Exploring the Future: Phase 1 - scoping current and future use of spatial Decision Support Tools (sDST) for integrated planning for land-use, biodiversity and ecosystem services across England

Final report to Defra (project code WC0794)

Smart, SM¹, Pearce-Higgins, JP², Wright, L², Comber, AJ³, Howard, DC¹, Maskell, LC¹, Jones, MLM⁴

1 NERC Centre for Ecology & Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, LA1 4AP
2 British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU
3 University of Leicester, University Road, Leicester LE1 7RH
4 NERC Centre for Ecology & Hydrology, Environment Centre Wales, Deiniol Road, Bangor, Gwynedd LL57 2UU
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1. Executive Summary

Project objectives
The aim of this project was to investigate the potential for providing a widely accessible evidence base and tools to enable national or local action in support of the following:
• an integrated approach to the creation of a resilient ecological network across England and the move from net biodiversity loss to net gain, by supporting healthy, well-functioning ecosystems and coherent ecological networks in terrestrial and freshwater ecosystems;
• assessment of options under projected future scenarios up to 2050 (based on the possible influences of land use and climate change);
• assessing how biodiversity objectives, different land use and demand would fit within a changing landscape and a multifunctional natural environment that delivers the vision in the Natural Environment White Paper (NEWP) and the new England Biodiversity Strategy, Biodiversity 2020.

These objectives were set against a backdrop of future and ongoing environmental change and new policy requiring information and tools to support the Localism agenda. The spatial scope of the study was explicitly England but with an expectation that the results and issues raised would be relevant to the interests of the devolved territories. The marine environment was excluded from the study.

Methods
The project was structured around two groups of tasks. Firstly, an assessment of users’ needs for data, scenarios, models and Decision Support Tools was undertaken based on a user group workshop and then a more widely distributed electronic questionnaire. The second strand was a series of structured reviews. These assessed current availability of tools, datasets and scenarios and their applicability to the needs of users that emerged from the consultation process. The user needs assessment and reviews were synthesised to support a statement of current capability and how this matches with users’ requirements now and up to 2050. In light of this, the final part of the project was to draft a series of options for further development work.

Results
Users’ needs assessment
The workshop attracted representatives from nine organisations: Anglian Water, Natural England, Forestry Commission, Defra, Mineral Products Association Biodiversity and Nature Conservation Group, Moors for the Future, National Trust, National Farmers Union, Norfolk County Council and Royal Society for the Protection of Birds. Combining their interests with the 219 responses from a wider range of sectors represented among questionnaire respondents, gave good coverage of most target sectors. Several groups were poorly represented or absent because responses were zero or very low. These sectors were agriculture, energy companies, consultants (which would include farm advisers), the transport sector and local community organisations.

The assessment of user needs gave clear guidance about what users would require from the potential development of sDST to help inform environmental decisions for the future. The first priority appears to be the provision of existing data about conservation designation, species and habitats at a range of spatial scales but with a strong emphasis on updating observations and increasing their spatial resolution. Such information should be presented as maps, with underlying data exportable to other software. The sDST should be easy to use but also provide information about data uncertainty. Interestingly, users wanted to be able to update and add additional
information, which may be a means to improve the quality and scope of data already held. The first priority is therefore very much about making data widely and easily available to inform and speed current decision making. There was appetite for further product development as simply producing a tool which presented information was not ranked highly by users, although would be an important first step.

Beyond this goal, there was secondary interest in the potential for the tool to present information about possible future impacts of different drivers such as land-use and climate change. Impacts of these on features of relevance to biodiversity conservation, such as the distribution and abundance of species, and the distribution and quality of habitats were the greatest perceived need.

Thirdly, there was an acknowledgement of the benefits of a tool which could help identify options for land-use planning to balance competing demands. This could potentially be the most complex aspect of a sDST to develop, but may be particularly useful to industry and agricultural sectors who are keen to identify potential win-win options where production or resource management goals are are optimised alongside other ecosystem services. Optimisation and trade-off tools were generally scored highly by most user groups (although did not necessarily reach the top-five ranking). It was clear from the workshop that some organisations are already developing such tools themselves.

**Localism**

New policy instruments such as Neighbourhood Development Planning (NDP), Nature Improvement Areas (NIA), Local Enterprise Partnerships (LEP) and Local Nature Partnerships (LNP) have information needs that should be facilitated by new information and tool development. The small scales involved again emphasise the importance of up-to-date observations at the finest possible resolution. The involvement of non-experts emphasises using transparent approaches and plain language, and the value of participatory approaches where local knowledge and expert understanding come together to produce shared visions of planning goals as well as developing local narratives about the impacts of climate, demographic and land-use change.

Localism places new responsibilities on Local Authorities to support the NDP process. They also have an increasing interest in the results of large-scale regional analyses that seek to quantify socially, economically and ecologically optimal land-use options. Simplified results would provide the wider spatial context within which NDP were embedded, and would help Local Authorities communicate opportunities and constraints to those developing a local vision for their area. Improving the evidence base and functionality that underpin Planning Screening Tools is also a more basic but nonetheless sorely needed area of development. Progress in this area would support better informed and better targeted local planning and development, and would also directly support Outcome 1 (Habitats and ecosystems on land) in the England Biodiversity Strategy.

**Users needs versus current capability**

There appear to be few technical obstacles to creating sDST that could provide novel analyses to underpin integrated, ecosystem-based, multi-functional land use planning at multiple scales in England. The main constraints are data availability and matching tool developments to user’s current and longer term needs. The principal requirements are as follows;
1. **Increasing data and knowledge availability.** Making progress in modelling changes in ecosystem services and biodiversity is strongly limited by scientific understanding of social-ecological system dynamics and by fundamental data that measure key properties, including model parameters and indicators of ecosystem service supply and demand. New datasets are increasingly required that measure potential ecosystem service supply yet there are also severe demands simply for more finely resolved and up-to-date biodiversity information. These constraints lessen with the increasing acceptability of results at coarser scales where the focus on local accuracy lessens. Unfortunately many end-users’ face decision-making at fine spatial resolutions in specific areas and so require more, better quality data at these resolutions.

2. **Clearly matching tools to users needs.** Many tools already exist or are under development yet many users have problems that could be tackled by better use of sDST. Future development should take care to avoid developing tools that are solutions to non-existent problems but instead focus on the real challenges confronted by decision-makers. This involves not re-inventing wheels and where possible, integrating new analytical outputs with existing local tools rather than expecting end users to universally adopt new platforms and software.

3. **Disseminating the results of complex multi-scale analyses.** Users’ require simple, cheap, tools that are easy to use but also recognise that emerging policy requirements and the emphasis on an integrated, cross-sector planning paradigm will require more complex spatial analyses. Future developments should therefore facilitate end users in their need for the outputs of new policy-relevant analyses but without foisting on them the technical burden of performing the analyses themselves.

4. **Adding to existing functionality.** Where there is an appetite for users to engage in their own analytical work, this is more likely to be facilitated by providing the technical means for new analyses to those who need them without requiring a major shift to different software systems. Bespoke, universally-compatible, problem-specific and free GIS ‘add-ins’ may be a way forward.

5. **Progressing complex ecosystem services analysis and impacts modelling.** The more technically and scientifically challenging work still needs to be done. Those with the technical expertise should continue to develop and apply tools that analyse cross-sector and cross-scale relationships and trade-offs so that vertical tensions (for example between local planning and conservation objectives and larger scale constraints and opportunities), and horizontal tensions (for example between different sectors such as agriculture, nature conservation, housing and flood defence), can be quantified and options determined for resolving them. Resolving these tensions is at the heart of a hierarchic ecosystem approach to planning. Particular issues to be tackled include drawing explicitly on local knowledge and interdisciplinary working between social scientists, economists and ecologists.

**A three-stage plan for developments under Phase 2**

1. Develop a one-stop-shop database of databases for information and datasets to support application of existing and future sDST at larger and smaller spatial scales.
2. Develop and apply methods for translating non-spatial scenarios of environmental change into depictions of plausible local impacts on ecosystems and land-use. This would involve a modelling component targeted at biodiversity and ecosystem services as well as participatory work that sought the input of local people into developing differing narratives of plausible future change that mattered to them.

3. Scope further options for collaborative delivery of new analyses to end users. This would include scoping specifications for applied science, policy and practice partnerships that would develop sDST to support a two-way information flow between an analytical hub, comprising a consortium of technical specialists, ecologists and social scientists, and a local network of end-users and biodiversity data-providers. Defra family members are likely to be closely involved as both technical specialists and end users given their experience in developing and applying tools to delivery of statutory duties.

Such an organisational model addresses;

a) The clear need for novel landscape-scale analyses aligned with a new cross-sectoral paradigm for integrated and ecosystem-based planning.

b) The increasing requirements of front-line users to apply these outputs in their decision-making; likely to include NIA, LNP and NDP.

c) The limitations on time and resources that prevent local users from executing these analyses themselves.

d) The need to improve the quality and resolution of data used to drive the spatial modelling, planning screening and ecosystem service assessments.
2. Project objectives

The aim of this project was to investigate the potential for providing a widely accessible evidence base and tools to enable national or local action in support of:

- an integrated approach to the creation of a resilient ecological network across England and the move from net biodiversity loss to net gain, by supporting healthy, well-functioning ecosystems and coherent ecological networks in terrestrial and freshwater ecosystems;
- assessment of options under projected future scenarios up to 2050 (based on the possible influences of land use and climate change);
- assessing how biodiversity objectives, different land use and demand would fit within a changing landscape and a multifunctional natural environment that delivers the vision in the Natural Environment White Paper (NEWP) and the new England Biodiversity Strategy, Biodiversity 2020.

Here we report conclusions and draft options from Phase 1, in which the main objective was a scoping study to identify users’ needs for spatial Decision Support Tools (sDST¹) set against a backdrop of the following:

1. Current and future decision-making priorities at multiple scales but with an emphasis on local scales i.e. parish, community, Neighbourhood Development Planning and Localism.

2. Future environmental change up to 2050

3. Policy targets set out particularly in NEWP and Biodiversity 2020.

4. Existing availability of tools, datasets, models and scenarios.

Figure 1. Project task structure.

