REGARDING THE POPULATION DYNAMICS INVESTIGATION USING ENVIRONMENTAL INFORMATION SYSTEMS

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Abstract: *The growth of organisms in a favorable environment is typically modeled by a simple exponential function, in which the population size increases at an ever-increasing rate. This is because the model, at their most simple, assume a fixed net "birth" rate per individual. This means that as the number of individuals increases, so does the number of individuals added to the population. This description of population change pre-supposes that resources for growth are always adequate, even in the face of an ever-increasing population. In the real world, resources become limiting for growth, so that the rate of population growth declines as population size increases.*

There are several numerical (bio-mathematical) models that simulate this behaviour, and here we will explore a model termed generalized "logistic" growth. The generalized logistic differential equation, dealt with in this paper, is a classical, but still useful model for describing the dynamics of a one-species population in an environment with limited resources.

This paper deals with the theoretical analyse (definition, properties) and some applications of the dynamic systems treated under the generalized logistic equation formalism. Also, there are presented a variety of growth curves based on extended forms of the classical Verhulst logistic growth equation and some applets realised in Wolfram Mathematica.

Keywords: *Environmental Informatics, population dynamics, growth models*

1. INTRODUCTION

Science and scientific knowledge of the world is at the base of everything that mankind has gradually accomplished, for the last century. Nowadays society would have had probably another view without mankind considerable scientific activities and revelations (discoveries). As time went by, these discoveries helped reshape our culture and society progress [5,6].

The importance of discoveries (e.g. Artificial Intelligence, Environmental Informatics) is evaluated by its economic impact or by the benefit that brings for a large number of people. Data transferring, modern transport, electricity and many others, are the "mature fruit" of epochal discoveries, purely scientific [5].

Environmental Informatics, as a scientific discovery, applies methods and information technologies for the collection, analysis, interpretation, dissemination and use of the environment's information. It also includes a wide range of disciplines that can be used to understand the specific environment issues: *artificial intelligence*, *neural networks*, *geographic information systems (GIS)*, *remote sensing*, *mapping services*, *data storage technologies (databases)*, *software engineering*, *mobile technology* and *the Internet*.

The main goal of Environmental Informatics is the creation of a research infrastructure related to the integration of research projects in key areas of academic and research activities [6]:

- *environmental science*: geology, geophysics, meteorology, biogeography;
- *chemistry* related fields: environmental chemistry, biochemistry, biotechnology, enzymology, chemistry technology, analytical chemistry;
- *biology* with related fields: ecology, ethology,'s biomonitoring, ecotoxicology;
- *physics* with related areas: environmental physics, biophysics, physics of solids;
- *mathematics* and the related fields: mathematical modeling, biostatistics, applied mathematics;
- *computer sciences* with related areas: artificial intelligence - soft computing, parallel computing and distributed, computational mathematics, bioinformatics.

The modern society (information society) in accordance with the actual changes and preocupations in the environment domain has provided various types of informatics resources (tools, methodologies, procedures) to manage and support the ideas and actions related to the environmental issues [4], as presented in Fig. 1.

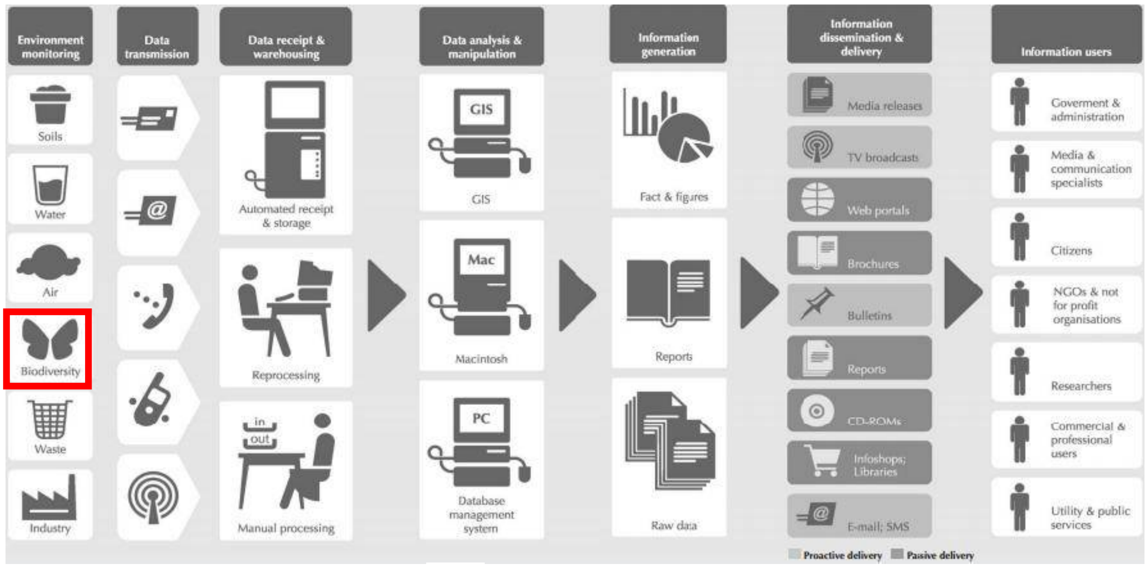

FIG. 1. The schematic diagram for EIS [10]

