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Abstract: A key aim of developing environmental models and software is to provide decision and information support to environmental policy and management. In developing such technologies we, as a community of scientists and computer specialists, hope to provide tools which exert a positive impact on policy and management processes, actions and outcomes. We want to contribute to a diverse range of objectives from better managing scarce resources, through mediating and avoiding conflict, to maintaining adaptivity and promoting sustainable development. As ever greater numbers of decision and information support tools (DISTs) are developed to support environmental decision making it is therefore important that we develop a clear understanding of the impacts we intend these technologies to exert, compared to the impacts they actually exert. So what impacts do environmental DISTs have on policy and management organisations and activities? The IS literature distinguishes between impacts based on scale (HCI – task – organisational) and life cycle stage. Within these categories internal (organisational) vs. external (action outcome) impacts, and perceived (e.g. perceived usefulness) vs. objective (e.g. reduction in task time) can be discerned. Environmental DIST developers tend to focus on external impacts to the neglect of internal impacts and the fact that organisations are typically the main means of policy and management action and therefore critical elements in the chain between information and outcome. Taking desertification as a case study area of environmental policy and management a questionnaire based study has shown that DISTs are viewed on the whole as yielding positive internal (efficiency) and external (effectiveness) benefits but that a range of negative internal impacts are of concern including training, cost and the need for organisational change. These are discussed.

Keywords: decision and information support tools; information systems; impact assessment; desertification.

1. INTRODUCTION

Key issues facing environmental policy and management organisations typically involve interactions between human and environmental processes which are spatially distributed (e.g. demography and river hydrology) and operate at different rates (e.g. urban expansion vs. flooding). Furthering the complexity facing such organisations, environmental issues may involve interactions between different processes at the same or different spatial (extent) and temporal (rate) scales located in hierarchical and nested structures [Holling *et al.* 2002].

Managing complex environmental issues therefore requires good quality information and the ability to manipulate such information to infer the potential outcomes of intervention *ex ante*. In this context decision and information support tools (DISTs) like GIS, computer models and decision support systems (DSS) can offer potential benefits to policy and management organisations through providing environmental information storage and analysis capabilities [Dale and English 1999]. GIS can be used to store spatial information on human and environmental processes and to derive useful indicators for management e.g. the calculation of flood risk from information on soil type, topography and river flow.

Computer models can be used to simulate human and environmental processes for the purpose of determining the likely outcomes of intervention *ex ante*. DSS can be used to evaluate options to identify optimal interventions e.g. the set of abstraction volumes along a river which yield maximum utility across all users.

However, concerns have been raised regarding the level of use of such tools and the possibility that a gap exists between the supply of information services from the academic research community in the form of DISTs and the actual information needs of environmental policy and management organisations [McIntosh *et al.* 2005, McIntosh *et al.* 2008]. It is clear that there is a strong need to interact closely with end-user organisations during development to ensure the usefulness of DISTs [Gottesdiener 2002, van Delden *et al.* 2007] But what impacts do DISTs have when they are used? Are they positive? Do they match with the expectations and ambitions of the designers? If not, what can be done?

To help answer these questions this paper will identify and characterise the kinds of impact that DISTs may have on environmental policy and management in terms of organisations and outcomes. This will be achieved through identifying and discussing key concepts and findings from the information systems (IS) literature along with some results from surveys of and interviews with organisations involved in developing and delivering desertification policy and management. These findings will then be discussed in relation to the kinds of impact which are typically expected by environmental DIST developers.

2. TYPES OF IMPACT IDENTIFIED IN THE IS LITERATURE

The IS literature provides a rich seam of theoretical and empirical knowledge regarding the use and impact of computer-based tools like DISTs. Indeed, we are classifying DISTs here as a type of IS – computer applications designed to provide information to groups of people acting purposefully [Checkland and Holwell 1999].

The IS literature has not been concerned with understanding how IS deliver external impacts e.g. resolving water shortages. Rather it has focussed on how IS lead to internal impacts within the context of different organisations e.g. cost reductions, productivity increases. As a consequence the kinds of impacts considered may not appear immediately relevant to the environmental context. However they help focus our attention on the means by which environmental policy and management outcomes are achieved – through organisation action.

In terms of characterising the impacts of using IS at the individual task level most of the characteristics are focussed on 'productivity change' (e.g. [Torkzadeh and Doll, 1999]) or improving 'performance' at the organisational level (e.g. [Tallon, 2000] [Seddon, 2002]) often in terms of efficiency [Andreu and Ciborra, 1996; Davis, 1989; Fiorito *et al.*, 2002; Nicolau *et al.*, 1995]. Efficiency is used here in the sense of the capacity of an IS to reduce the time and organisational costs or resources required to achieve aims and objectives.

