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Testing the ecosystem service cascade framework and QUICKScan software tool in the context of land use planning in Glenlivet Estate Scotland

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ABSTRACT

The concept of ecosystem services has been extensively studied in recent decades. Most studies have focused on describing the specific aspects such as production, spatial extent, valuation of services and the trade-off between services. Few studies however assess the practitioners' views on the frameworks, models or tools developed. In this paper, we report on a multi-stakeholder workshop where two tools were tested (i) the ecosystem service cascade framework was tested as a means to frame the issues and (ii) a participatory-spatial modelling method, QUICKScan, was tested as an aid to support discussion over natural resource management and planning in a multi-use landscape. A focused group discussion was utilised to determine stakeholders' views of the cascade framework and pre- and post-workshop questionnaires quantified the stakeholders' views of the QUICKScan method. The stakeholders identified both positive and negative aspects of both tools. The diversity of views expressed were associated with (i) the past experience of the individual with the issues discussed, (ii) the technical aspects of the tools i.e. the ability with GIS and (iii) the level of new shared knowledge they reported acquiring on the day which was related to their initial knowledge of the issue and area studied.

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1. Introduction

To manage the interdependence of human well-being and the environment in a sustainable manner has challenged humans for centuries (Chase-Dunn & Hall 1997). Towards the end of the twentieth century, the concepts of ecosystem services and natural capital gained predominance as a means to manage the environment. Schröter et al. (2014, p. 518) conducted a comprehensive review on the arguments related to the ecosystem service concept and highlighted the fundamental aspect that the 'ecosystem services concept offers a "platform" for bringing people and their different views and interests together'. In addition, they considered that 'One of the main characteristics of the ES concept is its interdisciplinary nature, i.e., it offers common ground for debate and methodological progress in different scientific fields' (Schröter et al. 2014, p. 519). The concept of ecosystem services, however, also has the potential to go further and help build bridges with practice based stakeholders through collaborative research processes that involve mutual exchange and learning relating to real world problems. These transdisciplinary research processes are thus better able to tackle complexity, dispersed knowledge and work in local contexts (Reyers et al. 2010). Indeed, a common theme in the ecosystem service literature is the context specificity of assessments, i.e. the issue, the people and their preferences and acceptance of any solution is influenced by the specific geographical and temporal location of the study. Stakeholders are commonly identified in terms of their common preferences based for example on similarities in their livelihoods, cultural values, economic outlooks and world views. The influence of personal identity and history may also play a role in stakeholder preferences for different ecosystem states (Martín-López et al. 2012).

The ecosystem service concept recognises that ecosystems provide multiple benefits to humans, but it is seldom possible to maximise all services and consequently decisions are required to manage the trade-offs between services. In this paper, we follow King *et al.* (2015) and use the term 'trade-off' to describe what happens when a land use or management decision leads to an increase in one service and a decrease in some other service or services. Trade-offs among ecosystem services can generate conflicts in natural resource management as people appreciate ecosystems and their services differently. In this study, land management decisions related to increased woodland were studied with consequential trade-offs between ecosystem services provided by wooded and non-wooded landscapes. Two ecosystem service tools where tested in a one day multi-stakeholder workshop; the 'ecosystem service cascade' framework

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(Haines-Young & Potschin 2010), and the participatory modelling method QUICKScan, which links stakeholder and decision maker knowledge and preferences to available spatial and spatio-statistical data, and is designed for group use (Verweij et al. 2016).

Many frameworks have been proposed to develop a common understanding between stakeholders. Dick et al. (2014) reviewed several frameworks and concluded there were four basic types which all had merit in particular situations: (i) frameworks aimed at interrogation of a single policy intervention or management change e.g. DPSIR (Smeets & Weterings 1999); (ii) frameworks which have many of the same components as type (i) in terms of drivers, pressures, states, etc. but fully recognise the ability, and, often, need to have targeted actions at several points in the chain rather than the linear approach of type (1) e.g. DPSEEA (Reis et al. 2015); (iii) feedback-focused ecological frameworks which tend to have a circular modus operandi e.g. FESP (Rounsevell et al. 2010); and (iv) combinations of these approaches which fully integrate the components of the former frameworks e.g. ISSE (Collins et al. 2007). The 'ecosystem service cascade' framework (Haines-Young & Potschin 2010), focuses on ecological structures and processes, with the adaptive DPSIR management cycle. This framework was considered suitable to conceptualise the problem investigated at the workshop and compliment the decision support tool tested, QUICKScan (Verweij *et al.*, 2016), as the latter also focuses on ecological structures and processes in a participatory, GIS, rule based approach and incorporates management options.

The use and development of decision support tools has shifted towards participatory approaches in recent years (Carberry et al. 2002; Nelson et al. 2002; McCown & Parton 2006). Central to participatory processes is the principle of actively involving stakeholders and their knowledge instead of treating them as passive recipients of knowledge (Kloppenburg 1991; Massey et al. 2006). The QUICKScan tool tested in this study is designed to support discussion and selection of management options among a group of stakeholders (Verweij *et al.*, 2016). QUICKScan uses a specific computer programme to be able to include stakeholder knowledge and preferences and calculate and visualise different scenarios for a selected geographical location. The results of each iteration feeds the discussion among stakeholders creating input straightaway for a next iteration, resulting in no loss of engagement or interest by stakeholders that can occur with complex scenario models which cannot compute changes in scenario as quickly (Verweij et al. 2016).

In this paper, we report (i) the background to the workshop in terms of scope, specific aim and selection of participants (ii) characterise the tools tested (the ecosystem service cascade and the QUICKScan decision support tool) and report the results of the ecosystem service assessments and (iii) report the views of stakeholders (focused group discussion about the cascade framework and a pre-workshop and post-workshop questionnaire for the QUICKScan tool). In the discussion, we explore the value of the approach taken from the stakeholders' perspective.

2. Method

2.1. Background of the workshop

To test the ecosystem cascade framework and the QUICKScan tool a one day multi-stakeholder workshop was organised. The scope, specific decision context and selection of participants invited to the workshop were agreed in collaboration with members of the Tomintoul and Glenlivet Landscape Partnership (TGLP). The TGLP aimed to use the rich heritage of the Glenlivet Estate, Scotland (Figure 1) to promote rural regeneration. The partnership recognised that the area is owned, managed and regulated by a complex range of organisations and many more groups and communities have a direct interest in it. They had accepted that an ecosystem approach, based on the area's natural and cultural capital would allow stakeholders to work together to manage the societal demands on the landscape. They were also in the process of applying to the UK Heritage Lottery Fund (HLF) to finance work focused on their aims. They, therefore, welcomed the opportunity to test the ecosystem service cascade framework and the QUICKScan software as potentially useful ecosystem service tools to frame arguments and reach agreement in the context of the HLF proposal.