Population grows over time as well as the modern technology implication in everyday life. Informatics become essential for all the fields related to technology and environment protection. Informatics resources are becoming nowadays more and more important for environmental management, planning and decision-making [4].

An exhaustive analysis of the environmental hazards in terms of physical, chemical, biological, geological, hydro-meteorological processes and their interactions is becoming critical, and not so extraordinary made without the support offered by the environmental information systems (EISs) and environmental informatics [4].

2. INTRODUCTION

Nowadays, significant efforts are required to analyze relevant data and environment information, simulate related processes, evaluate resulting impacts or scenarios and generate viable decision alternatives. The informatics resources developed in the last 3-4 decades have enabled and help us to investigate the complex interactions between the natural systems and engineered ecosystem, and also to search for sustainable strategies for a harmonious development. Environmental information and environmental information systems play an important role in decision-making in the field, being closely linked with environmental requirements in decades [7], and with environmental research methodologies [5]. The discussion on EISs as particular environmental research methodologies aims to identify characteristic attributes that allowed passage of environmental data to environmental information and from EISs to Environmental Informatics.

In the contemporary society the dynamism of the changes in all the domains of the social, cultural, economic and ecologic life is one of dominant constants. These transformations of the society represent solicitations and challenges that the academic structure and the mankind have to deal with; both through the way in which it organizes the knowledge and the learning, through the quality of the results in the end, and also through the ways in which it distributes them in the society, using, in most cases, the correspondence between the real world and the mathematical world [8] (Fig. 2).

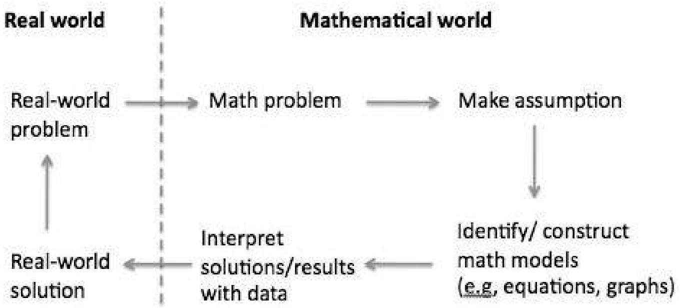

FIG. 2. Mathematical models as a relation between real and mathematical world

According to all the equations presented before it is essential to notice that every population models seems to be derived from the generalized logistic growth model [1], with different values for the ***α***, ***β*** and ***γ*** parameters [3,11], as presented in the Fig. 3.

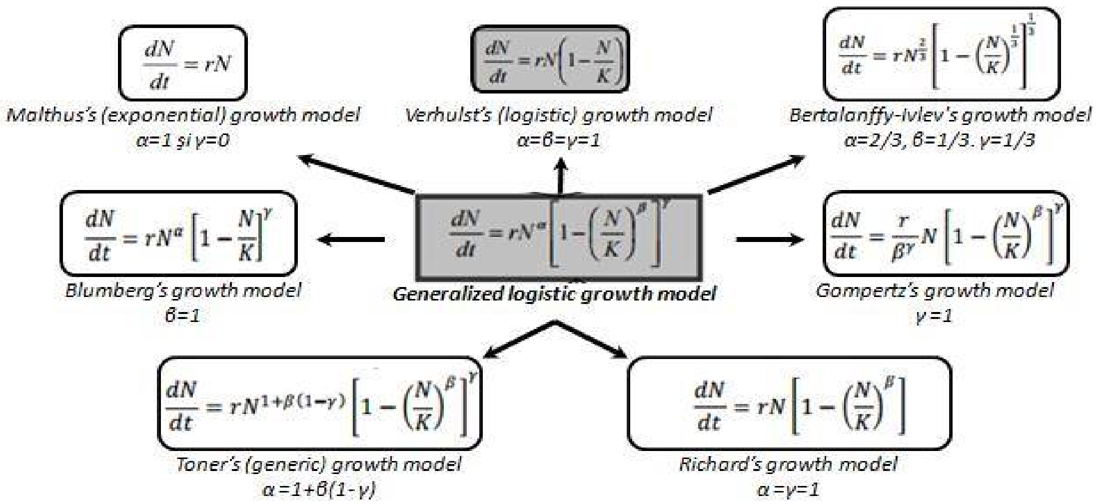

FIG. 3. The generalized logistic curve and its derivative models [11]

During recent decades the stirring up of the processes of globalization, practically in all spheres of present day civilization, has aggravated and brought numerous problems resulting from nature-society interactions. To overcome these problems, it is necessary to develop and adopt new concepts and techniques to study and evaluate the changes occurring on the earth ecosystem [2]. For this, application of information technology via Environmental Information Systems is the best option.

