Making an impact: how to design relevant and usable decision support systems for conservation

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Chapter 8

Making an Impact: How to Design Relevant and Usable Decision Support Systems for Conservation

Short title: Designing usable decisions support systems

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Abstract

Decision support systems (DSS) aim to provide evidence in a usable format for decision-makers, thereby improving the prospects for evidence-informed conservation policy and practice. These systems are usually software-based either in computer or app-form, but may exist in other formats such as on paper. Conservation decision-makers are typically faced with complex socio-environmental landscapes, competing stakeholder interests, and irreducible uncertainty. Consequently, conservation has been the focus for numerous decision support systems, which can help users to face the challenge of making trade-offs. Despite the many systems designed for conservation, there is not an accepted framework for how to develop systems that make an impact in practice. There is much evidence, however, to suggest that many systems are failing to make an impact in practice. This chapter draws on lessons learned from conservation and related disciplines on how to design good decision support systems that are desirable to intended end users. To this end, we suggest a five-stage process for participatory user-centred design – (1) identifying the user, (2) proving system value, (3) assessing available infrastructure and focusing on ease of use, (4) adopting a good marketing plan, and (5) establishing a long-term legacy – a process which could be used by researchers and funders alike to ensure that systems will be used by their intended audiences. Above all, we need to change our own design behaviour to increase the relevance and usefulness of the systems we are building. Acknowledging the reality that decision support systems will be implemented in complex and potentially data-sparse environments, we also reflect on how decision support systems can help decision-makers to deal with uncertain information. This final element seeks to establish the value both of quantifying uncertainty and communicating it in accessible ways to decision makers.

Keywords: decision support; decision support tools; decision support systems; evidence-based policy; evidence-informed policy; uncertainty

Contents

8.1 Introduction

The interfaces between evidence, policy, and practice have been the subject of much research in the fields of environmental management and conservation (e.g. Marshall *et al.*, 2016; Rose *et al.*, 2018a; Young *et al.*, 2014). In briefly summarising this large body of literature, there are several common themes which have led scholars to characterise these interfaces as complex and messy (Lawton *et al.*, 2007). The lack of linearity between evidence and decision has been commonly identified (see Evans *et al.*, 2017) and studies have widely described a 'gap' between the different worlds of science, policy, and practice (see Rose *et al.*, 2018a). Such a gap makes it difficult for evidence to be communicated to decision-makers, while the needs of practitioners and policy-makers struggle to shape scientific agendas (Arlettaz *et al.*, 2010). Decision-making, therefore, is usually never based on evidence alone, particularly in controversial or 'wicked' issue contexts, nor in fact should it be in a functioning democracy where values, beliefs, and interests matter (Owens, 2015; Rose, 2018). Furthermore, research has illustrated that evidence can take many forms, including knowledge that may be considered scientific within academic communities, but also lay or indigenous knowledges based on experience, observation, and a close place-based connection with the environment (Montana, 2017; see also Part I of this book).

In this chapter, we adopt a normative position which sees scientific evidence as important to robust decision-making. It is fair to take such a position in the light of continuing calls for 'evidence-based' or 'evidence-informed' decision-making in conservation (e.g. Gardner *et al.*, 2018; Sutherland and Wordley, 2017). In the simplest form, decision-makers desire evidence so that adopted policies have the best chance of succeeding in practice. Or put another way, they use evidence to minimise the chances of an incorrect decision and to increase decision transparency (if systems are designed to allow for transparency). In many fields, such as economics (OECD, 2015), medicine (BMJ, 1996), and increasingly conservation (Sutherland *et al.*, 2004), it is generally accepted that decisions should be informed by robust evidence. In medicine, for example, few, if any, patients would want their doctor to make a diagnosis without consulting the evidence. Patients would then expect their doctor to adopt an evidence-informed treatment plan based on clinical trials.

In nature conservation, a plea for evidence-informed decision-making has been made by a number of scholars (Gardner *et al.*, 2018; Sutherland *et al.*, 2004; Walsh *et al.*, 2015; Sutherland and Wordley, 2017). It is argued that we should expect conservation decision-makers, such as reserve managers, to base actions on evidence. If decisions are not evidence-informed, then actions may be undertaken that do not work, which wastes time and money without providing any tangible benefit to the target species or habitat, or indeed to people. There are, of course, differences between medical and conservation decision-making; for example, in medicine it is usually the case that a specific drug will cure a specific illness whether a patient has the same illness in Australia or Canada. Although conservation actions are somewhat generalizable (Roughgarden *et al.*, 1994), there is more uncertainty associated with comparing outcomes between different places, as there are far more factors to control for (Sutherland *et al.*, 2017). For example, a successful strategy to conserve coastal saltmarsh in East Anglia, UK, may be inappropriate in different parts of the UK, let alone in a different international context because a number of factors vary (such as tidal range, climate, level of development; see also Chapter 7).

Despite the challenges of comparability, it is still logical to argue that conservation actions would be more successful if they were informed by evidence of what works (Gardner *et al.*, 2018; Sutherland *et al.*, 2017). In the midst of a so-called 'communication gap' between science, policy, and practice, Dicks *et al.* (2014) highlight four formats in which scientific evidence can be presented to decision-makers – studies, systematic reviews, summaries, and decision support systems (Figure 8.1). Figure 8.1 provides a summary of these different formats, and notes the predominant style in which they are generally (but not exclusively) presented. Decision-makers could be government policy officials at different levels, reserve managers from NGOs, or other people who make environmental management decisions, such as farmers, fishers, or businesses.

Studies are single pieces of research that may describe the results of an intervention aimed at one or more species. Systematic reviews collate lots of single studies together to give a broad overview of the body of literature (similar in many ways to meta-analysis that seek to combine data from different sources), while summaries take the results of a systematic review and offer a precis in simple, non-academic language.

There are, however, problems with trying to deliver evidence in these formats to practitioners. Firstly, single studies may provide selective evidence, an issue that may be overcome by systematic reviews/meta-analyses, which can give an overview of the body of evidence. This overview is likely to be more robust, and studies have found that decision-makers welcome syntheses of evidence, rather than individual studies (Rose et al., 2018a). Systematic reviews though, like studies, are generally inaccessible to decision-maker communities (Rose et al., 2018a), or may be written in jargonistic, complicated language which is difficult to interpret. Summaries attempt to overcome this problem by presenting a clear precis in relevant language, but again this relies upon decision-makers finding this information, interpreting it, and applying it to a decision context.

Decision support systems (DSS), however, offer a further layer of sophistication, providing a route through which evidence can be delivered in a usable form (Dicks *et al.*, 2014). They tend to be computer-based, either in software- or app-based formats (although they can be paper-based), and incorporate evidence within the inner workings of the tool. In so doing, the tangible tool is able to take users through various decision stages towards a final decision. Systems can be dynamic in nature, in other words manipulating inputs provided by the decision-maker before suggesting evidence-based outputs, or they can act as information sources, offering further evidence in a cumulative decision process (Rose *et al.*, 2016). DSS aim to integrate complex process-based models in an accessible interface, helping decision-makers use data to solve unstructured problems (Addison *et al.*, 2013; McIntosh *et al.* 2011; Schwartz *et al.*, 2017), therefore acting as 'boundary objects', bridging the gap between scientific evidence and the decision-making process.

In this chapter, we will give an overview of research on DSS in conservation and related disciplines, with the express aim of identifying lessons to guide the design of good, impactful systems. As the discussion below will show, many DSS have been designed at great expense, but have sometimes failed to make an impact in practice as their intended audience did not use them. Since DSS have great potential to deliver evidence in a usable format to conservation decision-makers (and indeed to others outside of conservation), we thus need to ensure that they are well-designed so that they are actually used in practice. To this end, we draw out key principles for good system design and delivery with a focus on participatory user-centred design.