At the time of the workshop, the partnership was still embryonic, although many of the participants had worked together in the past. The Crown Estate, who manage the land did not wish the outcome from either ecosystem service tool tested (ecosystem service cascades framework and QUICKScan tool) to result in binding decisions on the day. Rather, it was agreed that the participants from the TGLP would test the tools to evaluate their practical usefulness. This principle of the day was made clear to participants in the background documentation provided to attendees prior to the meeting (Supplementary material 1)

Woodland creation was selected in consultation with the Crown Estate as the focal issue for the workshop as the opportunity for the community to review and input into the Crown Estate Forest Plan was offered in the TGLP proposal to the HLF as a test case for the partnership.

2.2. Workshop participants and programme

Representatives from the TGLP and other interested stakeholders were invited including representatives

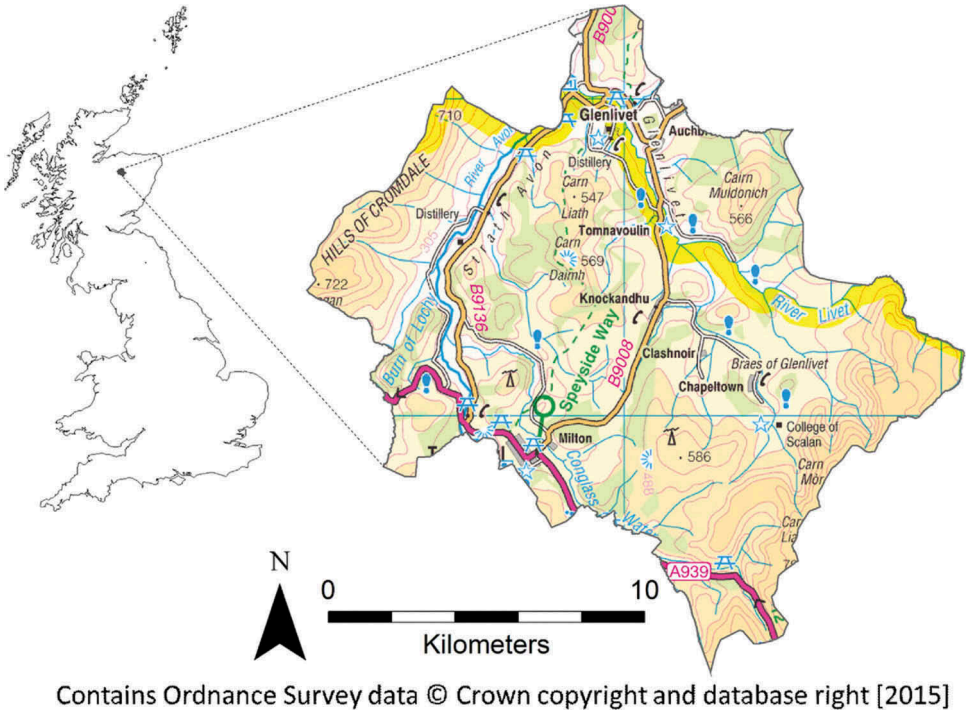

Figure 1. Map of UK and Glenlivet.

from the farming, fishing, bird protection, tourism, historical monuments, local development trust and Cairngorms National Park Authority. In total 15 people were invited to the workshop by telephone followed by email conformation with the background information for the day (Table 1). In addition a seven person research facilitation team attended the workshop.

The workshop (10:00–16:00) was divided into three sessions following a general introduction to the day and self-introduction of all participants at the workshop. The QUICKScan tool was introduced in the morning (10:30–12:30) when participants provided input data in the form of relevant ecosystem services. These inputs were programed into the software after lunch when the participants considered the Ecosystem Service Cascade Framework (13:30–14:30). In the final session of the day the software parameterised in the morning was demonstrated.

2.3. Ecosystem service tools tested

2.3.1. Ecosystem service cascade framework

The ecosystem service cascade framework was drafted by the research team using knowledge supplied by the stakeholders (Figure 2). The Crown Estate provided to the research team the visioning report for the estate woodland and the TGLP provided the stage one HLF proposal which detailed the management issues in the area.

The framework proposed defines the three habitats considered in the workshop i.e. woodland (broadleaf and conifer) riparian woodlands and wetlands. The ecosystem function box represents the interactions between biophysical structures, biodiversity and ecosystem processes that underpin the capacity of an ecosystem to provide ecosystem services e.g. timber production or the shade provided by the riparian woodland or the opportunity the wetland habitat

Table 1. Participants of the workshop and their role in the case study.

Role	Rationale for invitation
Farmer	Local farmer and member of TGLP Project Board and representative for the area to the CNPA
Farmer	Local farmer and member of TGLP Project Board
Land Agent Glenlivet Estate	Land agent for Crown Estate and member of TGLP Project Board
Tourist Operator	Conducts safari tours in the study area
Conservationist	Glenlivet Estate Countryside Manager
Operations officer Spey Catchment Initiative	Member of TGLP Project Board
Project Officer Spey Catchment Initiative	Member of TGLP Project Board
Forester	Senior forest manager with The Crown Estate
Conservationist	Member of Royal Society for the Protection of Birds and involved in HLF proposal
Conservationist	Member of Royal Society for the Protection of Birds, and will be officer in charge if HLF successful
Historian	Member of Royal Commission on the Ancient and Historical Monuments of Scotland and involved in HLF proposal
GIS expert	GIS expert at Royal Commission on the Ancient and Historical Monuments of Scotland
Representative of Cairngorms National Park Authority	Senior Land Management Officer in CNPA, Lead agency in HLF proposal, member of TGLP Board

CNPA: Cairngorms National Park Authority; TGLP: Tomintoul & Glenlivet Landscape Partnership; HLF: Heritage Lottery Fund.

