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COMPUTATIONAL MODELLING OF INDUSTRIAL ASSETS.

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ABSTRACT

In this paper, we considered the numerical method in predicting the biodiversity loss due to the variation of ξ *and* $\boldsymbol{\delta}$ *together on biodiversity scenario. However, when the model parameter values* ξ *and* $\boldsymbol{\delta}$ *are decreased, the industrial assets variable changes. By comparing the loss pattern in these two interacting industrial data, we have finite instance of biodiversity due to the application of numerical method (ODE45). The novel result we have obtained in this study have not been seen elsewhere.*

***Keyword**: ODE45, Ecosystem, Biodiversity, Matlab, Industrial Assets*

INTRODUCTION

Modeling and simulation of dynamical systems has always been an important issue in Science, Engineering, Biological sector, Medical sector and Agricultural sector. Most physical phenomena such as biological model, Agricultural model, fluid dynamics, control theory, e.t.c are often transformed into ordinary differential equation to give an explicit interpretation of the physical attributes in the model equation. The effectiveness of these equations in the world of modeling has prompted researchers in developing methods for seeking the solutions to these equations. According to Agyemang and Freedom (2009), the idea to use a differential equation systems based on dynamical systems to model the interaction between agriculture, industry and ecospheric assets started in 1994 with the pioneering work of Apedaile et al (1994), which followed later by the work of Solomonvich et al (1998) and then by Solomonvich et al (2001), Freedom et al (2007), Eleki and Ekakaa (2019) and Godspower et al (2020) studied a similar investigation using the model equation from

Agyemang and Freedom (2009). Industrial ecology has been an innovative idea that has come into play in the last two decades which gives the opportunity for improving businesses, social and environmental activities by restructuring the system of industry to a close-loop. The major assumption for this industrial ecology is to take energy and raw material as inputs and creat products and wastes can unlikely continue indefinitely (E.L Hagger, 2007). Frosch and Gallopoulos(1989) suggested a more integrated model such as industrial ecosystem. Their model adopts principles of nature like recycling, claim that economy can work as nature does. The system regulates itself and produces everything it consumed but also consumes everything it produces (Frosch 1995, Korhonen 2002). Industrial ecosystem is now a major way to copy the nature recycling in model since human beings produces waste, pollutant emission and over use resources. The link between the ecological system and mathematical theory has a long standing history. However, there is severe gap in the knowledge on how to predict the loss of Industrial assets using numerical simulation. It is against this background that we fully want to explore the application of a Matlab Algorithm to predict the loss of industrial assets.

In this paper, our work will be basically an extension work of Ibrahim A and Freedom H.I (2009) by considering the effects of decreasing the constant depreciation rate coefficient of industry and the per asset growth rate for industry in dealing with normal agriculture together.

Model Assumptions:

The model formulation in the sequel are defined as follows:

The growth of industrial assets also depends on the industry and thee constant depreciation rate coefficient of industry.

The growth of industrial assets depends on the interaction between the industry and itself together with the per asset depreciation rate coefficient of industry.

The growth of industrial assets depends on the interaction between the industrial assets and normal agricultural assets in which the per asset growth rate for industry deals with normal agriculture.

MATHEMATICAL FORMULATION

Following Ibrahim A and Freedom H.I (2009), Eleki and Ekakaa (2019) and Godspower et al (2020), we have consider the four system of nonlinear ordinary differential equation.

$$\frac{dx_1(t)}{dt} = \alpha_1 x_1 z - \beta_1 x_1^2 + \gamma_1 x_1 y - \rho_1 x_1 x_2 - \theta x_1 + \theta x_1 z$$

$$\frac{dx_2(t)}{dt} = \alpha_2 x_2 z - \beta_2 x_2^2 - \gamma_2 x_2 y - \rho_2 x_1 x_2$$
$$\frac{dy(t)}{dt} = -\xi y - \eta y^2 + \delta x_1 y$$
$$\frac{dz(t)}{dt} = -\kappa x_1 z + \kappa_1 z - \kappa_1 z^2 + \kappa_2 x_1 - \kappa_2 x_1 z$$

where all parameters are assumed to be positive constants except γ_1 which can be any real constant. $\alpha_1(\alpha_2)$ is inter competitive growth rate coefficient of normal (auxiliary) agriculture due to normal (auxiliary) agricultural activity for fixed z; $\beta_1(\beta_2)$ is the per asset diminishing returns rate coefficient for normal (auxiliary) agriculture in the absence of industry and auxiliary (normal) agriculture, $\gamma_1(\gamma_2)$ is the per asset terms of trade coefficient between normal (auxiliary) agriculture and industry, ξ is the constant depreciation rate coefficient of industry, η is the per asset (linear) depreciation rate coefficient of industry, δ is the per asset growth rate for industry in dealing with normal agriculture, $\rho_1(\rho_2)$ is the per asset competitive rate coefficient of auxiliary (normal) agriculture acting on normal (auxiliary) agriculture, κ is the per asset degradation rate coefficient of the ecosphere due to normal agricultural activities, κ_1 is the natural restoration rate coefficient for the ecosphere, κ_2 is the rate of effort input to restore the ecosphere by normal agriculture and θ is the net cost rate to normal agriculture to restore the ecosphere.

