Fuzzy Model for Sustainability Assurance Related to Environmental Protection

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***Abstract* — This paper aims to build a system based on fuzzy models that can be implemented in the assessment of ecological systems, to determine appropriate methods of action for reducing adverse effects on environmental and implicit the population. It is noted that this subject of research represent a high interest current in the world. In situations difficult to approach methods with modeling conventional, are proposed as a reliable alternative pathways to fuzzy logic-based modeling. Information systems may determine, based on data supplied by the beneficiary (government agencies, local authorities, economic agents), appropriate methods of action for reducing adverse effects on industry, agriculture, forestry, water management and human settlements. Fuzzy algorithms in this field is new, and presume definition, clear delimitation and the analysis of the system which performing the tasks specified.**

***Index Terms* — environmental assessment, fuzzy model, sustainability**

I. INTRODUCTION

Public concern about environmental issues has prompted activity to obtain a detailed understanding of ecosystems, to establish operative norms and ranges for typical environments and to remediate damaged environments. Environmental concerns are so deeply felt that they have become the basis for organized political activity on national levels. The dynamics of any socio-environmental system cannot be described by the rules of traditional mathematics. Sustainability is difficult to define or measure because it is inherently vague and complex concept.

In this paper, a fuzzy model was developed, which uses data sampled from different environmental indicators that were then processed via fuzzy logic algorithms to derive measures for ecological sustainability of the region. Fuzzy logic is able of representing uncertain data, and handling vague situations where traditional mathematics is ineffective. Based on this approach we have developed a fuzzy model which uses basic indicators of environmental integrity, as inputs and employs fuzzy logic reasoning to provide sustainability measures on the local levels. A sensitivity analysis identifies the factors affecting sustainability. In this study, trials were made to identify those factors that influence the environment. About twenty indicators were tested and classified according to sensitivity as promoting, impeding, or having no effect on sustainability.

The method could become a useful tool to decision makers as they strive towards sustainability.

II. MODEL PRESENTATION

Environmental performance assessment related to a town region or a district is becoming a major issue worldwide and particularly in Europe. To assess the performance of an environmental system is necessary to make an integrated analysis of a variety of factors and the existing relationships between these factors often form a complicated problem. Indicators are often used with other types of information. In order to cope with performance assessment of an environmental system specific tools are needed and creative approaches. This is why in this paper we proposed a model based on fuzzy logic to establish ecological sustainability of a specified region. Accordingly, to our methodology the ecological sustainability of the environmental system is composed from three modules: water quality (WATER) soil integrity (SOIL) and air quality (AIR). Fig. 1 illustrates the dependencies of sustainability components.

Figure 1. Dependencies of sustainability components.

The configuration of the model is shown in Fig.2. The model is composed from different sets of knowledge levels. The inputs of each knowledge level represent the parameters which can be provided by the user or composite indicators collected from other knowledge levels. By using fuzzy logic and IF-THEN rules, these inputs are combined to yield a composite indicator as output which represents an input for the subsequent knowledge level. For instance, the third order knowledge level that computes indicator AIR combines indicators TYPE 1, TYPE 2, and TYPE 3 indicators of air quality, which are outputs of fourth order knowledge level. Then, AIR is used in combination with SOIL and WATER as input for the first order knowledge level and so assesses ENVIRONMENT SUSTAINABILITY. The indicators from the third knowledge level were divided into three types of parameters because this way the analyze we believe would be is more accurate [1].

The model is flexible in the sense that users can choose the set of indicators and adjust the rules of any knowledge level according to their needs and the characteristics the environmental system to be assessed.