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¹ By Decision Support Tools we mean anything from simple GIS systems where users may overlay various spatial layers of interest, through to much more complex applications involving linked dynamic models and risk assessment tools. Often these systems will have a spatial interface and therefore be map-based.
The overall structure of the project is summarised in Fig 1. The project consisted of two main components. The first was an assessment of users’ needs based on a workshop and electronic questionnaire, both of which sought to engage with front-line decision-makers across key sectors. Second, a series of mini-reviews were carried out to describe existing capability in terms of sDST, risk assessment and trade-off methods, datasets and data availability to support sDST, scenarios of future change in land-use and climate, and lastly, deriving a specification for tools and data to support user needs under Localism. The user consultation exercise provided a detailed picture of the current and likely demands of a range of decision-makers for sDST. These results were then considered alongside the description of current capability from the mini-reviews. Bringing the two strands of evidence together allowed identification of gaps, whether existing capability might be efficiently harnessed and further developed to address users’ needs and under what circumstances new bespoke tools should be considered for development.

The spatial scope of the study was explicitly England but with an expectation that the results and issues raised might be sufficiently relevant to the devolved territories to attract their interest in a second phase.

### 2.1 Delivery of project objectives

Completion of project objectives is indicated in the next section by reference in italics to the relevant part of this report or the accompanying appendices.

**Objective 1) Characterise user groups and needs**
- Undertake consultation that will identify and characterise potential user groups, including their technical capacity. *Completed*. See Appendix 1.
- Determine interest amongst the devolved administrations in sharing information, participating and funding for Phase 2, which may take the scope to GB or UK level in the second phase. *Completed*. *A briefing note was prepared by the project team for circulation to devolved contacts by Defra. Appendix 2.*

**Objective 2) Determine and agree scenarios to apply in modeling**
- Work closely with the project Steering Group and others selected in (Task 1) to form a User Group for consultation, to determine appropriate future scenarios to apply such as those in the National Ecosystem Assessment, Land Use Futures project, the Natural England 2060 Visions Study). *Completed*. *Scenarios application within the context of future decision-making was explored during the User Group workshop (Appendix 1) and via the follow-up questionnaire study (Appendix 3). Scenarios were reviewed in Appendix 4.*
- Review the emerging policy context of the Natural Environment White Paper, the new England Biodiversity Strategy and the findings of the National Ecosystem Assessment and the Climate Change Risk Assessment. *Completed*. *See this report, section 3.*
- Review the relevant findings of other adaptation projects (such as ‘Developing tools to evaluate the consequences for biodiversity of options for coastal zone adaptation to climate change’ and ‘Priority habitats, protected sites and climate change, three investigations to inform considerations towards managing adaptation and mitigation potential’)) and other
relevant initiatives (e.g. those being undertaken by NE, EA, FC, devolved administrations and other Defra future scoping studies). Completed. Scenarios typologies and their current application were reviewed in Appendix 4.

Objective 3) Review spatial decision support tools and justify method adopted

- Undertake a brief review of existing spatial decision support tools (sDST) like: Environment Explorer, LUMOGAP, Refuge-GAP, BEST and InVEST. Completed. See Appendix 5.

Objective 4) Identify data sets and assess their suitability for use with the spatial decision support tools

- Review the suitability of LCM2007, and identify other potentially relevant data sets needed to support GIS based modelling tools to help give an integrated view of a range of issues and possible futures. Completed. See Appendix 6.
- In consultation with the User Group, assess the practicalities, costs and any other constraints to access and use of the data identified at different scales. Completed. See sections 6 and 7.

Objective 5) Develop recommendations for the Phase 2 project

- Completed. See section 7, this report.

Objective 6) Provide a case for the further development of the tool to support the government’s localism agenda

- Assess the capacity of the tool(s) to support the government’s localism and Big Society agendas by providing suggestions for development of the tool and/or data resources that would enable it to be used at the local scale to e.g. informed land use planning decisions. Completed. See Appendix 7.

Objective 7) Risk assessment

- Suggest how the proposed tools could be used to indicate the level and scale of risk of missing something that could have consequences for conservation objectives (Priority Habitats and species, and delivery of selected ecosystem services) associated with climate change and other land use pressures under each selected scenario. Completed. See Appendix 8 and discussion in sections 4.3, 6 and 7.

3. The policy context and future needs

3.1 Recent changes in policy emphasis and the need for a cross-sectoral approach to land-use, ecosystem services and biodiversity

Between December 2010 and Spring 2012, a number of influential reports and new policy instruments were published. Together these appear to be driving a paradigm shift in the way we view and solve the challenge of sustainable use of finite resources for a growing population in the face of environmental change. The challenges are summarised by the Foresight project (Foresight Land Use Futures Project, 2010). In the light of increasing pressures on land in the next 50 years, the report highlights the need to address a number of ‘systemic’ issues that if not addressed will likely
lead to unintended consequences and unsustainable outcomes\(^2\). Especially relevant are the following recommendations:

1. The need for an overarching perspective.
2. The need to improve conflict resolution between different sectors, spatial scales and levels of governance.
3. Private incentives are aligned as far as possible with social objectives and values to minimise tensions in the system and deliver better outcomes.
4. Opportunities for multifunctional land-use and benefits are identified and promoted.

Current examples of activities that seek to implement this kind of cross-sectoral philosophy on the ground include the Integrated Advice pilot targeted at farmers (ADAS 2012), the notion of Integrated Delivery to simultaneously benefit landscape, people and biodiversity (Swanton 2011), the Public Benefits Recording System (PBRS\(^3\)), led by the Forestry Commission, and the Natural England ecosystem service pilot areas where the aim is to explore how ecosystem services can form the basis of integrated land management (Natural England 2011).

There appears to be little doubt that in the next 50 years environmental change and increasing pressure on finite land area will necessitate better cross-sectoral land-use planning with an increasing focus on landscape resilience. For example the five main adaptation principles for conserving biodiversity in the face of climate change across England were listed by Smithers et al. (2008) as follows:

1. Maintain and increase ecological resilience
2. Accommodate change
3. Integrate action across all sectors
4. Develop knowledge and plan strategically
5. Take practical action now (ie. in 2008)

Application of all these principles could be facilitated by the use of appropriate sDST. For example, identifying optimal allocations of land-use while accommodating resilient habitat networks requires spatial analysis of the social-ecological system at multiple scales. This is a complex task. Many decisions are made at small scales where generalised assumptions about how social-ecological systems function may be inadequate. If local detail is critical then analyses based on generalised, ...

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\(^2\) Climate change for example, presents a possible opportunity to raise agricultural yields resulting from longer growing seasons but this assumes that nutrients and water are not limiting (CCRA 2012). Failure to manage the cross-sectoral demand for increasing water availability by agriculture and a growing population, and its spatial variability risks not realising this opportunity for increased domestic food production.

\(^3\) Regional applications have included spatial analysis of joint patterns of social deprivation and natural environmental value. This work helped support the Natural Economy Northwest Partnership vision to promote a prosperous future economy and thriving natural environment in northwest England.
‘average’ knowledge will be unreliable, models will fail to correctly project, relevance will be low, confidence will be lost and associated tools will not be used. The challenge is to identify efficient points of entry where maximum understanding and facilitation could be achieved for minimum resource input while recognising that development of a toolkit to solve all problems across all sectors, at all scales is unlikely to be feasible.

3.2 Decision-making in the context of environmental change

Targets to mitigate climate change were initially adopted under the Kyoto Protocol in 2005 and gained widespread international agreement. The adequacy of the targets originally set is now questioned as is our ability to achieve them, so adaptation to the changes that occur will need to be planned for. Yet climate change is unlikely to be the only driver of environmental change over the next 50 years (Table 1). Changes in land-use and demography will also interact with climate change. While the direction of these changes can be estimated as average trajectories across a country or larger region, projections are often highly uncertain and this uncertainty increases as the time horizon lengthens and the focus is on smaller areas. The challenges facing decision-makers therefore involve balancing current demands with the requirement for adaptation to future needs but set against a backdrop of ongoing environmental change whose local detail is highly uncertain. Many sources of measured and modelled information exist and could be developed to help estimate a range of options for spatial land-use planning given these uncertainties. The challenge is to jointly analyse these sources of information at the appropriate scale and in ways that yield new understanding that is of practical use to end-users. This challenge could be met in a number of ways. A potential approach is to develop sDST to help make informed choices based upon the best available knowledge. Here the results of a Scoping Study are presented that assessed the potential for such a decision support framework to deliver improved decision making for biodiversity and ecosystem services in a changing climate and given other drivers of environmental change.

3.3 Summary of current policy context

Aspects of the most significant new policy instruments are summarised highlighting where they call for actions whose delivery could be facilitated by sDST, where policy statements make explicit reference to new databases and software tools to aid decision-making and to inform the public, and where policy commitments rest on large-scale approaches to conservation, land-use planning and maintenance and restoration of habitat networks. A significant feature of these policies is that they were all published in the last two years yet they spell out major new policy commitments consistent with a new emphasis on multi-scale, more joined-up planning for land-use and biodiversity. A consequence is that front-line users’ current needs will probably not yet fully reflect these new policies. In our user consultation and mini-reviews we were therefore careful to solicit views as to how needs might change up to 2050 and the extent to which existing capability could meet existing as well as new policy requirements.

Natural Environment White Paper

http://www.defra.gov.uk/environment/natural/whitepaper/
Published on 7th June 2011, the Natural Environment White Paper (NEWP) commits to improving the quality of the natural environment in England moving to a net gain in the value of nature. Based on a roadmap of 92 commitments the aim is to arrest the decline in habitats and species and the degradation of landscapes, protect priority habitats and safeguard non-renewable resources and to support natural ecosystem functioning in town, countryside and at sea. These aims will be achieved as a result of joined-up action at local and national level to create an ecological network that is resilient to changing pressures. This overarching principle derives from the Lawton Review “Making Space For Nature”.

NEWP is a principle driver for this Scoping Study since delivery of a number of its commitments could be facilitated by focussed application of sDST. Examples include the review of advice and incentives for farmers (20), the provision of more coherent advice from the government’s environmental bodies to local partners (12), establishment of Nature Improvement Areas (8), development of Biodiversity Action Plans for transport agencies with an emphasis on green corridors and ecological networks (32,67), bringing together web-based information on the England natural environment through the ‘My Environment’ portal (78).