With the following precise model parameter values from Agyemang and Freedman (2009)

$$\alpha_1 = 3, \alpha_2 = 1, \beta_1 = \frac{1}{10}, \beta_2 = \frac{1}{10}, \gamma_1 = -\frac{1}{49}, \gamma_2 = \frac{1}{10}, \rho_1 = \frac{1}{10}, \rho_2 = \frac{1}{5}, \delta = \frac{1}{4},$$
$$\theta = \frac{6}{5}, \eta = \frac{1}{20}, \xi = 1, \kappa = 2, \kappa_1 = 2, \kappa_2 = 1$$

METHOD OF ANALYSIS

To tackle this environmental problem, we have fully explore the application of numerical method to model and predict the effect of decreasing ξ *and* $\boldsymbol{\delta}$ together by 5%, 10%, 15%, 20% and 25% on a biodiversity loss scenario for a fixed initial condition consisting of a point of values.

Table 1: Quantifying the effects of decreasing ξ *and* $\boldsymbol{\delta}$ by 5% on biodiversity loss in Industry using ODE45 numerical method

Example	LGS TIME (MONTHLY)	$y(old)$	$y(new)$	EBL (%)
1	1	4.0000	4.0000	0
2	31	8.5625	0.9489	88.9183

3	61	8.5626	0.7442	91.3088
4	91	8.5626	0.6911	91.9288
5	121	8.5626	0.6741	92.1272
6	151	8.5626	0.6681	92.1973
7	181	8.5626	0.6661	92.2207
8	211	8.5626	0.6653	92.2300
9	241	8.5626	0.6650	92.2338
10	271	8.5626	0.6649	92.2353
11	301	8.5626	0.6648	92.2356
12	331	8.5626	0.6649	92.2351
13	361	8.5626	0.6649	92.2347
14	391	8.5626	0.6649	92.2344
15	421	8.5626	0.6649	92.2344

LGS = Length of growing season
$y(old)$= Measures the Industrial asset volume when all model parameters are fixed at 100%
$y(new)$= Measures the Industrial asset volume when ξ *and* $\boldsymbol{\delta}$ are varied together.
EBL= Estimated Biodiversity Loss

Table 2: Quantifying the effects of decreasing ξ *and* $\boldsymbol{\delta}$ ttogether by 10% on biodiversity loss in Industry using ODE45 numerical method

Example	LGS TIME (MONTHLY)	$\boldsymbol{y(old)}$	$\boldsymbol{y(new)}$	EBL (%)
1	1	4.0000	4.0000	0
2	31	8.5625	1.4137	83.4898
3	61	8.5626	1.3025	84.7885
4	91	8.5626	1.2901	84.9331
5	121	8.5626	1.2883	84.9550
6	151	8.5626	1.2879	84.9592
7	181	8.5626	1.2880	84.9575
8	211	8.5626	1.2882	84.9561
9	241	8.5626	1.2882	84.9556
10	271	8.5626	1.2882	84.9559
11	301	8.5626	1.2882	84.9561
12	331	8.5626	1.2881	84.9563
13	361	8.5626	1.2881	84.9564
14	391	8.5626	1.2881	84.9564

15	421	8.5626	1.2881	84.9564

LGS= Length of growing season
$y(old)$= Measures the Industrial asset volume when all model parameters are fixed at 100%
$y(new)$= Measures the Industrial asset volume when ξ *and* $\boldsymbol{\delta}$ are varied together.
EBL= Estimated Biodiversity Loss

Table 3: Quantifying the effects of decreasing ξ *and* $\boldsymbol{\delta}$ t together by 15% on biodiversity loss of an Industrial asset using ODE45 numerical method