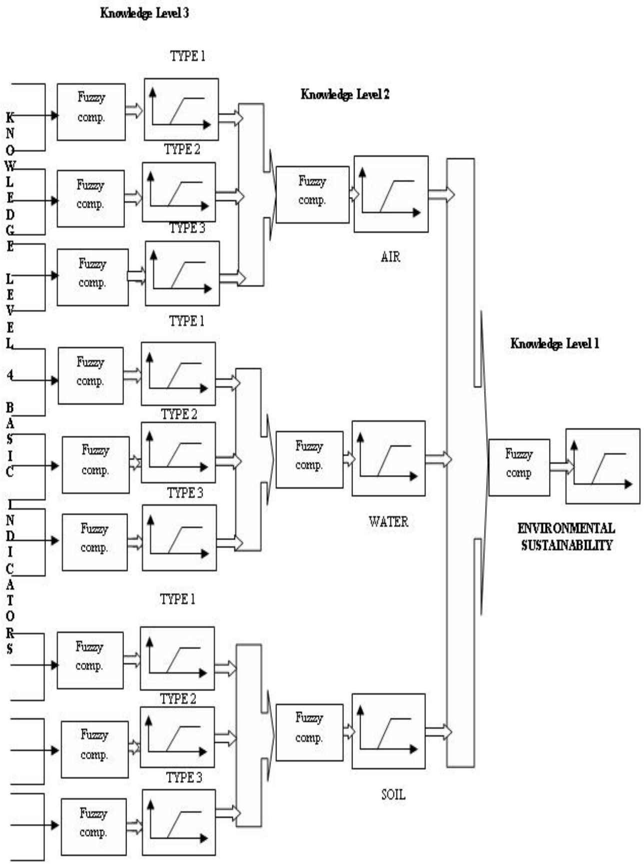

Figure 2. Configuration of environmental sustainability model.

III. ENVIRONMENT ASSESMENT METHODOLOGY

According to Fig. 2, the hierarchical structure of the evaluation problem consists of 4 levels. The first level represents the ultimate aim of the problem (environmental assessment), the second level represents decision criteria, the third level represents the evaluation criteria and the fourth level represents evaluation sub criteria.

The hierarchical structure is very useful for decomposing complex sustainability problems. The problem of environmental assessment is depending of many parameters such as air quality impact, water quality or soil integrity. Of course there are many factors that can influence the environment as biodiversity but this fact represent the object of another study more complex and more elaborate, and for the moment we consider that these three factors have the predominant role. These parameters are represented by the decision criteria; in the present paper the decision criteria are classified into three main categories namely AIR (air quality), WATER (water quality) and SOIL (soil integrity). In order to create the decision criteria several other parameters that affect the criteria are considered. These parameters are represented by evaluation criteria and so on.

The model uses a number of relevant knowledge levels to represent the interrelations and principles governing the various indicators and components and their contribution to the final decision of the expert system. The rules and inputs/outputs of each knowledge level are expressed symbolically in the form of words or phrases of a natural language and mathematically as linguistic variables and fuzzy sets. Examples of IF-THEN rules used in the model are:

- IF AIR is good AND WATER is bad, AND SOIL is good THEN QUALITY MANAGEMENT EVALUATION is average;
- By using fuzzy logic and IF-THEN rules, these inputs are combined to yield a composite indicator as output, which is then passed on to subsequent knowledge levels [3].

Fuzzy logic is a scientific tool that permits modelling a system without detailed mathematical descriptions using qualitative as well as quantitative data. Computations are done with words, and the knowledge is represented by IF-THEN linguistic rules. A system based on fuzzy logic can be considered an expert system which emulates the decision-making ability of human expert. The user supplies facts or other information to the expert system and receives expert advice for his queries. The internal organization of an expert system consists of a knowledge-base and an inference engine. The knowledge –base contains the knowledge with which the inference engine draws conclusions. The inference engine is a control structure which helps in generating various hypotheses leading to conclusions that from the basis of answers to user queries [4].

Fuzzy logic introduced by Zadeh permits the notion of nuance. It presumes that this condition could be anything from almost true/false to hardly true/false. Generally, a fuzzy set F in a universe of discourse X is described by a membership function μ_F, which maps the set X to the memberships space M [0,1]. The membership function μ_F (x) represents the grade of membership of x in F. The closer the value of μ_F (x) is to 1, the more x belongs to F [2]

The membership function that was used in the problem of environmental sustainability is shown in Fig. 3.

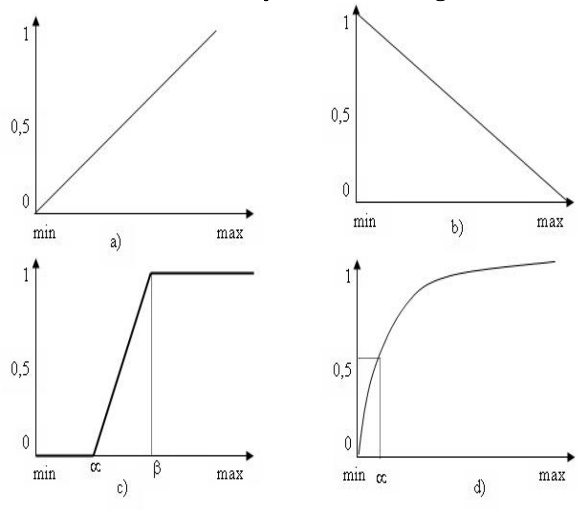

Figure 3. Membership function: a) linear increasing, b)linear decreasing, c) left trapezoidal, d)positive exponential.