However some studies go beyond the productivity factor at the individual level [Torkzadeh and Doll, 1999; Doll and Torkzadeh, 1998; Checkland and Holwell, 1999] to look at impacts including:

- Effectiveness: Ability of an application to help individuals achieve their aims.

- Task innovation: 'The extent to which an application helps users to create and try out new ideas in their work'.

- Management control: 'The extent to which an application helps to regulate work processes and performance'.

- Better understanding of the problem under analysis: 'The extent to which a computer-based information system is used to analyse cause-effect relationships'.

IS can also have an impact on individual perceptions and in doing so will significantly influence adoption outcomes. The two main perceived impacts that have been shown to be important to adoption are (i) perceived ease of use; and (ii) perceived usefulness, or

perceived relative improvement in users' job performance [Davis, 1989; Al-Gahtani and King, 1999].

At the organisational scale DeSanctis and Poole [1994] have framed the positive impacts of using IS in terms of improving decision outcomes - efficiency, quality, consensus and commitment.

3. DISTINGUISHING IMPACTS

Over the previous approximately four decades of IS research a number of important concepts and distinctions have been developed. Some of these are fundamental to understanding information use in organisations such as the distinctions made between data, information and knowledge by Checkland and Holwell [1999]. Others are more directly related to the nature and location of impacts exerted by IS such as the distinction between human-task-organisational levels made initially by Eason [1991] and the distinction between perceived benefits and objectively measurable benefits which lies at the core of major theories of IS adoption [Davis 1989]. We will focus on describing these concepts and distinctions here, first of all examining where impacts are exerted in terms of scale and location within an organisation, then in the context of IS (and by inheritance DIST) life cycle processes.

3.1. Scale of impact

It is necessary to have an appreciation of organisational structure and process when developing IS. There is a vast literature on organisational theory reaching back as far as the 1940s [Simon 1997] but only a few distinctions need be made to better appreciate IS impacts in terms of location.

It is useful to start by considering how work is undertaken by organisations. Checkland and Holwell [1999] distinguish between action (a set of activities linked together to pursue a purpose e.g. identifying areas of the world at risk of desertification) and activities (sets of tasks linked together to provide part of the transformation involved in a particular piece of action e.g. analysing data on vegetation state). The final level implicit in their conceptualisation is the task level – what individuals in organisations physically do (e.g. purchasing remote sensing data from a provider).

Following Eason [1991], Torkzadeh and Doll [1999] and Raz and Goldberg [2006] three main levels of analysis (or impact locations) can be distinguished when examining the organisational use of IS – (i) the **human-computer interaction (HCI) level**, which is concerned with how input and output device functionality including keyboard, mouse, graphical user interface layout etc. influence the performance of human interaction with computer systems generally (i.e. not in relation to particular tasks); (ii) **the task level**, which is concerned with how the IS attributes influence the performance of particular tasks by individuals, and; (iii) **the organisational level**, which is concerned with how IS and task attributes influence the performance of activities by groups, and across a whole organisation. IS may exert positive or negative impacts at each level in various ways. For example, at the HCI level an IS may be quicker or slower to use, with consequent impacts on the level of training required, and the efficiency of tasks and activities.

Improvements at the HCI level (e.g. controlling a PC through windows rather than DOS) don't however necessarily translate into positive impacts at the task level. Here impacts will relate to the fit between the structure of the task in terms of information inputs and outputs and the ability of the IS to satisfy inputs and handle outputs. Also the fit between the information demands of the task and the information quality attributes of the IS such as accuracy, trustworthiness, completeness, conciseness and objectivity [Nicolaou *et al.* 1995] will be important in determining the nature of the impact. Impacts at the task level might include changes to effectiveness or efficiency, output quality and reliability, learning, task restructuring and the generation of new ideas, which might also be termed learning.

However the information demands of tasks don't exist in isolation. Rather they exist within an organisational context – actions and activities (what Eason calls the 'organisational task'), a social system (other individuals) and a technical system (e.g. the IT infrastructure). Impacts at an organisational scale may be positive in terms of enhanced effectiveness or efficiency and cost reduction, they may involve costs arising from organisational change (restructuring actions, activities or tasks) or may involve costs arising from the need to build capacity (e.g. staff training or purchasing of new hardware).

It is worth distinguishing here between internal and external impacts. **Internal** impacts of DIST use are those such as have been just described – impacts within organisations on the structure and performance of tasks and activities by individuals and groups. **External** impacts can be distinguished as impacts on policy and management objectives and intervention outcomes – impacts felt externally from the organisation using the DIST. Citing work by Sterk *et al.* [2006], McIntosh *et al.* [2008] have argued that it is difficult to isolate the effects of DIST use on policy or management outcomes but that it is possible to isolate internal impacts such as learning within an organisation.