Example	LGS TIME (MONTHLY)	$y(old)$	$y(new)$	EBL (%)
1	1	4.0000	4.0000	0
2	31	8.5625	1.9245	77.5246
3	61	8.5626	1.8765	78.0852
4	91	8.5626	1.8743	78.1106
5	121	8.5626	1.8744	78.1098
6	151	8.5626	1.8744	78.1100
7	181	8.5626	1.8744	78.1101
8	211	8.5626	1.8744	78.1101
9	241	8.5626	1.8744	78.1101
10	271	8.5626	1.8744	78.1101
11	301	8.5626	1.8744	78.1101
12	331	8.5626	1.8744	78.1101
13	361	8.5626	1.8744	78.1101
14	391	8.5626	1.8744	78.1101
15	421	8.5626	1.8744	78.1101

LGS= Length of growing season
$y(old)$= Measures the Industrial asset volume when all model parameters are fixed at 100%
$y(new)$= Measures the Industrial asset volume when ξ *and* $\boldsymbol{\delta}$ are varied together.
EBL= Estimated Biodiversity Loss

Table 4.1.4: Quantifying the effects of decreasing ξ *and* $\boldsymbol{\delta}$ together by 20% on biodiversity loss of an Industrial asset using ODE45 numerical method

Example	LGS TIME (MONTHLY)	$y(old)$	$y(new)$	EBL (%)
1	1	4.0000	4.0000	0

2	31	8.5625	2.4459	71.4345
3	61	8.5626	2.4278	71.6470
4	91	8.5626	2.4275	71.6499
5	121	8.5626	2.4275	71.6499
6	151	8.5626	2.4275	71.6500
7	181	8.5626	2.4275	71.6500
8	211	8.5626	2.4275	71.6499
9	241	8.5626	2.4275	71.6499
10	271	8.5626	2.4275	71.6499
11	301	8.5626	2.4275	71.6499
12	331	8.5626	2.4275	71.6499
13	361	8.5626	2.4275	71.6499
14	391	8.5626	2.4275	71.6499
15	421	8.5626	2.4275	71.6499

LGS= Length of growing season
$y(old)$= Measures the Industrial asset volume when all model parameters are fixed at 100%
$y(new)$= Measures the Industrial asset volume when ξ *and* $\boldsymbol{\delta}$ are varied together.
EBL= Estimated Biodiversity Loss

Table 4.1.5: Quantifying the effects of decreasing ξ *and* $\boldsymbol{\delta}$ together by 25% on biodiversity loss of an Industrial asset using ODE45 numerical method

Example	LGS TIME (MONTHLY)	$y(old)$	$y(new)$	EBL (%)
1	1	4.0000	4.0000	0
2	31	8.5625	2.9572	65.4632
3	61	8.5626	2.9512	65.5345
4	91	8.5626	2.9509	65.5372
5	121	8.5626	2.9510	65.5368
6	151	8.5626	2.9510	65.5366
7	181	8.5626	2.9510	65.5366
8	211	8.5626	2.9510	65.5366
9	241	8.5626	2.9510	65.5366
10	271	8.5626	2.9510	65.5366
11	301	8.5626	2.9510	65.5366
12	331	8.5626	2.9510	65.5366
13	361	8.5626	2.9510	65.5366
14	391	8.5626	2.9510	65.5366

15	421	8.5626	2.9510	65.5366

LGS= Length of growing season
$y(old)$= Measures the Industrial asset volume when all model parameters are fixed at 100%
$y(new)$= Measures the Industrial asset volume when ξ *and* $\boldsymbol{\delta}$ are varied together.
EBL= Estimated Biodiversity Loss

DISCUSSION OF RESULT

In this paper, we have applied a mathematical model to discuss and predict the loss of Industrial assets by using a differential method of ordinary differential equation of order 45 (ODE45). From the result obtained (Table 1 to Table 5), we have seen that both y(old) and y(new) indicates the inclusion of the constant depreciation rate coefficient of industry and per asset growth rate for industry in dealing with normal agriculture which are given as 1and 1/4. However, we have discovered from the results that y(new) which remains due to the impact of decreasing ξ *and* $\boldsymbol{\delta}$ together from 5% to 25% is less than each values of y(old) that is the industrial assets volume when ξ *and* $\boldsymbol{\delta}$ together are varied is less that the industrial assets volume when all the model parameter values are fixed at 100%.

Conclusion

In this work, a computational and mathematical modelling of industrial assets using ordinary differential equations of order 45 (ODE45) was executed. The aim of these was to quantify the effect of decreasing the constant depreciation rate coefficient of industry and per asset growth rate for industry in dealing with normal agriculture to check the pattern of loss of biodiversity. The results shows that decreasing ξ *and* $\boldsymbol{\delta}$ together from 5% to 25% causes a huge loss in biodiversity.

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