Biodiversity 2020; England Biodiversity Strategy

Biodiversity 2020 builds on the NEWP commitments and also sets out how actions are aligned with global and EU commitments made at Nagoya and set out in the EU Biodiversity Strategy (2011). Biodiversity 2020 also emphasises the value of the new research presented by the UK National Ecosystem Assessment. Using the ecosystem services framework, the NEA provides much of the evidence base highlighting the need for better valuation of nature’s benefits and a realisation that a more joined-up landscape-scale approach to conservation is necessary if the supply of ecosystem services is to be ensured. Four priority areas for action up to 2020 are set out as follows;

1. A more integrated large-scale approach to conservation on land and at sea.
2. Putting people at the heart of biodiversity policy
3. Reducing environmental pressures.
4. Improving our knowledge.

Within the text of Biodiversity 2020, a number of further action points specifically highlight commitments to development and application of tools to assist in delivering these outcomes. These include the ‘My Environment’ portal and further research to be carried out under the second phase of the NEA.

National Planning Policy Framework

Published on 27 March 2012, the impact of the new guidance has yet to be fully understood. However, the wording of the NPPF cites previous planning policy on biodiversity (para 113) and

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6 Numbers refer to each ‘commitment’ as listed in Annex 1 of the White Paper.
8 See page 34 of Biodiversity 2020.
therefore appears to maintain previous commitments to the conservation of habitat networks as follows “Local authorities should aim to maintain networks by avoiding or repairing the fragmentation and isolation of natural habitats through policies in plans. Such networks should be protected from development, and, where possible, strengthened by or integrated within it.” Planning Policy Statement 9: Biodiversity and Geological Conservation (Office of the Deputy Prime Minister, 2005).” The NPPF also reinforces this aspiration in light of Biodiversity 2020 and the Lawton Review by explicitly stating that Local Authorities should “set out a strategic approach in their Local Plans, planning positively for the creation, protection, enhancement and management of networks of biodiversity and green infrastructure” (para 114). This is also consistent with the biodiversity duty on local authorities (section 40 of the Natural Environment & Rural Communities Act 2006) and with article 10 of the EC Habitats Directive. However, the stipulations of PPS9 are no longer binding within the NPPF and this represents a weakening of the position on wildlife conservation and biodiversity.

New policies are also included whose implementation would benefit from new spatial analysis such as the first ever policy to identify and protect areas of tranquillity (para 123). This could be reasonably interpreted as novel measurement of an ecosystem service. More generally, the NPPF calls for the planning system to recognise the wider benefits of ecosystem services (para 109). The NPPF also includes reference to sustainable development and hence the need to reconcile socio-economic development with stewardship of the countryside and its ecosystems. There would seem to be ample scope for developing sDST to help analyse planning options given this aspiration.

**Localism Bill**

The Localism Bill is an attempt to de-centralise decision-making and place more power into the hands of local communities regarding planning, development, local expenditure and the delivery of public services. To do this it abolishes a number of top-down instruments such as Regional Strategies and the Standards Board regime and introduces new instruments such as the ‘community right to buy’ and Neighbourhood Development Plans (NDP).

In order for local communities to exercise these new freedoms they will still need to take account of existing constraints on development imposed for example by statutory designations for wildlife, protection of agricultural land and national planning for large infrastructure. Defining and negotiating options for local development needs to be based on an understanding of these multiple land uses in any particular local area. To do this requires locally accurate data and analysis of those data. Limited new funding is available to assist Local Authorities in supporting the NDP process. In addition Local Authorities may increasingly use the Community Infrastructure Levy imposed on developers to support local visions newly articulated under Localism and NDP.

**Water White Paper**

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While the White Paper sets out the considerable progress that has been made in tackling water quality issues over recent years, it emphasises the legal imperative of the Water Framework Directive to restore function to impaired aquatic ecosystems across England. The White Paper sets out a vision for a “catchment-based approach” to tackling over-abstraction and pollution against the growing pressure from demographic and especially climate change.

### Table 1: Possible futures - projections of environmental change across England in the next 40 years

<table>
<thead>
<tr>
<th>Sector</th>
<th>Summary of changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water availability</td>
<td>The Environment Agency use four scenarios from ‘uncontrolled demand’ through to ‘sustainable behaviours’ coupled with climate change under high or low emissions scenarios. By 2050 if uncontrolled demand and no adaptation via sustainable approaches is applied then demand for water in England &amp; Wales could increase by 35%. A reduction in demand of 15% could be achieved if the ‘sustainable behaviour’ scenario is followed in conjunction with low emissions. Based on a catchment-scale analysis the report shows that unmet demand for water reaches its highest levels in the 2050s under the worst-case scenario. This equates to a deficit of around 8 times the volume of water needed annually to currently supply homes within greater London. The variation in projected unmet demand is much higher between CC scenarios than between behavioural adaptation responses highlighting the apparently narrower room for adaptive manoeuvre relative to the uncertainty in the emissions driven climate projections. Their main conclusion is that despite uncertainty, all scenarios predict less water available by 2050s than today. Also the challenge of significant unmet demand is likely to be felt not just in the south east but in the south west and parts of northern England(^\text{12}). As a result of projected change in the seasonality of rainfall, by 2050 English river flows in winter could increase by 10 to 15% but decrease in late summer and early autumn by between 50 and 80%.</td>
</tr>
<tr>
<td>Forestry</td>
<td>A 4% increase in newly planted forests by 2050 is recommended by the Read Report to help meet the legally binding emissions reduction target of 80% by 2050 (Climate Change Act 2008). New planting would contribute to abatement of 10% of estimated GHG emissions at that time bringing forest cover to 16% from 12% of the UK. Climate change poses risks (pests and diseases but principally water shortage) and opportunities (novel tree species)(^\text{13}). A substantial increase in woodfuel production in England could arise from new planting and exploiting under-managed woods(^\text{14}) consistent with a planned eight-fold increase in renewable energy use by 2020(^\text{15}).</td>
</tr>
<tr>
<td>Climate change, impacts and flooding</td>
<td>By 2050 mean sea level rise at London is expected to be between 13 and 18cm over 2010 levels. Under high emissions scenario and by 2050, the central estimate is of a 3.7 °C increase in summer mean daily maximum temperature in SE England, 3.8 °C in NW England and 4.3 °C in SW England(^\text{16}). Agricultural land at</td>
</tr>
</tbody>
</table>

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\(^\text{14}\) [http://www.forestry.gov.uk/website/forestry.nsf/byunique/infd-7wmh6q](http://www.forestry.gov.uk/website/forestry.nsf/byunique/infd-7wmh6q)  
\(^\text{15}\) The UK Renewable Energy Strategy ([www.decc.gov.uk](http://www.decc.gov.uk))  
\(^\text{16}\) [http://ukclimateprojections.defra.gov.uk/21708](http://ukclimateprojections.defra.gov.uk/21708)
risk of frequent flooding is projected to double by 2050\textsuperscript{17} while the risk of a drought as severe as 1976 could remain unchanged or increase to more than 1 in every 10 years by the end of the century\textsuperscript{18}.

**Population density**

Population is expected to increase in some parts of England by over 40\% by 2050 yet these areas coincide with present-day stresses on water supply and aquatic ecosystems\textsuperscript{19}. The south east region is projected to have the largest absolute increase in number of households. Here the population is expected to increase to between 9.4 and 12.9 million by 2050\textsuperscript{20}. Across England the population is projected to rise from 51 to 65 million by 2050\textsuperscript{21}.

**Energy**

Given uncertainties over possible future developments in the energy sector the National Grid employs scenario-based projections rather than a single forecast. Each of the three scenarios used makes assumptions about the economic background, fuel prices, developments in the heating and transport markets and electricity demand. All three scenarios assume the same level of energy demand derived from economic forecasts made by Experian Business Strategies. These Scenarios project initially to 2030 and then with less detail to 2050. The “Gone Green” scenario represents a future in which all renewable and carbon emissions targets are met. “Slow Progression” is similar but environmental targets are met later. “Accelerated Growth” assumes more rapid offshore windfarm development. All three scenarios predict increased dependency on gas imports as offshore capacity declines but an overall net reduction in total energy demand by 2050. All scenarios reflect an emphasis on low carbon energy, which is a fast moving policy agenda, being delivered by a range of measures such as the UK Renewables Obligation and driven by EU targets in the Renewable Energy Directive and Fuel Quality Directive. EU policy to promote energy from renewable sources and to reduce GHG emissions is set out in the 20:20:20 Energy package and is detailed in the provisions of two Directives: the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). RED stipulates that by 2020,15 \% of the UK’s energy consumption should come from renewable sources. It also includes a 10\% target for the use of renewable energy in transport fuel. The RED also sets out a series of environmental sustainability criteria which aim to address inter alia direct land use change by stipulating that bio-fuels should not be grown on land with highly biodiverse grasslands, primary forests and peatlands. Any bio-fuel utilised in the EU must meet these criteria in order to count towards the 2020 target. The Climate Change Act put a legal obligation on the Government to cut UK greenhouse gas emissions by 80\% by 2050. To help explore possible ways of achieving this obligation, the Department of Energy and Climate Change (DECC), as the lead department, published in July 2010 the first version of an Excel model, the 2050 pathways model.

\begin{footnotesize}
\begin{enumerate}
\item[21] Demographic Change and the Environment (2011). The Royal Commission on Environmental Pollution. 29\textsuperscript{th} report. HMSO, London.
\end{enumerate}
\end{footnotesize}
4. Methods

4.1 Identifying the needs of potential users of sDST

To provide an informed foundation for future tool development, guidance from end-users was essential in ensuring the relevance of tools thus avoiding the promotion of ‘solutions in search of a problem’. The scoping study therefore involved a consultation exercise with stakeholder groups carried out in two phases. First, a user group workshop was convened and the results from this used to guide the construction and dissemination of an electronic questionnaire. The aim of the consultation was to identify current usage of sDST and how these needs were envisaged to change up to 2050. Responses from the user group could then be interpreted to produce guidance on desirable and undesirable aspects of sDST, highlighting the extent to which they are used or not and then determining in what ways tools could be developed or improved to increase their relevance. The user consultation also explored the future and current relevance to users of the following additional issues; i) Localism and the engagement of the public and local communities, ii) the availability of data at desirable resolutions and quality, iii) the ease of use and desirability of applying scenarios of change in land-use and climate to facilitate planning and policy delivery, iv) the relevance of ecosystem services both as a conceptual framework and an emerging policy driver that needs to be supported by new datasets on ecosystem service supply.

