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Organisational drivers for, constraints on and impacts of decision and information support tool use in desertification policy and management

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ABSTRACT

Arguments for the potential benefits that environmental decision and information support tools (DISTs) bring to managing complex environmental issues like desertification are well rehearsed. However our empirical understanding of the reasons why particular DISTs are or are not used by different policy and management organisations, and the impacts they have on the work of those organisations is substantially weaker. Such understanding is needed to determine whether concerns raised in the literature about poor adoption and use of DISTs are correct, to understand why, and to remedy them. This paper presents a thematic analysis of 31 exploratory interviews with representatives of 14 desertification policy and management organisations operating at different scales about their use of DISTs; specifically GIS, remote sensing, simulation models, statistical models and DSS. DISTs of all types were found to be used along with other sources of decision and information support including hard-copy maps, aerial photography, databases, academic literature and local participation. GIS was most widely used, by 9 of the organisations interviewed. From the interview data a generic conceptual model identifying the organisational drivers for, constraints on and impacts of DIST use in desertification policy and management organisations is developed and discussed. Drivers were grouped into those concerned with system attributes (e.g. ease of use, flexibility) and those concerned with how information is used organisationally (e.g. to facilitate communication, assessment of desertification). Barriers including DIST information attributes such as reliability and uncertainty, and additional financial investment arising from training, employment and infrastructure procurement were identified. Impacts were grouped into structural changes, individual work changes and financial investment needs. No systematic variation was evident in the drivers, constraints or impacts of use according to DIST type, although GIS was the most widely used DIST and consequently was associated with a larger number of each. Results are discussed in relation to existing theory and evidence on information system and DSS adoption and use, and found to be in agreement. The paper finishes with a set of recommended improvements to DIST design processes to enhance the uptake of and positive benefits associated with use.

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1. Introduction

Defined as loss of soil fertility in the arid and semi-arid regions of the world which causes serious impacts on soil quality, biodiversity of habitats and the socio-economic structure of affected populations (UNCCD, 1994), desertification is thought to be one of the most widespread environmental threats to human kind (Darkoh, 1997). More than 37.6 million Km^2 of land has been reduced in productivity across the world as a consequence of the problem (Kosmas et al., 2003). Common driving forces of desertification include a mix of social and environmental processes including land abandonment, aquifer overexploitation, urban sprawl, and agricultural overexploitation of land, but these vary geographically and interact in complex, locally and contextually contingent ways (Long Martello, 2004). Despite international political efforts as encapsulated in the UN Convention to Combat Desertification (UNCCD) which came into force in 1994, there are no signs of success, the problem simply continues to grow (UNCCD, 2007). One of the key barriers to combating desertification has been identified as a lack of robust assessment methods for identifying priorities for policy and management action, for monitoring the impacts of actions and programmes, and for generating understanding about the drivers of desertification (Geist, 2005; Veron et al., 2006; UNCCD, 2007). It is within this gap that a role for environmental models and software (EMS) can be found.

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Examining the literature on EMS reveals well rehearsed arguments about the potential benefits these technologies will bring to environmental policy and management formulation and delivery organisations and processes (McIntosh et al., 2009). Cited potential policy and management benefits include inter alia, improved analysis and understanding of complex environmental processes and phenomena, the ability to generate knowledge about the relationships between social and environmental processes, the ability to evaluate the likely effects of different actions ex ante and improvements to stakeholder dialogue and engagement processes (for examples see Barr and Sharda, 1997; Guimães Pereira et al., 2003; Cockerill et al., 2004; Matthies et al., 2007). Given such potential benefits it is not surprising that EMS have been identified as part of the solution to the problems of combating desertification.

EMS which have been identified as suitable for direct use by environmental policy and management organisations are often variously referred to as decision support systems or DSS (see for example Matthies et al., 2007), although the precise meaning of the term DSS can veer some way from traditional definitions which have roots in operational research (OR) and are often couched in terms of software architecture e.g. 'a decision support system … is a system that supports … decision making by assisting in the organisation of knowledge about ill-structured, semi-structured or unstructured issues. The primary components … are a *database management system* (DBMS), a *model-based management system* (MBMS) and a *dialog generation and management system* (DGMS)' (Sage, 1991). Given their OR roots DSS are also usually associated with some kind of optimisation analysis to determine which management option performs best against a set of criteria – the notion of decision making in DSS (McCown, 2002a).

However there is considerable variation in the architectural form that environmental DSS, or EDSS, may take (e.g. the set of EDSS reviewed by Matthies et al., 2007). There is also variation in the extent to which DSS employ optimisation techniques and automatically identify the 'best' option for given problem, with some DSS offering 'what-if' analysis instead (see McCown, 2002b). Further, some EMS developed for direct policy and management use such as GIS, provide information support through storage, manipulation and output facilities rather than optimisation based decision analysis. Calling such tools DSSs would not be appropriate. Indeed, one could question whether DSS that do not generate optimal solutions, including various kinds of simulation model, should be classified together with DSS that do. They offer different kinds of functionality and consequently will support organisational processes in different ways.

Given the range of EMS types which are developed for direct use by policy and management organisations we will use the term Decision and Information Support Tools (DISTs) (McIntosh et al., 2009) in this paper to (i) distinguish such technologies from EMS not intended for policy and management application, and; (ii) to encompass the range of uses which may vary from more traditional decision support notions of problem structuring and optimal option identification, through 'what-if' option appraisal analysis to more routine information management, analysis and visualisation. Examples of DISTs which have been developed for desertification policy and management include remote sensing software, Geographical Information Systems (GIS), DSS and simulation models including integrated assessment models (see Diez, 2009 for a brief review of desertification DISTs).