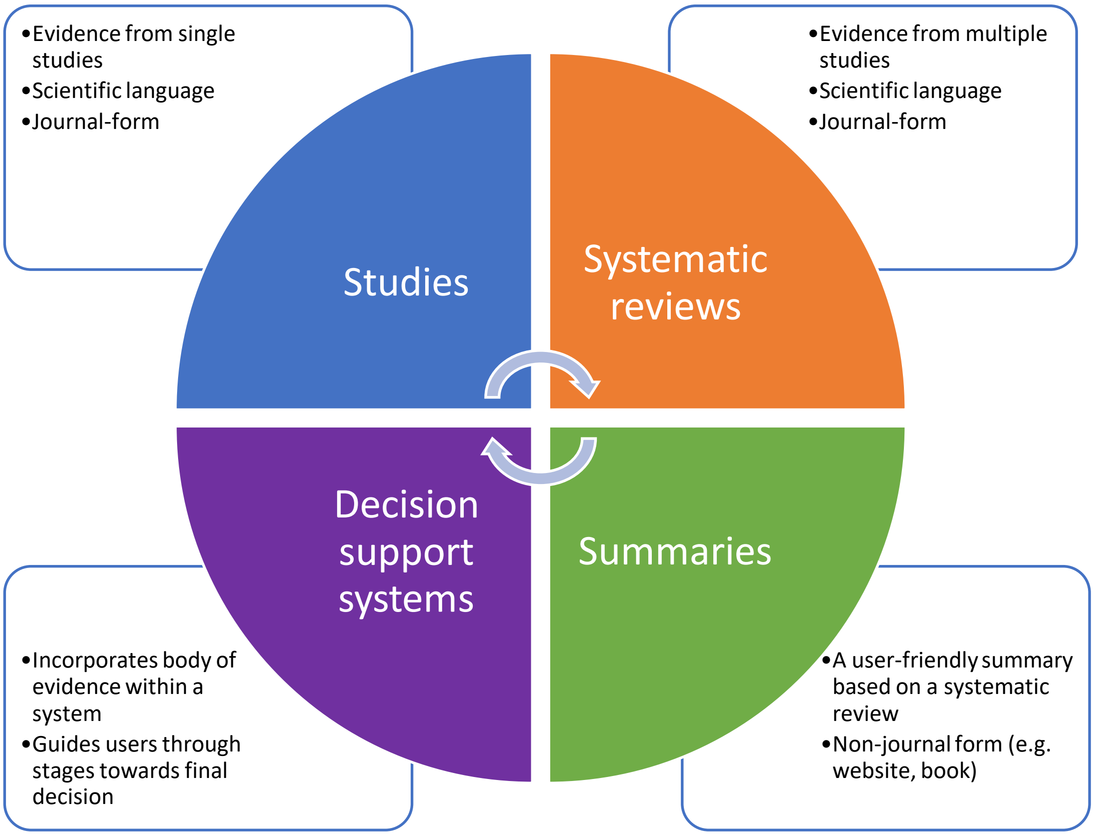

Figure 8.1 Four routes through which evidence may be communicated to decision-makers, with a description, and the format in which they are usually presented (based on the '4S hierarchy', Dicks *et al.*, 2014)

8.2 The Use of Decision Support Systems Beyond Conservation

A proliferation of formal decision-support approaches has developed to assist with evidence challenges in decision-making (Ascough *et al.* 2008). DSS are increasingly considered, by both policy-makers and experts, to be productive routes to support complex decision-making structures (Van Kouwen *et al.* 2007). As previously stated, they can help to deliver evidence in a usable form for decision-makers and may help them to overcome complex challenges associated with biological, socio-economic, and political trade-offs (Bower *et al.*, 2018). But, we make it clear at this early stage of the chapter, that we do not present an argument that sees DSS as the only way to make conservation decisions, nor do we say that the advice of such systems should be blindly followed. Systems will only ever contribute to decisions, since there are other forms of knowledge (e.g. place-based knowledge) available, which can sometimes be just as valuable as the information behind technical algorithms (Rose, 2018).

Before looking specifically at conservation DSS, it is worth reflecting on the considerable research on system design and uptake which has been conducted in fields with similar characteristics to conservation - medicine, agriculture, and coastal management are good examples because all should involve practitioners (e.g. doctor, farmer, coastal manager) making evidence-informed decisions. Much of this research draws on behavioural models which identify the factors affecting uptake of decision support systems or technology in general. The most well-known of these models is the Unified Theory of the Acceptance and Use of Technology by Venkatesh *et al.* (2012), which predicts that various factors determine technology uptake - these include whether the system performs well (performance expectancy), whether it is easy to use (effort expectancy), as well as a range of social (e.g. habits) and personal characteristics (IT education, age), and facilitating conditions (e.g. IT infrastructure). In medicine, DSS have been designed to help medical practitioners use evidence to support their decisions (Rawson *et al.*, 2017; Shibl *et al.*, 2009; Thursky and Mahemoff, 2006). Thursky and Mahemoff (2006), for example, report on the successful introduction of an antibiotic prescribing system for Intensive Care Unit use. This system reduced the time taken to perform prescribing tasks and it was readily used in practice. Furthermore, Shibl *et al.* (2009) discuss systems aimed at improving the use of evidence by General Practitioners. Their study concluded that various factors influenced system use, which built on the early work of Venkatesh and others – namely, performance expectancy, ease of use, existing decision habits, facilitating conditions, and age, experience, and gender (Shibl *et al.*, 2009).

In agriculture, there has been much research on the subject of decision support system adoption over at least two decades (see Rose *et al.*, 2016). Much research, however, has found limited uptake of systems by their intended end audience, usually farmers (Gent *et al.*, 2013; Hochmann and Carberry, 2011; McCown, 2002). In response to the problem of implementation, studies have set out to identify successful characteristics of systems that are actually used in practice; for example, Rose *et al.* (2016) listed fifteen factors that influence whether a system is used (Box 8.1).

Box 8.1 Fifteen design features of effective decision support systems (from Rose *et al.*, 2016)

1. ***Performance expectancy*** – how useful a system is and whether it works well
2. ***Ease of use*** – how easy a system is to use
3. ***Peer recommendation*** – a system that is recommended by peers has a greater chance of widespread uptake
4. ***Trust*** – how far end users trust the evidence underpinning the system or the manufacturer themselves
5. ***Cost*** – whether a system is free, cheap, or expensive to buy is a key factor
6. ***Habit*** – whether using a system matches existing decision-making habits or not, flagged by Rose *et al.* (2016) as a key factor.
7. ***Relevance to user*** – a system which gives information relevant to the user is important
8. ***Farmer-adviser compatibility*** – whether a system was used by linked advisors
9. ***Age*** – younger farmers tended to use computer-based systems more
10. ***Business scale*** - bigger farmers used more decision support
11. ***Farming type*** – different farming enterprises (e.g. arable *versus* livestock) used systems more or less often
12. ***IT education*** – farmers with higher IT education used computer-based decision support
13. ***Facilitating conditions*** – farms with good internet or broadband connectivity were more likely to use DSS
14. ***Compliance*** – whether a system helps farmers satisfy legislative or market requirements was important
15. ***Marketing*** – the user had to know about the system in order to use it

There are thus a number of important considerations for system designers, which move beyond well-known criteria such as performance and ease of use. In addition, designers need to understand who the users are, including their decision-making habits, age, level of IT education, workflows, and individual circumstances, as well as assess the necessary infrastructure (e.g. connectivity) for system use, and adopt strategies for marketing, delivery, and implementation. Thus, it is inadequate merely to design a sophisticated system which is easy to use.