User Group Workshop

In addition to the project team (CEH, BTO, University of Leicester and Defra) potential users represented at the workshop were as follows:

Anglian Water
Natural England
Forestry Commission
Mineral Products Association Biodiversity and Nature Conservation Group
Moors for the Future
National Trust
National Farmers Union
Norfolk County Council
Royal Society for the Protection of Birds

A range of other organisations were also invited to the workshop but were unable to attend. These included a number of local authority ecologists from county and district councils, various consultancies, representatives of the energy industry, Environment Agency, Wildlife Trusts, JNCC, Peak District National Park, SNH, Scottish and Welsh Government, Rivers Trust. Many of these organisations agreed to provide input via the questionnaire survey that followed the workshop.

After introductory sessions outlining the scope and aims of the project and workshop, the remainder of the day was structured around three break-out groups of four or five potential users. All groups answered the following questions:
1. Which land-use and planning decisions are you involved with now and which new decisions are likely to become more important through to 2060?
2. How do users carry out their decision-making now and are mechanisms for decision-making likely to change through to 2060?
3. What would users require from new sDST? What aspects should be avoided?
4. What are the most important datasets that people use and how are these needs likely to change in the future?
5. How relevant is the new Localism agenda to users? How would it impact their decision-making?

Rapporteurs notes were synthesised into a workshop report (see Appendix 1). Conclusions from the workshop are reported in section 5.1.

**User needs questionnaire**

Following the workshop, an electronic questionnaire survey was constructed in order to capture the needs of a wider range of potential users of sDST. The survey was designed using the Survey Monkey online survey tool (www.surveymonkey.com), which allows the anonymous collection of responses. Questions were designed based on the results of the user-needs workshop held in the autumn, and in collaboration with the Defra Project Steering Group. The questionnaire survey is reported in full in Appendix 3.

The questionnaire was circulated to contacts in a range of organisations. Potential participants were sent a covering letter giving background to the project, an explanation of why the views of potential users were important and the benefits to them of completing the questions, and a link to the questionnaire. The initial contacts were asked to forward the questionnaire on to their colleagues or via accessible mailing lists. The list of organisations and contacts to whom the questionnaire was sent is given in Table 2. Each organisation was sent a second reminder email after a week, and if no response had been received to emails after two weeks a third email was sent offering an extension to the deadline for completing the questionnaire.

**Table 2.** List of organisations or contacts to whom the questionnaire was circulated.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Details of subsequent circulation (if known)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defra family (Defra, NE, FERA, FC, EA).</td>
<td></td>
</tr>
<tr>
<td>Association of Local Government Ecologists</td>
<td>UK-wide mailing list. One contact subsequently forwarded to Association of Local Environmental Records Centre mailing list.</td>
</tr>
<tr>
<td>Town and Country Planning Association</td>
<td>E-newsletter to all members</td>
</tr>
<tr>
<td>Norfolk Biodiversity Partnership</td>
<td>E-newsletter to more than 1000 members</td>
</tr>
<tr>
<td>RSPB</td>
<td>Regional RSPB staff</td>
</tr>
<tr>
<td>National Trust</td>
<td>Other NT staff</td>
</tr>
<tr>
<td>Moors for the Future</td>
<td>A range of partners in the Peak District</td>
</tr>
<tr>
<td>The Rivers Trusts</td>
<td>All local rivers trusts in UK</td>
</tr>
<tr>
<td>Mineral Products Association Biodiversity and Nature Conservation Group</td>
<td>All group members</td>
</tr>
<tr>
<td>EDF Energy</td>
<td>Single contact asked to forward to colleagues</td>
</tr>
</tbody>
</table>
Anglian Water  |  Single contact asked to forward to colleagues
Country Land and Business Association  |  
Campaign to Protect Rural England  |  
National Association for AONBs  |  Sent to lead partners for all UK AONBs
British Institute of Agricultural Consultants  |  
ADAS  |  Single contact asked to forward to colleagues
Renewable UK  |  
Farming Link (Web magazine)  |  
National Farmers Union  |  Single contact asked to forward to colleagues
Wildlife and Countryside Link  |  
Warwick Crop Centre  |  Single contact asked to forward to colleagues
English National Park Authority Association  |  Sent to representatives of each National Park
Agriculture and Horticulture Development Board  |  Contact agreed to circulate to further contacts
Wildlife Trusts  |  
Community organisations in Cumbria  |  Single contact in Department of Social Sciences at Lancaster University asked to send out to a number of local community groups.

After the deadline for completing the questionnaire, the anonymous results were downloaded from Survey Monkey and summary statistics produced, breaking down the data into different user groups where sample sizes allowed (Appendix 3).

### 4.2 Mini reviews

The second strand of the project comprised a series of mini-reviews focussing on the following topics;

1. Decision Support Tools for analysis of ecosystem services.
3. Scenarios of land-use and climate change up to 2050.
4. Datasets and the availability of data to drive the successful application of tools at multiple scales.
5. Localism and the specific requirements for developing tools to meet the needs of local communities often of non-experts newly empowered to play a role in local development via, for example, the Neighbourhood Development Planning process.

All reviews are available as appendices. The conclusions from each are summarised in the next sections.

**Synthesis of user needs assessment and mini-reviews**

A one day meeting of the project team was convened to draw out conclusions and options for future sDST development by matching our newly acquired information on user needs with existing
capability described in each review. Key points emerging from this meeting are reported in 5.1 and were used as the basis for a set of final draft options for further development under a possible Phase 2 of the project (section 7).

5. Results

5.1 Summary of the user group workshop

A wide range of potential and real applications of tools were discussed. Crudely, two different types of user can be defined from the workshop responses. The first are a population of potential users involved in the strategic delivery of particular policies or services, such as statutory agencies, local authorities, utilities and national NGOs, many of whom are familiar with the use of sDST. A number of these have the resources to fund and develop bespoke sDST to meet individual strategic needs, and indeed are doing so, but are also clear about not requiring sDST in certain circumstances, particularly if such tools add to the complexities of decision making. For any potential sDST to have wide traction with this group of users, it must reduce the complexity of decision making and therefore ultimately save time and money. At the opposite end of the spectrum are a second, potentially large but ill-defined, population of potential local users empowered through the Localism Bill. This would include members of the public, parish councils and community groups many of whom may not realise yet that they are intended to be the beneficiaries of new opportunities under Localism and many of whom may not have the time or technical skills to operate sDST. However they may well benefit from the development of increasingly comprehensive and user-friendly tools such as online map-based databases that provide local information. An additional group of users with needs for detailed information and new kinds of integrated spatial analyses may yet coalesce around the formation of Nature Improvement Areas (NIA) and Local Nature Partnerships (LNP) with linkage through to Local Enterprise Partnerships (LEP).

Given the range of users, their decision-making challenges, scales of operation and the likelihood of rapid change in users needs as new policy deliverables increase in impact, a tiered approach to the development of any tool was suggested by some. This should include in the first instance prioritising the presentation of existing environmental, biological, social and planning data layers in a user-friendly manner via a single portal. This would provide a one-stop location that would increase the efficiency of decision making, as well as facilitating access to information for the non-specialist. Using existing GIS approaches, it would be relatively straightforward to present this information appropriately at a range of potential spatial scales. Given the need to consider future changes depicted by different scenarios, a second phase to the work could then potentially develop capability for projecting change based on existing environmental and biological layers in response to particular pressures. This information would be of similar complexity to the existing data layers, but enable users to examine what potentially different futures would mean for their area of interest. Thirdly, and most complex, it would be desirable to develop pilot examples where integrated decision making is facilitated by the combination of the current situation with presentation of future scenarios to help users identify the most optimal solutions for achieving local objectives. For example, based on existing (and likely future) models of species distribution or ecosystem service provision in relation to climate and land-use, for a given scenario, it would be possible to develop a framework within which users could explore the consequences of different decisions on those
species and ecosystem services. This would provide considerable functionality for a subset of users (given the additional complexity involved), but built upon an existing platform presenting current and projected future data layers for all users to explore.

The theme of considering tool developments as a tiered set of goals of increasing complexity was subsequently reinforced by the questionnaire survey and by the mini-reviews.

5.2 Electronic questionnaire

Profile of respondents

A total of 219 people responded to the questionnaire. More than half of these worked for local government, with at least 20 respondents from national government, statutory advisory bodies and conservation charities. There was a poorer response from the agricultural sector and other industries, environmental consultancies, community and voluntary organisations (Fig 2).

![Figure 2. Distribution of answers to the question “what sort of organisation do you work for”](image)

Based on these samples, the results were split into the following six groups for subsequent analyses of potential differences in requirements between different user groups:

- Local / Regional Government (117 respondents)
- National Government (24 respondents)
- Statutory Advisory Body (29 respondents)
To summarise, responses to the questionnaire were from a wide-range of sectors and potential users. The large number of respondents from local government is particularly informative, as the localism agenda places additional responsibilities on them in terms of providing information and help to local communities. Users had a wide-range of interests. Most were involved in decision-making that required consideration of biodiversity and conservation issues. A significant proportion of respondents also had a high level of experience with existing spatial decision support tools. Given the strong biodiversity interest, it is possible that the majority of local government respondents were local government ecologists, rather than planners or representatives of other interests, although there are no data to further explore that breakdown. Usefully, respondents were involved in decision-making across a range of spatial scales from habitat-patch to landscape scales in the case of local government, to landscape to country scales in the case of Statutory bodies and National Government.

In short, by achieving 219 responses from a wide-range of potential users with a high degree of sDST experience, the conclusions derived from this questionnaire are considered robust. Although there was a relatively poor response from agricultural and industrial sectors, their views were well-captured at the user-needs workshop (Appendix 1).

**Existing usage of sDST**

A total of 61% of the respondents had practical experience of using sDSTs. All sectors had a majority of respondents who used sDST with the exception of the conservation charity sector. Those who used sDST did so with a high frequency. More than 60% of respondents who had used sDST did so at least once a week. This means that many of our respondents had a high degree of familiarity with the issues raised by the questionnaire, although the proportion of users from National Government, Statutory Advisory bodies and conservation charities using sDST fell below 50%.

