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Spatial multicriteria analysis for sustainability assessment: A new model for decision making

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ABSTRACT

Policy makers have to consider the sustainability perspective in strategic planning decisions. Identifyand measure the level of sustainability, through its three dimensions, is a priority. Therefore, the aim of this work is to present a new model, called GeoUmbriaSUIT, integrating Multicriteria Analysis and Geographic Information Systems, specifically developed for helping Decision Makers to take policy decisions about sustainability in planning. The model provides outputs which are easy to be understood by not experts; the evaluation path is traceable and transparent, thanks to back analysis.

To better explain the potentiality of GeoUmbriaSUIT and its functioning, a case study about Malta is described. Our results showed that in four regions of Malta the best dimension was the environmental one, while only for two regions (Northern Harbour and Southern Harbour) respectively the economic and social dimensions obtained the best scores. The integration of MCDA-GIS resulted to be a useful tool for sustainability assessment.

1. Introduction

Sustainable development is the guiding principle to address policies and development strategies at global level (Griggs et al., 2013). Every policy decision should be made taking into account not only the economic perspective, but at least also the social and environmental ones (Bohringer and Jochem, 2007). Despite the consideration of new dimensions of sustainability for example the institutional, cultural and technological ones, the main effort should be to identify, understand and measure first of all the economic, social and environmental dimensions (Sala et al., 2013). In addition to this, in the allocation of public funds for the development of human activities, decision makers should try to support those areas experiencing difficulties in achieving a balance between economic prosperity, social equity and environmental protection, and therefore requiring more urgent economic incentives to reach sustainability (UNCTAD, 2015).

In order to achieve these objectives, decision makers need adequate technical support, since the basis of good decision making rests on ex ante evaluation, in progress monitoring and ex post evaluation. However, sustainability assessment is one of the most complex types of appraisal methodologies (Sala et al., 2015).

Sustainability assessment can be developed using many different approaches, depending on the objectives, the scale and the scope (Cinelli et al., 2014). As a result, the literature on this topic is growing, offering a wide variety of different approaches (Bond et al., 2012). Some examples of models for sustainability assessment can be found in Boggia and Cortina (2010), who developed a methodological approach based on multi-criteria analysis to assess sustainability in specific areas, Kropp and Lein (2012) and Lombardi and Ferretti (2015), who produced aggregated indexes of sustainability, Lopez and Monzon (2010), who proposed a MCDSS working with three different indices, and the United Nations model called “dashboard of sustainability” (2015).

Waas et al. (2014) identified four different purposes of sustainability assessment in a decision-making strategy for sustainable development:

- Information generation for decision-making.
- Operationalization and forum for participation, debate and deliberation.
- Social learning.
- Structuring complexity.

Being a multi-dimensional concept, the assessment of sustainability is no longer based on a single indicator but on a set of indicators (Singh et al., 2012), which are mostly focused on economic, social and environmental measures (Pollesch and Dale, 2016). A basic requisite for a meaningful use of indicators and indices is the possibility to aggregate and make them comparable (Bohringer and Jochem, 2007). As a matter

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of fact, the most appropriate tool for evaluating sustainability is a set of indicators, integrated in a tailored assessment methodology (). Multi-Criteria Decision Analysis (MCDA) is one of them (Cinelli et al., 2014).

MCDA assumes a central role in the multi-dimensional evaluation process. It is used to solve complex problems by assessing all the variables, both individually and collectively, and assigning specific importance to each one (Cortina and Boggia, 2014). Thus, MCDA has been widely used to evaluate sustainability (Liu, 2007; Shmelev and Labajos-Rodrigues, 2009) and has been indicated as the appropriate tool for its assessment (Munda, 2005; Bond et al., 2012). One of the current research challenges in sustainability assessment is moving from multi-disciplinarity towards transdisciplinarity via interdisciplinarity (Sala et al., 2013). MCDA is a typical transdisciplinary approach.

An important feature of sustainability assessment is its ability to provide decision makers with an evaluation of both global and local systems, considering short and long time reference periods, in order to determine actions to be implemented in a certain area (Ness et al., 2007). The practice of ranking countries can be a way to stimulate decision makers to improve their position (Dahl, 2012) and therefore their national levels of sustainability. However, the evaluation cannot be solely at a national level, although it is perhaps the most significant one (Dahl, 2012) and the most applied in international fora (Canavese et al., 2014). Systems at a local level must be investigated in order to have effective and realistic evaluations of specific territorial contexts, and to determine sound planning actions. Sustainable development is considered achievable if it originates on the local level; a bottom-up approach from local to supra-national (Ravetz, 2000). According to the European Union Policy, one of the most important drivers of sustainable development is the subsidiarity principle: the individual and the civil society must act freely, limiting the intervention of the institutions only when necessary.[1] Accordingly, the interventions must be made to the institutional level closest to the people, with the widest possible participation.