What do we know about the extent to which different types of DIST are used by desertification policy and management organisations, why they are (or are not) used and what impacts they have organisationally? Reading the EMS, GIS and remote sensing literatures reveals a cogent set of arguments expressing both general and technology/application context specific concerns about the likelihood of DIST benefits being realised, and calling for socio-technical research to improve our understanding of organisational and user aspects of DIST design and use (e.g. Reeve and Petch, 1999; McCown, 2002a,b; McIntosh et al., 2005, 2007, 2009; Diez and McIntosh, 2009; Giupponi et al., 2007a; Georgiadou and Stoter, 2009). However beyond these concerns we do not have much empirical evidence, and none published with regards DIST use by desertification policy and management organisations. There is a need for greater evidence to verify the concerns expressed and to characterise the nature of any adoption and use problems which exist. On the basis of such evidence action can then be taken by DIST developers to change DIST development practices, by DIST implementation managers to change implementation process practices, or by DIST funders to promote other, potentially more effective ways of scientifically supporting policy and management organisations than DISTs.

What evidence we do have about the organisational use of DISTs tends to be by proxy and in the form of a review of evidence from another field (e.g. the review of how different organisational factors influence information system design, adoption and use by Diez and McIntosh, 2009) or an analysis of theoretical expectation (e.g. the analysis of how 'bureaucratic' factors such as training and standard operating procedures influence GIS adoption by public organisations by Obermeyer, 1990). Within the EMS literature the ambition to empirically evaluate DSS can be found but only supported by studies which focus on technical rather than user oriented aspects (e.g. Sojda, 2007).

The most systematic empirical analysis of adoption problems with regards DISTs was conducted by McCown (2002b). McCown reviewed the usage of a range of agricultural DSS and found that adoption had either failed in the first place or dropped off sharply after a period of initial interest. He attributes these failures to a number of causes which can be broadly encapsulated as (i) an misconception of how knowledge is acquired and used in decision-making processes by potential DSS users, and; (ii) that users use DSS as part of a process of adapting their management practices in the face of change, then abandon use once they have learned what they need.

Surprisingly, despite high levels of usage (e.g. estimated to be 80% of larger US city and council planning organisations by Budic, 2003 and Holden, 2000 cited in Goelman, 2005), the GIS literature is not replete with empirical evidence on the organisational drivers for, constraints on or impacts of GIS use (Reeve and Petch, 1999). However, there is some evidence. For example, Goelman (2005) presents an interview-based empirical analysis of the way in which GIS and planning technologies are used by municipal planners. He found that the impacts of GIS were influenced by a number of factors including the degree of centralised control of technology roll-out within an organisation, and individual employee perceptions of what technology is able to do and to do easily compared to other ways of carrying out the same task. These influences meant that the actual use and impacts of GIS were not as initially expected and fell short of the functional capabilities of the technology. In exploring the diffusion of GIS within US local government through a series of 4 case-studies Nedović-Budić (1996) identified a series of individual employee determinants of GIS use including perceived relative advantage, previous computer experience, exposure levels to the technology and the extent to which the employee engages in networking. In the context of using GIS to support collaborative water resource management in rural Idaho, Ramsey (2009) describes how the way in which the GIS had been set up to solve a particular problem representation rather explore a range of possible problem representations, fears amongst users about bias inherent within the GIS representation and further user concerns that the GIS would only show what everyone knows to be the problem, resulted in rejection of the GIS as a support tool.

Looking at remote sensing technology, de Leeuw et al. (submitted for publication cited in Georgiadou and Stoter, 2009) found that of 300 papers published between the early 1990s and 2007, not a single one actually described how the technology was used to support policy making. The furthest any paper went was to demonstrate potential benefit without empirical support.

The contribution of this paper will be to tackle this lack of evidence about the use of DISTs by policy and management organisations within the area of desertification. More precisely, the objectives of the paper will be to:

1. identify which DISTs and other sources of decision and information support are used by desertification policy and management organisations across a range of governance scales;
2. identify the factors which drive the implementation of DISTs by those organisations;
3. identify those factors which constrain those organisations from implementing DISTs, and;
4. identify the types of impacts influenced or created by DISTs on the functioning and outputs of those organisations.

Following a literature search to determine which DISTs are in use or of potential use to desertification policy and management organisations, remote sensing, GIS, simulation models, statistical models and DSS were selected for particular attention. However, organisational representatives were able to discuss other DISTs and sources of decision and information support if they so wished (see the next section for interview details).

In fulfilling these objectives, the ambitions of the paper are to contribute to practice and to theory. To DIST development practice by identifying organisational constraints on DIST adoption and use, and negative impacts of use which can then be tackled during development. To theory and practice by identifying the elements of a conceptual model capable of explaining organisational DIST adoption and use following a tradition of such models in the information systems (IS) literature (e.g. the TAM3 model of Venkatesh and Bala, 2008). Such a model could be used in principle to guide managers in user organisations to more effectively manage the implementation and on-going use of DISTs.

Section 2 describes the overall research method, organisational sampling rationale and specific techniques employed. Section 3 presents the results of the interviews carried out with the sample of desertification policy and management organisations whilst Section 4 discusses the main results in relation to theory on information system adoption and use, and in relation to improving DIST development and implementation management practices for desertification policy and management organisations.