**Requirements for a decision support tool**

Of the features listed, the most highly rated were, in order of preference:

- Produce maps to visualise data/outputs spatially
- Present information at a range of spatial scales
- Simple and easy to understand with reference to a manual (doesn’t require training)
- Able to contribute own data to the tool
- Export outputs as data files or for use in other software

See Table 3 for further detail.

**Table 3.** Summary rank (1 – most important) of the potential features of a future spatial decision support tool, divided by sector (ALL – all responses, LG – Local Government, NG – National

<table>
<thead>
<tr>
<th>Feature</th>
<th>ALL</th>
<th>LG</th>
<th>NG</th>
<th>SAB</th>
<th>CC</th>
<th>LRC</th>
<th>IA</th>
</tr>
</thead>
<tbody>
<tr>
<td>That you can present information at a range of spatial scales</td>
<td>2</td>
<td>3</td>
<td>4=</td>
<td>4</td>
<td>3=</td>
<td>5=</td>
<td></td>
</tr>
<tr>
<td>(rather than the scale of information being fixed to particular resolutions)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>That you are able to contribute your own data to the tool?</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>3=</td>
<td>1=</td>
<td>2=</td>
</tr>
<tr>
<td>That the tool is simple and easy to understand with reference to a user-manual (as opposed to requiring training)?</td>
<td>3</td>
<td>2</td>
<td>4=</td>
<td>2</td>
<td>2</td>
<td>9=</td>
<td>7=</td>
</tr>
<tr>
<td>That the tool combines information and evaluates trade-offs</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>7=</td>
<td>14</td>
<td>2=</td>
</tr>
<tr>
<td>between different competing decision solutions to present a suggested, optimal, solution (as opposed to simply providing information)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>That the rule for combining information and evaluating trade-offs</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>11=</td>
<td>3=</td>
<td>2=</td>
</tr>
<tr>
<td>between decision solutions can be defined by the user, as opposed to fixed within the tool?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>That the tool simply presents information / raw data for you to take and use in the most appropriate manner to inform decision making?</td>
<td>12</td>
<td>10</td>
<td>13</td>
<td>9=</td>
<td>9=</td>
<td>7=</td>
<td>13</td>
</tr>
<tr>
<td>That the tool includes ways of quantifying ecosystem services?</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>11=</td>
<td>13</td>
<td>13</td>
<td>9=</td>
</tr>
<tr>
<td>That you can model ecological phenomena such as changes in the viability of species populations under different configurations of habitat size, shape and connectedness?</td>
<td>10</td>
<td>8</td>
<td>12</td>
<td>13</td>
<td>11=</td>
<td>9=</td>
<td>14</td>
</tr>
<tr>
<td>That the tool integrates other state-of-the-art predictive models eg. flood risk, land-use change?</td>
<td>11</td>
<td>11</td>
<td>9</td>
<td>9=</td>
<td>14</td>
<td>7=</td>
<td>9=</td>
</tr>
<tr>
<td>That you can present information on historical trends in the</td>
<td>13</td>
<td>13</td>
<td>11</td>
<td>11=</td>
<td>9=</td>
<td>9=</td>
<td>11=</td>
</tr>
<tr>
<td>information presented / outputs?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>That you can include scenarios of future impacts of different drivers such as land-use and climate change, in the search for optimal land-use options?</td>
<td>7</td>
<td>9</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>12</td>
<td>5=</td>
</tr>
<tr>
<td>That you can produce maps to visualise the data / outputs spatially?</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1=</td>
<td>1</td>
</tr>
<tr>
<td>That you can output results as graphs or tables?</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td>7=</td>
<td>3=</td>
<td>7=</td>
</tr>
<tr>
<td>That you can export outputs as data files for use in other programmes?</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3=</td>
<td>3=</td>
<td>11=</td>
</tr>
</tbody>
</table>

In summary, any sDST should produce maps and spatial outputs, including files for export to other packages, which present information at a range of spatial scales. It should be cheap, simple and easy to understand, although flexible enough for users to add their own data to the tool. Developing an easy to use tool to make relevant data available to users at a range of spatial scales should be the first priority. This should present information about data uncertainty. There was some interest in the tool being able to present scenarios of likely future impacts of drivers, although only from some sectors, and the tool being able to optimise potential solutions to decisions, but in a user-defined way. Ultimately therefore, users were more interested in the development of a formal decision support tool rather than tools that simply present the raw data.

In general, the lowest demand was for a tool that combines information and evaluates trade-offs to suggest an optimal solution, although this was highlighted as useful by respondents from the Industry and Agriculture sectors. There was more interest in such a development if users were able to define the trade-offs themselves, which was scored more highly (Table 3) than a tool which simply
presents information / raw data (Table 3). There was also little interest in a tool that integrates other state-of-the-art predictive models, or presents information on historical trends.

**Requirements for underpinning data**

Respondents were asked to consider their data requirements now, and in the future. At present, users were most interested in data relating to conservation or biodiversity being represented. Thus, information about conservation designation, habitat quality and species distributions were most highly ranked. These remained important in the future, but with additional requirements about other potential changes, such as climate change and land-use change (Table 4). Datasets which received the lowest scores (both now and in the future) were genetic diversity, socio-economic and industry-specific datasets, soil type and management history.

**Table 4.** Datasets rated as most important by respondents now and in the next 50 years listed in descending order of importance. These ratings were supplied in response to the question “What sort of data would you want represented in a spatial decision-support tool? Indicate the importance of each dataset to your current work and also what you see an increasing need for in the next 10 to 50 years.”

<table>
<thead>
<tr>
<th>CURRENT USAGE</th>
<th>FUTURE NEEDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation designations</td>
<td>Habitat quality</td>
</tr>
<tr>
<td>Habitat quality</td>
<td>Conservation designations</td>
</tr>
<tr>
<td>Species distributions</td>
<td>Species distributions</td>
</tr>
<tr>
<td>Land management</td>
<td>Land management</td>
</tr>
<tr>
<td>Land cover</td>
<td>Land cover</td>
</tr>
<tr>
<td>Land cover</td>
<td>Climate change</td>
</tr>
<tr>
<td>Land use change</td>
<td></td>
</tr>
</tbody>
</table>

There was additional variation in the future needs listed by individuals from different sectors. Information about climate change, land-use change and flood risk were required as high priorities by national government, statutory advisory bodies and industry / agricultural interests, whilst information about agri-environment schemes, species population size and soil type were listed by single sectors. Flood risk and species population size in particular were generally ranked highly by most sectors, even if outside the top five in most cases. Interestingly, information about habitat quality and land management were regarded as more important than land cover, although potentially much more difficult to obtain across large areas. Users would clearly prefer all environmental data to be available at as fine a spatial scale as possible, but recognised that for climate change projections, landscape (c.10x10km) or county (c.100x100km) scales are the most appropriate resolution at which it should be interrogated.

As with concerns about sDST, the largest barrier to using existing data was cost, although unreliability of data, that data were not available electronically, lack of expertise to process and use data in a useful way, and difficulties in accessing data were also problems for many potential users of a sDST. At present, the largest barriers to users obtaining and utilising new datasets that they felt would be needed for more effective current and future-decision-making were a lack of staff time, the cost of collection by external consultants, and lack of in-house analytical/modelling skills.
To summarise, users ideally require a wide-range of data to be made available at fine spatial resolutions in order to underpin the development of a new sDST. The highest priorities relate to provision of datasets on land management, land cover and habitat quality, conservation designation and species distributions, each of which more than 70% of respondents requested at 1km scales or less. Such data should be cheap, reliable, and easily available without requiring significant in-house expertise or time to process.

Requirements for scenarios

Potential users recognised that the twin pressures of climate change and land-use change are likely to increasingly affect their decision making. Any potential tool development which involves presenting future scenarios, should therefore consider likely changes in each of these land uses in particular: water resource management, biodiversity conservation, agriculture, woodland and forestry, flood management and recreation (Table 5). Tools should also be able to draw on projections of likely change in habitat quality, species distribution, diversity and abundance, with a particular emphasis on species and habitats requiring legal protection.

Requirements for information on ecosystem services

Respondents were asked to consider in more detail the ecosystem services which might influence their decision-making. This provides a greater level of detail about what it is about particular land-uses which users find of interest. The following were scored as important by more than 75% of respondents: Habitats of conservation concern, Habitat quality, Species of conservation concern, Species diversity, Habitats requiring legal protection, Species requiring legal protection, Wild species diversity, Species population size, thus indicating and re-enforcing the strong biodiversity focus of those answering the questionnaire. A range of other potential goods and services were scored as important by more than 50% of respondents, with services associated with water (whether maintaining the water cycle, water quality regulation, flood regulation, fresh water availability) and recreation (whether recreation and tourism, aesthetic values, cultural values, education and sense of place) clearly priorities.

Table 5. Scores of the current (a) and future importance (b) of different potential land-uses in making decisions (ALL – all responses, LG – Local Government, NG – National Government, SAB – Statutory Advisory Body, CC – Conservation Charity, LRC – Local Record Centre, IA – Industry and agriculture). Scores of $S \geq 0.3$ (in bold) are the most important.

<table>
<thead>
<tr>
<th>a)</th>
<th>ALL</th>
<th>LG</th>
<th>NG</th>
<th>SAB</th>
<th>CC</th>
<th>LRC</th>
<th>IA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water resource management</td>
<td>-0.1</td>
<td>-0.2</td>
<td>-0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Biodiversity conservation</td>
<td>0.7</td>
<td>0.7</td>
<td>0.4</td>
<td>0.7</td>
<td>0.9</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.1</td>
<td>-0.1</td>
<td>0.2</td>
<td>0.5</td>
<td>0.0</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Woodland and forestry</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
<td>0.1</td>
<td>-0.5</td>
</tr>
<tr>
<td>Flood management</td>
<td>0.1</td>
<td>0.2</td>
<td>-0.2</td>
<td>0.3</td>
<td>0.0</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Energy production</td>
<td>-0.4</td>
<td>-0.5</td>
<td>-0.3</td>
<td>-0.2</td>
<td>-0.4</td>
<td>0.0</td>
<td>-0.6</td>
</tr>
<tr>
<td>Residential and commercial development</td>
<td>0.1</td>
<td>0.2</td>
<td>-0.5</td>
<td>0.3</td>
<td>-0.1</td>
<td>0.5</td>
<td>-0.5</td>
</tr>
</tbody>
</table>
There were some significant differences between the different sectors. Whilst local government, statutory advisory bodies, conservation charities and local records centres each followed this general ranking of scoring biodiversity-relevant goods and services most highly, national government, industry and agriculture also scored a number of other ecosystem services equally or more highly, including soil formation and quality, water cycling, fresh water provision, quality and flood regulation, primary production, food and fuel production (Fig 3).