Considering all these aspects, the aim of this work is to present our model for sustainability assessment at territorial level, called GeoUmbriaSUIT, which integrates the MCDA framework and Geographic Information Systems (GIS) (Massei et al., 2014). Spatial MCDA and the creation of a multi-criteria spatial decision support system (MCSDSS) combine the data management of GIS with the judgment capabilities of MCDA (Massei et al., 2014). A MCSDSS is part of the larger group of Spatial Decision Support Systems and it consists of three parts (Malczewski, 2010): a geographical component (database and management system), a MCDA model-based system and an interface. How much the MCDA and GIS parts are integrated and the presence of a unique interface determines the level of integration of the system. Several authors (Chakhar and Martel, 2003; Laskar, 2003; Chakahar and Mousseau, 2008; Massei et al., 2014,b; Ottomano Palmisano et al., 2016a,b) used a classification into three categories based on the level of integration: indirect, built-in and complete integration. However the only type of integration which allows to use the same database, interface and to access both the MCDA and GIS tools at any time during the analysis, is the complete one (Malczewski, 2010; Massei et al., 2014). More details on the theoretical ground of integration can be found in Chakhar and Martel (2003), Chakhar and Mousseau (2007) and Malczewski (2010).

Real life applications of MCDA-GIS integration have grown significantly in the last twenty years. Several authors focused on the usefulness of application in urban planning (Banai, 2005; Kropp and Lein, 2013; Lombardi and Ferretti, 2015), sustainable management and planning of forests (Sheppard, 2005; Store, 2009), catchment basins (Macleod et al., 2007; Prato and Herath, 2007; Kang and Lee, 2011) and ecological areas (White and Fennessy, 2005; Ferretti and Pomarico, 2013). However, examples of MCDA- GIS strategic sustainable planning applications are still rare (Banai, 2005; Ferretti and Pomarico, 2012; Lopez and Monzon, 2010; Manos et al., 2010; Ottomano Palmisano et al., 2016a,b). The present work describes a new integrated tool suitable for strategic and sustainable planning: GeoUmbriaSUIT. The case study where the model is applied is Malta, an island state in the middle of the Mediterranean Sea and the southernmost member of the European Union.

GeoUmbriaSUIT can be used at local, regional and national level, for comparing sustainability of different territorial areas. The three dimensions of sustainability are represented by means of a specific set of indicators. Currently, the model we proposed is the first Multi-Criteria Spatial Decision Support System (MCSDSS), based on a complete integration of MCDA and GIS, especially developed for evaluating sustainability. As of July 2017, GeoUmbriaSUIT has been downloaded by several scholars and experts within the sector. In particular, the plugin has been installed 13,271 times in total. This has meant that over the last three years the model has been tested at international level on many occasions. It was presented at international conferences (Ottomano Palmisano et al., 2015; Paolotti et al., 2015; Rocchi et al., 2015; Boggia et al., 2016; Paolotti et al., 2016) and the first release of the version has already been applied to an Italian case study (Ottomano Palmisano et al., 2016a). The version presented here is the stable release.

The paper is structured as follows: after a description of the methodology used (Section 2) and of the case study (Section 3) results and discussions are presented in Section 4. The main conclusions to the study are presented in Section 5 of this paper.

2. Methodology: the new model GeoUmbriaSUIT

In this section we present our MCDA-GIS model, GeoUmbriaSUIT (http://plugins.qgis.org/plugins/), aimed to evaluate sustainability of certain areas at local, regional or national level using multiple criteria that cover environmental, economic and social aspects. We developed GeoUmbriaSUIT in 2014; it represents an evolution of the model UmbriaSUIT 1.0,[2] developed by Boggia et al. (2007). GeoUmbriaSUIT consists of a plugin[3] working in QuantumGIS (GIS Development Team, 2017), which is free and open-source GIS software, widely used in several fields and applications. The model allows for a complete MCDA-GIS integration (Massei et al., 2014): it means, as explained above, that MCDA and GIS use the same interface and the same database. The MCDA approach is activated inside the GIS software exactly like any other analysis function.

Following is a brief description of the model. A complete manual of GeoUmbriaSUIT and a guide to installation are available at: http://maplab.alwaysdata.net/geoUmbriaSUIT.html.

[1] Official Journal of the European Communities (OJ) C112, 20 December 1973, page 7.

[2] UmbriaSUIT 1.0 is a monitoring tool of environmental and socio-economic aspects of a territory, for integrating the sustainability principle in local planning, developed in collaboration with Regional Environmental Protection Agency of Umbria (Italy). It was based on a weighted summation algorithm, calculated on two sets of indicators, environmental and socio-economic, obtaining an index of sustainability to compare different territorial areas.

[3] Among the many existing capabilities for geographic analysis, there is the possibility of developing tools for customization of the software, by creating plugins. The plugin is a not standalone program that interacts with another program to expand or extend its original functionality, allowing the use of new features not present in the main software. GeoUmbriaSUIT is basically a plugin, written in python language, which uses the library (set of functions or data structures) made available by the same QGIS to perform the processing requested by the user. In addition to perform the calculations provided by the algorithm evaluation, input and output data can be managed like any other geographic data and the user is free to operate additional geostatistical analysis, geoprocessing operations or reporting. It represents, in fact, the perfect integration of a multi-criteria analysis procedure with the geographical instrument. The type of data processed by the plug-in is the vector format.