2. Research methodology

2.1. Conceptual model of DIST use

As the paper aims to identify the influences on and impacts of DIST use, we use a life-cycle based conceptual model as framework for both designing interviews and locating results. Following Diez and McIntosh (2009) we consider that the life-cycle of a DIST, like the life-cycle of an information system (IS), consists of three processes – pre-implementation, implementation and post-implementation. The process of implementation (or adoption) has come under intense study within the field of IS research for largely commercial, non-environmental policy or management organisations. The process of DIST design and development (what we term pre-implementation) and the relationship between DIST use and organisational performance (post-implementation) have also come under study, but of markedly less intensity, within the same literature. A review of empirical work to explain and understand different outcomes across the life-cycle of an IS was provided Diez and McIntosh (2009). Taking the methodology developed by Jeyaraj et al. (2006) they classified the factors found in the literature into three categories (best, potential, worst) according to the strength of their influence on the processes of pre-implementation, implementation and post-implementation. The best predicting factors (i.e. those with the strongest evidence) for different outcomes across each of the three life-cycle stages are described in Table 1. These will be discussed in relation to the results of this study in Section 4.

2.2. Research strategy

The research reported here should be viewed as one part of a structuralist retroductive research strategy as described by Blaikie (2007). The aim is to identify the elements of a general (i.e. not organisation specific) conceptual and explanatory model of desertification policy and management organisational DIST use covering both reasons why DISTs are used or not (pre-implementation and implementation) and the impacts they have (post-implementation). The model elements generated will necessarily be tentative as the research is exploratory rather than confirmatory in nature. Further research will be required to confirm and understand the elements more precisely. An exploratory design is appropriate given the current lack of empirical evidence.

2.3. Sample design

Sampling involved three processes – (i) identification of organisations, (ii) selection of organisations and (iii) identification of individuals within selected organisations. Web Search engines were used for the identification of organisations. At this stage only the organisations meeting the following two relevance criteria were considered:

- Organisations must have action programmes focussed on or executed in areas affected by, or under risk of, desertification.
- Organisations must have either (i) directly participated in decision making (e.g. ministries); (ii) directly supported decision making (e.g. research centres, universities); (iii) executed actions derived from political decisions, or; (iv) exerted political pressure (e.g. non-governmental organisations, trade unions).

Organisations spread across a range of governance scales from global through regional (e.g. European or African) and national to sub-national were deliberately identified with the aim of capturing as much variation in DIST use as possible. In doing so the aim was to increase confidence in the completeness of the conceptual model elements (influences on and impacts of DIST use) identified. At the national and sub-national scales resource constraints meant that it was only possible to interview organisations from a few European countries. Spain and Portugal were selected based on a mixture of ease of access, the researcher being able to speak Spanish and their extant and growing problems with desertification. At sub-national scale only sample of regional and local organisations were interviewed again due to resource constraints.

23 Organisations were identified and members of each organisation then contacted by phone, email or letter to ask for their participation in the interview. Snowballing was used to identify members of each organisation available for interview. Members from 14 of the 23 organisations agreed to participate in interviews (see Table 2).

To ensure validity of results multiple members of each organisation were interviewed wherever possible. It would have been desirable to conduct between 4 and 5 individual interviews per

Table 1
Relationships between best predictors and outcomes for pre-implementation, implementation and post-implementation IS life-cycle stages (from Diez and McIntosh, 2009).

Process	Best predictor	Outcomes influenced	Type of relationship	Description of the relationship
Pre-implementation	User participation	User satisfaction	+	Involving users is likely to improve the quality of design decisions
		Success	+	Users are less likely to accept a IS unless they exert influence on its development
		Success	−	User participation can lead to some expectations that cannot be late satisfied by IS developers.
Implementation (individual and organisational scales considered together)	Behavioural intention	Actual system use	+	Individual use behaviour is driven by intention to use
	Computer experience	Adoption	+	More experience leads to more positive beliefs about technologies. Adoption is therefore more likely
	External pressure	Adoption and adoption intention	+	The adoption of IS is more likely if there is pressure from other organisations for work to be done or reported on in a particular way
	Information sources (external)	Adoption intention	+	IS are seen as devices for a better storage and management of information. Hence, their adoption is more likely if an organisation has to handle large volumes of information from external sources
	Perceived usefulness	Actual system use	+	The use of a IS is more likely if the user can foresee performance benefits as a result of IS use
	Professionalism (IS unit)	Adoption and adoption intention	+	The adoption of IS is more likely if IT departments are aware of the functionalities of the IS
	Subjective norms	Adoption	+	Perceived social peer pressure to adopt has been shown to significantly influence individual scale adoption outcomes
	System quality	Actual system use	+	Higher system quality tends to lead to more user satisfaction. The more satisfied the user is with the system the more he/she will be inclined to use it
	Top management support	Adoption	+	Locking in support from top managers has a strong positive influence on the adoption of IS. Typically developers must convince managers that IS will have positive performance impacts
	User support	Adoption	+	The adoption of a IS is more likely if user support is high. User support in turn is positively influenced by satisfaction with the characteristics of the IS (e.g. ease of use, contribution to better performance)
	User training	Actual system use	+	There is a direct relationship between training and use levels – more training also entails higher users' perceived relative advantage of the system, which in turn enhances the likelihood of IS use
Post-implementation	User satisfaction	Success	+	User satisfaction drives the continued use of IS

organisation for data reliability and results validity. However, it was not possible to find more than 2 or 3 people available for individual interviews in each organisation, partly because desertification was found to be an issue without large numbers of staff devoted to it, and partly because it was not always possible to find contact details of the staff involved.