Other studies have shown the importance of involving users in the design of agricultural decision support systems (Allen *et al.*, 2017; Evans *et al.*, 2017; Nelson *et al.*, 2002; Lindblom *et al.*, 2017) so that products are relevant, usable, trusted, well-known, sustainable, and easy to use. Indeed, participatory user-centred design in which users are involved in the conception, design, and implementation phases is now widely considered to be vitally important (McIntosh *et al.*, 2011; Parker and Sinclair, 2001; Rose *et al.*, 2018b; Santoro *et al.*, 2013). We discuss user-centred design in more detail later in this chapter. Important also to note is the tendency to focus on changing the behaviour of users in relation to technology, rather than focusing on the design of the product itself. This has resulted in users being blamed for non-adoption, rather than the technology, which may have been poorly designed (de Oca Munguia and Llewllyn, 2020).

8.3 Using Decision Support Systems in Conservation

There are many examples of DSS being used to make evidence-informed decisions in conservation (e.g. in strategic land conservation planning) (Gibson *et al.*, 2017; Anderson, and Rex, 2019). While decision-making in conservation sometimes involves conducting interventions in 'the dark' without good data (Cook *et al.*, 2010; Regan *et al.*, 2005), there is often at least some evidence of what is likely to work (Sutherland *et al.*, 2017). The strength of this evidence will vary by taxa or location, but there are generally some studies that will help to guide the intervention. This evidence of what works has, for example, been usefully synthesised by the 'Conservation Evidence' platform, which is described in more detail below. DSS can take this synthesised evidence and use it to underpin risk-based conservation decision-making, increasing the chances that policies or interventions will be effective, thereby saving time, money, and effort, and helping to achieve objectives (Addison *et al.*, 2013; Dicks *et al.*, 2014; Sutherland *et al.*, 2017).

In their analysis of system use, Gibson *et al.* (2017) provide many examples of systems, including the Ecosystem Management Decision Support System, which is used to guide landscape analysis in the USA, and Marxan, which is a tool designed for cost effectiveness analysis in relation to the selection of conservation areas. It is claimed that the latter system has over 6,000 users across 182 countries (CITE). A further suite of systems was the subject of a user testing workshop by Rose *et al.* (2017), and McIntosh *et al.* (2011) identified a number of different systems for environmental management. Furthermore, a team at the University of Queensland have built a decision support system to help policy-makers with biodiversity offsetting, and there is evidence that this collaboration between researchers and government has been successful (see *http://www.uq.edu.au/research/impact/stories/a-calculated-approach/*).

Interestingly, a study in Pennsylvania by Rittenhouse *et al.* (2018) on the use of the 'SILVAH-Oak' decision support tool, which provides forest management alternatives based on ecological and decision thresholds, found that managers used it as a key part of decision-making. They found that a large percentage of forest managers (69%) were following recommendations made by the tool, although there was sometimes disagreement based on the threshold data.

A systematic literature review would likely identify a plethora of systems that could be used to inform conservation. It is speculated, however, that returned papers would describe what systems do (e.g. Bottero *et al.*, 2013), rather than exploring how, why, and if they are used (Rose *et al.*, 2016).

8.3.1 Examples of successful Decision Support Systems

Below we provide six examples of DSS that are being used to guide decision-making in conservation at various scales, choosing to focus on a range of decision-maker audiences: policy-makers, practitioners, and business users. Although these systems have tended to be developed by Western conservationists (although a detailed review might challenge this assertion), many are being applied globally. It is worth noting here that some scholars have argued that decision support system development for environmental management needs to be better encouraged in developing countries (see e.g. Mackay *et al.*, 2018 - context of Pacific Small Island Developing States).

7. *Tool: Conservation Evidence (https://www.conservationevidence.com/)*

Purpose: Conservation Evidence, a project led from a group at the University of Cambridge (UK) collates evidence on conservation interventions (see Sutherland et al. 2019). Scientific literature that is usually locked behind paywalls or difficult to find is summarised in plain English and made available for free on Conservationevidence.com. Alongside the website, there is an offline pdf and hard copies of synopses and 'What Works in Conservation'. This project also identifies where there is no evidence and can inform future research and conservation efforts. The search function helps searching through the 5,400 individual studies (1,700 interventions) using keywords and filters. This helps decision makers find studies on similar topics in similar systems and countries. End users can also download a bespoken summary of evidence by selecting the interventions that they are interested in, this creates their own offline reference document unique to their questions.

The evidence for an intervention is then assessed using the Delphi technique (Mukherjee *et al.*, 2015) giving a score for effectiveness, certainty of evidence and potential harms of the interventions for the target group (i.e. 'set longlines at night to reduce seabird bycatch' in some cases can increase bycatch of white-chinned petrels but decrease other types of bycatch). This tool also tries to integrate both grey literature (evidence from unpublished sources such as government agency documents or organisations reports) and non-English evidence into the tool by searching and summarising the literature. For non-English studies, the title is displayed in the original language along with the English title. It is also possible to search the grey literature and non-English literature in a similar way, for example, the subject (birds) and language (Japanese) to refine the evidence further. Furthermore, an associated journal, Conservation Evidence, allows practitioners to send in evidence of successful or failed interventions, which is then automatically integrated into the decision support system.

End users: Decision makers ranging from a nature reserve manager to a policymaker can easily find the available evidence summarised in short paragraphs organised under groups such as amphibians, control of freshwater invasive species or Mediterranean farmland.

Format: Web application

Evidence of use/outcomes: the website has on average 24,000 page views per month and 11,500 frequent users (used over 50 times). It has been used by conservation NGOs from small (Echo) to large (Society for the Protection of Birds Netherlands). For example, the People's Trust for Endangered Species check the system before they decide on what interventions to perform and, ask those seeking funding to reference 'Conservation Evidence' materials in applications and to write up the effectiveness of interventions for the associated journal. Furthermore, the funding body, the Whitley Fund for Nature require applicants to demonstrate the effectiveness of interventions by referring the 'Conservation Evidence' materials and also encourage authors to write up their findings for the associated journal.

8. *Tool: Toolkit for Ecosystem Services Site-Based Assessment (TESSA)*

Purpose: TESSA is a decision support tool for carrying out ecosystem services assessments. It provides practical stepwise guidance to producing baseline estimations of ecosystem services (provisioning, regulating, cultural and supporting services) and their value at the site-scale. TESSA guides the user through a selection of relatively accessible, low-cost and simple methods. The methods allow the user to identify which ecosystems services may be important at a site and to evaluate the magnitude of benefits that people currently obtain from, compared with those expected under an alternative state (e.g. changing land use, restoration, degradation of the site). The toolkit is designed to overcome obstacles such as costs and complexity by providing practical guidance and methodologies to assess ecosystem services. The interactive PDF takes the user through steps to identify (i) which services may be significant at a site of interest; (ii) which data are needed to measure them; (iii) which methods or sources can be used to obtain these data; and (iv) how to effectively communicate the results (Figure 8.2).

