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Design of a data-driven environmental decision support system and testing of stakeholder data-collection

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ABSTRACT

The aims of this paper are to present the requirements and top level design of a decision support system that facilitates the exchange of environmental information between local level and higher levels of government, as well as to assess the possibility to include the local individual in the decision making process. The design of a tool for data collection and exchange of available data also aims to predict impacts of small-scale locally oriented actions by the local administration and residents on incomes and biodiversity, monitor results of the decisions that follow such prediction and inform central policy assessors to enable appropriate tuning of regulatory and fiscal incentives. The potential of data gathering for use in a DSS was tested by case studies across Europe. The main challenges for implementing effective environmental decision support are now more socio-economic than technical, requiring also a more local-orientated attitude of researchers and government.

1. Decision support systems background and concepts

Decision Support Systems (DSSs) are computerized systems which are based on two main pillars. Information Systems Science contributes to the planning and the application of DSSs with the supply of the necessary tools, materials and software, while the Sciences of Operational Research and Management provide the general theoretical frameworks for the analysis of various decisions. Other disciplines are also used to various extents in DSSs, including Systems Science, Artificial Intelligence, Cognitive Science and Psychology (Eom, 2008). Thus, modern DSSs are truly interdisciplinary. Indeed, Alter (2004) correctly states that contemporary DSS has developed into an umbrella term spanning a broad range of systems and functional support capabilities.

Arnott and Pervan (2008) analyze in depth the academic field of decision support systems in an exhaustive literature review; Holsapple and Whinston (1996) and Holsapple (2008) provide the basic structure of a DSS, while Manos et al. (2010a) presented a simpler, yet more concise and model-driven description of a DSS architecture. Liu et al. (2010) review the current research efforts with regard to integrated DSS and Power (2001, 2008) identifies five generic DSS types, as follows: model-driven DSS, data-driven DSS, knowledge-driven DSS, document-driven DSS and communications-driven DSS. According to this scheme, model-driven DSSs emphasize access to (and manipulation of) deterministic, optimization and/or simulation models and use limited amounts of data, which differentiates them from the data-driven DSSs that are capable of utilizing huge data warehouses. A project to develop the top level design for a Transactional Environmental Support System (TESS, www.tess-project.eu) was funded under the European Commission's 7th Framework Programme (FP7), as a system to synthesize mainly the first two of these DSS categories, using deterministic, stochastic and simulation models in various risk analysis scenarios that may also require large sets of geo-spatial data. The project ran from 2008 to 2011 (Kenward et al., 2013a).

DSSs often attempt to offer solutions in modern managerial environments which are full of redundant and complex information, in which rapidly evolving situations engage a number of individuals in the decision making process – very often on an international level. In these circumstances, DSSs projects have been known to fail (Arnott and Dodson, 2008), even at the stage of requirements analysis and initial development. That is why, especially in ambitious and complex projects like TESS, which need to involve state of the art web technologies (Bhargava et al., 2007; Zahedi et al., 2008), careful planning is an essential prerequisite, especially in order to check the feasibility of the system design and to ensure that the final users will actually use and promote it.

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Although technology for environmental DSS in both rural (Benson, 1995) and urban (Culshaw et al., 2006) conditions is long-established, a major lesson from these previous projects was the need to build a system that fits the requirements of users, by working with them throughout the design process.

2. Current status of environmental research in the EU

Topics like sustainable development, farm regional planning, climate change, waste management, food supply chain management, environmental protection and biodiversity conservation plus a number of other relevant issues are becoming major focal points of international research. All are interconnected; a major imbalance in one tends to affect the others and most can benefit from adaptive management. For both these reasons, a critical factor stressed by the Environmental European Agency report (Schutyser and Condé, 2009) is that continually updated datasets are needed. With our entire economy underpinned by ecosystem services, and biodiversity an important component in the ability of the ecosystems to deliver much needed services, how will appropriate datasets be obtained and updated at a regular basis? Who will fulfill the task and with what funds?

The Natura 2000 network of protected areas is a cornerstone of nature conservation policy in the European Union, covering many areas that are being enlarged through updates and expansion of EU political borders (Maiorano et al., 2007). In addition, directives for Environmental Impact Assessment (EIA), complemented by Strategic Environmental Assessment (SEA) have been defined and introduced by the EU as a requisite for projects and programmes having a significant effect on the environment. But biodiversity at local level is still declining at alarming rates across Europe (e.g. Thomas et al., 2004), despite measures like the growth in number of nationally designated protected areas in 39 European countries (Schutyser and Condé, 2009). The European target of halting the loss of biodiversity by 2010 has slipped away (Dimas, 2009) and moved a decade ahead, to 2020 (EU COM, 2011). In many circumstances, a regulatory framework is simply not enough (Manou and Papathanasiou, 2009) because a myriad small and locally based land-use decisions outside protected areas summate to change the environment. The resulting habitat degradation and loss is often not immediately perceivable, as Kuussaari et al. (2009) explain with the notion of 'extinction debt'. DSS design in TESS was aimed specifically at these small and locally based decisions.