2.4. Interview design and delivery

Semi-structured interviews with open questions were selected. Individual interviews were deemed better than focus groups as the latter have been reported to favour the appearance of a leader within the group, resulting in lower levels of participation of the other interviewees. Further, focus groups can create difficulties for interviewers when trying to identify different standpoints for each of the questions asked (Corbetta, 2003; Bouffard and Little, 2004).

Soft Systems Method (SSM) (Checkland and Holwell, 1999) was selected as an appropriate theoretical framework to structure the interviews because of the focus and emphasis it gives to understand how tasks and activities are linked together to provide a basis for organisational action, and how information is used as part of taking such collective action. SSM typically involves gathering and analysing information about each of the elements of the CATWOE mnemonic rule for an organisation:

(i) C (customers, clients): 'Victims or beneficiaries' of actions.
(ii) A (actors): The players (individuals, groups, organisations) that perform the transformation (T; defined below).
(iii) T (transformation): the fundamental character of organisational action – the conversion of material or information inputs into material or information outputs. The description of 'transformation' should include information on the activities carried out by actors, information needs, information sources used to support the process, and performance criteria.
(iv) W (worldview): Researchers' view of the situation – organisations can usually be defined as having different purposes depending on the viewpoint of the observer so it is important that the researcher exposes his/her perspective.
(v) O (owners): Those entitled to 'control' the transformation process.
(vi) E (environmental constraints): Difficulties or limitations encountered by members of organisations when carrying out a particular action.

Interviews were structured using the CATWOE framework around four main topics:

- Organisational action (to gain a systemic understanding of how the organisation is involved in taking desertification policy or management action);
- Information needs and use (to understand current and desired information use);
- Drivers for and constraints on DIST implementation and use, and finally;
- Impacts of DIST use.

The transformation component of each organisation was characterised by the following aspects – actions and activities carried out by actors, information needs, information sources employed to support those actions (e.g. DISTs), and key performance criteria. Information needs were defined as the information required to carry out an action (Gottesdiener, 2002) and key performance

Table 2
List of organisations contacted and interviewed.

Organisation	Number of members contacted	Number of members who agreed to participate
Global Environment Facility (GEF)	4	4
Food and Agricultural Organisation (FAO)	14	4
International Fund for Agricultural Development (IFAD)	2	2
United Nations Development Programme (UNDP)	11	0
United Nations Environment Programme (UNEP)	3	0
Global Mechanism of the UNCCD (GM)	12	1
World Meteorological Organisation (WMO)	1	1
European Commission (including JRC)	13	6
Observatoire du Sahara et du Sahel (OSS)	1	1
Comite Permanent Inter États de Lutte contre la Sécheresse dans le Sahel (CILSS)	1	1
Ministry of Environment of Spain	2	1
Ministry of Agriculture, Fisheries and Food	1	0
CSIC	1	1
Water Department of the Jucar River Basin	1	0
Water Department of the Segura River Basin	1	1
Regional Department of Environment of Andalusia	2	2
Regional Department of Environment of Castilla La Mancha	2	0
Regional Department of Environment of Murcia	16	5
Regional Department of Environment of Valencia	1	0
Regional Department of Agriculture of Andalusia	1	0
Regional Department of Agriculture of Castilla La Mancha	1	0
Regional Department of Agriculture of Murcia	2	1
Regional Department of Agriculture of Valencia	1	0
Total	94	31

indicators as qualitative or quantitative metrics employed to evaluate the success of an action by an organisation.

A copy of the questions asked at the interviews is given in Table 3. The coherence and clarity of the interview questions were tested by piloting the interviews with various members from a European funded project spread across Cranfield University (UK), Leeds University (UK), Kings College London (UK), RIKS bv. (The Netherlands), Lund University (Sweden), CSIC (Spain) and ENEA (Italy).

31 Face-to-face, semi-structured, tape recorded and transcribed interviews were conducted over the course of four months. Interviews followed ethical practice guidelines as set out by the British Psychological Society covering aspects such as anonymity and data handling.

2.5. Data analysis

Interviews were transcribed then analysed following a thematic approach (see for example Braun and Clarke, 2006) to develop the categorisation of drivers, constraints and impacts which form the elements of the conceptual model. The thematic analysis was performed three times to check for reliability of coding.

3. Research results – identifying drivers for, constraints on and impacts of DIST use

Interview results indicate that the use of DISTs is common in desertification policy and management organisations as the use of DISTs was reported in all but four organisations. GIS was by far the most commonly used DIST type, by 9 out of the 14 organisations interviewed. Simulation models were next most commonly used in line with remote sensing (3 organisations for each), statistical models were employed by 2 organisations and DSS by 1. 2 organisations didn't use any DISTs at all, instead relying on hard-copy maps in one case, and non-spatial databases in another. 1 organisation used 3 DIST types, 4 organisations used 2 and the rest used 1, except for the 2 organisations which used none.

The non-DIST sources employed for decision and information support included hard-copy maps (4 organisations), scientific literature (4 organisations), aerial photography (3 organisations), non-spatial databases (2 organisations) and local participation (1 organisation). Of these 2 organisations employed 3 sources, 2

Table 3
List of interview questions.

