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The decision support matrix (DSM) approach to reducing environmental risk in farmed landscapes

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ABSTRACT

Modern intensive farming is an essential reality of modern life which brings major benefits but results in environmental pressures in constant need of solution, from increased flood risk and soil erosion to nutrient and pesticide export. The Decision Support Matrix (DSM) approach described here utilizes visualization and communication tools to help reduce environmental risk in farmed landscapes. Drawing on methods from physical and human geography, from mathematical modelling to participatory action research, the approach captures research expertise and local knowledge in forms accessible to farmers, land-use managers, planners and policy-makers. Conceptual models, easy-to-use interactive tools and examples of good and bad practice are co-developed by researchers and stakeholders, resulting in tools that enable practitioners to better understand the risks associated with specific land-use practices and assess measures to attenuate those risks. Most importantly it encourages users to take steps to reduce environmental risks.

This paper sets out the philosophy underpinning the DSM approach and describes the tools developed. Examples are given of how the approach has been applied successfully to phosphorus and nitrate export, and to flood risk associated with arable and livestock farming.

1. Introduction

There are many environmental pressures within rural catchments which need to be addressed urgently. As global demand for land and food increases, negative trade-offs between farming and the environment are becoming harder to avoid especially under predicted climate change scenarios. It is thus increasingly important to find ways of reducing environmental impacts whilst maintaining agricultural production and the economic viability of farms (Foresight, 2011; McGonigle et al., 2014). In Europe, this is situated in a legislative framework within which multiple pressures must be addressed simultaneously. For example, the Habitats Directive (Council Directive 92/43/EEC) promotes the maintenance of biodiversity by requiring European Union (EU) Member States '*to take measures to maintain or restore natural habitats and wild species at a favourable conservation status*' (JNNC, 2015); the EU Water Framework Directive (WFD) of 2000 (2000/60/EC) aimed to achieve '*good ecological status in all waterbodies by 2015*'; and the Floods Directive (2007/60/EC), which came into effect in 2007, required states to prepare preliminary flood risk assessments for all river basin districts by 2011, followed up with flood hazard maps in 2013. By 2015, Member States should have flood risk management plans, ready to link into the next cycle of river basin management plans (2016–2021) (European Commission, 2010). Intense farming makes a major contribution to problems such as increased flood risk, soil erosion and poor water quality in rural catchments (O'Connell et al., 2004, 2007; Heathwaite et al., 2005 and CIRIA, 2013). This means that there is great potential for agricultural practitioners to play a significant role in reducing multiple risks through better land-use management (Alphen and Lodder 2006; Grabs et al., 2007; Shrubsole 2007; Everard et al., 2009; WMO, 2009; Rouillard et al., 2014). Greater understanding by farmers, land managers, practitioners and policy-makers of the ways in which farmed landscapes contribute to risks and the ways in which those risks might be mitigated can be an essential component in improving practice. However, it is important to recognise that stakeholders such as farmers have a wealth of knowledge which can contribute to better understanding of the processes, practices and potential solutions to problems. The co-production of knowledge can be a key to successful intervention (Wakeford, 2010). Recent more integrated approaches to land and water management take account of this, with natural scientists, sociologists, economists, farmers

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and regulators all contributing knowledge that can assist in resolving agriculturally-derived issues (Hewett et al., 2010; Oliver et al., 2012).

Further, there is a need to attempt to solve problems with more holistic solutions at multiple scales. Winter et al. (2011) argue that the overwhelming focus on integration at a catchment level has led to a neglect of the importance of the sub-catchment (i.e. smaller sub-units within a catchment) as an equally appropriate unit of hydrological analysis (e.g Buck et al., 2004). They suggest that many of the management decisions relevant to water quality are made by land occupiers and, therefore, that the identification of relevant socio-spatial units – the 'private spaces' of land holdings – may be as important or more important to the effective management and planning of water resources as catchment-level planning (Winter et al., 2011). Issues such as cross-sectoral policy making (e.g. agriculture, forestry), land-use planning and integrated ecosystem service management (e.g. water management, nature protection, tourism) make it necessary to involve multiple stakeholders (Sterk et al., 2009). Increasing demands from a public that is scrutinizing decision-making regarding land-use management and its effects on environmental conditions and ecosystem services add additional complexity (Newham et al., 2000; Messner et al., 2006; Milligan et al., 2009; Furst et al., 2010).

There is little doubt that in recent years there had been a significant shift in stakeholder-scientist relationships from one of knowledge transfer to one of knowledge exchange, learning and two-way communication of information and advice (Wakeford, 2010; Welch et al., 2014; Maynard, 2015). This is a positive development for interdisciplinary researchers with ambitions to build credible agricultural Decision Support Systems and needs to be embraced (Oliver et al., 2012).

