



The assessment of local sustainability using fuzzy logic: An expert opinion system to evaluate environmental sanitation in the Algarve region, Portugal



Daniel Canavese^{a,*}, Neli Regina Siqueira Ortega^b, Margarida Queirós^c

^a Federal University of Paraná, Coast Campus, Matinhos, Brazil

^b University of São Paulo, School of Medicine, Center of Fuzzy Systems in Health, São Paulo, Brazil

^c University of Lisbon, Center of Geographical Studies, Lisbon, Portugal

ARTICLE INFO

Article history:

Received 17 June 2013

Received in revised form

17 September 2013

Accepted 19 September 2013

Keywords:

Fuzzy logic

Fuzzy knowledge-based modeling

Sustainable development

Environmental health assessment

Local-regional assessment

Decision making support

ABSTRACT

Understanding the relationship between environmental factors and public health is critical to improving sustainability at a sub-national level. Proposals to evaluate the status of environmental health in a region must consider factors including the diversity of indicators, geographical scale, incomplete or inaccurate data and the need for focused methodologies that capture the complexity of this subject. This paper presents the design of a system based on expert knowledge to assess environmental sanitation in cities in the Algarve region of Portugal. It was used fuzzy logic to assess uncertainties in the system. Conceptually, the use of fuzzy sets theory is simple and can integrate human expertise. The current proposal demonstrates the usefulness of aggregating information and opinion-based classifications to categorize municipalities according to their environmental health characteristics. The analysis shows that improved environmental sanitation conditions have been observed in municipalities located in the region's center. In the west, municipalities have worse conditions not only in environmental health but also in other sustainability indicators. A main feature of the system, presented here, is the ability for users to select variables to be considered by experts and opinion-makers without re-modeling, which allows the system to be adapted to different situations and scenarios. Therefore, the assessment method based on fuzzy logic is useful to investigators looking for a more systemic assessment of sustainability.

© 2013 Published by Elsevier Ltd.

1. Introduction

Environmental health has been a main concern since the origin of sustainable development concepts (WCED, 1987; United Nations, 1992). The relationship between environmental factors and public health is central to improving sustainability. Increased focus on this subject has expanded interest in investigations conducted at the regional level. At this scale, researchers may help authorities respond to specific demands and promote more effective local policies. For this reason, the main players involved in this key issue have been interested in exploring environmental health factors at the regional level. However, this method of evaluation has encountered challenging perspectives.

The number of proposed indicators used to assess environmental health at the regional level has increased. Fortunately, as suggested by Tanguay et al. (2010), there are a considerable number of indicators that have been proposed to assess sustainability. Nevertheless, choosing among them and setting a reference group has

been a difficult task. There is a lack of consensus on which indicators are indispensable because this decision is not only based on scientific knowledge and techniques but also, as noted by Rametsteiner et al. (2011), involves political negotiation.

The geographical scale of analysis plays a significant role on the selection of indicators. Moldan et al. (2012) discuss that although environmental limits at the planetary level are now quite evident, sustainability is interlinked with geographic scales. At the same time, the majority of indicators focus on a national scale, and research on this issue at local and regional levels is still relatively new. Although various initiatives have been developed to date, there are no standard criteria to determine what information would better represent the different geographical scales (Ramos, 2009; Singh et al., 2009; Dahl, 2012).

Similarly, when considering the use of tools for data analysis, different methodologies have been used to capture the complexity of environmental health issues. Some authors have argued that sustainability analyses should use concepts from complex theory and post-normal science (Ravetz, 2004; Gatrell, 2005; Hezri and Dovers, 2006; Queirós, 2009; Canavese et al., 2012). This theoretical perspective contributes to a wider and more holistic view of the field. There is an urgent need for methodologies based on

* Corresponding author. Tel.: +55 4197105103.

E-mail address: daniel.canavese@ufpr.br (D. Canavese).

quali-quantitative information and expert knowledge that take into consideration the uncertainty and inaccuracies of the data or methodologies. Methods used to study environmental health at a regional level have to manage issues such as diverse indicators, unequal data availability at different geographical scales and incomplete or inaccurate data.

1.1. The contributions of fuzzy logic

Fuzzy logic, a theory formally presented in 1965 by Zadeh, has appropriate contributions to this work. Some of its general properties, such as the capacity to deal with uncertainty, the ability to model complex realities, the use of subjective information based on human knowledge and experience, the relatively simple math involved and the capacity to provide precise answers, prove that it can be used as an adequate modeling tool (Ross, 1995; Ortega et al., 2008; Massad et al., 2008; Zadeh, 2008). The fuzzy sets theory has already been used in diverse applications of interest to this study (Silvert, 1997, 2000; Massad et al., 1999; Mckone and Deshpande, 2005; Ocampo-Duque et al., 2006; Icaga, 2007; Marchini et al., 2009; Ascough et al., 2008; Janssen et al., 2010; Prato, 2010).

