BERKELEY PUBLICATION AND RESEARCH INTERNATIONAL
09.30.2019
Journal of Med., Biological and Pharm. Sci. Vol. 10 No. 3

# NUMERICAL ANALYSIS OF BIODIVERSITY OF TWO COMPETING PLANT SPECIES DUE TO CHANGING PLANT DISEASES CONDITION

P.O. FELIX[1], E.N. EKAKA-A[2] AND N. EKE[1], P. NWAGOR.[1]

*[1]Department of Mathematics/Statistics, Ignatius Ajuru University of Education. Rumuolumeni Rivers State. [2]Department of Mathematics, University of Science and Technology, Nkpolu, Rivers State.*

## ABSTRACT

*This paper has discussed the numerical analysis of biodiversity gain of two interacting plant species with changing plant diseases conditions in a harsh climate like the Arctic. MATLAB ODE 45 was used to quantify the effect of plant diseases conditions on the two interacting plant species. It was observed that as the plant disease condition was decreased, the crop yields increased while as the plant disease condition increased, the crop yields decreased.*

## Introduction

The two intrinsic growth rate increase the growth of the two plant species on the simplified assumption that the birth rate outweighs the death rate. This key hypothesis support the mathematical ideology that the two plant species will grow positively exponentially over time.

**Introduction:**

A plant becomes diseased when it is continuously disturbed by agents that produce abnormal physiological process that disrupts the plant's normal structure, growth and function (Encyclopedia Britannica (2002)). Plant disease is a state in which the normal state and nature of a plant is disrupted. The effect of plant disease on plant growth can be visible according to the percentage effect of the diseases. An increased in percentage effect of the diseases decrease the crop yield while decrease in percentage effect of the disease increases the crop increases the crop yield.



ISSN: 1211-4401

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This standard mathematical result is a tractable mathematical principle but does not offer a meaningful biological implication in the sense that plant species does not grow indefinitely over time because there is an harvesting time and other factors such as the intra competition coefficient, inter competition coefficient and the plant disease factors which act to inhibit the growth of the two plant species

The increased growth rate of plant production enhances food security. The plant species can be affected by intrinsic growth rate, intra competition coefficient, inter competition coefficient, initial condition and plant diseases. Plant disease is one of the major factors that inhibits growth rate which in turn affect crop production.

A severe decrease in the plant disease condition has the potential to predict a bigger volume of biodiversity gain while a severe increase in the plant disease condition has the potential to predict a bigger volume of biodiversity loss. Biodiversity loss influences ecosystem functioning and its impact on goods and services. Biodiversity loss decreases the stability of ecosystem function through time and the impact of biodiversity is nonlinear and saturating in any single ecosystem.

## Mathematical Formulations

Following Ekaka a (2009), we have considered the following system of continuous nonlinear first order differential equation.

$$\frac{dx(t)}{dt} = \alpha_1 x - \beta_1 x^2 - r_1 xy - k_1 x^2 y \qquad (1)$$

$$\frac{dy(t)}{dt} = \alpha_2 y - \beta_2 y^2 - r_2 xy - k_2 xy^2 \qquad (2)$$

With the initial condition $x(0) = x_0 > 0$ and $y(0) = y_0 > 0$ .

Following Ekaka-a (2009), we have considered the following parameters values;

$\alpha_1 = 0.168, \alpha_2 = 0.002, \beta_1 = 0.0020339, \beta_2 = 0.000015, r_1 = 0.0005, r_2 = 0.00002$, with the assumption that the plant disease are $k_1 = k_2 = 0.1$.

For the purpose of clarity, the variables for this model equations are defined as follows:

$x(t)$ represents plant species 1 biomass at time t in the unit of months

$y(t)$ represents plant species 2 biomass at time t in the unit of months

$t$ represents time in the unit of months

$\alpha_1$ represents the intrinsic growth rate of the plant species 1 biomass

$\alpha_2$ represents the intrinsic growth rate of the plant species 2 biomass

$\beta_1$ represents the intra competition coefficient due to the interaction of the population x to inhibit the growth of x plant species biomass

$\beta_2$ represents the intra competition coefficient due to the interaction of the population y to inhibit the growth of y plant species biomass

$r_1$ represents the inter competition coefficient due to the interaction of the population y to inhibit the growth of the x population.