Due to pressure from natural selection which involves achieving a high efficiency of the reproduction process, can be fairly easily notice that the general populations trend is to grow numerically. Because the main function of living organisms that grow in terms of numbers is the reproduction in order to perpetuate the species, any model that would try to describe the dynamics of a population should include reproduction [8]. There are two important models of population growth that are based on the reproductive process: the exponential and logistic models (Fig. 4).

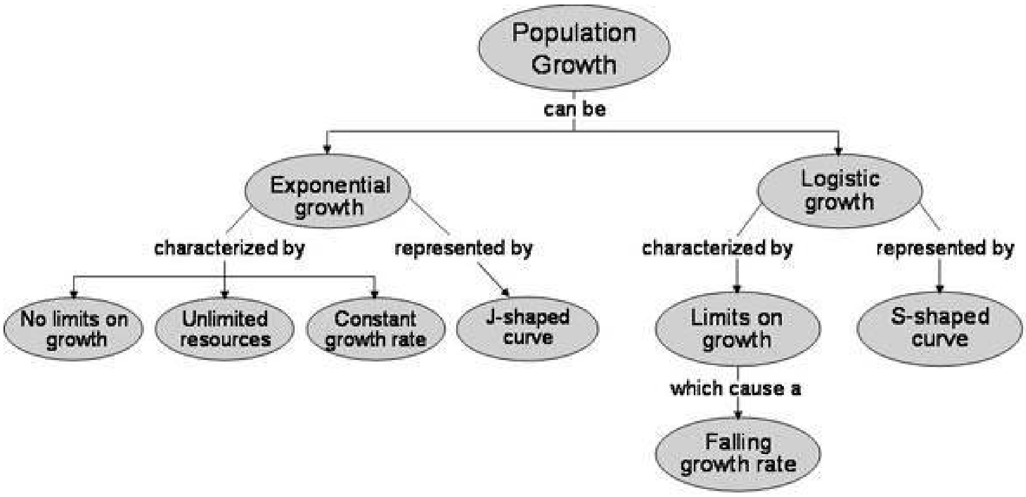

FIG. 4. The main mathematical models of population growth and their properties (source: www.goldiesroom.org)

Since we especially brought to discussion the mathematical modeling as the main vector used in ecological analytical research for studying the complex behavior of dynamic ecological systems, as there are populations, in the following we will present some applications (applets) realized in Wolfram Language of Mathematica software.

Designed for the new generation of programmers, the Wolfram Language, the world's most productive programming language, has a vast depth of built-in algorithms and knowledge, all automatically accessible through its elegant unified symbolic language.

In the following examples we used the *manipulate* function, because it gives immediate access to a huge range of powerful interactive capabilities. For any expression with symbolic parameters, the mentioned function automatically creates an interface for manipulating the parameters, according to the Computable Document Format (CDF) created by Wolfram Research company.

```
Manipulate[
 Plot[K / (1 + (K / N - 1) Exp[-r Kt]), {t, 0, 20},
  PlotRange -> {-5, 100},
  AxesLabel → {t, population }, Axes -> True,
  ImagePadding -> {{15, 15}, {15, 15}},
  ImageSize -> {400, 220}],
 {{N, 0.1, "Initial population (N)"}, 0.001, 100,
  Appearance -> "Labeled"},
 {{r, 0.15, "Rate of increase (r)"}, .01, 4,
  Appearance -> "Labeled"},
 {{K, 4, "Carrying capacity (K)"}, .01, 90,
  Appearance -> "Labeled"},
 ControlPlacement → Top]
```