Questions
Could you provide some information on the purpose of your work (or your organisation)?
Do you have a specific target group, either internal or external to your organisation, which will benefit from the output of this work? Are you aware of how this target group will use the output information and what they will use it for?
Who is involved in this action within your organisation? Has it been necessary to go outside your organisation to find people with the skills and/or resources to carry out this action?
What are the activities involved in this particular action?
What information do you require in order to carry out each action? Where do you obtain that information from?
What information and processes, not provided by the tools you use, would help you work better?
How do people involved in this activity measure its performance? Do you use any indicators (environmental or others)? Which ones?
Are there any constraints that reduce the performance of that activity?
Why did the people involved in this activity start using these DSTs?
In your opinion, what impact/-s has the implementation and further use of DSTs had on the way people involved in this activity work?
What costs or changes (e.g. economic investment, role changes, training, etc.) were involved in using DSTs?
Why are these tools used instead of computer-based DSTs?
What changes would be required to implement computer-based DSTs?
What are possible barriers for the implementation of computer-based DSTs?
What tasks might be supported by computer-based DSTs?
In your opinion, how would DSTs help improve the performance of your work?

organisations employed 2 sources, 4 organisations employed 1 source and 6 organisations employed no non-DIST sources of decision and information support.

Thematic analysis of the interview data revealed that some of the drivers for, constraints on and impacts of could be grouped together as they referred to aspects of a single type of driver (or constraint, or impact). Thus, three main types of drivers were identified as influencing pre-implementation and implementation processes:

1. Mandate of organisation – responsibility of an organisation to make particular decisions
2. Potential uses of information – purpose for which the information provided by a DIST is used
3. Provision of more detailed information – an organisation experiencing a need for more detailed information
4. System attributes – technical and usability characteristics of a DIST

At post-implementation, three main types of impacts were perceived to occur when DISTs are implemented:

1. Changes to execution and performance of work – changes that affect the way people work and/or the results of people's work as a result of using a DIST
2. Changes to organisational structure – changes to the way an organisation is set up in terms of objectives, responsibilities, constitution of departments or divisions, and work protocols
3. Financial investment – allocation of financial resources to the provision of training, the employment of personnel or the acquisition of computers.

The following paragraphs present the interview results which can also be found in Table 4. The quotes and definitions provided by interviewees for some of the drivers, barriers and impacts are given in the text to help illustrate meaning. The bold numbers indicate the frequency with which drivers, barriers and impacts were mentioned during interviews (number of interviews, not number of organisations).

3.1. Drivers of DIST implementation

The analysis of results suggests that the wide implementation of DISTs in desertification policy and management organisations is driven, amongst other aspects, by the various tasks DISTs can support. First of all, DISTs can be used as analysis tools for the forecasting (**1**), assessment (**4**) and monitoring (**4**) of desertification. The contribution of DISTs for better understanding processes was one of the drivers most commonly pointed out by interviewees, having been mentioned in **4** occasions. Process understanding was defined as the role of "*DISTs to help users understand what is really happening on the ground, to know the trend or severity of desertification and to know the impacts of our work*".

In addition to their potential as analysis tools, the adoption of DISTs is also driven by their contribution to facilitate communication (**2**) and participation (**3**). As recognised by interviewees, DISTs do not only improve communication inter-organisationally ("*DISTs facilitate communication with other organisations because information is made publicly available*") but also with stakeholders in general ("*You can show your stakeholders what happens in the environment if you do something*"). Higher levels of stakeholder participation are perceived to be possible because DISTs have system techniques, such as mapping capabilities, that make easier the presentation and interpretation of results: "*The maps generated by the DISTs are good vehicles to encourage the participation of users because you can graphically represent the status of a process at a particular time and the correct interpretation of the map does not require user expertise*".

2 Interviewees revealed that the implementation of DISTs in their organisations had been driven by the role of DISTs in supporting decision making through the provision of more abundant and detailed information: "*We can provide policy makers with a picture of the ground which is much more informative than what they had in the past*".

By looking at the list of drivers, we can also conclude that the implementation of DISTs is also motivated by the ability of these tools to collect (**1**), manage (**2**), integrate (**5**) and update (**2**) information as it becomes available. Information integration was in fact the driver most frequently mentioned at the interviews, having been identified as one of the main determinants of success in the analysis of desertification: "*You can take legal, socio-economic and physical information on an area. This is essential because you cannot study desertification in the country by only looking at physical data*".

Other drivers of DISTs implementation include ease of use (**4**), low cost (if similar DISTs to the one to be implemented already exist in the organisation) (**2**) and flexibility (**1**) or "*the capability to do more things than what you would do by hand or with a hard-copy map*".

It was finally observed that the mandate of organisations is also a determinant of DIST implementation – i.e. the implementation of DISTs is more likely if required by an organisation's own mandate.

3.2. Constraints on DIST implementation

Judging by the number of times each of the constraints in Table 4 were mentioned, it seems that the there are two main groups of factors which hinder the implementation of DISTs in desertification policy and management organisations – the attributes of DIST output information, and the organisational investment required.

As regards the nature of output information the main concern of potential DIST end users relates to uncertainty (**12**) caused by the numerous assumptions, in turn motivated by the lack of high-quality data regarding desertification processes, that need to be made in both the analysis and interpretation of results: "*Some simulation models are very complex and the output is very much subjected to our assumptions. If we change assumptions, we get a completely different picture*". The scarcity of high-quality data on desertification also justifies the level of unreliable information that, according to one interviewee, characterises the information generated by DISTs: "*It is not possible to create very reliable tools at a fine scale because of the low quality of data*". A different explanation was given by interviewees when elicited about the implications of incomplete (**2**) and irrelevant information (**5**). Thus, interviewees recognised that some of the DISTs developed so far need to be improved in the future so that a better understanding of desertification can be gained: "*Remote sensing is very useful to monitor moisture content, erosion and plant cover changes but it does not provide information on humus content, texture and, in general, any information at low spatial scale*". On the other hand, several interviewees agreed that more relevant DISTs could be developed if there was a more continuous contact between DISTs developers and end users: "*Current DISTs are not adapted to users' needs. Scientific tools are only thought to win a project proposal, for papers, but they do not address any of the burning questions that we need to answer. There is no communication between the user and the developer so the developer is not always aware of what the user needs*".