$r_2$ represents the inter competition coefficient due to the interaction of the population x to inhibit the growth of the y population

$k_1$ represents plant diseases affecting plant species 1 biomass

$k_2$ represents plant diseases affecting plant species 2 biomass

## Notations

The key method of analyzing the proposed problem is defined as follows:

PB1 (old) column represents the data values of the first plant species biomass when all the model parameters values are fixed indexed by the unit of time

PB1 (new) column represents the data values of the first plant species biomass when parameter values of $k_1$ changes and all other model parameter values fixed.

PB2 (old) column represents the data values of the second plant species biomass when all the model parameter values are fixed.

PB2 (new) column represents the data values of the second plant species biomass where all the model parameters are fixed except $k_2$

g/A represents grams per area of plant cover.

EBG(%) represents the estimated biodiversity gain in percentage for the first plant species biomass and the second plant species biomass due to the effect of the plant disease scenario.

When the new biomass of the first plant species and the new biomass of the second plant species with the satisfying length of the growing season outweighs, then a biodiversity gain has occurred.

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## Method of Analysis

The key method of analyzing the proposed problem in these work is defined as:

$$EBG(\%) = [\frac{PB1\ (\text{new}) - \text{PB1 (old)}}{\text{PB1 (old)}}](100)$$

## Results

Table 1: Calculating the effect of equal plant disease condition on the yields of two plant species and its implication on biodiversity: $k_1 = k_2 = 0.005$

| PB1(old) g/A | PB1(new) g/A | EBG1(%) | PB2(old) g/A | PB2(new) g/A | EBG2(%) |
|---|---|---|---|---|---|
| 1.2000 | 1.2000 | 0.00 | 1.4000 | 1.4000 | 0.00 |
| 1.2110 | 1.4020 | 15.77 | 1.2004 | 1.3901 | 15.81 |
| 1.2447 | 1.6350 | 31.36 | 1.0482 | 1.3783 | 31.49 |
| 1.2955 | 1.9027 | 46.87 | 0.9270 | 1.3643 | 47.18 |
| 1.3602 | 2.2089 | 62.40 | 0.8270 | 1.3481 | 63.02 |
| 1.4375 | 2.5576 | 77.92 | 0.7427 | 1.3293 | 79.00 |
| 1.5267 | 2.9526 | 93.40 | 0.6703 | 1.3080 | 95.13 |
| 1.6275 | 3.3975 | 108.76 | 0.6074 | 1.2838 | 111.37 |
| 1.7401 | 3.8956 | 123.88 | 0.5521 | 1.2569 | 127.65 |
| 1.8647 | 4.4499 | 138.64 | 0.5031 | 1.2271 | 143.91 |
| 2.0018 | 5.0624 | 152.89 | 0.4594 | 1.1945 | 160.03 |
| 2.1521 | 5.7348 | 166.47 | 0.4202 | 1.1594 | 175.94 |
| 2.3163 | 6.4677 | 179.23 | 0.3848 | 1.1219 | 191.51 |
| 2.4950 | 7.2611 | 191.02 | 0.3529 | 1.0823 | 206.67 |
| 2.6893 | 8.1141 | 201.72 | 0.3239 | 1.0409 | 221.33 |
| 2.9001 | 9.0252 | 211.21 | 0.2976 | 0.9983 | 235.42 |
| 3.1284 | 9.9923 | 219.41 | 0.2736 | 0.9547 | 248.91 |
| 3.3753 | 11.0127 | 226.27 | 0.2518 | 0.9108 | 261.77 |
| 3.6421 | 12.0836 | 231.78 | 0.2318 | 0.8668 | 273.99 |
| 3.9298 | 13.2017 | 235.94 | 0.2135 | 0.8231 | 285.61 |