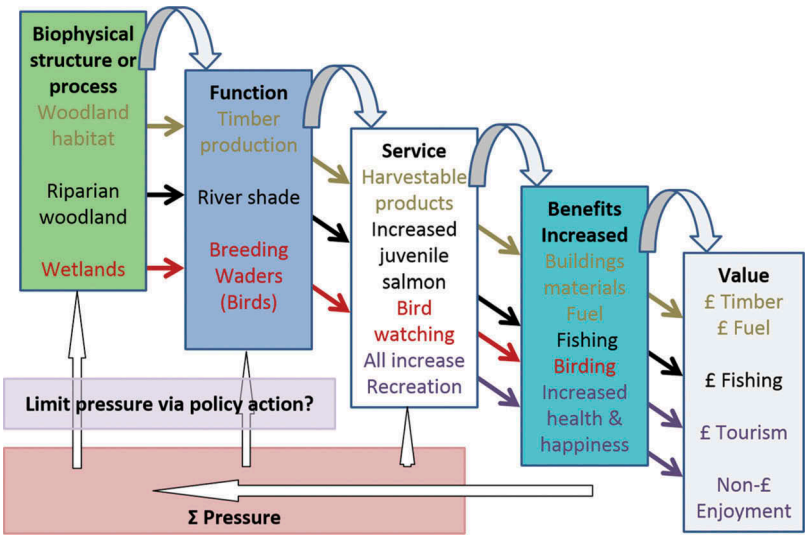

Figure 2. Cascade model (Haines-Young and Potschin, 2010) for woodland & wetland management in the area considered by the Tomintoul and Glenlivet Landscape Partnership (TGLP) in their proposal to the UK Heritage Lottery Fund (HLF).

provides for wading birds including lapwings and snipe.

The ecosystem services provided to humans from these landscapes is considered to be the harvestable products from the woodland which are essentially timber construction material and biomass for energy (summarised in the diagram as building materials and fuel). These have real market value and hence in the cascade model are depicted as £Timber and £Fuel. Woodlands provide other services including the opportunity for recreation which is also provided by the other habitats considered i.e. riparian woodland and wetlands. The benefits to humans from recreation is summarised as increased health and happiness which are considered to have some market value in terms of tourism and some non-monetary aspects which are summaries in the cascade model as enjoyment.

In addition, the riparian woodland is considered important to mitigate against climate change as the trees will provide shade and reduced water temperature in the river which is considered essential to the survival of juvenile salmon. The benefit to humans is considered the act of fishing which has a market value (depicted in the cascade model as £Fishing).

The wetland habitat provides the opportunity for birds to feed and breed and the benefits humans obtain is the ability to watch the birds. There is not considered a direct market for bird watching because the Countryside and Rights of Way Act 2000 ensure the right of individuals to walk on open countryside away from paths and to enjoy the natural environment responsibly and unhindered (depicted generally in the cascade model as £Tourism and Non-£ Enjoyment).

The data to examine the stakeholders' perceptions of the cascade framework were collected using the focus group method. The focus group discussion was planned and conducted by a facilitator who actively stimulated discussions within a group.

Information was provided to this stakeholder group beforehand to inform them of the focus group process, anticipated outputs and outcomes. This information also emphasised that involvement in the discussions was voluntary and requested the consent of the group participants to audio record the discussion. A focus group guide was also developed to help create and maintain an open discussion during which group members could easily contribute.

To stimulate the discussion around the ecosystem service cascade framework each participant was given copies of the initial framework (Figure 2). The participants were then asked the question 'from your perspective, how useful is the cascade framework?' During the discussion, where appropriate, the facilitator probed to help the group highlight the advantages and disadvantages of the cascade framework.

Data transcription was done verbatim and the data analysed qualitatively following a thematic approach, as described by Ryan and Bernard (2003) and using an open, inductive research approach (Bryman 2015). Thus, no predefined concepts were imposed on the discussion. In the analytical process the data was iteratively categorised into themes to identify common issues within the group discussion.

2.3.2. Quickscan: discussion support tool

To harmonise the participants' mental pictures of the study area and to acquaint them with the computer programme, several base maps were used during the introduction of the workshop: the 2007 UK Land cover map (Morton et al. 2011) clipped to the boundary of the Glenlivet Estate, elevation, topographical

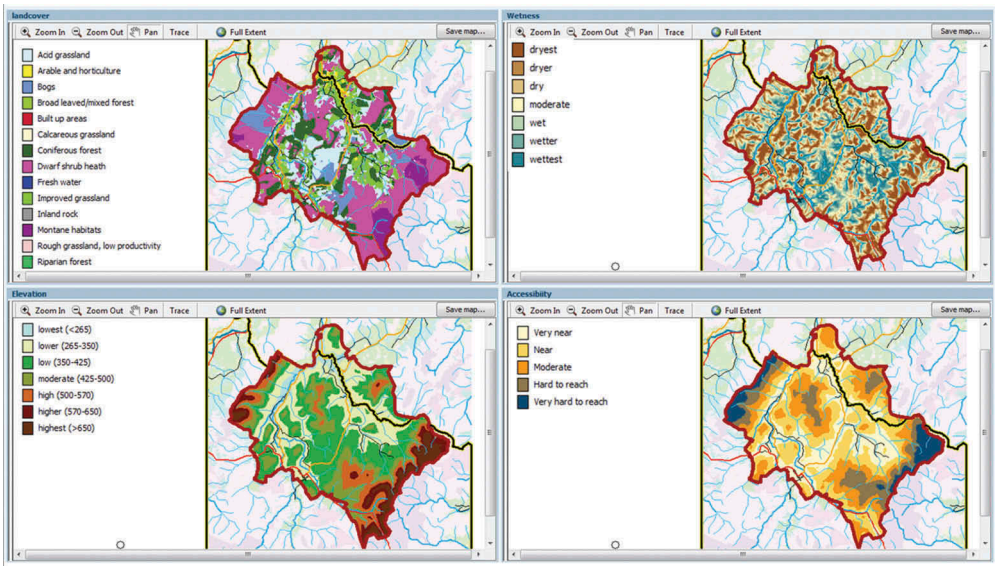

Figure 3. Current land cover, elevation, topographical wetness and accessibility of the Glenlivet Estate, Scotland.

wetness and accessibility (Figure 3). To acquaint the participants with the computer programme, an example of ecosystem service mapping was demonstrated by relating land use to an arbitrary ecosystem service by encrypting qualitative conditional knowledge (e.g. 'IF land use is deciduous forest THEN timber production is moderate').

