They also support their analytical results with numerical simulations. In all these studies, non-have to the best of our knowledge investigated the impact of random disturbance on the forest biomass, density of the wood based industry and the density of the synthetic based industry. Hence, this work intends to investigate this using the ODE 45 solver in line with Nafo [7].

2. Materials and Methods

The deterministic dynamical system in which a dynamical system with five random noise perturbation scenarios of, no random noise, random noise of 1.5, 2.0, 2.5 and 3.0 random noise perturbation is considered.

The Mathematical model which have been used to examine the proposed problem is based on Bazuaye and Omorogbe [8] of a first order ordinary differential equations. This differential equation is given as

$$\frac{dB}{dt} = \phi B \left(1 - \frac{B}{q}\right) - d_1 BW,$$

$$\frac{dW}{dt} = \alpha_1 BW - c_1 WS - d_2 W, \qquad (1)$$

$$\frac{dS}{dt} = K - c_2 WS - d_3 S,$$

With non-negative initial population defined as:

$$B(0) = B_0 > 0, W(0) = W_0 > 0, S(0) = S_0 > 0 \qquad (2)$$

Where the parameters are defined as follows:
$B(t)$ is the population of the forest biomass at any time t;
$W(t)$ is the population of wood based industries at any time t;
$S(t)$ is the population of synthetic industries at any time t;
ϕ is the intrinsic growth rate at which forest population grows logistically without wood based industries;
q is the carrying capacity;
c_1 is the competitive effect of forest density on wood based industries;
c_2 is the competitive effect of wood based industries on forest biomass;
K is the amount of synthetic supplied to the synthetic industries;
d_1 is the rate of depletion of the forest biomass;
d_2 is the natural rate of depletion of the wood industries;
d_3 is the natural rate of depletion of the synthetic industries;
α_1 is the rate at which wood industries grows in the presence of forest biomass.

The model is divided into three sectors: The forest biomass density, density of wood based industries and density of synthetic industries.

2.1. The Random Disturbance of the Forest Biomass Density

$$\frac{dB}{dt} = \phi B \left(1 - \frac{B}{q}\right) - d_1 BW \qquad (3)$$

$$\Phi = 0.0417, q = 0.0278, d_1 = 0.0236, W = 0.0097 \qquad (4)$$
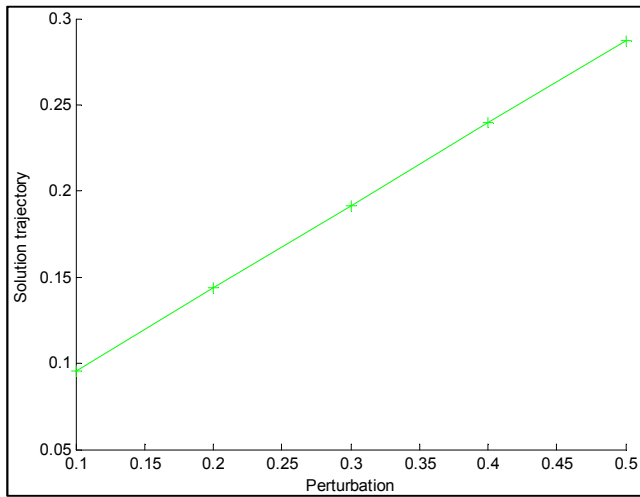
Simulating with the following parameters values

Table 1. *Quantifying the effect of a random disturbance having: no intensity, 1.5, 2.0, 2.5 and 3.0 intensity on the forest biomass density using ODE 45numerical solver.*

Number of iterations.	φ_{RAD} : Nill	φ_{RAD} : 1.5	φ_{RAD} : 2.0	φ_{RAD} : 2.5	φ_{RAD} : 3.0
1	0.1200	0.1800	0.2400	0.3000	0.3600
2	0.1184	0.1775	0.2367	0.2959	0.3551
3	0.1152	0.1752	0.2336	0.2919	0.3503
4	0.1152	01729	02305	0.2881	0.3457
5	0.1137	0.1706	0.2275	0.2844	0.3412
6	0.1123	0.1685	0.2246	0.2808	0.3369
7	0.1109	0.1663	0.2218	0.2772	0.3327
8	0.1095	0.1643	0.2191	0.2738	0.3286
9	0.1082	0.1623	0.2164	0.2705	0.3246
10	0.1069	0.1604	0.2138	0.2673	0.3207
11	0.1057	0.1585	0.2113	0.2642	0.3170
12	0.1044	0.1567	0.2089	0.2611	0.3133
13	0.1033	0.1549	0.2065	0.2581	0.3098
14	0.1021	0.1531	0.2042	0.2552	0.3063
15	0.1010	0.1515	0.2019	0.2524	0.3029
16	0.0999	0.1498	0.1998	0.2497	0.2996
17	0.0988	0.1482	0.1976	0.2470	0.2964
18	0.0978	0.1467	0.1955	0.2444	0.2933

Number of iterations.	φ_{RAD} : *Nill*	φ_{RAD} : **1.5**	φ_{RAD} : **2.0**	φ_{RAD} : **2.5**	φ_{RAD} : **3.0**
19	0.0968	0.1451	0.1935	0.2419	0.2903
20	0.0958	0.1436	0.1915	0.2394	0.2873

Table 1 above is represented in the figure below.