To conclude, consideration of potential future scenarios of change within sDST should involve presenting changes in biodiversity, conservation, water resource and flood management, agriculture, woodland and forestry and recreation land-uses. In more detail, these should be

---

**Table:**

<table>
<thead>
<tr>
<th>Service</th>
<th>LG</th>
<th>NG</th>
<th>SAB</th>
<th>CC</th>
<th>LRC</th>
<th>IA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>-0.1</td>
<td>0.0</td>
<td>-0.6</td>
<td>-0.1</td>
<td>0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.1</td>
<td>0.1</td>
<td>-0.2</td>
<td>0.2</td>
<td>0.5</td>
<td>-0.4</td>
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<td>0.6</td>
<td>0.8</td>
<td>0.7</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Biodiversity conservation</strong></td>
<td>0.8</td>
<td>0.9</td>
<td>0.7</td>
<td>0.7</td>
<td>0.9</td>
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</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>0.4</td>
<td>0.2</td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
<td>0.6</td>
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<tr>
<td><strong>Woodland and forestry</strong></td>
<td>0.5</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>-0.3</td>
</tr>
<tr>
<td><strong>Flood management</strong></td>
<td>0.6</td>
<td>0.7</td>
<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Energy production</strong></td>
<td>0.2</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Residential and commercial development</strong></td>
<td>0.2</td>
<td>0.3</td>
<td>-0.3</td>
<td>0.4</td>
<td>0.1</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>0.1</td>
<td>0.2</td>
<td>-0.5</td>
<td>0.2</td>
<td>-0.1</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Recreation</strong></td>
<td>0.3</td>
<td>0.4</td>
<td>-0.1</td>
<td>0.3</td>
<td>0.4</td>
<td>0.8</td>
</tr>
</tbody>
</table>

---

**Figure 3.** The percentage of respondents that classed a range of ecosystem goods and services as important for decision making (see Appendix 3 for sectoral break-downs of this figure).
underpinned with information about likely changes in habitat quality, species distribution, diversity and abundance, with a particular emphasis on species and habitats requiring legal protection. Information about the provision of a range of ecosystem services associated with water provision and recreation were also high priorities for consideration.

**Synthesis of results**

This assessment of user needs has given some clear guidance about what users would require from the potential development of sDST to help inform environmental decisions for the future. The first priority appears to be the provision of existing data about conservation designation, species and habitats at a range of spatial scales. Such information should be presented as maps, with underlying data exportable to other software. The sDST should be easy to use but also provide information about data uncertainty. Interestingly, users wanted to be able to update and add additional information, which may be a means to improve the quality and scope of data already held. The first priority is therefore very much about making data widely and easily available to support current decision making. However, there was appetite for further product development; simply producing a tool which presented information was not ranked highly by users, although would be an important first step.

Beyond this goal, there was secondary interest in the potential for the tool to present information about possible future impacts of different drivers such as land-use and climate change. Impacts of these on features of relevance to biodiversity conservation, such as the distribution and abundance of species, and the distribution and quality of habitats was the greatest perceived need, and could be developed by taking advantage of existing modelling approaches that link species and habitats to climate and land-use information.

Thirdly, there was an acknowledgement of the benefits of a tool which would help identify options for land-use planning to balance competing demands. This could potentially be the most complex aspect of a sDST to develop, but may be particularly useful to industry and agricultural sectors who are keen to optimise decision making for economic reasons, and was generally scored highly by most user groups (although did not necessarily reach the top-five ranking). It was clear from the workshop that some organisations are already developing such tools themselves (Appendix 1).

**Coverage of user groups; missing or under-engaged sectors**

Although a wide range of potential user groups responded to the questionnaire (Fig 2), several groups remain poorly represented or absent because responses were zero or very low. These sectors are agriculture, energy companies, consultants (which would include farm advisers), the transport sector, local community organisations, the renewable sector and developers.

The under-representation of water, minerals and agriculture in the questionnaire was to some extent compensated by effective and enthusiastic representation in the user group workshop from Anglia Water, NFU and the Mineral Products Association Biodiversity and Nature Conservation Group.
5.3 Summary of reviews

5.3.1 Review of scenarios

None of the scenarios or scenario models reviewed for this project (or known by the team) exist as sets of finely resolved projections of impacts at say 1km or smaller scales (Table 6). Scenarios most commonly exist as internally coherent ‘storylines’ associated with particular sectors with sufficient detail present for the scenario to be used as input for tools and techniques that estimate impacts at local scales. A key aspect of translating the sector-based scenarios into possible local impacts is in hypothesising and modelling the interactions between sectoral changes. For example how will climate change constrain options for land-use change and how might these interactions limit the scope for adaptation over time? Some scenarios present impacts in terms of changes to ecosystem services and may be suitable for defining the scope or domain of sDST by linking national or non-spatial trajectories of change through to impacts on biodiversity, land-use and ecosystem services. Focussing on local areas, impacts analysis becomes a dialogue between stakeholders rather than a purely analytical task applied to data. For example combining GIS tools with Bayesian Belief Networks (BBN) can be an effective way of mobilising expert knowledge, public opinion and quantitative evidence to produce plausible notions of how social-ecological systems may respond to drivers of environmental change in a specific area (village, valley, city, county). An additional benefit of the BBN approach is that uncertainty is flexibly yet explicitly introduced (Haines-Young 2011). Communities of decision-makers motivated by a statutory remit have also used workshop-based qualitative narrative exercises to define plausible futures in order to help prioritise action in the present (Creedy et al. 2009; Kass et al. 2011). By highlighting sources of uncertainty likely to be important in determining which ‘future’ may pertain, sector-specific questions arise that could be tackled by focussed modelling and impacts analysis. In themselves, none of the scenarios reviewed are capable of providing spatially explicit parameter values for local systems yet they do provide the basis for such analyses.

Scenario use; examples of current applications

A number of sectors currently employ scenarios in order to estimate the scope of future problems and opportunities (Table 6). A defining feature of some scenarios is that they can powerfully delineate undesirable futures that may only be avoided by taking action in the present. Scenarios that are most effective at this appear to be those that are communicated as narratives that gradually link the present with the past. Thus the final outcome appears possible because of the plausibility of the unfolding storyline. By showing how the situation 50 to 100 years in the future can be directly linked back to decisions made in the present such scenarios challenge the option of inaction on the basis of lack of knowledge or political will. For example Shell Oil have a history of using scenarios to scope out likely future energy demand given different approaches to energy consumption, generation and perceived future scarcity. Currently two scenarios project to 2050, called ‘Scramble’ and ‘Blueprints’. In the ‘Scrambles’ story line, policy pays little attention to likely peak oil and does

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22 See Table 1 in Kass et al. (2011). The ‘critical uncertainties’ column indicates considerable scope for model-based projections of change across many sectors.
23 http://www.shell.com/home/content/future_energy/scenarios/
not emphasise energy efficiency until climate shocks increase and supplies dwindle. ‘Blueprints’ on the other hand, plays out the increasing global perception of the likely consequences of climate change from untrammelled economic and population growth. This leads to integrated action toward diverse energy efficient technology and renewables. Both scenarios narrate the gradual change that takes us from now to two very different outcomes by 2050. Similarly the UK National Grid has defined three scenarios – Slow Progression, Gone Green and Accelerated Growth – that project possible total energy demand, energy sources and CO₂ emissions up to 2030 with a less precise forward look to 2050²⁴. Energy scenarios that combine user-specified levels of demand with different energy sources can also be readily explored using the Department of Energy and Climate Change (Decc) carbon calculator²⁵. Users can also select ‘example pathways’ that implement scenarios of supply and demand already explored by policymakers, for example those constructed by National Grid or Friends of the Earth. The application then maps the total area needed for each energy source under each scenario as a proportion of Britain. This rudimentary yet readily understandable type of output suggests that further impacts modelling would be feasible to estimate more explicitly where new energy production should be optimally located and therefore which land uses and ecosystem services would be impacted. The tool is currently being updated to accommodate impacts on air quality and biodiversity (Helen Pontier pers.comm.).

A recent and globally unique example of the applications of scenarios right through to spatially explicit mapping of ecosystem impacts is the UK National Ecosystem Assessment. Six scenarios of socio-economic change up to 2060 were used as a basis for analysing changes in ecosystem services and human-wellbeing (Haines-Young et al. 2011). These were constructed by defining groups of projected changes in drivers guided by users’ questions about environmental change and its consequences. The relationship between these scenarios and other scenario-based studies was also described. Analyses of scenario-related impacts were carried out by ecosystem service category, by broad habitat and by 1km square across Britain reflecting habitat and place-based perspectives already explored in Haines-Young & Potschin (2007). Impacts modelling involved estimating the response of each habitat type and its service-providing potential, to the change in each driver. A rule-based matrix linked a series of key factors that could be quantified within each 1km square across Britain to each scenario projection of average land-cover change. Factors included altitude, landscape designation, woodland potential, agricultural land classification and temperature change. These rule-based relationships constrained the magnitude and location of the impact of each scenario on the starting mosaic of habitats in each 1 km square. The UK NEA analysis was a unique an innovative step forward in combining scenarios with the best data and knowledge to achieve a social-ecological assessment of simultaneous impacts on ecosystem services at the finest achievable resolution. However, in the last paragraph of the chapter the authors still highlighted the potential