3.2. IS life cycle processes

In addition to level or scale, impacts can be distinguished in terms of where they lie within the overall life cycle of an IS. The IS literature distinguishes between a number of different processes across the life cycle of an IS from design to abandonment. The various processes identified can be grouped into three life cycle stages – pre-implementation, implementation and post-implementation. Figure 1 depicts the relations between these processes.
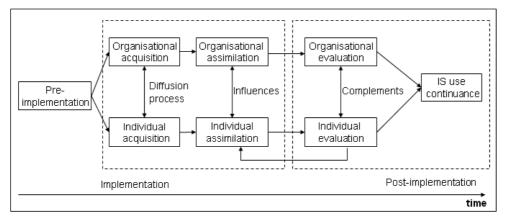

Figure 1. Processes involved in IS development and use

Pre-implementation is framed as the process of design and development prior to adoption by individuals or organisations [Hevner *et al.* 2004]. Implementation is framed as the process by which IS are taken up and used by organisations and may occur in various ways from bottom-up (driven by individual adoption behaviour to try out new technologies) or top-down (driven by organisational scale decisions to purchase software for example) involving processes of acquisition (influenced by diffusion) and assimilation into working practices [Al-Gahtani and King 1999, Fichman and Kemerer, 1997 Karahanna et al., 1999, McFarland and Hamilton 2006]. Post-implementation is used to describe the set of processes involved in continued use of a DIST and is viewed by some researchers as an extension of implementation [Liao *et al.* 2007]. It is framed in terms of individual scale evaluation of the benefits of using an IS, which may be largely informal, and organisational evaluation involving a more formal process of appraising the costs and benefits of IS use [Fitzgerald 1998, Kumar, 1990, Smith and Smith, 2007]. Table 1 shows how different IS life cycle processes can be categorised into these stages.

Table 1. Information system life cycle processes and their categorisation

Life cycle process	Process category

Design	Pre-implementation
Diffusion	Implementation
Adoption	Implementation
Implementation	Implementation
Acceptance	Implementation
Use	Implementation
Evaluation	Post-implementation
Assessment	Post-implementation
Continuous use	Post-implementation

For the outcomes of adoption to be successful (i.e. for an IS to be taken up and used by members of an organisation) it has been shown empirically that the members of that organisation involved must perceive that there are positive impacts (benefits) to themselves for example in terms of improving work efficiency or effectiveness [Davis 1989, Al-Gahtani and King 1999, Venkatesh *et al.* 2002]. The importance of perceived impacts within post-implementation has also been argued for [Liao *et al.* 2007].

It is therefore necessary when considering the impacts of DIST to separate out those which might be termed **perceived** (i.e. the impact that a DIST has on an individual's perceptions regarding its usefulness to that individual in his/her work) from those which might be termed **objective** and relate to measurable impacts such as productivity gains or greater achievement of policy objectives. Clearly most of the impacts that a DIST will exert will occur during the implementation and post-implementation stages, but important perceived impacts can be exerted during pre-implementation as a consequence of participatory and user oriented development approaches being employed.

4. CASE STUDY – DIST IMPACTS WITHIN DESERTIFICATION POLICY AND MANAGEMENT ORGANISATIONS

4.1. Introduction

Following the definition provided by UNEP in 1994, desertification is defined as 'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities' causing the loss of soil productivity and poverty. It is a significant problem with FAO, UNESCO and WMO estimating that over 1.5 billion people are affected. It is also representative of the kinds of complex environmental issues that DISTs might help us understand and manage effectively.

However, like most areas of environmental policy and management there is little or no literature examining the kinds of DISTs which are used, the role that they play or the impacts that they have. To help shed light on these points a questionnaire was designed and delivered via the web to build up a picture of DIST use and impact within desertification policy and management organisations across the globe.

Purposive sampling was employed to identify organisations to send a request to complete the questionnaire. The key criterion employed was current involvement in desertification policy or management activities (e.g. conservation, rehabilitation, assessment, monitoring) in arid or semi-arid areas. Desertification policy and management involves a diverse range of organisations ranging from government departments and agencies through NGOs, Universities, research centres and businesses to United Nations agencies (e.g. UNCCD, FAO, GEF etc.). All were included if they satisfied the main selection criterion. Over 400 email requests to complete the questionnaire were sent out to identified individuals within each organisations spread across the organisational types and geographic areas as follows:

- Government (64%), UN (18%), universities (9%), NGO (4%), trade unions (3%), private (1%).