Two more constraints related to the characteristics of the information used and generated by DISTs listed in Table 4 included the need for validation (**1**) ("*we always need some validation on the*

Table 4
Interview results – drivers for, constraints on and impacts of DIST use (see text for description of each).

Driver/constraint/impact	Description	
Driver	Mandate of organisation	
	Potential uses of information	Desertification assessment
		Desertification monitoring
		Facilitation of communication
		Facilitation of participation
		Forecasting
		Helping decision making
		Improving process understanding
	Provision of more detailed information	
	System attributes	Data collection
		Data management
		Ease of use
		Flexibility
		Information integration
		Information updating
		Low cost
Constraints	Financial investment	Computer acquisition
		Employment (additional)
		Training provision
	Information attributes	Uncertainty
		Irrelevance
		Incompleteness
		Unreliability
	Mistrust of developer	
	Need for support to use DIST	
	Need for updating of information in DIST	
	Need for validation of DIST	
	Scarcity of documentation	
	Tool complexity	
	New work protocols	
Impacts	Changes to execution and performance of work	Better effectiveness
		Better efficiency
		Capability to perform new activities
		Facilitation of information dissemination
		Freeing up time for other work
		Improved participation & decentralisation of decision making
		Improved communication internally and externally
	Changes to organisational structure	Allocation of new responsibilities
		Establishment of new units or departments
		Independence from other organisations
		New mandate of organisation
		New work protocols
	Financial investment	Computer acquisition
		Employment (additional)
		Training provision

ground that confirms the validity of DISTs outputs; the need for validation may also lead to the postponement of decisions") and the need for updating (**4**). The need for information update was identified both as a driver and a barrier for DIST implementation. Whereas DISTs can store, integrate and manipulate information as it becomes available, it should also be borne in mind that "*the manipulation of the DIST is sometimes difficult*", indicating that DIST complexity can be an implementation constraint.

As for organisational requirements, it is remarkable the number of interviewees that identified the need for financial investment and the need for changes in work protocols as constraints on DIST implementation (**9**). Financial investment was perceived as required in terms of the provision of training to staff, the acquisition of computers, or the employment of more people to, for instance, "*validate on the ground the results provided by the DISTs*". Changes in work protocols required or encouraged by the implementation of DISTs were perceived negatively by 5 interviewees, even if the use of DISTs provides beneficial impacts such as facilitation of communication with stakeholders, the assessment of the extent of desertification or the adoption of decisions. These interviewees argued that "*some members of staff of organisations are not keen on implementing new work protocols, especially if they have been using the same protocols for years*". One more organisational requirement arose as a barrier in one of the interviews – the need for support (**1**). The implementation of DISTs is unlikely unless developers have the support from users: "*I see good products that fail because they do not have support. I see that in the academic community. The academic community spends little money on the marketing and support but there is much intensive development*".

Other barriers for DIST implementation include the complexity of the tool (**4**), mistrust towards the work of the developer (**2**), and the scarcity of documentation accompanying the DISTs (**1**), necessary to understand the functionalities of the tool. The quality and quantity of the documentation is particularly relevant if the end user did not participate at the design and development stages of the DIST.

3.3. Impacts of DIST use

17 Different impacts of DIST use were identified in the interviews. 10 of these 17 impacts (58.8%) were grouped together under

the 'changes to the execution and performance of work' category. Two of the impacts of DIST use proposed by SSM were pointed out by various interviewees – effectiveness and efficiency. **9** Interviewees argued that DIST implementation had led to better levels of organisational effectiveness and **7** of them also concluded that DISTs helped increase organisational efficiency: "*With a DIST we can take a more informed decision and we do not need to discuss for a long period of time; with a monitoring tool, for instance, we can have a better grasp of a problem and quicken the decision-making process*". However, interview results reveal that it cannot be assumed that the implementation of DISTs is always coupled with higher levels of effectiveness and efficiency. **2** Interviewees indicated that, even if DISTs provide more and better information to support the decision-making process there are a number of mediating organisational factors that can prevent the realisation of better efficiency including administrative processes: "(…) it is all up to our very complicated project system. We are working now to reduce it and the aim is to reduce it to 22 months of average. We need to simplify our way of working".

Besides changes in performance, DIST implementation is viewed as a precursor of higher levels of stakeholder participation (having being mentioned by **9** interviewees) and better communication with both stakeholders and other members of the organisation where the DIST is being used (**6**). Interviewees perceive DISTs as being able to manipulate and present complex information in an easy-to-understand format, which facilitates discussion with, and participation, of non-experts and stakeholders in general.

Some of the factors that constituted a constraint on DIST implementation were also listed as impacts e.g. financial investment and the emergence of new work protocols. Financial investment was one of the aspects most frequently pointed out by interviewees as an impact of DIST use with the total number of responses broken down as follows – training (**10**), employment (**12**) and computer acquisition (**8**).

Looking at the frequency of each factor, the impact most frequently indicated by interviewees related to organisational structure is the establishment of new units or departments (**6**) responsible for the validation of results on the ground, the update of information or the dissemination of information: "*It is not only necessary to set up knowledge management departments for data and information sharing but to establish groups that can work on the ground and validate the work carried out in the headquarters*".