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²⁵ http://2050-calculator-tool.decc.gov.uk/ For the energy related sectors (electricity, heat, energy efficiency and transport), the model allows users to select from four increasing levels of effort for each low carbon technology or measure (e.g. onshore wind, offshore wind, biofuels, nuclear, home insulation etc). For example, for onshore wind (where there are currently 3,000 turbines in the UK), the level two effort (described as “ambitious but reasonable”) would entail 18,000 turbines by 2050, with level four (described as “heroic” and “at the extreme end of what is physically plausible”) comprising 30,000 turbines. After selecting the level of effort for each technology, the calculator tells you whether your chosen pathway adds up to the 80% emissions reduction target for the UK.
weaknesses of the approach and gave a clear signpost for the way ahead; “scenarios are only as good as our understandings of the way in which ecosystem structure and function support the output of ecosystem services. Unfortunately in many cases we lack this vital knowledge. Thus an important next step would be to develop a new generation of data-driven, multifunctional ecosystem models to explore the future of ecosystem services in the UK.”
<table>
<thead>
<tr>
<th>Project</th>
<th>App.</th>
<th>Scenarios</th>
<th>Spatial domain</th>
<th>Time-frame</th>
<th>Spatial resolution</th>
<th>ES</th>
<th>Driver</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEA</td>
<td>EO</td>
<td>Green &amp; pleasant land</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✔️</td>
<td>Conservation of biodiversity &amp; landscape</td>
<td>(Haines Young et al. 2011)</td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Nature @ work</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✔️</td>
<td>Population growth and new technology</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>World markets</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✔️</td>
<td>Economic growth - liberalisation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>National security</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✔️</td>
<td>Self sufficiency &amp; efficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Local stewardship</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✔️</td>
<td>Reduced consumption and intensity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Go with the flow</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✔️</td>
<td>Business as usual</td>
<td></td>
</tr>
<tr>
<td>HCHV</td>
<td>EO</td>
<td>Restoration</td>
<td>UK</td>
<td>2030</td>
<td>generalised but limited regional interpretation</td>
<td>✔️</td>
<td>long-term governance, dematerialised consumption</td>
<td>(Hodge et al. 2006)</td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Krypton Factor/Alchemy</td>
<td>UK</td>
<td>2030</td>
<td>generalised but limited regional interpretation</td>
<td>✔️</td>
<td>long-term governance, material consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Survivor</td>
<td>UK</td>
<td>2030</td>
<td>generalised but limited regional interpretation</td>
<td>✔️</td>
<td>short-term governance, dematerialised consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Strike it rich/Jeopardy</td>
<td>UK</td>
<td>2030</td>
<td>generalised but limited regional interpretation</td>
<td>✔️</td>
<td>short-term governance, materialised consumption</td>
<td></td>
</tr>
</tbody>
</table>

Table 6 Examples of scenarios that could be used to parameterise sDST for use in England and the UK, presenting some of their characteristics. Project indicates the origin of the different scenarios. App indicates the approach either EO (expert opinion) or MM (mathematical model). ES indicates the level to which ecosystem services are presented, Driver indicates the driving force(s) considered to cause change and Source is where additional information can be found.
<table>
<thead>
<tr>
<th>Project</th>
<th>App.</th>
<th>Scenarios</th>
<th>Spatial domain</th>
<th>Time-frame</th>
<th>Spatial resolution</th>
<th>ES</th>
<th>Driver</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy 2050</td>
<td>MM</td>
<td>Low carbon</td>
<td>UK</td>
<td>2050</td>
<td>generalised</td>
<td>✓</td>
<td>80% reduction in GHG emissions</td>
<td>(Ekins &amp; Skea 2010)</td>
</tr>
<tr>
<td></td>
<td>MM</td>
<td>Resilience</td>
<td>UK</td>
<td>2050</td>
<td>generalised</td>
<td>✓</td>
<td>Secure energy supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM</td>
<td>Reference</td>
<td>UK</td>
<td>2050</td>
<td>generalised</td>
<td>✓</td>
<td>Business as usual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM</td>
<td>Low carbon resilience</td>
<td>UK</td>
<td>2050</td>
<td>generalised</td>
<td>✓</td>
<td>80% GHG reduction and resilience</td>
<td></td>
</tr>
<tr>
<td>NE-STEEP or ScENE</td>
<td>EO</td>
<td>Connect for Life</td>
<td>England</td>
<td>2060</td>
<td>generalised</td>
<td>✓✓✓</td>
<td>Multi functional land management</td>
<td>(Kass et al. 2011) or</td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Go for Growth</td>
<td>England</td>
<td>2060</td>
<td>generalised</td>
<td>✓✓✓</td>
<td>Rapid change driven by monetary value</td>
<td>(Schultz 2011)</td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Keep it Local Succeed</td>
<td>England</td>
<td>2060</td>
<td>generalised</td>
<td>✓✓✓</td>
<td>Self sufficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>through Science</td>
<td>England</td>
<td>2060</td>
<td>generalised</td>
<td>✓✓✓</td>
<td>Biotechnology &amp; technical control</td>
<td></td>
</tr>
<tr>
<td>Foresight Futures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenarios</td>
<td>EO</td>
<td>World markets</td>
<td>UK</td>
<td>2020</td>
<td>generalised</td>
<td>✓</td>
<td>Personal independence, material wealth and mobility</td>
<td>(Berkhout &amp; Hertin 2002)</td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Global responsibility</td>
<td>UK</td>
<td>2020</td>
<td>generalised</td>
<td>✓</td>
<td>High levels of welfare within communities with shared values</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>National enterprise</td>
<td>UK</td>
<td>2020</td>
<td>generalised</td>
<td>✓</td>
<td>Material wealth within a nationally rooted cultural identity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Local stewardship</td>
<td>UK</td>
<td>2020</td>
<td>generalised</td>
<td>✓</td>
<td>Sustainable levels of welfare in local communities</td>
<td></td>
</tr>
</tbody>
</table>

Table 6 (contd) Examples of scenarios that could be used to parameterise sDST for use in England and the UK, presenting some of their characteristics. **Project** indicates the origin of the different scenarios. **App** indicates the approach either EO (expert opinion) or MM (mathematical model) **ES** indicates the level to which ecosystem services are presented, **Driver** indicates the driving force(s) considered to cause change and **Source** is where additional information can be found.
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<thead>
<tr>
<th>Project</th>
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<th>Spatial domain</th>
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<th>ES</th>
<th>Driver</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALARM</td>
<td>MM</td>
<td>BAMBU</td>
<td>Europe</td>
<td>2080</td>
<td>Mixed, NUTS2 for drivers</td>
<td>✓</td>
<td>Business as usual baseline</td>
<td>(Reginster &amp; Rounsevell 2006)</td>
</tr>
<tr>
<td></td>
<td>MM</td>
<td>GRAS</td>
<td>Europe</td>
<td>2080</td>
<td></td>
<td>✓</td>
<td>Growth strategy with liberal, globalised, deregulated growth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM</td>
<td>SEDG</td>
<td>Europe</td>
<td>2080</td>
<td></td>
<td>✓</td>
<td>Backcasting scenario to represent integrated social, environmental and economic sustainability</td>
<td></td>
</tr>
<tr>
<td>CH Food</td>
<td>EO</td>
<td>Just a Blip</td>
<td>Global</td>
<td>2100</td>
<td>Global translated to UK</td>
<td>✓</td>
<td>Short term price increase long term trend remains stable</td>
<td>(Chatham House Food Supply Project 2008)</td>
</tr>
<tr>
<td>Supply</td>
<td>EO</td>
<td>Food inflation</td>
<td>Global</td>
<td>2100</td>
<td>Global translated to UK</td>
<td>✓</td>
<td>High food prices for a protracted period but system continues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Into a new era</td>
<td>Global</td>
<td>2100</td>
<td>Global translated to UK</td>
<td>✓</td>
<td>Per capita production falls so yields increase sustainably</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Food in crisis</td>
<td>Global</td>
<td>2100</td>
<td>Global translated to UK</td>
<td>✓</td>
<td>Disrupted system high prices famine and panic.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 6 (contd)** Examples of scenarios that could be used to parameterise sDST for use in England and the UK, presenting some of their characteristics.

- **Project** indicates the origin of the different scenarios.
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<th>Spatial resolution</th>
<th>ES</th>
<th>Driver</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foresight</td>
<td>EO</td>
<td>Leading the Way</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✓</td>
<td>High adaptation to change with dispersed population and activity</td>
<td>(Foresight Land Use Futures Project 2010)</td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Valued Service</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✓</td>
<td>Concentrated but flexible activity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EO</td>
<td>Competition Rules</td>
<td>UK</td>
<td>2060</td>
<td>Generalised</td>
<td>✓</td>
<td>Little adaption and resistant to change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM/EO</td>
<td>A2</td>
<td>Global</td>
<td>2100</td>
<td>Generalised</td>
<td>✓</td>
<td>Slower growth more regionalism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM/EO</td>
<td>B1</td>
<td>Global</td>
<td>2100</td>
<td>Generalised</td>
<td>✓</td>
<td>Sustainable development with social and environmental conscientiousness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM/EO</td>
<td>B2</td>
<td>Global</td>
<td>2100</td>
<td>Generalised</td>
<td>✓</td>
<td>Self supporting sustainable development with regional and sub-regional diversification</td>
<td></td>
</tr>
</tbody>
</table>

**Table 6 (contd)** Examples of scenarios that could be used to parameterise sDST for use in England and the UK, presenting some of their characteristics. **Project** indicates the origin of the different scenarios. **App** indicates the approach either EO (expert opinion) or MM (mathematical model). **ES** indicates the level to which ecosystem services are presented, **Driver** indicates the driving force(s) considered to cause change and **Source** is where additional information can be found.
From scenarios to impacts; issues of scale and cross-sectoral integration

Detailed sector-oriented tools exist that translate ‘what-if’ scenarios of change in land-use into expected impacts. For example the FARMSCOPER tool evaluates the impact of farm practices and mitigation measures on diffuse pollution given variation in farm type\textsuperscript{26}. Being sector and impact specific, considerable detail is included hence outputs are expected to have high local realism and accuracy. Building in interactions with, and responses to, other drivers is technically feasible (Holman et al. 2005, 2008) but a less costly approach might be to ensure that FARMSCOPER outputs can be included as a new yet static set of evaluation tables within existing tools, such as LUCI/Polyscape, that are already designed to assimilate new data layers and to be updated with locally accurate data as part of a participatory process that solicits local knowledge and opinion. Similarly the PEDAL2 model targets phosphorus export and mitigation measures in agricultural catchments. A guiding principle in model design is again that local realism is maximised by allowing the model to be updated with new information when this becomes available\textsuperscript{27}.