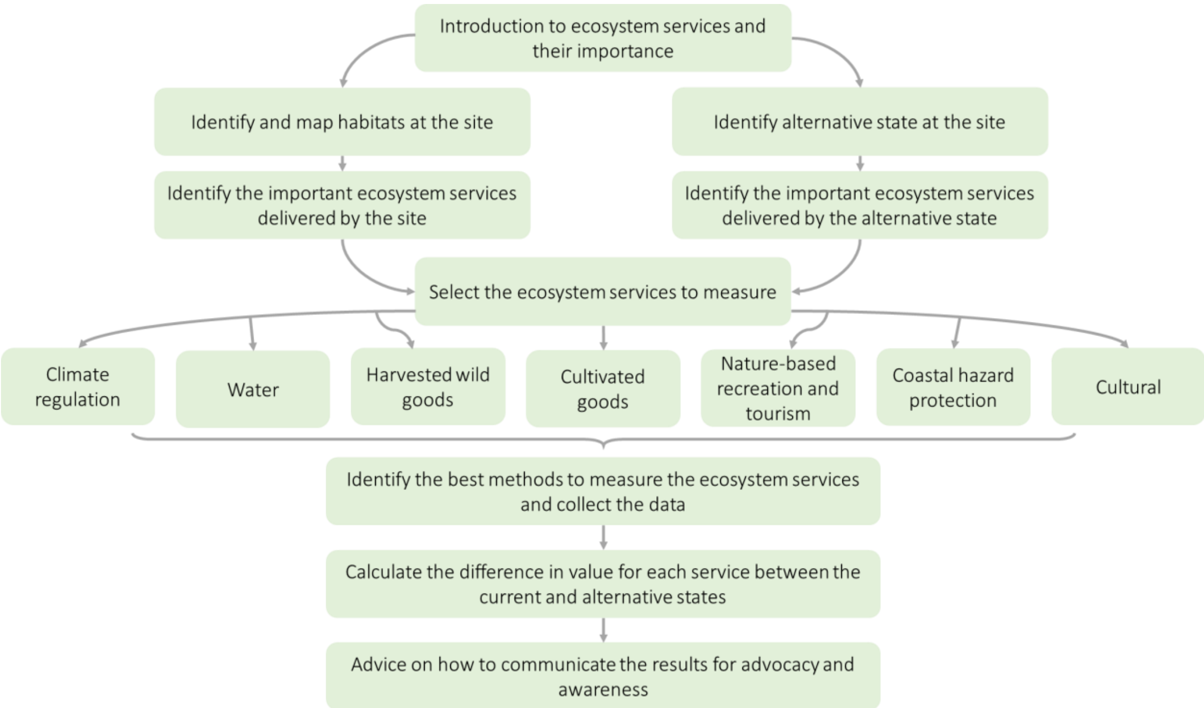

Figure 8.2 Diagram showing the steps within the TESSA toolkit. Within each step, there are a series of structured flow charts and decision-trees which guide the user through the methods required to collect data and the processes by which to estimate ecosystem services using these data. Adapted from 'Measuring and monitoring ecosystem services at the site scale' BirdLife International. Available at: http://www.birdlife.org/worldwide/science/tessa-publications and http://datazone.birdlife.org/sowb/sowbpubs#Ecoservices2011http://tessa.tools/

The toolkit has attempted to find a balance between simplicity of inputs and usability of outputs (Figure 8.3) and therefore excludes consideration of some of the more advanced ecosystem service science. It can be applied by non-experts within a limited time, using limited resources and at a relatively low cost, yet still provides scientifically robust information (Peh *et al.* 2013). The toolkit recommends using existing data where appropriate and places emphasis collecting accessible field data.

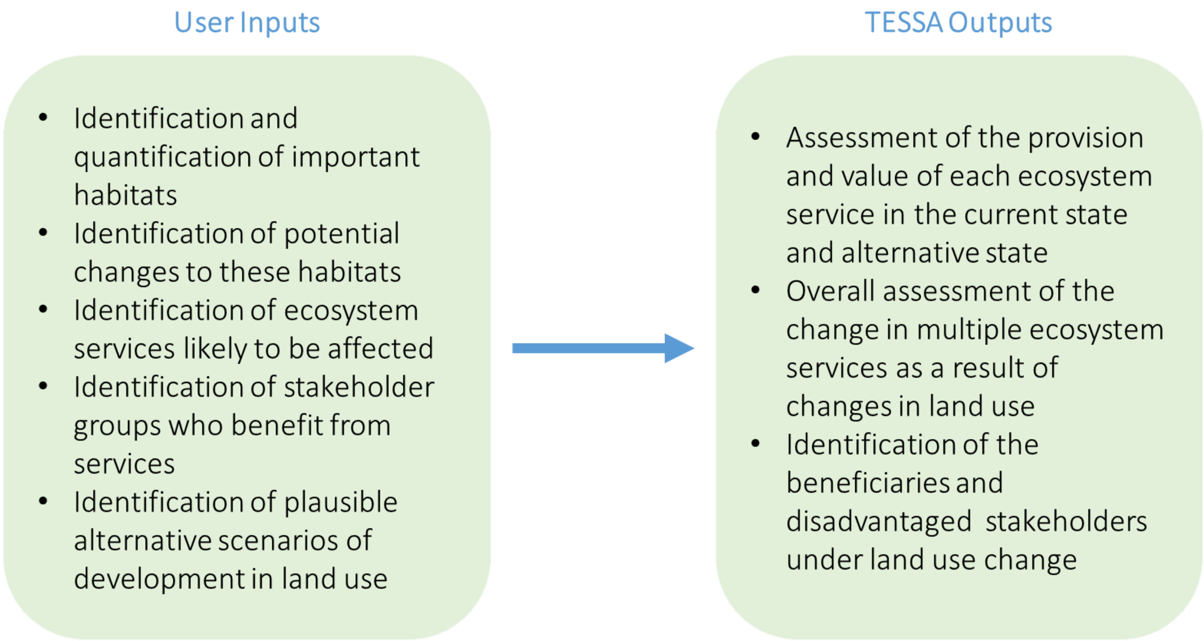

Figure 8.3 User inputs and outputs of TESSA Toolkit

End users: It is aimed at supporting non-specialist conservation practitioners and decision makers at the local scale

Format: Downloadable and interactive PDF

Evidence of use/outcomes: TESSA has been used to assess varying ecosystem services in a wide range of locations (Table 8.1), including Kenya, Uganda, Cameroon, Nepal, Cambodia, Vietnam, China, Dominican Republic, Fiji, Romania and the UK. See links here: http://www.birdlife.org/assessing-ecosystem-services-tessa/case-studies and here: http://www.birdlife.org/worldwide/science/tessa-publications. The methods are designed as templates and allowing users to adapt them to local conditions at a particular site.

Table 8.1 Some examples of TESSA usage in academic literature

Use location	Project description	Reference
Nepal, Phulchoki Mountain Forest Important Bird and Biodiversity Area (IBA)	Compared multiple ecosystem service values (including carbon storage, greenhouse gas sequestration, water provision, water quality, harvested wild goods and nature-based recreation) provided by the site in current state and a state where community forestry practices had not been implemented.	(Birch *et al.* 2014)
Centre Hills, Monserrat	Estimate the effect of feral livestock control on ecosystem services – global climate regulation, nature-based tourism, harvested goods and water provisioning. TESSA was employed to measure and compare ecosystem service provision in the presence and absence of feral livestock.	(Peh *et al.* 2015)
Nepal – across network of 27 Important Bird and	Participatory rapid appraisal approach used to assess ecosystem services – developed as part of a more	(Thapa *et al.* 2016)