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Table 2: Calculating the effect of equal plant disease condition on the yields of two plant species and its implication on biodiversity: $k_1 = k_2 = 0.02$

| PB1(old) g/A | PB1(new) g/A | EBG1(%) | PB2(old) g/A | PB2(new) g/A | EBG2(%) |
|---|---|---|---|---|---|
| 1.2000 | 1.2000 | 0.00 | 1.4000 | 1.4000 | 0.00 |
| 1.2110 | 1.3658 | 12.78 | 1.2004 | 1.3541 | 12.80 |
| 1.2447 | 1.5487 | 24.42 | 1.0482 | 1.3052 | 24.52 |
| 1.2955 | 1.7494 | 35.04 | 0.9270 | 1.2538 | 35.25 |
| 1.3602 | 1.9686 | 44.73 | 0.8270 | 1.2003 | 45.14 |
| 1.4375 | 2.2068 | 53.52 | 0.7427 | 1.1452 | 54.19 |
| 1.5267 | 2.4648 | 61.45 | 0.6703 | 1.0891 | 62.48 |
| 1.6275 | 2.7432 | 68.55 | 0.6074 | 1.0327 | 70.02 |
| 1.7401 | 3.0425 | 74.85 | 0.5521 | 0.9763 | 76.83 |
| 1.8647 | 3.3636 | 80.38 | 0.5031 | 0.9206 | 82.99 |
| 2.0018 | 3.7072 | 85.19 | 0.4594 | 0.8659 | 88.48 |
| 2.1521 | 4.0744 | 89.32 | 0.4202 | 0.8128 | 93.43 |
| 2.3163 | 4.4660 | 92.81 | 0.3848 | 0.7615 | 97.90 |
| 2.4950 | 4.8833 | 95.72 | 0.3529 | 0.7122 | 101.81 |
| 2.6893 | 5.3274 | 98.10 | 0.3239 | 0.6651 | 105.34 |
| 2.9001 | 5.7997 | 99.98 | 0.2976 | 0.6204 | 108.47 |
| 3.1284 | 6.3014 | 101.43 | 0.2736 | 0.5782 | 111.33 |
| 3.3753 | 6.8339 | 102.47 | 0.2518 | 0.5383 | 113.78 |
| 3.6421 | 7.3987 | 103.14 | 0.2318 | 0.5009 | 116.09 |
| 3.9298 | 7.9971 | 103.50 | 0.2135 | 0.4659 | 118.22 |

Table 3: Calculating the effect of equal plant disease condition on the yields of two plant species and its implication on biodiversity: $k_1 = k_2 = 0.05$

| PB1(old) g/A | PB1(new) g/A | EBG1(%) | PB2(old) g/A | PB2(new) g/A | EBG2(%) |
|---|---|---|---|---|---|
| 1.2000 | 1.2000 | 0.00 | 1.4000 | 1.4000 | 0.00 |
| 1.2110 | 1.3010 | 7.43 | 1.2004 | 1.2898 | 7.45 |
| 1.2447 | 1.4105 | 13.32 | 1.0482 | 1.1884 | 13.38 |
| 1.2955 | 1.5290 | 18.02 | 0.9270 | 1.0950 | 18.12 |

| | | | | | |
|---|---|---|---|---|---|
| 1.3602 | 1.6573 | 21.84 | 0.8270 | 1.0091 | 22.02 |
| 1.4375 | 1.7961 | 24.95 | 0.7427 | 0.9300 | 25.22 |
| 1.5267 | 1.9462 | 27.48 | 0.6703 | 0.8572 | 27.88 |
| 1.6275 | 2.1086 | 29.56 | 0.6074 | 0.7902 | 30.10 |
| 1.7401 | 2.284 | 31.26 | 0.5521 | 0.7285 | 31.95 |
| 1.8647 | 2.4734 | 32.64 | 0.5031 | 0.6717 | 33.51 |
| 2.0018 | 2.6779 | 33.77 | 0.4594 | 0.6194 | 34.83 |
| 2.1521 | 2.8986 | 34.69 | 0.4202 | 0.5712 | 35.94 |
| 2.3163 | 3.1365 | 35.41 | 0.3848 | 0.5269 | 36.93 |
| 2.4950 | 3.3928 | 35.98 | 0.3529 | 0.4861 | 37.74 |
| 2.6893 | 3.6688 | 36.42 | 0.3239 | 0.4485 | 38.47 |
| 2.9001 | 3.9659 | 36.75 | 0.2976 | 0.4139 | 39.08 |
| 3.1284 | 4.2852 | 36.98 | 0.2736 | 0.3821 | 39.66 |
| 3.3753 | 4.6282 | 37.12 | 0.2518 | 0.3528 | 40.11 |
| 3.6421 | 4.9964 | 37.18 | 0.2318 | 0.3258 | 40.55 |
| 3.9298 | 5.3911 | 37.19 | 0.2135 | 0.3009 | 40.94 |