Some other organisational structure impacts of DIST use were identified through the thematic analysis of the interviews – independence from other organisations (which can assist effectiveness and efficiency) (**1**), allocation of new responsibilities within an organisation (**1**) and emergence of new organisational mandates (following the creation of capacity through DIST use) (**1**).

3.4. Drivers, constraints and impacts by DIST type

The results presented in Table 4 are shown organised by the DIST type(s) they were associated with by interviewees in Table 5. In some cases the association between drivers, constraints and impacts was assumed by virtue of the fact the interviewee mentioned using a particular DIST type but then didn't refer explicitly to that DIST type when discussing drivers etc.

Looking over the results in Table 4 it can be seen that GIS, the most frequently used DIST type is associated with the most drivers, constraints and impacts. A need for desertification monitoring support is the most common driver across the DIST types (all except for DSS) along with low cost (GIS, statistical models and simulation models) and (perceived) ease of use (GIS and statistical models). Information uncertainty was the most commonly perceived DIST

Table 5
Drivers for, constraints on and impacts of DIST use by DIST type.

DIST type	Drivers	Constraints	Impacts of use
Remote sensing	Data collection Desertification assessment Desertification monitoring	Financial investment Need for validation of DIST Need for updating of information in DIST Uncertainty	Better effectiveness Better efficiency Establishment of new units or departments Improved participation & decentralisation of decision making Investment in computers Need to hire people Training provision
GIS	Data management Desertification assessment Desertification monitoring Ease of use Facilitation of communication Facilitation of participation Forecasting Information integration Information updating Helping decision making Low cost Mapping capabilities Improving process understanding Provision of more detailed information	Tool complexity Financial investment Irrelevance Mistrust of developer Need for support to use DIST Need for validation of DIST Need for updating of information in DIST New work protocols Scarcity of documentation Uncertainty Unreliability	Better effectiveness Better efficiency Capability to perform new activities Establishment of new units or departments Facilitation of information dissemination Freeing up time for other work Improved communication internally and externally Improved participation & decentralisation of decision making Investment in computers Making more people aware of the effects of decisions Need to hire people Possibility to take more informed decisions Training provision
Statistical models	Desertification monitoring Ease of use Low cost	Need for updating of information in DIST Uncertainty	Investment in computers Need to hire people Training provision
Simulation models	Desertification monitoring Low cost	Mistrust of developer New work protocols Uncertainty	Better efficiency Investment in computers Need to hire people Training provision
DSS	Facilitation of communication	Incompleteness Uncertainty	Better efficiency Improved communication internally and externally Improved participation & decentralisation of decision making

constraint (all types) along with the need to update information used by DISTs (remote sensing, GIS and statistical models). The most common impacts of DIST use were improved efficiency (all types except statistical models), the need to invest in acquiring more computers (all types except DSS which was only used by 1 organisation), the need to invest in training (all types except DSS), the need to hire people (all types except DSS) and improved participation and decision-making decentralisation (remote sensing, GIS and DSS). No systematic variation in drivers, constraints and impacts was evident. In fact the range of reported drivers, constraints and impacts for each DIST type appears related to the number of organisations reporting the use of that DIST type.

4. Discussion of results

The research reported here contributes to empirically characterising DIST use by desertification policy and management organisations, the reasons why and the organisational impacts of those doing so. The results offer the opportunity to assess the transferability of evidence from IS literature to environmental DIST concerning the factors which influence pre-implementation and implementation processes, and the outcomes of post-implementation (see Diez and McIntosh, 2009 for a review). The results also offer an opportunity to improve both DIST development and implementation management practices through revealing the constraints and negative impacts of DIST use in particular. The results provide only limited insight into the relationship between DIST use and the achievement of desirable policy or management objectives such as stopping the spread of desertification, but do appear to support claims that DISTs are beneficial in organisational effectiveness and efficiency, and therefore by assumption, outcome terms.

This discussion will focus on the following two aspects – (i) comparing interview findings and the findings of IS research with a view to identify potential similarities and differences between DISTs for desertification policy and management and IS in terms of organisational influences on implementation and use, and; (ii) describing how, based upon interview findings, DIST development and implementation management practices could be improved.

4.1. Comparing literature review findings and interview findings

IS literature represents a potentially rich seam of empirical knowledge about the determinants and consequents of DIST use. Regarding drivers and barriers for IS implementation, early work on this issue started in the 1960s although activity became particularly significant from the 1980s onwards and now constitutes many hundreds of peer reviewed papers. In addition to empirical analyses there are a range of notable theories of IS adoption that are relevant to understanding the drivers for and constraints on IS use. One of the most relevant theories is the Diffusion of Innovations Theory (also known as the Innovation Diffusion Theory). This theory proposes that the main factors driving the implementation of IS are relative advantage, compatibility, trialability, complexity and observability (Rogers, 2003). The appropriateness of this theory for explaining IS adoption (it wasn't developed to do this specifically) has been empirically demonstrated (Taylor and Todd, 1995). Perhaps the most well known and well tested theory of IS adoption is the Technology Acceptance Model (TAM) (Davis, 1989; Al-Gahtani and King, 1999), which posits that perceived usefulness and perceived ease of use determine the intention of an individual to implement and use a system. TAM is now in its third version, TAM3 (Venkatesh and Bala, 2008) and substantially more sophisticated. However we do not have evidence to demonstrate the extent to which these theories and their underlying empirical base are transferable to understand environmental DISTs like those used by desertification policy and management organisations.