Figure 1. *A graph random disturbance having: no intensity, 1.5, 2.0, and 3.0 intensity on the forest biomass density using ODE 45numerical solver.*

2.2. The Random Disturbance of the Density of Wood Based Industries

Similarly, for the density of wood based industries, we have

$$\frac{dW}{dt} = \alpha_1 BW - c_1 WS - d_2 W, \qquad (5)$$

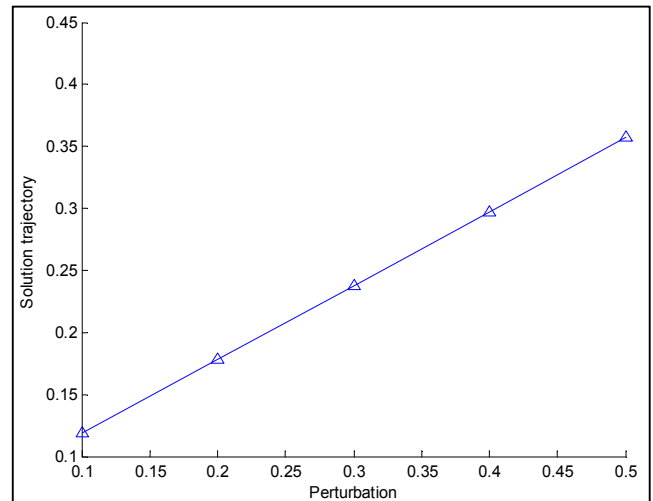Simulating with the following parameters values

$$\alpha_1 = 0.025, c_1 = 0.034, d_2 = 0.015, B = 0.56 \quad (6)$$

Table 2. *Quantifying the effect of a random disturbance having: no intensity, 1.5, 2.0, 2.5 and 3.0 intensity on the density of wood-based industries using ODE 45numerical solver.*

Number of iterations.	W_{RAD}:**Nill**	W_{RAD}:**1.5**	W_{RAD}:**2.0**	W_{RAD}:**2.5**	W_{RAD}:**3.0**
1	0.1200	0.1800	0.2400	0.3000	0.3600
2	0.1199	0.1799	0.2399	0.2999	0.3598
3	0.1199	0.1798	0.2398	0.2997	0.3597
4	0.1198	0.1798	0.2397	0.2996	0.3595
5	0.1198	0.1797	0.2396	0.2995	0.3594
6	0.1197	0.1796	0.2395	0.2993	0.3592
7	0.1197	0.1795	0.2394	0.2992	0.3591
8	0.1196	0.1794	0.2393	0.2991	0.3589
9	0.1196	0.1794	0.2392	0.2989	0.3587
10	0.1195	0.1793	0.2391	0.2988	0.3586
11	0.1195	0.1792	0.2389	0.2987	0.3584
12	0.1194	0.1791	0.2388	0.2986	0.3583
13	0.1194	0.1791	0.2387	0.2984	0.3581
14	0.1193	0.1790	0.2386	0.2983	0.3579
15	0.1193	0.1789	0.2385	0.2982	0.3578
16	0.1192	0.1788	0.2384	0.2980	0.3576
17	0.1192	0.1787	0.2383	0.2979	0.3575
18	0.1191	0.1787	0.2382	0.2978	0.3573
19	0.1191	0.1786	0.2381	0.2976	0.3572
20	0.1190	0.1785	0.2380	0.2975	0.3570

Table 2 above is represented in the figure below.

Figure 2. *A graph random disturbance having: no intensity, 1.5, 2.0, and 3.0 intensity on the density of wood based industries using ODE 45numerical solver.*
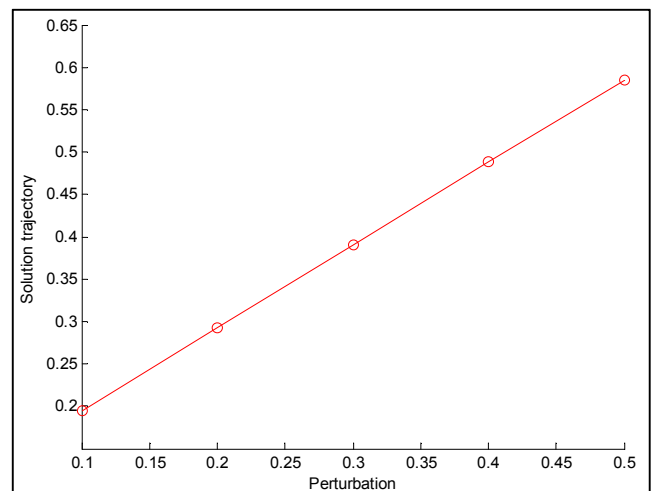
Figure 3. *A graph random disturbance having: no intensity, 1.5, 2.0, and 3.0 intensity on the density of Synthetic based industries using ODE 45 numerical solver.*