During a 10 min plenary session an inventory of the study area's ecosystem service was made, directly followed by a prioritisation. For the prioritisation each participant was given 5 stickers which they could distribute onto their preferred ecosystem service. They were allowed to put multiple stickers on a single ecosystem service.

The top five ecosystem services were chosen (timbre provision, wader bird habitat provision, recreational fishing, recreational hiking and cattle grazing) and the participants were divided in five groups. Each group was given the task to create a rule which would allow the mapping of their focal ecosystem service on to a base maps presented. See (Figure 4) as an example of the result for the chosen ecosystem service of 'Wader birds' i.e. the quality of habitat suitable for wader birds was found to be dependent on land cover and wetness. Participants scored habitat quality in terms of: *none, little, moderate* and *a lot*.

During the workshop several forest expansion scenarios were developed by the participants. The scenario to expand commercial forests in the form of planted conifer plantations established on dwarf shrub and montane land cover classes up to 500 m elevation is reported here as an example (Figure 5). Note that this scenario is exploratory. It is unlikely that all areas below 500 m would be planted.

The results of the scenario revealed a restriction of the grouse to the higher elevations and highlighted the areas likely to be effected in a spatial explicit manner (Figure 6).

landcover \ wetness : Waders

	dryest	dryer	dry	moderate	wet	wetter	wettest
Acid grassland	Little	Little	Little	Moderate	A lot	A lot	Moderate
Arable and horticulture	Little	Little	Little	Moderate	A lot	A lot	A lot
Bogs	Little	Moderate	Moderate	A lot	A lot	Moderate	Moderate
Broad leaved/mixed forest	None	None	None	None	None	None	None
Built up areas	None	None	None	None	None	None	None
Calcareous grassland	Little	Little	Little	Little	Moderate	Moderate	Moderate
Coniferous forest	None	None	None	None	None	None	None
Dwarf shrub heath	Little	Little	Moderate	Moderate	Moderate	Moderate	Moderate
Fresh water	None	None	None	None	None	None	None
Improved grassland	None	Little	Little	Moderate	A lot	A lot	A lot
Inland rock	None	None	None	None	None	None	None
Montane habitats	None	None	None	None	None	None	None
Rough grassland, low productivity	None	Little	Little	Moderate	A lot	A lot	Little
Riparian forest	None	None	None	None	None	None	Little

Figure 4. Participant knowledge rule for wader bird habitat quality depending on land cover (listed vertically) and wetness (listed horizontally). Participants measure habitat quality in terms of: none, little, moderate and a lot.

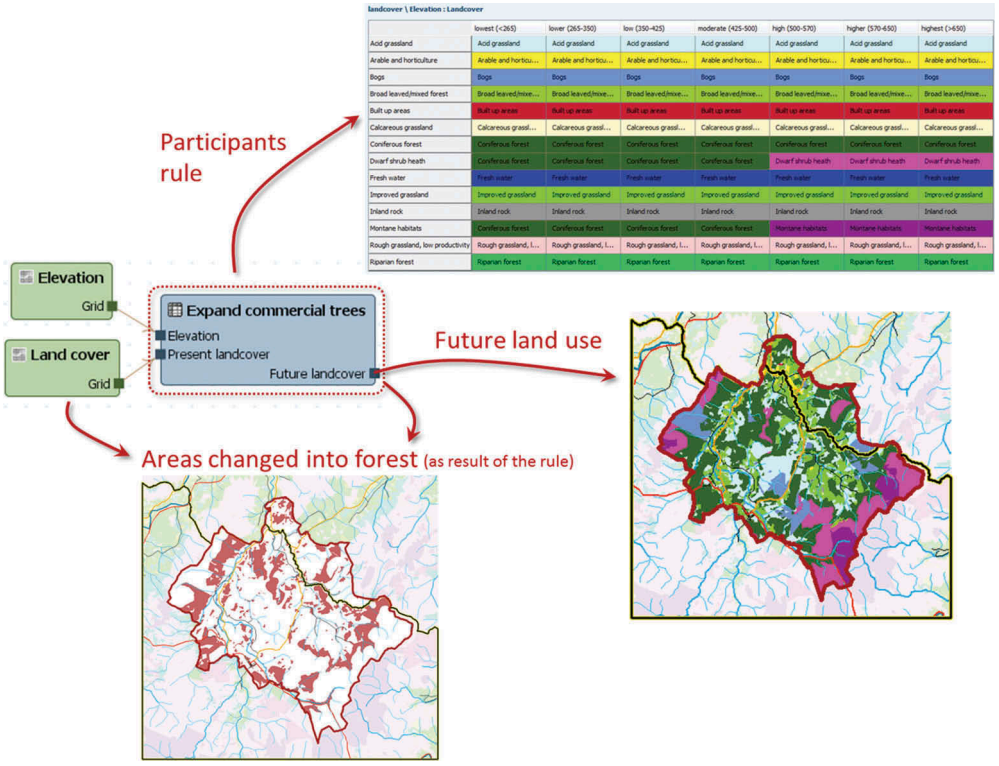

Figure 5. Land cover with expanded commercial forest planted on dwarf shrub and montane land cover classes up to 500 m elevation [Note land cover called Bogs is combination of Bog, grass dominated and Bog, heather dominated].