Biodiversity Areas (IBAs)	comprehensive methodology to measure services at individual sites using TESSA.	
UK, East England	Study quantifies the differences in ecosystem service (climate change regulation, cultivated goods, nature-based recreation, flood-risk mitigation) provision under two common mineral site after-use – nature conservation and agriculture.	(Blaen *et al.* 2015)
Wanglang National Nature Reserve, China	Study quantified the differences in ecosystem services (global climate change regulation, water related services, grazing and harvested wild goods, nature-based recreation) provision of two alternative conservation approaches: (i) existing strict regulation and (ii) local community use of natural resources	(Liu *et al.* 2017)
Bwindi Impenetrable National Park, Uganda	Pilot study to identify and assess the diversity of ecosystem services in the park and benefits to local stakeholders. Comparison between Bwindi, which is managed by the Uganda Wildlife Authority and Echuya Central Forest Reserve which has a Collaborative Forest Management agreement.	Nature Uganda, 2018
Sierra de Bahoruco National Park, Dominican Republic	Study to generate information about the benefits that people in the reserve receive from the ecosystem services (global climate regulation, water services, harvested wild goods, cultivated goods, nature-based recreation). Compared a well-conserved vision to a highly degraded state.	Angarita-Martinez *et al.* LINK
Natewa Tunuloa, Fiji	TESSA was applied at three forest sites, including Natewa Tunuloa, to identify and highlight the ecological and socio-economic values of forests and therefore sustainable forest management. Compared the current state with two alternatives – one featuring more logging and grassland and the other more plantation forest.	Valu *et al.* LINK
Khe Nuoc Trong, Vietnam	Part of a wider initiative to explore the potential to develop a sustainable management model for conserving the forest – TESSA was used to compare the global climate regulation, harvested wild goods, water provision and flood protection services under a 'business as usual' scenario of extraction and exploitation and a 'forest of hope' scenario of restoration and management.	Merriman *et al.* LINK
Copal Community Forest, Cameroon	Three sites in the COPAL community forest were investigated using TESSA – (i) the current community forest; (ii) certified cocoa plantations; (iii) non-certified cocoa plantation. The benefits in terms of global climate regulation, water services,, harvested wild goods and cultivated goods were valued.	Mbosoo LINK
Yala Swamp Complex, Kenya	TESSA study assessed the value of harvested wild goods and cultivated goods through surveys in 16 villages within the area. The alternative state was a better managed Yala wetland, which used the Lake Kanyaboli National Reserve as a comparison site.	Akwany LINK

9. *Tool: Ape Seizure Database*

Purpose: The Ape Seizure Database was developed for recording instances of seized apes (i.e., chimpanzees, gorillas, orangutans and bonobos) in order to tackle the illegal trade of great apes and ensure their long-term survival. Data is uploaded on the ground via smartphones, and the records are then validated by a panel of great ape experts from around the world. The system is fully responsive and caters to users with poor and unstable internet connections.

End user: This tool is used on the ground by The Great Apes Survival Partnership (GRASP), an alliance of nearly 100 *national governments, conservation organizations, research institutions, UN agencies,* and *private companies*.

Format: Web Application and Database

Evidence of use/outcomes: Data gathered through the Apes Seizure Database enables users to quantify displaced apes and improves accuracy in terms of scale and scope of illegal trade to better inform decisions and efforts for tackling illegal activity. The tool also helps identifying key geographic areas of concern where law enforcement efforts need to be strengthened[1].

10. Tool: Protected Planet https://protectedplanet.net/

Purpose: This is a publicly available online platform that provides up-to-date spatial data and site information on the World's 237,000 protected areas (see Figure 8.4). Data on protected areas is updated monthly with submissions from governments, non-governmental organizations, landowners and communities. Protected Planet is managed by the UN Environment World Conservation Monitoring Centre (UNEP-WCMC) with support from IUCN and its World Commission on Protected Areas (WCPA). Users can access information on protected areas, statistics, and download data from the World Database on Protected Areas (WDPA). The database is updated on a monthly basis and the website has the most up-to-date information.

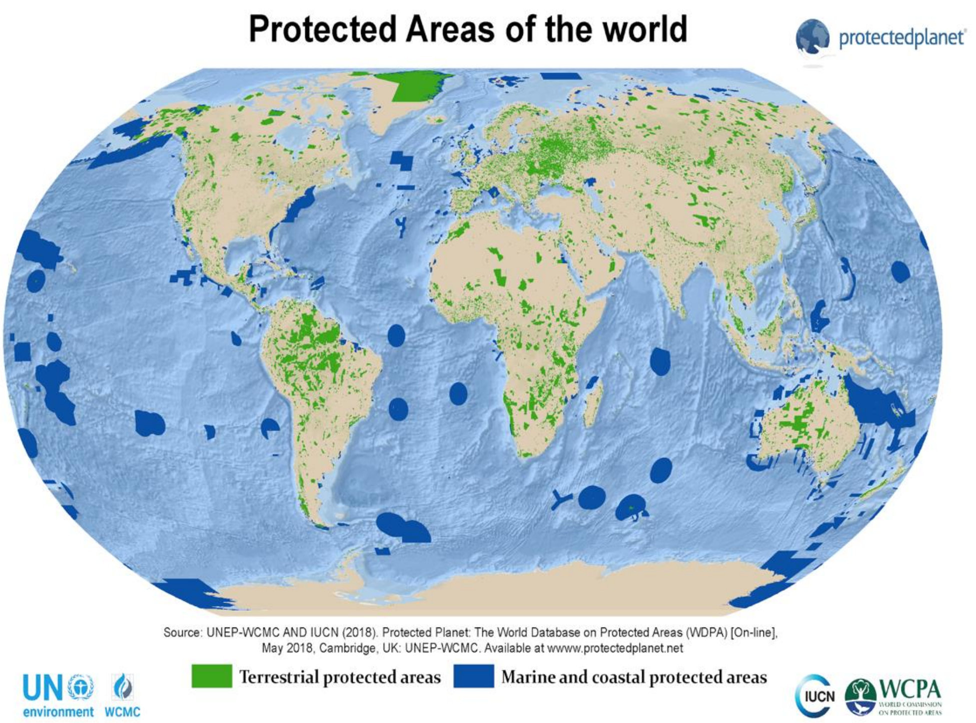

Figure 8.4 Protected Planet image (source embedded in image)

[1] For more examples of use and outcomes see http://www.bbc.co.uk/news/science-environment-37513707

End users: National governments, academics/scientists, businesses

Format: Web Application

Evidence of use/outcomes: Protected Planet provides up-to-date protected area data that informs decision-making, policy development, and conservation planning. A range of businesses (including finance, mining, and oil/gas) use the information for identifying biodiversity risks and opportunities. The WDPA is a key resource for tracking progress towards the achievement of global targets. For example, the WDPA data is used for five official indicators for Aichi Biodiversity Target 11 (regarding Protected Areas) of the CBD Strategic Plan for Biodiversity 2011-2020[2], and official indicators for three targets within the Sustainable Development Goals - namely Targets 14.5 of Goal 14 (Life below Water), and 15.1 and 15.4 of Goal 15 (Life on Land)[3]. The Millennium Challenge Corporation (MCC), a US government aid agency, uses data from the WDPA to measure the effectiveness of policies related to Natural Resource Protection in order to assign funds to recipient countries.[4]

11. *Tool: Online Reporting System http://ors.ngo/*

Purpose: To streamline national reporting for Multilateral Environmental Agreements (MEAs) and support countries with meeting their reporting obligations to MEAs
End user: Secretariats of MEAs, and country officials reporting on MEAs.

Format: Web Application

Evidence of use/outcomes: This tool streamlines the reporting obligations contracting parties have to the various MEA secretariats and makes data available to inform decisions on biodiversity. The tool is being used by 8 MEAs, including the Convention on International Trade in Endangered Species (CITES), the Ramsar Convention on Wetlands of International Importance (Ramsar), and the Convention on the Conservation of Migratory Species (CMS).