## 2.3. The Random Disturbance of the Density of Synthetic Industries

The density of synthetic industries. is given as

$$\frac{dS}{dt} = K - c_2 WS - d_3 S \qquad (7)$$

Simulating with the following parameters values

$$k = 0.037, c_2 = 0.035, d_3 = 0.015, S = 0.06 \quad (8)$$

Figure 4 below shows the relationship between the solution trajectory and the different degrees of perturbation for the forest biomass, density of the wood based industry and the density of the synthetic based industry.
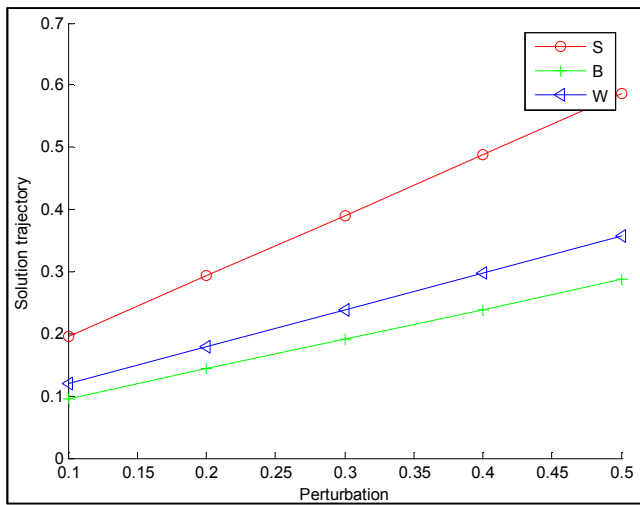
Figure 4. *A graph of the relationship between the solution trajectory and the different degrees of perturbation for the forest biomass, density of the wood based industry and the density of the synthetic based industry.*

From figure 4, it indicates that the biodiversity gain for density of synthetic based industry is higher than the density of the wood based industry follows by the forest biomass.

Table 3. *Quantifying the effect of a random disturbance having: no intensity, 1.5, 2.0, 2.5 and 3.0 intensity on the density of Synthetic based industries using ODE 45 numerical solver.*

Number of iterations.	S_{RAD}:Nill	S_{RAD}:1.5	S_{RAD}:2.0	S_{RAD}:2.5	S_{RAD}:3.0
1	0.1200	0.1800	0.2400	0.3000	0.3600
2	0.1240	0.1860	0.2480	0.3100	0.3720
3	0.1280	0.1920	0.2560	0.3200	0.3841
4	0.1320	0.1980	0.2640	0.3301	0.3961
5	0.1360	0.2040	0.2720	0.3400	0.4080
6	0.1400	0.2100	0.2800	0.3500	0.4200
7	0.1440	0.2160	0.2880	0.3600	0.4320
8	0.1480	0.2219	0.2959	0.3699	0.4439
9	0.1519	0.2279	0.3039	0.3798	0.4558
10	0.1559	0.2338	0.3118	0.3897	0.4677
11	0.1599	0.2398	0.3197	0.3996	0.4796
12	0.1638	0.2457	0.3276	0.4095	0.4914
13	0.1678	0.2516	0.3355	0.4194	0.5033
14	0.1717	0.2575	0.3434	0.4292	0.5151
15	0.1756	0.2634	0.3513	0.4391	0.5269
16	0.1796	0.2693	0.3591	0.4489	0.5387
17	0.1835	0.2752	0.3670	0.4587	0.5504
18	0.1874	0.2811	0.3748	0.4685	0.5622
19	0.1913	0.2870	0.3826	0.4783	0.5739
20	0.1952	0.2928	0.3904	0.4880	0.5856

3. Discussions of Results

For a random noise variation over repeated simulations as shown on Table 1, it is observed a relatively smaller prediction of biodiversity gain on the forest biomass density between a no random disturbance and a random noise of 1.5, whereas for a random noise variation of 2.0 over 3.0 we have observed a bigger prediction of biodiversity gain on the forest biomass density. The same scenario is repeated for the wood based industry (Table 2) and synthetic based industry (Table 3). However, the biodiversity gain in synthetic based industry is sharper than the wood based industry throughout the simulation processes.

On the basis of this present study, a random noise inclusion which may be considered as having a negative effect, has turned out in this scenario to have a positive effect on the ecological services. This result further re-enforces the work of Godspower *etal* [9].

4. Conclusion

From the study, it is observed that not all random noise driven factors do predict biodiversity loss. We have utilized the technique of a numerical simulation to predict that a higher random noise perturbation has the potential to predict higher degree of biodiversity gain than a lower random noise perturbation, in line with the work of Bazuaye [10], Eke *etal* [11], Bazuaye [12], Bazuaye and Ijomah [13].

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