In the area of sustainability, Andriantiatsaholiniana and Phillis (2001) developed a methodology using fuzzy logic, to examine the sustainability of cities, states and countries. Similarly, in his investigation, Prato (2005) determined that conventional approaches are incompatible with the numerous uncertainties in ecosystem assessments and that the use of fuzzy logic overcomes this problem. Nevertheless, the author states that fuzzy logic requires more data than other approaches, which can be partially explained by the fact that the theory aggregates quantitative and qualitative data in addition to information provided by human knowledge. Fuzzy logic has been used in a variety of approaches involving sustainability assessments. For example, both Liu (2007), while developing a multi-criteria decision-making system which addresses subjective judgments, and Beynon and Munday (2008), while considering uncertainty in environmental footprint estimations, used fuzzy logic. Recently, Canavese and Ortega (2013) proposed a fuzzy rule-based system to develop an indicator to integrate factors dealing with health and health sanitation. Fuzzy logic appears to be suitable for incorporating both ecosystem complexity and expert opinion. Considering that both are predicates of this study, fuzzy logic was chosen as a key aspect of the methodology used.

1.2. Region overview

The Portuguese region of Algarve, with 16 municipalities, corresponds to 5% of the total national territory with a coastline of approximately 200 km (Fig. 1). It is located in the southern part of the country, bordering Spain and the Atlantic Ocean. According to census data developed by the National Institute of Statistic (2011), the region has a total of 448,000 inhabitants that represent nearly 4% of the total Portuguese population.

In this region, which is the second most-visited destination in the country, tourism is the main economic activity. This sector plays an important role in determining investments and directing local policies. Both the Ministry of Health and the Ministry for the Environment have administrative delegations located in the city of Faro.

Coelho et al. (2010) have researched alternative strategies used to evaluate Algarve's sustainability. They developed a framework to promote the selection of key indicators and to involve regional stakeholders. One of the motivations behind this framework is the desire to decentralize public policy-making to cities or local communities; for that reason, their strategy is intrinsically connected to regional values, concerns and hopes. The studies of Ramos (2009)

and Mascarenhas et al. (2010) investigated local sustainability indicators that are of common interest to the municipalities of the Algarve region. The authors presented a consensus list of indicators to support sustainability benchmarking. In addition to issues such as economics, education and social assistance, environmental sanitation is one of the consensus indicators included in their studies.

Establishing both a list of indicators of interest to all of the municipalities of Algarve as well as mutually agreed-upon standards is an indispensable starting point for monitoring and planning. Here it is presented the development of an expert knowledge-based system using fuzzy logic, to assess environmental sanitation in the municipalities of Algarve.

2. Methodology

The system, designed for analyzing the state of environmental sanitation in Algarve's municipalities, was conceived considering the following: (I) the application of fuzzy sets theory and its seminal theory, (II) the participation of a pool of experts and their contributions, (III) the use of available local information about environmental sanitation, and (IV) an operational goal of assessing the sustainability status of the region with a synthesized numeric value.

To be part of the expert's pool, the participants had to meet established criteria. It was selected local stakeholders in the public and environmental health fields, taking into consideration the stakeholders' job titles and length of employment. These selected professionals also agreed to voluntarily participate in workshops lasting from 1 to 2 h. Four professionals from the local Ministry of Health who were involved in environmental management and had an average seniority of ten years participated in this study.

The concepts of fuzzy sets theory are based on fuzzy logic. While in classical logic the membership of sets is binary (0 or 1), in fuzzy logic there are multiple degrees of membership (μ) valued in the real interval from 0 to 1. Fuzzy logic may be considered to be a generalization of the classical bivalent logic. Concretely, that logic is closer to human reasoning, which is a useful property when dealing with the development of a system based on expert knowledge and available data.

There are two parts of this theory used in the development of linguistic models. The first is *fuzzification*. The fuzzification phase aims to organize a knowledge base that captures the experts' knowledge about a topic. It represents the translation of the expert and observed data into fuzzy sets and a corresponding knowledge base composed of inference rules describing different implications among these fuzzy sets. The second phase, referred to as the *defuzzification* phase, involves the results of the model, manipulating uncertainty and providing a well-defined output. The fuzzy logic toolbox in MATLAB (The Math Works, 2009) package was used.

The resulting environmental sanitation scores have been compared with other sustainable development indicators. A Spearman correlation analysis was performed between the synthetic score as well as two quantitative indicators. The first one is the Human Development Index (HDI), which combines indicators of life expectancy, education and income (United Nations, 1990). The second one is the Synthetic Index of Quality of Life (ISQV), a measure based on a set of indicators in three areas, physical conditions, social conditions and economic conditions (Manso and Simoes, 2009).

2.1. The fuzzy system architecture

Fig. 2 displays a diagram of the architecture of the obtained fuzzy system. It represents the experts' final proposal, which was reached by consensus. The evaluation of the state of environmental

Download English Version:

<https://daneshyari.com/en/article/4373367>

Download Persian Version:

<https://daneshyari.com/article/4373367>

[Daneshyari.com](https://daneshyari.com)