The term Decision Support System (DSS) usually refers to computer-based information systems used for recording, storing, processing and disseminating information to support group or individual decision-making (Burstein and Holsapple, 2008; Diez and McIntosh, 2009; Volk et al., 2010). In the past, DSS have been defined as computer-based tools that assist managers with solving ill-structured problems (Morton, 1971; Sprague and Carlson, 1982; Loucks, 1995; de Kok et al., 2009). The purpose of agricultural DSSs is to translate wider policy concerns for sustainable agriculture and water resources under climate change into operational, flexible and adaptive 'on the ground' responses (Oliver et al., 2012). In the field of landscape and river basin management, most DSSs make it possible to draw information from geographical information systems and/or supply interdisciplinary multi-criteria analyses of the hydrological, ecological and economic consequences of different management strategies, based on pre-calculated scenarios or model coupling (Burstein and Holsapple, 2008; Lautenbach et al., 2009). However, historically there has been poor uptake of such systems by stakeholders such as farmers (McCown, 2002) and few are currently used to inform policy or to drive policy analysis (Van Delden et al., 2011; Oliver et al., 2012). One major reason for this is that many DSSs are developed by technical experts who are removed from potential end-users such as farmers, land managers and policy-makers, resulting in tools that are complex and difficult to use. There is often also a sense of distrust in models and tools developed in isolation from practitioners. Further, a lack of involvement of local stakeholders can result in modelling outcomes that are neither understandable to them nor help to answer their questions and hence fail to lead to improved environmental management (Dupas et al., 2015). Thus, there is a real need for DSSs that are accessible, trusted and easy to use. The Decision Support Matrix (DSM) approach aims to fulfil that need by bridging the gap between scientists, policy makers and practitioners. The approach is a collaborative one, encouraging a sense of ownership in end-users. It results in tools where the problems and solutions are readily recognised by the practitioners and decision-makers at whom they are aimed. As a consequence the tools tend to get used more readily. The DSMs developed to date have been applied to agricultural systems. They combine expert hydrological evidence with local knowledge of runoff patterns (Hewett et al., 2004, 2009, 2010; Wilkinson et al., 2013). They are effective communication tools that have helped guide the way to real interventions (Posthumus et al., 2008; Wilkinson et al., 2014).

This paper describes the philosophy and development of the DSM approach. The approach applies human and physical geographic approaches to resolve a variety of environmental problems in particular those resulting from modern intensive farming such as nutrient pollution and flooding. It helps to assess, manage and improve understanding of risk from a multi-stakeholder perspective and proposes solutions to problems drawing on knowledge from practitioners, policy-makers and researchers from multiple disciplines. Examples of how the DSM approach has been applied to specific environmental problems are presented, along with the specific tools developed to address those problems. One DSM, the Nitrate Export Risk Matrix (NO_3RM), is presented in detail to convey the concepts underpinning the DSM approach.

2. The DSM approach

The DSM approach involves the development of tools that help visualize and communicate the risks associated with different farming practices and make it possible to explore options to manage runoff. It developed in recognition of the fact that a number of environmental problems such as flooding, erosion and nutrient pollution arise from the alteration of the catchment hydrological cycle (O'Connell et al., 2007). Increases in the intensity of farming play a critical role in exacerbating these problems. It is thus vital that underlying processes and practices are better understood.

A DSM is not a single tool, but is rather a set of tools including examples of good and bad practice, simple tools for assessing specific fields and practices, and advice on interventions to improve outcomes.

The underlying philosophy behind the DSM approach is that effective problem solving has to involve partnerships between researchers and stakeholders. Discussion between primary stakeholders, such as farmers, residents and local traders, secondary stakeholders such as legislative bodies, local and national authorities, and others such as scientists and the research community, is essential in developing the tools. Knowledge and experience are shared and fed into tools that capture and convey problems and potential solutions. The approach draws on methods from human and physical geography. There are two primary theoretical strands underpinning the approach: a set of hydrological principles and Participatory Action Research (PAR) (Chambers, 1994; Brydon-Miller et al., 2003; Hall, 2005; Kindon et al., 2007).

DSMs are described as DSSs in the inclusive sense defined by Power (1997), i.e. they are simply information systems that support decision making. According to Alter's taxonomy for DSS, a DSM fits in the category "suggested model" in that it leads to a suggested decision for a fairly well-understood task (Alter, 1980; Hewett et al., 2010).

There are four key elements to the DSM approach, which are outlined here and discussed in more detail below:

1. Conceptual models: These provide better understanding of the factors which impact on risk. The two principle types of conceptual models employed are: (i) diagrams capturing extremes; and (ii) the two- or three dimensional matrices onto which risks are mapped;