12. *Tool: The Cool Farm Tool (https://coolfarmtool.org/coolfarmtool/)*

Purpose: An online greenhouse gas, water, and biodiversity calculator for farming helping farmers/growers, food manufacturers, and retailers to improve environmental management. The mission of the Cool Farm Alliance, which is comprised of a network of industry groups, supermarkets, universities, and others (see below), is to enable millions of growers around the world to make more informed on-farm decisions that reduce their environmental impact. The Cool Farm Tool enables on-farm greenhouse gas calculations for all major crops globally; biodiversity assessments for farms in temperate forest biomes; and soon, water footprinting for 25 crops globally' (from Cool Farm Alliance website, https://coolfarmtool.org/coolfarmtool/). The biodiversity component of the tool allows farmers and buyers to see which species are

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[2] The list of Aichi Biodiversity Targets and official indicators for the CBD Strategic Plan for Biodiversity 2011-2020 is available here: https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-28-en.pdf
[3] The list of SDG targets and official indicators is available here: https://undocs.org/A/RES/71/313
[4] More information on users and outcomes soon to be published in Heather C Bingham, Diego Juffe Bignoli, Edward Lewis, Brian MacSharry, Neil D Burgess, Piero Visconti, Marine Deguignet, Murielle Misrachi, Matt Walpole, Jessica L Stewart and Naomi Kingston. *The World Database on Protected Areas: the past, present and future of a major conservation database* (in review).

benefiting from management practices, suggest different strategies, and monitor impacts on biodiversity. It is free for farmers.

End user: Across the supply chain, including farmers, food manufacturers, and retailers

Format: Online application

Evidence of use/outcomes: The Cool Farm Alliance is now comprised of well over 30 members, including agricultural industry groups (e.g. Yara, Syngenta), supermarkets (e.g. Tesco, M & S), food manufacturers (e.g. Kellogg's, Nestle, McCain), other food retailers (e.g. McDonalds), universities (e.g. Wageningen, Aberdeen), and environmental initiatives (e.g. European Initiative for Sustainable Development in Agriculture). Various service providers support tool implementation and training.

8.4 Barriers for Uptake of Decision Support Systems in Conservation

In a similar way to the studies outlined in the previous section, DSS in conservation are sometimes underutilised, or not used at all by their intended audiences (Addison *et al.*, 2013; Gibson *et al.*, 2017). Contrastingly with fields such as agriculture, however, there is much less critical social science research that has looked at the problem of lack of uptake in conservation (Dick *et al.*, 2017; Gibson *et al.*, 2017; Rodela *et al.*, 2017). This includes limited work on what practitioners think about systems that have been created for them (Dick *et al.*, 2017), such as GIS-based spatial tools (Bottero *et al.*, 2013; Rodela *et al.*, 2017). There is certainly a gap in the literature for further research of this nature. Of those few studies that have addressed the problem of implementation, the explanations are not dissimilar to those found to explain lack of uptake in fields such as agriculture or medicine. Prominent barriers to uptake include:

- *Lack of system relevance for decision-makers* - for example, a system does not help policy-makers address key policy objectives (Addison *et al.*, 2013; Gibson *et al.* 2017; Weatherdon *et al.*, 2017).

- *Limited trust between designer and user* - noted, for example, in studies by McIntosh *et al.* (2011), Addison *et al.* (2013), and Gibson *et al.* (2017). The lack of a user-centred approach, where intended end users are involved in the design process to ensure that systems are relevant and easy to use, may be a contributory factor here (Addison *et al.*, 2013; Rose *et al.*, 2018b). Poor communication between designers and stakeholders is also a problem (Addison *et al.*, 2013; Schwartz *et al.*, 2017).

- *Unstructured decision procedures don't fit with the use of systems* – mentioned, for example, in a study by Johnson *et al.* (2015). The authors describe how decision-makers, including conservation practitioners, rarely use systematic and transparent procedures through which to make decisions. In other words, decisions are not made in a step-by-step fashion with detailed consideration of the evidence, and transparency with respect to how the final decision was taken. Systematic DSS may, therefore, not fit in well with such 'messy' decision-making processes (Johnson *et al.*, 2015).

- *Poorly designed or maintained systems* - systems can be difficult to use, or may quickly become obsolete if they are not maintained after funding ends (Rose *et al.*, 2018b). Rittenhouse *et al.* (2018) found that early versions of the 'SILVAH-Oak' tool were not as user-friendly as possible, leading to some mistakes in its use.

- *Inflexibility when dealing with uncertain information* - some systems are perceived to be poor at working with uncertain or missing information (Gibson *et al.*, 2017), which is commonplace in the complex problem of conservation.

- *No evidence champions in organisations* – there is some evidence to suggest that systems will be used if they are championed first by particular individuals, who then recommend them to peers and colleagues (Gibson *et al.* (2017).

[see Gibson et al. (2017) and McIntosh et al. (2011) for more barriers]

Based on research in other fields, it is likely that factors such as poor delivery and lack of marketing, are also significant barriers to uptake (Rose *et al.*, 2016). The fact that similar design and delivery flaws are being noted in the conservation literature suggests that lessons have not been widely learned from other fields. Put simply, therefore, although there are examples of DSS being used in conservation, there are still prominent barriers to uptake which need to be overcome. The next section provides tips on how to conduct good user-centred design of systems. The aim of this exercise is to ensure that we design systems that users want to use in the first instance, and then that they continue using them once adopted.

8.5 Designing Usable, Impactful Systems: Tips for Good Participatory Design

With reference to the prominent barriers to uptake listed above, it makes logical sense that systems would be more impactful if they did not suffer from common design and delivery flaws. Although it is sometimes difficult to define what success looks like for DSS (McIntosh *et al.*, 2011), we argue that widespread use by the intended end user is a suitable measure. To overcome the problem of implementation, several protocols have been suggested, including by McIntosh *et al.* (2011)[5] and Rose *et al.* (2018b). Focusing on the latter protocol here, Rose *et al.* (2018b) constructed a multi-stage approach to guide the user-centred design of DSS. Shown in Figure 8.5, this approach attempts to reconfigure the dominant top-down knowledge transfer approach associated with existing decision support system projects. This process depends on involving the user at all stages (Addison *et al.*, 2013; Cerf *et al.*, 2012; Parker and Sinclair, 2001), embracing the end user ‘throughout the design and development process’ (McIntosh *et al.*, 2011, 1389).

[5] Five suggested stages of success were: (1) Design for ease of use, (2) Design for usefulness, (3) Establish trust, (4) Promote plan for longevity, (5) Start simple, develop incrementally (McIntosh *et al.*, 2011)

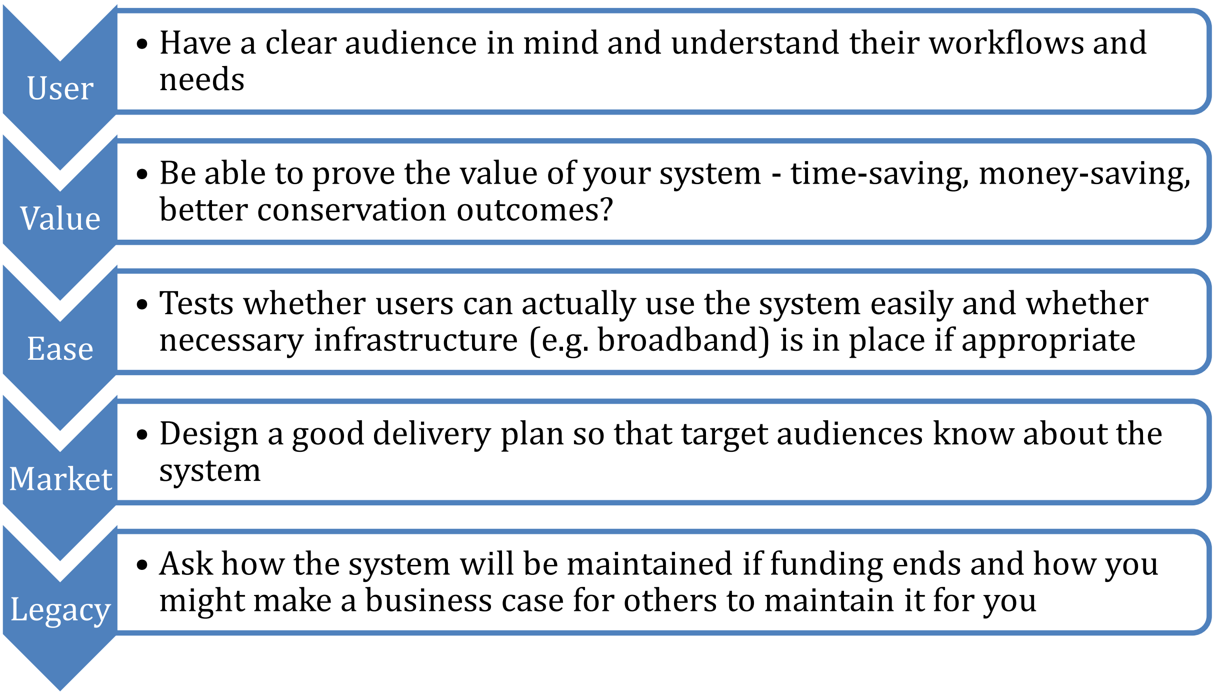

Figure 8.5 Five-stage process for designing an impactful decision support system (based on Rose *et al.*, 2018b).