The EU has funded much environmental research related to TESS, including a project on Governance and Ecosystem Management for the CONservation of BIOdiversity (www.gemconbio.eu, Manos and Papathanasiou, 2008) that lay foundations for the TESS project. GEMCONBIO brought together 12 partners from Greece, Sweden, UK, Germany, Belgium, Hungary, Romania, Iran, Indonesia, and Bolivia during 2006–2008 to explore the interactions of governance processes and institutions with sustainable development objectives and conservation of biodiversity across more than 30 thematic and geographic case studies. A worrying finding was that where biodiversity diminishes, local people may to lose interest in the natural environment, as shown by fewer people engaging in wildlife-related activities in the most urbanized parts of Europe (Kenward and Sharp, 2008). However, the strongest positive associations with conservation and sustainable use of biodiversity were for knowledge leadership and adaptive management (Kenward et al., 2011), which are quintessential characteristics of a DSS.

Other EU-funded projects relevant to data collection for biodiversity policy implementation – and therefore also directly relevant to the TESS – are ALARM, SCALES and EU BON. ALARM (Assessing LArge scale Risks for biodiversity with tested Methods, www.alarmproject.net), aimed *inter alia* to establish socio-economic risk indicators related to the drivers of biodiversity pressures as a tool to support long-term mitigation policies. The SCALES project (Securing the Conservation of biodiversity across Administrative Levels and spatial, temporal, and Ecological Scales, www.scales-project.net) has as a general objective to provide the most appropriate assessment tools and policy instruments to foster the capacity for biodiversity conservation across spatial and temporal scales and to disseminate them to a wide range of users, while EU BON (European Biodiversity Observation Network, www.eubon.eu) focuses on the delivery of near-real-time relevant data, both from on-ground observation and remote sensing, to the various stakeholders and end users ranging from local to global levels. A relevant COST (European Cooperation in Science and Technology, www.cost.eu) action was also launched in 2011, called HarmBio (Harmonizing global Biodiversity modeling, www.harmbio.eu), aiming to harmonize current biodiversity models and datasets in order to improve the reliability of future projections of biodiversity change (e.g. under various policy options which may be used to assist environmental decision making). The EEA (European Environmental Agency, www.eea.europa.eu) has launched the BISE (Biodiversity Information System for Europe, http://biodiversity.europa.eu) initiative for bringing together biodiversity datasets (albeit without analytic capabilities) and the Eye on Earth system (www.eyeonearth.org) that focuses on GIS data. On a global scale UNEP (United Nations Environment Programme) is working in parallel with the EU initiatives on the Global Environment Outlook, (GEO, www.unep.org/geo) and The Economics of Ecosystems and Biodiversity (www.teebweb.org).

3. Environmental decision making

De Marchi et al. (2012) provide a survey of formal methods available to help policy makers improve their decisions, while Moran et al. (2006) have worked in the analysis, implementation and assessment of public policies. Tsoukias et al. (2013) suggest a framework to support the use of analytics in the policy cycle – not only for environmental issues – and conceptualise it as "Policy Analytics". They correctly identify the need to use tangible and intangible public resources during the decision making process, the engagement of many diverse stakeholders with different and often conflicting interests, and the long time horizon needed for today's policy cycle. The role of stakeholders can often be complicated but their participation throughout will generally produce better decisions, as they are the ones who will bear the consequences of these same decisions (Voinov and Bousquet, 2010). Laniak et al. (2013) also introduce the concept of Integrated Environmental Modeling and using their own words this is 'inspired by modern environmental problems, decisions, and policies and enabled by transdisciplinary science and computer capabilities that allow the environment to be considered in a holistic way'.

It is in the above context that environmental decision makers need robust DSS tools; indeed, a resent advice paper prepared by the LERU biodiversity working group (League of European Research Universities, De Meester et al., 2010) recommends investing in interoperable databases using adopted standards as well as tools to use these data. Such DSSs combine environmental modeling techniques and IS technology in a fast-developing field; Jakeman et al. (2008), followed by Manos et al. (2010b) and Andreopoulou et al. (2011) all edited books on agricultural and other environmental decision support systems. Recently, McIntosh et al. (2011) identified the key research challenges for the development and adoption of Environmental DSSs and provided some recommendations for addressing them.