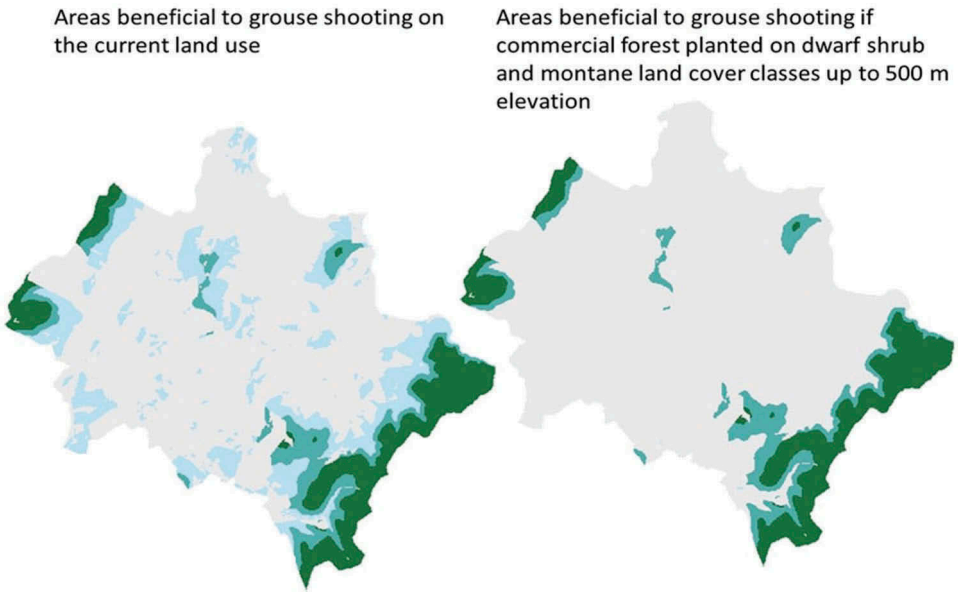

Figure 6. QUICKScan output showing the 'result map' i.e. estimated result of a land based rule to plant commercial forest on dwarf shrub and montane land cover classes up to 500 m elevation on grouse moors.

The discussion of the results of the scenario highlighted the areas where grouse shooting would no longer be possible which would affect rental income from shooting tenant and would also influence recreational use of the estate (reduced cultural ecosystem service of recreation both monetary and non-monetary units). The increased tree planting however would considerably increase timber production (provisioning service) and CO_2 capture (regulating service).

In order to discover the views of the stakeholder a pre- and post-workshop questionnaire was administrated to the participating stakeholders (see Rodela et al. 2015). The pre-test questionnaire gathered information about demographics, familiarity with GIS and with the topic discussed, people known from before and confidence in their own knowledge. While the post-test questionnaire gathered information about participants´ perception

Table 2. Format of numerical and open questions in the pre- and post-questionnaire.

Blocks of questions	Number Numerical Questions	Number Open questions
Pre-Questionnaire		
Demographic Information	3	1
Past experience with similar activities and topics	5	0
Past Knowledge of the specific topic	4	0
Past Shared understanding with participants	1	1
Time constraints today	3	0
Post-Questionnaire		
Experience with the activity	2	0
New Shared Knowledge from the day	7	1
New Shared Understanding from the day	6	0
New Learning from the day	2	2
Timing of meeting today	2	0
Transparency of tool demonstrated	4	4

Table 3. Summary of strengths and suggested improvements for the usefulness of the cascade model.

Themes	Strengths	Suggested Improvements
Communicating	• Structuring discussions • Transparency of decision making	• Local nomenclature to link with local context better
Understanding	• Links between different parts of the system • Simplifying complexity	• Less linear representation with different starting points possible
Coordinating	• Identifying actions to progress • Identifying collective objectives • Transparency of decision making	• Identify beneficiaries to: • link values with different groups of people • more explicitly signpost possible trade offs • better link with funders goals

about knowledge shared, up-graded and acquired, shared understanding, the visuals, timing, etc of the workshop. The questionnaires integrate open and closed questions, (Table 2) with questions aimed at assessing levels of satisfaction on a scale of three negative levels (−3, −2,−1), one middle neutral level (0) and three positive levels (+1, +2, +3). This scale has been used in previous empirical studies on decision support tool effectiveness (e.g. Inman et al. 2011). For practical reason the scale was converted into a 1 to 7 Likert scale when transcribing the answers into an Excel Spreadsheet. Thus, the scale initially used −3,−2,−1,0,1,2,3 was transformed into 1,2,3,4,5,6,7. Questionnaire data was also triangulated with non-obtrusive observation of the activity and more precisely handwritten notes were taken by the fourth co-author (who did not participate but only observed the activity) about group dynamics as well as comments and questions being asked during the QUICKScan session(s).

The blocks of questions (Table 2) were summed and divided by the number of questions in each block prior to a correlation analysis. A stepwise linear regression analysis was used to test which of the blocks of questions were significantly associated with the new learning which stakeholders had experienced on the day. Statistical analysis was performed using the statistical software package Genstat 16th Edition.

Participants were asked to complete the pre-test questionnaire before starting with the activities and the post-test questionnaire at the end of the day. In total 12 pre- and post-questionnaires were collected on the day and later telephone conversations to clarifications interviews were conducted with two participants.

3. Results

3.1. The stakeholders views of the cascade model

Three themes were identified relating to the usefulness of the cascade model from the multi-stakeholder focus group discussion. The findings on the practical usefulness of the cascade framework for each of these themes are presented below and are summaries in (Table 3).

3.1.1. Communication

Participants highlighted that cascade was useful to help facilitate communication within the group. One participant highlighted that the cascade could be useful to help provide a structure for discussions, 'rather than just a ramie around a table, you've got a structure to follow [for a discussion]', although another participant felt that 'all the points would have come out [anyway] because [the group] is so different from different organizations'. However, using the framework to improve transparency for external communication was also considered useful 'to present to the wider community our reasoning [...] if asked how we came to the decision'.

Participants in the focus group discussion also suggested ways the cascade model could be improved. One participant commented that using technical, generic categories, for example 'land-use categories' may be helpful to integrate and compare between different sites, however this did not represent local ways of understanding the system. This led one participant to comment that the cascade 'only really becomes useful [to the group] when it has the detail that relates to the area wherein the project is working'. Specifically, participants suggested improving the usefulness of the cascade model for local stakeholders by using local nomenclature, as one participant suggested there is a need to include 'site specific areas of riparian woodland so people have got in their heads a picture of the site rather than a generic term [...and] actually name the river and the stream'.

3.1.2. Developing an integrated understanding

Participants identified that the cascade framework was useful for helping to develop a more

integrated understanding, which is a core aspect of the ecosystem services concept. Specifically, participants also emphasised that the cascade model helped to 'start to work out where things fit' and to 'make you think differently'. Participants highlighted the need to bring together models for single processes and/or individual interests to facilitate more integrated thinking. Furthermore, participants also emphasised that the cascade is a simplified version of the system and 'is a useful illustration of the processes' and in reality these processes were too complicated to fully explore through the cascade framework.

However, participants also highlighted some potential improvements that may help the usefulness of the cascade in developing an integrated understanding. Specifically, participants emphasised that the layout of the cascade represents a specific perspective of how the components of the system interrelate, as one participant commented that the cascade model 'sort of presents issues as [...] as sort of a linear process, you know where everything just, even the word 'cascade suggests that there is an inevitability about it all, you know, that [values] will be down to the bottom [....] whereas [....] there are all kinds of different values'.