Following this process should prevent the design of flawed systems that do not adequately consider their end user. We will briefly discuss each stage:

1. *Think **user*** - identifying the user is key to understanding what their questions of interest are and their workflows. Understanding user's problems is important so that systems are relevant (Addison *et al.*, 2013); this will include identifying the needs of policy-makers, for example, how a system can help them to satisfy reporting requirements (French and Geldermann, 2005; Weatherdon *et al.*, 2017).
2. *Think **value*** - the system has to have value for the use If we want to make a difference in practice, the system has to be useful for the end user, and not just be scientifically sophisticated enough to result in an academic publication. The designer of the tool should be able to provide some metrics for the potential performance of the system; these may include, for example, the amount of time saved in making a decision or the amount of money saved in making a more effective, efficient decision.
3. *Think **ease** of use* - this is a key consideration, but this should be from the perspective of users. Systems must be easy to use, but testing must be conducted with the intended end user, rather than on like-minded colleagues. Furthermore, an assessment of the site of implementation is needed to check that the system can physically be used in a given location (e.g. internet access, IT knowledge). This is likely to vary by location. For example, remote rural locations, particularly in developing countries, are likely to suffer from poor broadband access, making it difficult to use internet-based systems. Different audiences are also likely to vary with respect to IT competency. There are many examples in the literature where innovations designed in a scientific 'laboratory' are unsuitable for application on the ground (see e.g. Lash *et al.*, 1996) and thus the context of implementation always needs to be considered before developing a system. It may be that paper-

based decision frameworks are required in areas of poor connectivity. In all cases, designers might also consider the language of their systems, and whether it can be available in multiple languages (see Amano *et al.*, 2016).

4. *Think* ***market*** - all businesses must market products in order to increase awareness. Why should it be any different for conservation DSS? Conservation policy-makers, practitioners, and business cannot use a system if they do not know that it exists.
5. *Think* ***legacy*** - DSS, including in conservation, often need to be maintained for accuracy. The business model should be considered at an early stage so that maintenance is guaranteed once, for example, academic funding ends. Designers may ask how they can convince third parties (e.g. businesses or NGOs) to maintain the system for them if it cannot be self-maintained in the long-term?

[all based on Rose *et al.*, 2018b]

To stress the point again, you cannot adequately address any of the stages above without considering and involving the user throughout. Research on co-innovation processes in agriculture, for example, encourages designers to ensure that a range of relevant actors are brought together allowing shared priorities to be identified and mutual trust to be built (Fielke *et al.*, 2017).

While it has been claimed that the design of decision support systems has become more participatory (see e.g. Dick *et al.*, 2017), there is limited evidence that user-centred practice is widespread. One example may be the QUICKSCAN software tool for ecosystem services decision-making (Dick *et al.*, 2017), which used stakeholder workshops in Scotland (representatives from farming, fishing, bird protection, tourism, Cairngorms National Park Authority etc.) to test the tool and provide feedback on its relevance and usability. Yet, it is unclear whether this process was truly participatory in the sense that users were involved at the conception phase. All too often, researchers or other tool designers have an idea to build a system and then initiate a participatory exercise to validate the idea (Chilvers and Kearnes, 2016). This fact was noted by Mann and Schäfer (2018) who reported on a so-called transdisciplinary water and land management in Germany in which a decision support system was originally intended to be user-centred. However, designers seldom involved the end users in the development process, and a system was produced with limited relevance. Hence, pro-innovation, top-down bias still often predominates.

Many previous projects have unwisely involved intended users at a late stage, trying to identify ways of incentivising uptake and perhaps even changing behaviour. Yet, if intended end users were involved at an early, upstream stage, then the ability to design a relevant and usable tool, which users trust and have knowledge of, is much enhanced (Fielke *et al.*, 2017; McIntosh *et al.*, 2011; Parker and Sinclair, 2001; Rose *et al.*, 2018b). Users would be more likely to adopt it in the first instance, and then continue to use it as it would be relevant and user-friendly.

Consequently, as a research community, we need to make progress in two areas in order to build the capacity for participatory research. Firstly, we need to understand better how to engage end users better so that we can establish successful two-way dialogue, and we then secondly require a clear methodology for involving users in system design which does not currently exist (Rodela *et al.*, 2017). This will require a change in research and design cultures to move away from top-down knowledge transfer, which builds a product and then tries to influence or change user behaviour to adopt it. We need to change our own behaviour so that we can build tools that match the workflows of end users, fit their tasks, and understand their needs and constraints (Gibson *et al.*, 2017).

We may need help to do so. If developers of systems, including researchers, are going to invest time and money into a trans-disciplinary mode of participatory development, then encouragement is needed. In academia, we need better incentives to focus on impact, rather than scientific publication, and much greater emphasis on impact from those who fund research (see Rose et al., 2019; Tyler, 2017). One simple idea is to encourage funders of research to require applicants, and subsequently successful bidders, to report against the five-step criteria above when applying for, or carrying out, the project. Such a reporting protocol would ask developers to show that they have (1) considered their audience, (2) identified a system that would be useful and relevant, (3) assessed the site/s of implementation and tested ease of use from a user perspective, (4) considered how to market the product, and (5) developed a long-term sustainability plan. Satisfactory reporting against such criteria would limit the chances of a system being designed that was useless, irrelevant, poorly designed, and poorly maintained.

Thus far, we have provided tips about how designers can change their behaviour to develop better systems. However, it is worth noting that decision-makers need to play their part too if decision support systems are to be better utilised (Johnson *et al.*, 2015). Johnson *et al.* (2015) describe how conservation practitioners may require better training to use decision support systems, although presumably this would not have to be too onerous if systems were easy to use in the first instance. Furthermore, they describe how messy decision-making processes, which are rarely transparent and step-based, do not lend themselves to the systematic use of decision support systems. Addison *et al.* (2013) would concur as they argue that unstructured decision-making might lead to subjective judgements that rely on hidden assumptions or individual interests. In response to this problem, Addison *et al.* (2013) suggest that conservation decision-makers should adopt structured decision-making frameworks which encourage a transparent step-based approach. Ultimately, the adoption of structured decision-making frameworks creates the right conditions for DSS to be used; to this end, it is argued that problems must be clearly formulated between those designing systems and end user decision-makers, communication should be effective between all stakeholders, and system designers should ensure that their product is relevant to decision contexts.

However, the ideal of structured decision-making is not easy to achieve. While we may wish that conservation decision-making was systematic, evidence-informed, and transparent (Sutherland and Wordley, 2017; Gardner *et al.*, 2018), in reality it is usually complex and multi-faceted with several 'decision-makers' (including stakeholders) involved in the process (Evans *et al.*, 2017). With this in mind, therefore, it is perhaps worth remembering a point that we stressed at the start of this chapter. Decision support systems are useful tools which can make a contribution to decision-making; however, they will only ever be a contributory tool and not the only factor in that decision-making. We should not expect the unstructured nature of most conservation decision-making to be replaced easily with a structured process where DSS tell users what to do. Thus, they may be used as a decision aid within a messy process, but designers should try as hard as possible to ensure that systems are flexible enough to work in such scenarios (see section below).