Diez and McIntosh's review (2009) (see Table 1) of the literature on the influences and outcomes of the IS life-cycle concludes that most relevant drivers of DIST implementation are user participation, behavioural intention, computer experience, external pressure, perceived usefulness, professionalism of the DIST unit, subjective norms, system quality, top management support, user support and training. Interview results partly agree with Diez and McIntosh's findings as some of the drivers of DIST implementation mentioned by interviewees are the same as those mentioned in the literature i.e. the case of user participation, external pressure, system quality, top management support and user support. However, there are also a number of differences between literature review and interview findings, which suggests that the drivers motivating DIST implementation in desertification policy and management organisations are not always the same as those in the organisations considered in IS literature which are mostly commercial in orientation.

First of all, computer experience, professionalism of the DIST unit and subjective norms do not seem to drive DIST implementation in desertification policy and management organisations. That subjective norms does not appear in the list of drivers or constraints indicates that peer pressure towards DIST implementation is not important in desertification policy and management. Second, training was not perceived by interviewees as a driver for DIST implementation but as a barrier at organisational scale. Finally, there are some differences in the way 'system quality' was defined in the literature and the interviews. Whereas the literature defines a good quality system as one that provides high-quality information – in terms of relevance, completeness, reliability, understandability and level of detail – and is easy to use, interview findings contend that a good quality system is one that meets the following attributes:

- Easy to use
- Provision of high-quality information – in terms of relevance, completeness and reliability
- Flexibility
- Low cost of implementation
- Capability to integrate and update information
- Data management and mapping capabilities

The IS literature has traditionally emphasised the importance of perceived usefulness as a driver for IS implementation, and a useful IS has been regarded as one that improves the effectiveness and efficiency of organisations (Davis, 1989; Al-Gahtani and King, 1999). Interview findings suggest that perceived usefulness may also be a driver for DIST implementation in desertification policy and management organisations in terms of the functionalities that DISTs offer to better assess, monitor and forecast desertification, and to improve communication which are positively related to organisational effectiveness.

4.2. Lessons of interview findings for DISTs development and implementation management

Most of the organisations where interviews were conducted used DISTs to support their work. However, this does not imply that each organisation is fully satisfied with the DISTs they use, or that it is not necessary to improve their development or implementation management. Bearing in mind the list of constraints and negatively perceived impacts listed in Table 4 the development and implementation of DISTs could be enhanced if the following recommendations were taken into account:

1. *Minimise costs* – desertification policy and management organisations are clearly most deterred by the financial costs of using DISTs, in a number of ways from the costs of employing new people to use the DISTs or to carry out newly created support roles such as data gathering to the costs of acquiring new computers. They are deterred by the need to pay for training to use DISTs, and they are deterred by the need to (and potentially the costs involved) in updating DIST information and databases, and obtaining support. Strategies are required to ensure that DISTs are easier and less costly to use (see below) and that DIST information and databases can be easily updated through existing monitoring programmes rather than requiring the user organisation to create new, bespoke programmes. Ensuring that DISTs are accompanied by clear, easy to implement and low cost validation approaches to ensure the user organisations can be confident in outputs without the need to invest in new data gathering activities is likely to improve uptake and use.
2. *Make DISTs easier to use independently* – DIST use is constrained by the need for and cost of training, both of which could be minimised by good, user-centred interface and functionality design which avoids the creation of DISTs which are too complex to use. Further the need to seek support and to internally provide training could be minimised through simpler tool design and the provision of adequate documentation.
3. *Establish trust between developers and users* – potentially linked to the need for (continual) validation of DIST outputs is the issue of trust. User organisations are less likely to employ DISTs from developers they do not trust. Creating and investing in the creation of a trusting relationship will take time but is likely to result in greater uptake. Such relationships are fundamental to ensure uptake.
4. *Ensure the information needs and tolerances of the user organisation are understood* – in the area of desertification poor data quality is an issue which affects the likelihood of DIST use. However some users are willing to accept DIST output information that is less than perfect e.g. incomplete, uncertain etc. Investing in time to understand the main information attribute needs of users and the levels of data quality they are willing to accept will help avoid mis-design.

5. Conclusions

The objectives of this paper were to investigate the organisational use, impacts and reasons for use of DISTs in desertification policy and management. Interview findings show that some of the conclusions drawn by empirical work in the area of IS are also applicable to understand DIST use by desertification policy and management organisations. However, the study has shown that there is a set of drivers for use specific to the field of desertification policy and management.

The main constraints on the implementation of DISTs in desertification policy and management organisations relate to the financial investment required and the low quality of DIST outputs, which is not necessarily caused by technical flaws of the DISTs but by the scarcity of data generally in the area. These results suggest that higher levels of DIST implementation could be achieved if more data were available, indicating a priority for investment.

Taking the list of constraints as a proposal for a better design of DISTs, it has been observed that some of our recommendations for improving development practices have also been suggested elsewhere (e.g. Giupponi et al., 2007b; McIntosh et al., 2009).

To improve the general understanding established by this research there is a need to both broaden the geographic areas sampled as these were under-sampled at national and sub-national scales. Further, there is a need to deepen the analysis by investigating the reasons for use and the impacts of using different types of DIST through detailed case-study investigation, potentially using a process research rather than a variance research designs, and some form of ethnographic observation. However, it is hoped that the results presented here provide a useful glimpse into the world of the users of DIST technology, and are sufficiently detailed to help guide the improvement of DIST development now.

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