3.1.3. Coordinating action

Participants emphasised that the cascade was also useful for helping to coordinate action. Specifically, the usefulness of the cascade framework to organise information and identify next steps was also highlighted as one participant emphasised fitting information into the boxes of the cascade may 'help clarify your thinking about how you were then going to progress'. This led one participant to comment that there is a need to clearly set out the available information on the different components of the system to improve the transparency of group decisions to reduce the influence of powerful interests within the group over 'less vociferous [....] who [may be] a bigger group of people than the two loud mouths who are selling it', and pushing specific objectives in the process.

Participants also however identified some areas that may improve the frameworks usefulness in coordinating action. Specifically, participants' agreed that beneficiaries were important to identify in the framework, particular in situations with potentially competing interests, as one participant highlighted about the different components of the cascade model 'the benefits and value [boxes in the model, but], value to who?'. This led another participant to emphasise the importance of focusing on beneficiaries to support funding bids such as the HLF which will 'be driven by caveats [the funders] attached to it, [....] it is important who the value is coming to'.

3.2. Stakeholders views of quickscan software tool

In total 12 participants (6 males, 6 females) completed both the pre- and post-questionnaires (late arrival resulted in one stakeholder not participating). The respondents where aged between 20 and 59 year (average 27.4). Respondents reported that 83% had already taken part in a participatory activity but only 42% had taken part in a participatory activity related to a GIS based decision-support tool and only 4 (33%) considered they were very familiar with GIS. On average the participants knew 7 people in the workshop (range 0–10). Seven of the participants considered that they shared the same position on the topic investigated as participants whom they knew from before while two did not know and one answered that in their opinion they did not share the same position as others in the room on the topic to be discussed.

The participants scores from the pre-questionnaire revealed that on average (Table 4) they scored their past experience and interest in the topic positively i.e. above 3 (mean score of 5.8 and 6.5), but were less familiar with GIS (mean score 4.7). They perceived to be on average also relatively knowledgeable about the topic and considered others also knowledgeable (mean score 5.5–6.3). There was the widest range of views expressed to the questions related to the time constraints with some scoring the minim for all three questions (i.e. it was not important that they finished on time, they were not in a hurry and they were not usually under time pressure) while others scored maximum for at least one of these questions at the other extreme.

The post-workshop questionnaire revealed (Table 5) that the respondents on average considered the day had provided a positive experience, they had

Table 4. Average score and standard deviation of responses from pre-test questionnaire on a scale from 1–7.

Question	Average score	Standard deviation
Past experience with similar activities and topics		
How familiar are you with GIS?	4.7	1.75
How much the topic that will be discussed interests you?	6.5	0.65
How much the topic that will be discussed touches upon your personal well-being/ interests?	5.8	1.07
Past Knowledge of the specific topic		
Do you feel to have good knowledge about topics in your area of work?	6.3	0.43
Do you often engage with colleagues who have knowledge in other areas of work?	6.2	0.69
Are you knowledgeable about the topic that will be discussed today during the session?	5.5	0.87
How much do you think other people who will be participating to the workshop are knowledgeable about the topic that will be discussed?	5.7	0.75
Time constraints today		
How important is it for you to finish the activity promptly?	4.4	1.66
Are you in hurry today?	3.5	1.55
Are you usually under time pressure?	5.4	1.04

Table 5. Responses from post-test questionnaire.

Question	Average score	Standard deviation
Experience with the activity		
How would you evaluate your own experience during the Quick Scan participatory session?	5.4	0.76
How would you evaluate other participants' experience during the Quick Scan participatory session?	5.3	0.92
New Shared Knowledge from the day		
How much of your own knowledge and expertise have you shared with other participants during this session?	4.9	0.49
Have you acquired new knowledge about the issues discussed?	5.4	1.04
Have you up-graded knowledge you already have?	4.9	1.32
Has the Quick Scan tool helped you to verbalise knowledge you already have?	4.6	1.26
Has the Quick Scan tool helped you to share knowledge you already have?	4.6	1.38
How much of your own knowledge and expertise you feel that is integrated in the final outcome?	4.2	1.21
Do you think the final result integrates well environmental as well as socio-economic aspects?	4.8	1.16
New Shared Understanding from the day		
How you evaluate the discussion between participants during the session?	5.8	1.28
How much have you contributed to the discussion?	5.1	1.26
How much have other participants contributed to the discussion?	5.8	0.60
Do you agree with the opinions that the majority of the participants have expressed during the session?	5.4	1.19
Do you disagree with the opinions that the majority of the participants have expressed during the discussion?	3.1	1.38
Has your opinion on these topics somehow changed as a consequence to the discussion and data presented?	3.6	1.04
New Learning from the day		
How easy it was for you to understand the outcomes produced by QUICKScan?	4.8	1.30
Quick Scan helped you in any way to understand the opinions other participants' have on these topics?	4.8	1.09
Timing of meeting today		
Has the presentation and discussion of the options presented taken too much time?	2.6	1.50
Has the overall session taken too much time to complete?	2.8	1.57
Transparency of tool demonstrated		
To what extend were maps and other visual material produced helpful as a support to the discussion?	5.8	1.30
Have you found the processes behind the outcomes/maps obtained comprehensible to you?	5.3	1.16
Do the final outcomes reflect the input of all participants?	5.4	0.86
Are you satisfied with the outcome reached?	4.8	1.16

Table 6. Correlation between blocks of questions.

Experience with the activity	1	-								
New shared knowledge	2	0.6981	-							
New shared understanding	3	0.5342	0.6316	-						
Past experience	4	0.2827	0.3575	0.4475	-					
Time pressure	5	−0.0994	−0.3852	−0.2124	−0.3033	-				
Timing of meeting	6	−0.1716	−0.4656	−0.6003	−0.4621	0.1915	-			
Transparency of tool	7	0.7269	0.8795	0.5439	0.3531	−0.5273	−0.4568	-		
New learning	8	0.6807	0.9008	0.6884	0.6547	−0.3293	−0.4636	0.7885	-	
Past knowledge	9	0.1154	0.1174	0.4014	−0.2899	0.4485	−0.3644	0.0759	0.0268	-
		1	2	3	4	5	6	7	8	9

learnt new knowledge and shared understanding from the day's activities (i.e. mean scores above 4) although on average they had not changed their opinion on the topics as a consequence of the discussion and data presented. They rated the tool as transparent and maps and other visual material produced helpful as a support to discussion but considered the presentation and discussion of the options presented had taken too much time (mean score 2.6–2.8).