In order to combine evaluation criteria two methods were used: weighted average and weighted product described in Eqs. (1, 2):

$$V_i = \sum_{j=1}^{n} w_j * v_{ij} \tag{1}$$

$$V_i = \prod_{j=1}^{n} v_{ij} \cdot w_j \tag{2}$$

where V_i - represents the final grade of area *i*, w_j - represents the relative importance weight of criterion *j*; v_{ij} - represents the grading value of area *i* under criterion *j* and *n* represents total number of criteria.

IV. CASE STUDIES

To test the environmental assessment methodology the model has been applied to the town of Iasi in Romania. Iasi is located in the northeast part of Romania, having an area of 3770 ha and a population of 340.000. Until the middle of ‘90 the town was an important industrial center in Romania. Since then, the economy is unfortunately decreasing, but pollution with solid and liquid waste, toxic waste has reached high values.

The primary components of environmental sustainability (AIR; WATER, and SOIL) and their sensitivities to various input indicators were computed (Table 1). If the derivative with respect to a basic indicator is positive, then the indicator is classified as promoting indicator because an increase of his value will lead to a higher sustainability. On the other hand, if the derivative is negative, then the indicator is classified as impeding indicator, because an increase of his value will reduce the degree of sustainability. If the derivative is zero, then it is accepted the idea that the respective parameter has no substantial effect upon de sustainability (Table 2). According to the sensitivity analysis projects can be proposed to improve promoting indicators, and taking measures to correct impeding factors.

TABLE I. PARAMETERS USED IN THE SUSTAINABILITY MODEL

Component	Type 1	Type2	Type 3
AIR	(1) SO_2 emissions, (2) CO_2 emissions (3) CH_4 emissions	(4-8) Atmospheric concentration of greenhouse and ozone depleting gases: CO_2 , NO_2 SO_2 CH_4 CFC-12	(9) Fossil fuel use, (10) Primary electricity production (11) Public transportation
WATER	(12) Water pollution (13) Urban per capia water use (14) Freshwater withdrawals	(15) Annual internal renewable water sources	(16) Percent of urban wastewater treated
SOIL	(17) Solid and liquid waste generation (18) Population density (19) Growth rate (20) Commercial energy use	(21) Net energy imports (22) Domesticated land (23) Forest and wood-land area	(24) Primary enery production (25) Nationally protected area (26) Urban households with garbage collection

According to the sensitivity results, a sustainable environment is dependent on enhancing the following factors in order of importance:

Percent of urban wastewater treated and *Forest and wood-land area* and decreasing the following impeding factors:

Water pollution, NO2 emissions, Freshwater withdrawals; Solid and liquid waste generation, SO2 emissions

TABLE II. GRADIENTS OF ENVIRONMENTAL SUSTAINABILITY

	Description of indicator	***Gradients of environmental sustainability***
SOIL		
1	Solid and liquid waste generation	-0,00125
2	Population density	-0,00064
3	Growth rate	0,0000
4	Domesticated land	0,0000
5	Forest and wood-land area	0,00250
WATER		
6	Urban per capia water use	-0,00265
7	Freshwater withdrawals	-0,00249
8	Phosphorus concentration	-0,00479
9	Water pollution	-0,00415
10	Percent of urban wastewater treated	0,00257
AIR		
11	Atmospheric concentration of greenhouse and ozone depleting gases: CO_2 , NO_2 SO_2 CH_4 CFC-12	-0,00219
12	NO2 emissions	-0,00513
13	SO2 emissions	-0,00514

V. CONCLUSIONS

Policy makers need a tool based on scientific information to forecast the effects of future actions on sustainability and establish policies for sustainable development.

In this paper we developed a model, an attempt to provide an explicit and comprehensive description of the concept of sustainability. Using linguistic variables and linguistic rules, the model gives quantitative measures of ecological sustainability. A sensitivity analysis of the model permits to determine the evolution of sustainability variables subject to perturbations in the value of basic indicators. Then, the problem of sustainable decision-making becomes one of specifying priorities among basic indicators and designing appropriate policies that will guarantee sustainable progress.

The model proposed provides new insights of sustainable development, and it may serve as a practical tool for decision – making and policy design at the local or regional levels.

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