- Europe (40%), international (31%), Africa (12%), America (10%), Asia (7%)

90 responses were received, with 5 discarded due to their being incomplete. Respondents were spread as follows across organisational type and role, respondent position and geographic location (all declared by the respondent):

- Government (50.6%), universities (16.9%), NGOs (12.9%), UN agencies (11.8%)

- Research (52.3%), policy and management (39.5%), education (20%), technical assistance (7%), commercial activity (2.3%)

- Operational / technical (18.6%), senior management (16.3%), middle management (12.8%), directors (10.5%), co-ordinators and supervisors (9.4%), researchers (5.9%)

- Europe (46.5%), international (12.8%), Africa (11.6%), Asia (9.3%)

4.2. Results

The full results cannot be presented here due to space limitations so only those relevant to impact will be discussed. Table 2 shows which DISTs are used by desertification policy and management organisations. 76.5% of respondents indicated that their organisation use some form of DIST with GIS being the most commonly used tool and DSS the least commonly used. 23.5% of respondents did not use any DIST for a range of reasons which will not be covered here.

Respondents were asked to rate the benefits provided by the DISTs their organisation uses in terms of effectiveness (defined as the ability of the tool to help achieve organisational aims) using a 6 point likert scale (strongly agree – strongly disagree plus 'no answer') and efficiency (defined as the ability of the tool to help achieve aims more quickly) using a binary true / false. 72.3% of respondents strongly agreed that DISTs contribute to organisational effectiveness, with only 1.5% disagreeing. 95.4% agreed with the statement that the DIST they use contribute to improving organisational efficiency, with 4.6% disagreeing. Of course these responses only came from those respondents who use DISTs so do not reflect the views of those who do not.

Table 2. Use of DISTs by desertification policy and management organisations

Types of computer-based IS	Percentage
Geographical Information Systems	64.7
Remote Sensing	47.1
Statistical models	37.6
Simulation models	35.3
None	23.5
Decision Support Systems	20.0

The three most frequently mentioned benefits arising from the use of DISTs were speed of information processing (21.5%), data management capacity (16.9%) and improved understanding of (environmental) processes (12.3%). When asked to rate the benefits of DISTs over other sources of information respondents listed greater processing speed (20%), greater information reliability (13.3%), enhanced ability to convince others of output (13.3%) and enhanced effectiveness as a consequence of using them (13.3%).

For those respondents who do not use DISTs to handle information the most frequent three reasons why were a lack of skills within the organisation (35%), poor cost-effectiveness (26.7%) or the respondents being at a 'policy level' where information is provided by other organisations (26.7%). Other sources of information used were found to be external literature (65%), followed by expert consultation (60%), internal literature (60%), hard-copy maps (50%), spreadsheets (50%), mathematical or statistical analyses (35%) and laboratory experiments (10%), with the reasons why listed including good information reliability and detail, satisfaction of organisational information demand, contribution towards achieving organisational goals, cheap, easy to understand and no particular skills being required or skills already exist or no training required.

Respondents were asked to list management issues which reduce the level or extent of DIST usage. The responses are essentially concerned with the organisational changes required to implement new IS – need for training courses (46.7%), need for additional financing

(26.7%), the need for capacity building within the organisation (26.7%), a need to employ more staff (20%), additional time costs (13.3%) and the need to establish new protocols of work (6.7%).

5. CONCLUSIONS

From the desertification case study it can be seen that DIST impacts are largely viewed as positive, covering both internal (e.g. efficiency) and external (e.g. effectiveness) types. However it is also clear that a substantial number of organisations do not use DISTs, partly because other information sources are seen as adequate, and partly because of concerns about the impact of adopting DISTs in terms of organisational change. Adopting DISTs is seen by these people as involving additional cost burdens including training, hiring new staff, the financial cost of purchase, the need to restructure tasks and the potential that DISTs might make organisational performance slower.

It is here that we return to the point made earlier about the type of impacts that DISTs have on organisations. Typical environmental DIST developers are thinking about how to improve policy and management outcomes including for example better managing scarce resources, maintaining adaptivity and promoting sustainable development. Attention is generally not paid to the means by which such outcomes arise – and these means are, largely, organisations involved in formulating and delivering policy or management action.

It is clear that negative internal impacts, particularly around cost and training, are key organisational concerns within the context of desertification and need to be addressed. Concerns may be assuaged by measures such as incorporating and delivering good quality low cost training as part of the DIST 'package' sold to client organisations, or by calculating the costs involved in adapting the client organisation to the DIST and identifying ways in which the DIST design might be changed to minimise the need for organisational (activity and task level) change. Of course, communicating and convincing members of the client organisation of the benefits of DIST adoption will also be of use, but will require thought about what those benefits will be internally as well as externally, and some measurement of how they stack up against the necessary costs of implementation. Such analysis of costs and benefits is not typically done within the realm of environmental DIST development, and is an area for development.

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