Environmental Modelling & Software 98 (2017) 63–74

Contents lists available at ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

What do we know about decision support systems for landscape and environmental management? A review and expert survey within EU research projects

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ARTICLE INFO

Article history:
Received 18 October 2016
Received in revised form
14 July 2017
Accepted 29 September 2017
Available online 9 October 2017

Contents

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https://doi.org/10.1016/j.envsoft.2017.09.012
1364-8152/

1. Introduction

Due to globally rising food demand and the scarcity and depletion of natural resources, agricultural productivity and environmental conservation need to be managed simultaneously (Buckwell et al., 2014). The development of information and decision support systems (IS/DSS) is expected to support effective and resource-efficient management of agricultural and environmental systems through the application of a scientifically sound and robust knowledge basis. Decision support tools can help tackling the complexity and trade-offs between agricultural and environmental systems (Manos et al., 2010). Subsequently there has been an increased effort in the recent years to develop frameworks, information platforms and other instruments and processes of knowledge transfer to inform and support decisions in agriculture, landscape and environmental management (Andersson-Sköld et al., 2014; Kersten et al., 2002; McIntosh et al., 2008, 2011; Romañach et al., 2014; Tayyebi et al., 2016a; Volk et al., 2010).

In general, IS/DSS are based on the principles of knowledge exchange and transfer, which encompass co-production, transformation and translation of knowledge (Fazey et al., 2013). Through these processes knowledge is transferred from one entity (e.g. place, person, ownership) to another (Major and Cordey-Hayes, 2000) and one of the units is affected by the experience of the other (Argote and Ingram, 2000). Therefore the effectiveness of these systems requires the consideration of (i) the relevant actors and their roles as scientists, stakeholders and end-users, (ii) the knowledge characteristics to be transferred (Hall et al., 2000) as well as (iii) the interface through which knowledge is transferred to end-users. IS/DSS tools connect scientists, stakeholders and end-users, such as policy makers or practitioners, to enable effective transfer of policy-relevant knowledge (King, 2006), methods and operational skills (Kim et al., 2011) and to support evidence-based decision-making (Holmes and Clark, 2008). By providing computer-based interactive, flexible, and user-oriented information, particular IS/DSS aim to facilitate knowledge transfer processes to improve the accessibility to existing knowledge beyond the individual's reach and making it more independent from the relational context (Kim et al., 2011). IS/DSS enable knowledge management activities which often address complex management problems (Sojda, 2007), collaborative information sharing and social and organizational learning (Evers et al., 2016), especially between research and the practice of policy and decision-making. Due to the complexity of the human-environment interaction, the diversity of land use actors, political aspirations and regulations, and the juxtaposition of scientific and practitioner's knowledge, the facilitation of knowledge transfer through IS/DSS in agriculture, landscape and environmental management is particularly important.

However, the extent to which research effectively influences land-use related policy making and practice, e.g. through IS/DSS depends on a number of factors. This includes the relevance, legitimacy and accessibility of the knowledge (Contandriopoulos et al., 2010; de Vente et al., 2016). In addition, Reed et al. (2014) suggest that an adequate representation of the different stakeholders' knowledge needs and priorities, the development of long-term and trusting relationships based on a two-way dialogue between different stakeholders, the delivery of tangible outputs that are of value for (at least some of) the stakeholders and monitoring and reflection on the knowledge transfer process are proposed principles for the successful practice of transferring knowledge. Nevertheless, a low adaptation to user needs and capabilities has been repeatedly found in IS/DSS (van Delden et al., 2011). Often, due to different languages and paradigms within which policymakers and developers operate and by cultural and technical barriers (Tayyebi et al., 2016b). Besides, very few IS/DSS take into account trade-offs both between different ecosystem services and beneficiaries or users and ways of handling these trade-offs. For example, it is easy to imagine users' conflicts with regards to the production and consumption of ecosystem services related to agri-environmental issues such as agricultural non-point pollution, farmland biodiversity, etc. In addition, also the lack of public, inexpensive accessibility to tools and data are limiting the applicability and use of tools (Tayyebi et al., 2016a).

Over the past decade, many research projects in the field of agriculture, environmental and landscape management have developed a wider range of IS/DSS to disseminate accessible and applicable academic knowledge for decision and policy making. These systems and tools differ in the kind of analytic or generic information and type of targeted users, such as land managers, policy makers, stakeholders or scientific community (Kersten et al., 2002; McIntosh et al., 2008). There are also differences regarding the extent to which end-users have been involved within the IS/DSS development process, which has been recognised as a factor influencing their effectiveness.

However oftentimes the experience and knowledge about the IS/DSS development and implementation is rather fragmented among the developers. Beyond small scale comparative analyses of IS/DSS (Lynam et al., 2007; Volk et al., 2010) and empirical surveys among developers (McIntosh et al., 2011), structured reviews of the heterogenic landscape of IS/DSS are seldom in the literature. Few available comparative studies have identified a number of challenges and features, which are critical for the success, including consideration of relevant scales and policy context, engagement with stakeholders and requirements, as well as complexity issues (Denzer, 2005). Users frequently find that the information provided in the IS/DSS does not fit their needs both spatially and regarding the time horizon, precluding of using the tool for decision-making (van Delden et al., 2011). Others examined rather practical features, such as technical requirements, financing, longevity and updating (McIntosh et al., 2011). However, there is only little empirical evidence about the actual situation of IS/DSS tools which have been developed in the past and their compliance with the formulated requirements. To the extent of our knowledge, this study is the first systematic empirical analysis of the different support systems used for complex agricultural and land management decisions.

The objective of this paper is to provide an overview of the IS/DSS tools in the field of agriculture, landscape and environmental management developed within research projects funded by the European Union (EU), assessing common specifications and functionalities of the knowledge transfer, including users interaction during the development, and identifying future development approaches. To this end, a structured review of IS/DSS tools developed during the last ten years as well as a survey among tool developers is carried out. The overall objective is to contribute to the better design of IS/DSS focused on agriculture, landscape and environmental management.