Table 4: Calculating the effect of equal plant disease condition on the yields of two plant species and its implication on biodiversity: $k_1 = k_2 = 0.095$

| PB1(old) g/A | PB1(new) g/A | EBG1(%) | PB2(old) g/A | PB2(new) g/A | EBG2(%) |
|---|---|---|---|---|---|
| 1.2000 | 1.2000 | 0.00 | 1.4000 | 1.4000 | 0.00 |
| 1.2110 | 1.2191 | 0.67 | 1.2004 | 1.2085 | 0.67 |
| 1.2447 | 1.2587 | 1.12 | 1.0482 | 1.0601 | 1.14 |
| 1.2955 | 1.3141 | 1.44 | 0.9270 | 0.9404 | 1.45 |
| 1.3602 | 1.3829 | 1.67 | 0.8270 | 0.8409 | 1.68 |
| 1.4375 | 1.4640 | 1.84 | 0.7427 | 0.7565 | 1.86 |
| 1.5267 | 1.5569 | 1.98 | 0.6703 | 0.6837 | 2.00 |
| 1.6275 | 1.6614 | 2.08 | 0.6074 | 0.6202 | 2.11 |
| 1.7401 | 1.7777 | 2.16 | 0.5521 | 0.5643 | 2.21 |
| 1.8647 | 1.9062 | 2.23 | 0.5031 | 0.5145 | 2.27 |
| 2.0018 | 2.0474 | 2.28 | 0.4594 | 0.4701 | 2.33 |
| 2.1521 | 2.2019 | 2.31 | 0.4202 | 0.4302 | 2.38 |
| 2.3163 | 2.3705 | 2.34 | 0.3848 | 0.3942 | 2.44 |

| | | | | | |
|---|---|---|---|---|---|
| 2.4950 | 2.5540 | 2.36 | 0.3529 | 0.3616 | 2.47 |
| 2.6893 | 2.7534 | 2.38 | 0.3239 | 0.3320 | 2.50 |
| 2.9001 | 2.9695 | 2.39 | 0.2976 | 0.3051 | 2.52 |
| 3.1284 | 3.2036 | 2.40 | 0.2736 | 0.2806 | 2.56 |
| 3.3753 | 3.4566 | 2.41 | 0.2518 | 0.2582 | 2.54 |
| 3.6421 | 3.7298 | 2.41 | 0.2318 | 0.2377 | 2.55 |
| 3.9298 | 4.0244 | 2.41 | 0.2135 | 0.2190 | 2.58 |

## Discussion of Results

In Table 1, within the length of a growing season of twenty months, it was observed that as the plant disease condition ware decreased equally from 0.1 to 0.005, the predicted old biomass of the first and second plant species specified as 3.93 grams per area and 0.21 grams per area increased to new plant species biomass of 13.20 grams per area and 0.82 grams per area respectively. A biodiversity gain has occurred as a result of this variations having the percentage quantified values of 235.94 and 285.61 for the first and second plant species for the first and second plant species respectively.
In Table 2, as the plant disease condition were decreased equally from 0.1 to 0.02, the predicted old biomass of the first and second plant species specified as 3.93 grams per area and 0.21grams per area increased to new biomass of the first and second plant species of 8.00 grams per area and 0.47 grams per area respectively. This variations resulted to biodiversity gain with percentage quantified values of 103.50 and 118.22 respectively for the first and second plant species within the length of twenty months growing season.
In Table 3, the predicted old biomass of the first and second plant species, specified as 3.93grams per area and 0.21grams per area are increased to new plant species biomass specified as 5.39 grams per area and 0.30 grams per area respectively due to the effect of the decrease in plant disease condition from 0.1 to 0.05. The result of this variations caused biodiversity gain having percentage quantified values of 37.19 and 40.94 respectively for the first and second plant species when the length of the growing season of twenty months.