8.6 Using Decision Support Systems for Uncertain, 'Wicked' Problems

As an additional consideration to the above steps, it is worth mentioning how DSS may be used to address uncertain problems. Environmental decision-making is characterised by situations in which some factors or outcomes are not known (Hulme 2005; Regan *et al.* 2005) because predictions of environmental change can be highly uncertain (Ascough *et al.* 2008; Newbold *et al.* 2016; Polasky *et al.* 2011). This uncertainty in environmental decision-making arises from (i) the non-linear nature of the bio-physical processes which underpin the system, (ii) the variable impacts of the socio-political processes which surround the system and (iii) difficulties, imprecision, and inaccuracy in collecting empirical information about these processes and their impacts (Morgan and Henrion, 1990). Effective environmental management can thus be considered a function of the ability to make good decisions under uncertainty and limited knowledge of all parameters (Polasky *et al.* 2015; Wynne, 1992).

In complex, uncertain conservation problems, it is difficult to interpret recommendations made by decision support systems (Gibson *et al.*, 2017). A user might not necessarily trust the evidence underpinning the system, or the context-specific nature of conservation may mean that systems work better in some places than others. Yet, it is unrealistic to expect that decision support systems can only be used in situations where there is little or no uncertainty. Such uncertainty-free scenarios rarely exist, and thus we need to help users understand how systems can be used to address complex problems.

Coastal zone management can provide a useful case study example of DSS use under uncertainty. The coastal zone arguably represents one of the most complex systems for management, characterised by interactions between natural hydrology, geomorphic and bio-physical processes and socio-cultural and political influences (Arkema *et al.* 2013; French 2004; Nicholls *et al.* 2007). Coastal management is characterised by many of the challenges identified by Maier *et al.* (2008): (i) it is concerned with complex systems, many of which are not well-understood; (ii) it tends to involve large numbers of stakeholders, with competing objectives; and (iii) there are multiple potential management options. In many cases, nature conservation is a key component of coastal zone management.

Consequently, coastal decision makers are placed in a situation of high political stakes, substantial uncertainties, and numerous potential solutions (Sarewitz 2004), a situation not atypical of most conservation management scenarios. DSS have been used to offer guidance across varying areas of coastal decision-making, including aquaculture site-selection (e.g. Halide *et al.* 2009; Nath *et al.* 2000) and fisheries optimisation (e.g. Rice & Rochet, 2005), flood warning systems (e.g. Alfieri *et al.*, 2012; Billa *et al.*, 2006), and marine spatial planning (e.g. Duarte *et al.*, 2016; Villa *et al.*, 2014) (see Table 8.2).

Table 8.2 Examples and brief description of emerging generation of integrated models for decision support at the coast (based on Van Kouwen *et al.* 2007; Van Dongeren *et al.* 2016; FAST 2015; ARCoES 2016, Peh *et al.* 2013).

Decision Support System	Description	Areas of uncertainty	Communicating uncertainty
FAST project MI-SAFE Tool	User-friendly tool showing coastal profiles, flood risk and attenuation from vegetation. Uses satellite imagery alongside, where available, in-situ vegetation properties, elevation and sediment stabilisation data.	Resolution of input data, applicability of model to different areas and coastline types	Colour coded bands which describe the level of confidence attached to each data series for a particular area

RISC-KIT	Suite of tools for assessing risk and vulnerability to coastal storms and flooding, including risk assessment frameworks, a storm impact database, a high-resolution quantitative evaluation hotspot risk reduction analysis tool, a multi-criteria analysis tool, and a web-based management guide.	Input data uncertainty, nested scales with greater detail at smaller scales	Hotspot analysis allows user to zoom in on area. Use of detailed descriptions and data from past storm events
ARCoES	Series of animations and interactive mapviewer which illustrate the potential sea level rise and storm surge risk for populated coastal areas	Input data uncertainty (e.g. DEM resolution) and model uncertainty	Scenarios variable by sea level and storm surge, disclaimer describing uncertainty
CTESSA	Interactive PDF document which guides users through a suite of practical methods to assess the ecosystem service provision – coastal hazard regulation – of a particular site	Resolution of collected data, accuracy of data using simple methods, uncertain future boundary conditions.	Assess against two plausible 'alternative states' which restricts the outcomes. Disclaimer describing uncertainty and visual aids to show confidence in methods

Coastal DSS use various methods to account for and communicate uncertainty, as illustrated by Table 8.2. For example, scenario modelling allows tool users to assess outcomes under varying conditions. The use of scenarios is often supported through GIS and mapping interfaces which integrate and spatially resolve varying social, environmental, and economic information into a common interactive interface. Almost all coastal tools aim to communicate spatial uncertainty using maps as part of their outputs. For example, ARCoES provides an interactive map-viewer to display sea level and storm surge risks (Knight *et al.* 2015) and the RISC-KIT tool allows the user to zoom into 'hotspots' (Van Dongeren *et al.* 2016). The MI-SAFE tool attempts to provide a simple visualisation of the various scenarios for the user by colour-coding results (i.e. green for more confident, red for least confident). In CTESSA, the uncertain nature of coastal hazards is clearly explained, thus, being transparent about uncertainties could be useful. These output maps are used alongside sketches (Milligan *et al.* 2006), animations (Lieske *et al.* 2014) and even some 3D visualisations (Jude *et al.*, 2006; 2008) to communicate uncertainty at the coast to stakeholders.

Moving forwards, we could learn lessons about communicating uncertainty in conservation DSS from these coastal management examples. Firstly, we should be transparent about the uncertainties present in using the system to guide management. Secondly, we could find ways of presenting uncertainty in a clear fashion, for example by presenting different colour-coded scenarios showing the level of confidence of each recommendation. Thirdly, we could aim to ensure that systems use engaging visualisations to enable the user to understand uncertainties. Ultimately, these steps will improve the usability of systems in uncertain situation and increase trust from users.

8.7 Concluding Remarks

This chapter has shown the enormous potential for decision support systems to make a difference in conservation, improving the chances of evidence-informed decision-making. We should, therefore, all be interested in ensuring that systems are designed in such a way as to make them impactful on the ground. It serves no one in the conservation community to support the design of systems that will just 'sit on the shelf'. To ensure impact, systems must be relevant, useful, easy to use, sustainable, and well-marketed, so that they are used by their intended audience.

We suggest that researchers make use of the five-stage design protocol outlined above, crucially involving the user at every stage in a participatory user-centred approach. We also argue that funders and other supporters of system design, which can include research councils, government agencies, technology companies, and conservation NGOs, should use the outlined protocol (or something similar) to judge the strength of research proposals that seek to build a decision support system. If applicants are required to make it clear how they intend to: identify and characterise a clear audience (stage 1), determine a useful purpose (stage 2), assess existing infrastructure for the system (stage 3), ensure ease of use (stage 4), establish a clear delivery plan (stage 5), and (stage 6) guarantee long-term sustainability, then the chances of an obsolete system being produced will be limited.

Applicants who are able to show that their methodological approach will, over the course of time, involve the user to satisfy each stage, should be supported and required to report on their progress against each milestone throughout the project. Applicants who are not able to show convincingly that users will be involved to determine such things as relevance and ease of use should not be funded, or at least not prioritised if the aim of the funder is to support activities that are going to make an impact on the ground, rather than simply be published in a high impact academic journal. This will require a simultaneous recalibration of academic reward systems to prioritise and reward policy relevant impact work (see Tyler, 2017).

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