There were strong correlations between the responses to the blocks of questions (Table 6). The correlation analysis involving all the numerical scores to the blocks of questions reveal strong positive correlations between: 'Past experience with similar activities and topics'; 'New Shared Knowledge from the day'; 'Transparency of tool demonstrated' and 'New Learning from the day'. The 'New Shared Knowledge from the day' and also strongly correlated with 'New Shared Understanding from the day'.

The accumulated analysis of variance from the stepwise regression (Table 7) revealed that the scores the participants provided for the blocks of questions related to 'New Shared Knowledge from the day' and the 'Past experience with similar activities and topics' were significantly (Figure 7) associated with their scores for 'New Learning from the day' activities (92.5% of the variance accounted for by the model).

Table 7. Accumulated analysis of variance from a stepwise regression to determine the influence of the blocks of questions asked in the pre- and post- (see Tables 4 and 5) on 'New Learning from the day' activities (note only significant terms in the model reported).

Change	d.f.	s.s.	m.s.	v.r.	F pr.
New_Shared_Knowledge	1	11.9691	11.9691	118.43	<001
Past_experience	1	1.8713	1.8713	18.52	0.002
Residual	9	0.9096	0.1011		
Total	11	14.75	1.3409		

The answers to the open questions associated with the numerical scores assessing the participants assessment of the new learning from the day (Table 8) revealed that participants viewed the QUICKScan tool as useful for encouraging shared understanding.

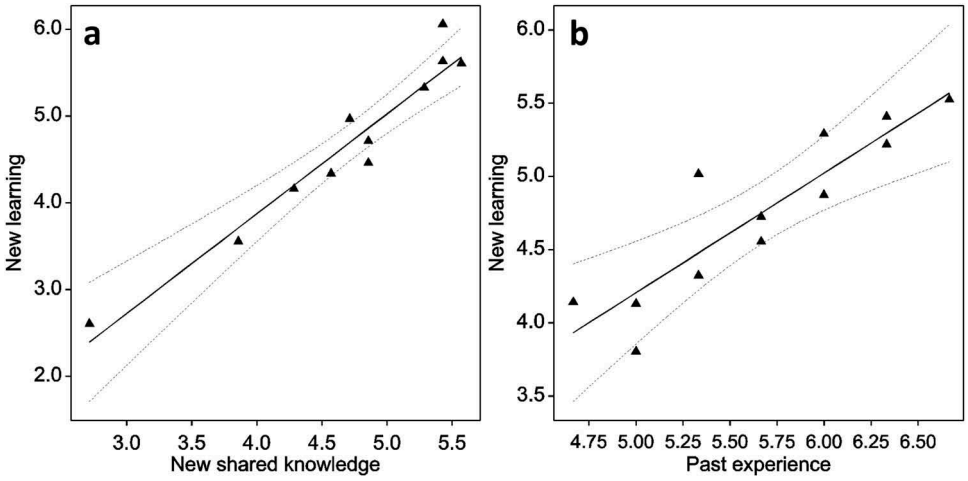

Figure 7. Predicted and actual scores for (a) 'New shared knowledge from the day' and (b) 'Past experience with similar activities and topics' regressed against model adjusted scores for 'New learning from the day' activities.

Table 8. Responses to the two open questions related to the new learning on the day.

Positive influence on learning experience	Negative influence on learning experience
Please describe in your own words what contributed positively towards your learning experience and in which ways this occurred?	*Please describe in your own words what contributed negatively towards your learning experience and in which ways this occurred?*
this is a good method of identifying and defining issues and potential conflicts between various interests	[no response]
seeing how QUICKScan works; apparent case of use, seeing scenarios, that it can handle a range of data	hands on would be useful
great to see people talking dispassionately	None
the ability to see conflict areas helps to decide on future decisions and change	seems quite a complicated procedure for producing maps, training required
good stakeholder engagement	slightly confused delivery
use of QUICKScan as a means of showing openness and clarity of thinking on how a decision may have been reached.	the system is complex and would require a dedicated person to input and help with facilitation in getting Mc rules correctly answered.
how it was put across	very complex computer system
the iterative process of discussing various benefits (profile) with others	overcomplicated – to many variables need to focus on conflict areas or benefits
demonstration of software and using examples	[no response]
the hands on demonstration of QUICKScan	after lunch focus group was vague
demonstration of what QUICKScan can do	discussion of concepts model confusing – doing a worked example would be more beneficial
[no response]	[no response]

4. Discussion

In this study we report the co-application of two ecosystem service tools by scientists and stakeholders in a workshop setting. The tools were used as part of an ecosystem service assessment to consider the trade-offs when planning a change of land use e.g. creating woodland and wetlands as part of a funding proposal. There are several reported methods for conducting ecosystem service assessments which all essentially follow the same principles; for example Rosenthal et al. (2015) proposed an iterative stakeholder engagement framework to build capacity in ecosystem service assessment through six general steps. We followed their framework and carried out step one i.e. scope the process, by discussion with key stakeholders and analysis of the TGLP proposal to the HLF. The second step i.e. collect and compile data was undertaken prior to the day of the workshop and focused primarily on land cover maps, elevation maps, topographical wetness, accessibility management units of the area, and analysis of the Glenlivet Estate forestry plans. Rosenthal et al. (2015) propose that the third step is to develop scenarios; this step was undertaken by the stakeholders at the workshop creating rules within the QUICKScan tool and discussing the linkages between the biophysical and social components of the ecosystem service cascade framework. The forth step 'analyse ecosystem services' was accomplished by both tools i.e. discussion of ecosystem service identified in the cascade framework and the outcomes of the QUICKScan scenarios. The synthesis of results, and communication of resulting knowledge (Rosenthal et al. 2015; fifth and six steps) were delivered to the stakeholders at the workshop in the articulation of the ecosystem service cascade framework (unchanged by discussion from initial presentation; Figure 2) and the output of the QUICKScan tool.