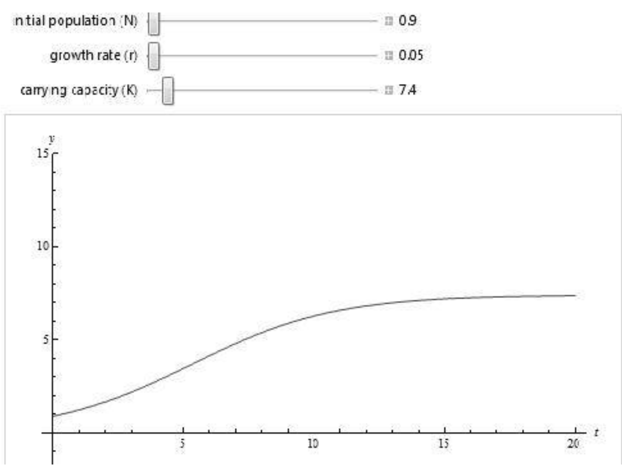

FIG. 5. A simple logistic equation model considering *N*, *r* and *K* parameters

As it can be observed, the simplified form of the logistic equation (Fig. 5) is a powerful expression for a single population dynamics. It can lead to population size prediction in reasonable intervals, if there is a sufficiently large number of data about population size in time and space, at least 3 parameters: *N* - initial population at time t_0, *r* - rate of increase and *K* - the carrying capacity of the environment. To the same extent, we obtain the same graphic if considering a particular family of curves (Fig. 6).

```
Manipulate[If[fam,
  Plot[Evaluate[Table[x[t, N, r], {N, 0.01, 1, 0.1}]], {t, 0, 10},
   ImageSize -> {450, 300},
   PlotRange -> {0, 1},
   PlotStyle -> Table[{Thickness[0.007],ColorData["SunsetColors"][i]}, {i, 0.01, 1, 0.1}],
   AxesLabel -> {Style["t", Italic, 12], Style["x(t)", Italic, 12]}],
  Plot[x[t, N, r], {t, 0, 10},
   ImageSize -> {450, 300}, PlotRange -> {0, 1},
   PlotStyle -> {Thickness[0.01]},
   AxesLabel -> {Style["t", Italic, 12], Style["x(t)", Italic, 12]}]],
  {{N, 0.067,"Initial population (N)"}, 0.01, 1, Appearance -> "Labeled",
  Enabled -> Dynamic[ !fam]},
 {{r, 0.96, "Rate of increase (r)"}, -2, 2, Appearance -> "Labeled"},
  {{fam, True, "Family of curves"}, {True, False}}, ControllerLinking -> True,
  Initialization :> ({x[t_, x0_, r_] := 1/(1 + (1/x0 - 1)*Exp[(-r)*t])};
   ReleaseHold[HoldComplete[{x[t_, x0_, r_] := 1/(1 + (1/x0 - 1)*Exp[(-r)*t])}]])]
```

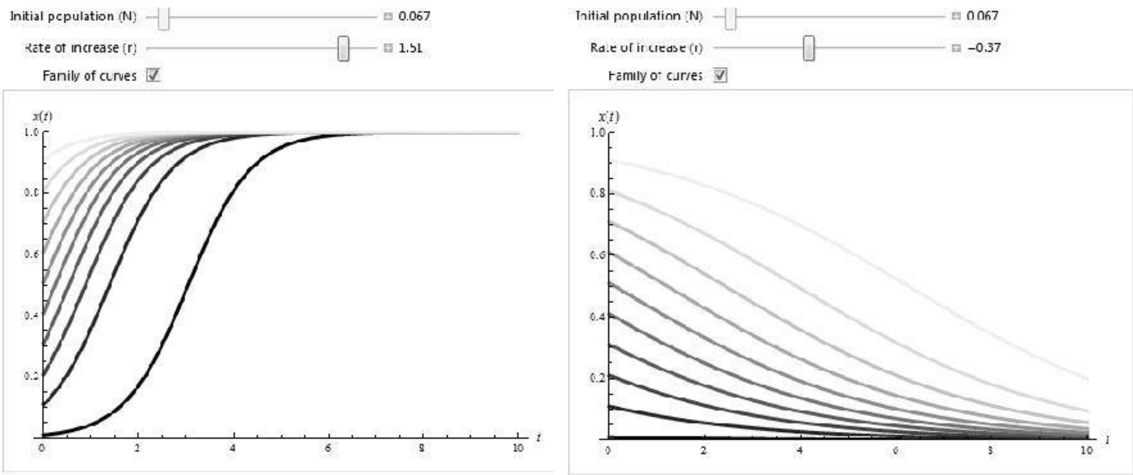

FIG. 6. The logistic equation behavior considering a particular family of curves

CONCLUSIONS

Nowadays, much attention is being paid to the problem of population growth and this has led also to an increase of interest in mathematical ecology. The growth of organisms in a favourable environment is usually modeled by a simple exponential function, in which the population size increases at an ever-increasing rate.

In the real world, resources become limiting for growth, so that the rate of population growth declines as population size increases. There are several numerical (bio-mathematical) models that simulate this behaviour, and we explore the generalized "logistic" growth model, which is a classical, but still useful model for describing the dynamics of a one-species population in an environment with limited resources.

Population modeling became of particular interest to biologists. The logistic population model, the Lotka–Volterra model of community ecology, life table matrix modeling, the equilibrium model of island biogeography and variations there of are the basis for ecological population modeling today.

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