In Table 4, the predicted old biomass of the first and second plant species are specified by 3.93 grams per area of plant cover and 0.21 grams per area of plant cover respectively are increased slightly to 4.02g/A and 0.22g/A as the new plant species biomass due to the effect of a plant disease. As a result of this variations, a biodiversity gain has occurred, having the percentage quantified values of 2.41 and 2.58 respectively for the first and second plant species when the length of the growing season is twenty months.

## Conclusion

We have applied the method of ODE 45 simulation analysis to predict the effect of equal plant disease effect on two competing plant species and obtain novel results that we have not seen elsewhere which are in tandem with the crop science disease control policy. In this study it was observed that the biodiversity gain increased as the plant disease condition decreased. As to have higher crop yield emphasizes should be made on having minimal disease condition.

## References

Offei S.K., Owuna-Kwakye M and Thottoppilly G. (1999). First report of East African Cassava Mosaic Begonovirus in Ghana.

Ogbe F.O. et al (1999). Plant Diseases 83:398

Enwikipedia.org/wiki/plant-diseases-epidemiology (2018)

Ekaka-a E.N (2009) Computational and Mathematical Modeling of Plant Species interactions in a harsh climate, University of Chester, United Kingdom

Loreau M., Naeem S.,Inchausti P., Bengtsson J., Grime J.P., Hector A., Hooper D.U., Huston M.A., Raffaelu D., Schmid B., Tilman D. and Wardle D.A. (2001). Ecosystem Functioning and Biodiversity, 294.

Sran T., Hammond and Niklas K.J. (2011), Computer simulations of plant biodiversity in stable and unstable environments. Journal of Biological Systems, 19 (1), 1-17.

Divine J. A., Williams R.J., Martinez N. D. (2002). Network Topology and Species Loss in Food Webs. Journal of Santa Fe Institute USA.

Ekaka-a E.N., Chukwuocha E.O. and Nafo N.M. (2012). Role of Numerical Method in the sensitivity analysis of a density parameter in a passivation rate interaction. J. App. Sci. Environ. Manage, 16 (3), 281-285.

Cardinale B.J., Duffy J.E., Gonzalet A., Hooper D.U., Pernings C., Venail P, Narwani A., Mace G.M., Tilman D., Wardle D.A, Kinzig A.P., Daily G.C., Loreau M., Grace J.B., Larigauderie A., Srivastava D. and Naeem Shalid (2012). Impact of Biodiversity Loss on Humanity, 486 (7401), 59-67.

Atsu J.U. and Ekaka-a E.N (2017). Modeling Intervention with respect to Biodiversity Loss. International Journal of Advanced Engineering Management and Science, 3(9), 927.

Kumar P. (2010). The Economic of Ecosystem and Biodiversity, London, 456.

Spash C.L. (2015). Buldozing biodiversity: The Economics of Offsets and trading in nature. Journal of Biological Conservation. 192, 541-551.

Igwe P.Y., Atsu J.U., Ekaka-a E.N. and Nwaobulu A.O (2018). Modeling the Increasing Differential Effects of the first Internal Competition Coefficient on the Biodiversity, 4(10), 737.

Ekaka-a E.N (2009) Computational and Mathematical Modeling of Plant Species interactions in a harsh climate, University of Chester, United Kingdom.

Ford N.J, Lumb P.M. and Ekaka-a E.N (2010), Mathematical Modeling of plant species interactions in a harsh climate, Journal of Computational and Applied Mathematics 234, 2732-2744.