It was agreed that the testing conducted at the workshop should be framed in an academic setting rather than attempt to genuinely select areas of Glenlivet Estate for new woodland or wetland creation. While this was accepted by all participants during the day, participants wanted to see and understand how their knowledge explicated during the workshop was turned into maps and charts. Participants used the opportunity to try out extreme timber expansion scenarios and observe the reactions of others. Some participants wanted to focus on field level and were disappointed at the level of detail of the prepared maps. Three types of knowledge have been recognised in relation to ecosystem service: instrumental, conceptual and strategic. (Waylen & Young 2014). It was clear that some stakeholders wished to use the knowledge generated as instrumental i.e. of direct use to solve the problem of where new planting should occur on the estate. The academic setting of the workshop constrained the production of knowledge which could be used as instrumental. Rather the knowledge created was of conceptual use i.e. to change the mind sets about the decision to plant new woodland. It is relevant to note therefore that the views expressed by the stakeholders about the tools tested were not influenced by a decision which went against their personal wishes. The academic setting of the study therefore effectively restricted the potential impact of the ecosystem service assessments conducted.

Ruckelshaus et al. (2015) proposed a framework for detailing the ways through which biodiversity and ecosystem service information can successfully have impact by informing decisions and creating change in real-world situations. They identified four pathways and levels of impact (i) conduct research (ii) change perspective (iii) generated action and (iv) produce outcomes. In answer to the question 'Has your opinion on these topics somehow changed as a consequence to the discussion and data presented?' only one stakeholder responded positively and 67% score this question as neutral. Stakeholders therefore reported that they had not changed their perspective on the management issue discussed following the ecosystem service assessment conducted, but as commented earlier this may have been because of the academic setting of the workshop and the lack of knowledge produced which could be used directly to create new woodland.

The stakeholders did however report new shared understanding following the demonstration of the QUICKScan tool and emphasised that the cascade framework was useful for developing a more integrated thinking within the group, which is a core component of the ecosystem services concept, moving from single issue or sector based thinking. This was identified as an important step in progressing to tangible decisions and coordinated action. There is also strong evidence that some stakeholders acquired new learning from using the tools (Table 3, 5, 8). Analysis of the numerical scores provided in the pre- and post-questionnaire for the QUICKScan tool revealed that the stakeholders assessment of the new learning they had achieved at the workshop was positively related to their assessment of the new shared knowledge they acquired on the day and their past experience with similar activities and topics (Table 7 and Figure 7). It was clear at the workshop that some stakeholders struggled to engage with the abstract thinking involved in the use of the GIS tool and the maps produced and commented that it would be more useful simply to have a field visit to the areas of potential woodland creation. Others commented that they considered the tool may have been more useful at a larger scale than the Glenlivet Estate for example the whole Cairngorms National Park (Supplementary material 2). Both tools tested can be used at a wide range of scales and have been utilised at continental, regional and local scales (Maes et al. 2012; van Oudenhoven et al. 2012; Wang et al. 2012; Verweij et al. 2014; Murguia et al. 2015; Mononen et al. 2016).

The TGLP is an exciting new initiative and cuts across the traditional UK land decision making which is primarily driven by national level policies and individual land owners desires. Most UK land-related policies and associated science continue to be compartmentalised by both scale and sector and seldom acknowledge nexus interconnections. Given the system lock-in and the lengthy policy-making process Sharmina et al. (2016) called for the development of alternative ways of providing dynamic, flexible, practical and scientifically robust decision support for policy-makers. In this context however it was used at the local scale when conducting the ecosystem service assessment but the multi-stakeholder decision context of the TGLP requires tools with similar properties. The QUICKScan tool was developed with this aim in mind (Rodela et al. 2015). The QUICKScan tool was found by some stakeholders in this study to be sufficiently flexible to be relevant at the local scale tested (230 km^2). The spatially explicit representation in the form of maps was welcomed by most stakeholders. Maps are recognised as particularly helpful for spatially explicit decision making and monitoring of the consequences of decisions and are often used as a communication tool (de Groot et al. 2010, Maes et al. 2012) although others have noted challenges related to scale, data and scientific credibility of maps (e.g. see Hauck et al. 2013). The lack of spatial representation was highlighted as a limitation of the ecosystem service cascade framework (i.e. desire for local nomenclature to link with local context better). However, the

cascade framework helped illustrate an integrated group thinking, which was also important for the use of the QUICKScan tool and the development of ecosystem services assessments more generally. The stakeholders appreciated that both tools had merit to communicate in terms of structuring discussion and providing transparency of decisions made (Tables 3 and 5), however in the current testing at this local scale some stakeholders felt that the QUICKScan tool was overly complex (Tables 3 and 8). The high scoring assigned to knowledge, learning and shared understanding compared with the lower scores associated with changing perception of the ecosystem service decision being considered, may be linked to the opportunity participants had to take an active role and contribute with their own knowledge and expertise throughout the day i.e. production of conceptual use knowledge (Rodela et al. 2015), compared with the lack of knowledge of instrumental use resulting from the academic setting of the workshop. Both tools tested allowed the stakeholders to apply and develop their local knowledge of ecosystem services which has been identified as important by other researchers (e.g. Hauck et al. 2013).

5. Conclusion

The aim of the workshop from the stakeholder perspective was to determine if the ecosystem service concept as articulated by the ecosystem service cascade framework was helpful to generate useful nexus thinking about the complex interaction of ecosystem services, and if the QUICKScan decision support tool was helpful to plan the location of woodland on the Glenlivet Estate. The aim of the researchers was to determine the stakeholder's views of the tools tested in order to improve them.

A wide range of views were expressed by the stakeholders concerning both tools with some reporting positively that the tools aided communication, transparency of coordinated action, shared learning, exploration of scenarios and their likely impacts and mutual understanding while others assessed the tools as too generic, technically demanding and overcomplicated for the scale of the focal study. Analysis of individual responses revealed that (i) past experience of the individual with the ecosystem service concept and the technical aspects of the tools and (ii) the level of new shared knowledge they acquired on the day which was related to their knowledge of the issue and area studied all contributed to their views of the tools tested. Both natural and social scientists were involved in the workshop which was highlighted as beneficial to interpret the workshop outcomes. This research highlights the importance of tools adapted to the local context in collaboration with stakeholders to help facilitate a more transdisciplinary approach to ecosystem service research in order to maximise uptake of the concept.

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