At large spatial scales scenario impacts modelling has also been usefully applied. Here though policy relevance centres more on estimating plausible large-scale patterns and less on achieving accurate forecasting within any specific 1km square (Verboom et al. 2007; York et al. 2003; Trisurat et al. 2010; Alkemade et al. 2009; Arnoult et al. 2010). While acceptable for large-scale policy analysis, the generalised predictions from such models may well be a poor match with detailed local observations because the models are not sophisticated enough to capture the conditioning effects of local factors (Medici et al. 2012). Building a sufficiently comprehensive model of smaller-scale ecological responses relies on the existence of adequate data. For example the adequacy of datasets describing the coupling of environment and species will vary between types of species. For mobile species mainly constrained by climate and land use, occupancy data from larger grid cells can be adequate (see Box 1A). For plant species, sampling at finer resolutions is necessary to avoid confounding beta and alpha diversity (Huston 1999) and to spatially match species presence with abiotic factors such as pH and wetness that can interact with and condition responses to drivers such as land use and climate change (Pakeman et al. 2008; Rowe et al. 2011; Smart et al. 2010a). In addition spatial distributions are often used to mimic temporal change (Box 1). While pragmatic, this assumes that observed patterns represent an equilibrium and that change over time will result in an outcome that resembles the observed spatial change in the data used to build the model (Araújo & Rahbek 2006). This also relies on the assumption that if future changes involve prediction outside the ranges of the environmental variables that constrained the spatial model then predictions will still be robust. Moreover, time lags between ecological response and operation of a driver such as land-use change or pollution are well documented and need to be carefully considered when building and interpreting models based on space for time substitution (Vellend et al. 2006; Lindborg & Eriksson 2004; Strengbom et al. 2001). Mechanistic models try to get around this problem by directly simulating temporal processes of population growth and dispersal (Terry et al. 2004). They can work well but often require costly parameterisation which inevitably means that fewer driving variables, ecosystem types and impacted taxa are modelled or that species dynamics are generalised between and within functional types invoking a new assumption that the variability between species within a functional group is not important. In order to validate and parameterise such generalisation steps,

\textsuperscript{26} [http://www.adas.co.uk/Home/Projects/FARMSCOPER/tabid/345/Default.aspx](http://www.adas.co.uk/Home/Projects/FARMSCOPER/tabid/345/Default.aspx)

\textsuperscript{27} [http://www.lec.lancs.ac.uk/cswm/ pedal\_2/po.php](http://www.lec.lancs.ac.uk/cswm/pedal_2/po.php)
choice of study species is critical since a small number of well modelled species ought to be representative of the dynamics of the larger number of taxa in the same functional guild or plant functional type (De Wries et al. 2010; Wright et al. 2006; Moorcroft et al. 2001).

Model applications at 1 km square resolution are readily achievable for GB for a range of ecosystem services (see Box 1 and Haines-Young et al. 2011). This reflects the wealth of data available coupling species and environment at complementary scales and the availability of census products such as the satellite land cover map 2007\(^{28}\) that resolve land cover down to a minimum mappable unit of 0.5ha. The 1km square scale arguably represents a compromise where the precision of simulated patterns provides maximum spatial information supported by the ecological knowledge underpinning the model but where predictions are not so finely resolved that they can be unrealistically interpreted as expectations of presence or absence in a specific habitat patch. Whilst based on the best available datasets, the 1 km square scale will still not meet the evidently increasing needs of end-users for more finely resolved models and data (Fig 6 in Appendix 3).

It is possible that the approaches and architectures employed by large-scale tools could be tailored to finer resolutions (e.g. Holman et al. 2008) but to do so will often require new intensive data gathering not achievable in all places because of cost. Given the trade-off between local model accuracy versus the size of the spatial domain to be modelled, a reasonable goal would be to promote cross-scale compatibility of outputs and approaches. This could be as simple as ensuring that coarsely resolved modelling outputs are in a compatible format and can be used as the starting point for local impacts modelling and that the modelling techniques applied at the large scale can be readily and continually updated with more accurate local data when available. This would require collaborative working between technical specialists and local stakeholders. Specialist expertise is likely to be needed to develop model architecture as well as pathways for efficient and simple two way flows of information; for example dissemination to locally based end-users of modelled output layers that depict the broader spatial context and, in addition, creating web-enabled applications for receipt of updated local data so that the large-scale modelling is always running on the best available and most finely-resolved datasets. In some cases, increasing the accuracy of impacts modelling may require specialist expertise and resources to record key datasets. For example, the application of farm-scale Greenhouse Gas (GHG) emissions tools in Wales has shown that Carbon footprinting is inaccurate and biased toward excessively high N\(_2\)O emissions from organic soils when generalised emission factors were used since these reflected the much higher release seen in drained lowland peats as opposed to uncultivated wetter organic soils typical of Welsh farmland (Little & Smith 2010). The costs of assembling locally specific data will be weighed against the gain in model accuracy at the scale of interest and may often mean that modelling is based on generalised parameter values. The vital issue is then being able to estimate and understand the significance of the resulting reduction in local accuracy of the sDST output (e.g. Clark et al. 2010). A first step here is clearer, more intuitive representations of uncertainty (Slingsby et al. 2011; Page et al. 2008) an aspect that was also highly desirable to user questionnaire respondents (see Appendix 3).

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\(^{28}\) [http://www.ceh.ac.uk/LandCoverMap2007.html#improved]
BOX 1: Examples of biodiversity impacts modelling for British species using scenarios of change in global drivers

A. Using sample surveys to produce indicative outputs at fine-scales.

The BTO’s Breeding Birds Survey provides information about the density of breeding birds from about 3000 randomly distributed squares per year. Recent developments have used this sample data to model breeding bird density as a function of land-cover, climate, and spatial covariates. These can be used to produce predicted surfaces of current abundance to indicate likely suitability for a particular species, which may be used in the absence of more detailed data, with appropriate caveats (Fig 4a). The same approach has also been used to produce maps of changes in deer density across England (Newson et al. 2011) (Fig 4b).

By then replacing the predictor variables describing current climate and land-use with variables of future projected change in the same terms, the models can be easily adapted to make predictions of change in abundance in response to changing climate.

Figure 4. Map of current curlew density (a) based on BBS data modelled as a function of land use, climate and spatial terms, and future projected curlew density under a high climate change scenario by 2080 (Renwick et al. 2012). Map of current Muntjac abundance (b) based on BBS data modelled as a function of land cover and spatial terms. All maps produce modelled output at a 1km resolution.

B. Modelling the impact of pollutant deposition and climate change on ombrotrophic Sphagnum in upland Britain.

In peatlands, cultural and regulating ecosystem services are delivered by ombrotrophic Sphagnum species that build the peat mass, sequestering carbon and co-dominating habitats of high conservation importance. In this context Sphagnum species can be considered as a single functional type. The realised niche of this small group of species was empirically modelled using Countryside Survey data consisting of records of amalgamated Sphagnum species from British peatlands matched with spatially coincident measurements of pH, soil moisture, carbon:nitrogen ratio and
canopy height (Smart et al. 2010b). Two modelling techniques were used to explore the desirability of using multiple modelling methods to best estimate the uncertainties surrounding model-based projection of scenarios into local ecological impacts. The two empirical models were run forwards in time to explore the interacting effects of atmospheric pollutant deposition and climate change up to 2050. Model inputs were derived firstly from a biogeochemical process model that simulated the impact of projected sulphur and nitrogen deposition change on peat properties. Secondly, climate variables in the model were adjusted according to both the UKCIP02 and UKCP09 projections (Fig 5).

![Figure 5](image_url)

Figure 5. Modelled change (2010 to 2050) in mean % ombrotrophic Sphagnum cover per 4m\(^2\) mapped at the 1 km squares for UK peatland. Projections driven by a) climate only (UKCP09, 50%tile values at high emissions) and b) climate plus atmospheric sulphur and nitrogen deposition (FRAME model projections; CEH Edinburgh). See Smart et al. (2010b).

### 5.3.2 Review of datasets

The objective of this review was to explore issues surrounding the suitability and availability of potentially relevant data sets needed to support sDST in light of users’ needs. The intention was not to comprehensively review every potential dataset but instead to select representative datasets that illustrate issues that need to be considered in tool development. The review also took into account of the views from the assessment of users’ needs regarding issues surrounding data availability, accessibility and use at present and up to 2050.

Important attributes of existing datasets and future requirements were considered under the following headings and are fully reported in Appendix 6:

- Spatial resolution,
- Spatial extent
- Format
Summary of the review

In general, geographically comprehensive datasets increase in availability as spatial resolution reduces but the situation varies across datasets. SDST should therefore be able to quantify the extent to which analytical outputs vary as a function of variation in the resolution of the input data. Differences in data resolution and availability also highlight the need for up and down-scaling techniques where statistical or process models are used to impute estimates of key variables at scales required by users but where real observations do not exist. A notable biological example is the use of species-area relations to estimate potential diversity change given habitat fragmentation or restoration (Verboom et al. 2007; Thomas et al. 2004 but see He & Hubbell 2011). While techniques exist to achieve these goals their application needs to be increasingly accompanied by estimates of uncertainty and clear guidance on interpretation. Given variation in the attributes of available datasets, standard criteria are desirable to classify datasets into the quality of the evidence they provide. This should enable quicker and easier assessment of dataset quality. The IPCC distinction between Tier 1 and 3 estimates of GHG emission factors is a useful example of a systematic attempt to classify evidence and analysis by the generality of the input data. In some circumstances, there may be an obvious limit to acceptable data quality. For example, during scoping for development of a Planning Screening Tool (PST) in Kent, users agreed that only biodiversity observations held at 100m resolution or better would be used to populate the tool because coarser data would trigger too many alerts often highlighting observations at considerable distance from the proposed development29.

The relevance of ecosystem service datasets to potential end-users is likely to grow as their needs increasingly reflect policy deliverables packaged in terms of the ecosystem service concept (see for example Jones et al. 2012). Whilst a rapidly developing field, agreed definitions, standardised methods and criteria for the measurement, mapping and monitoring of ecosystem services are not yet available to practitioners who may not be experts in the emerging science of social-ecological systems. Frameworks such as that provided in the UK National Ecosystem Assessment help yet currently there is no consensus on how to separately measure and then integrate data on ecosystem service potential, realised supply and public/private demand for different services. Moreover, cultural indicators of ecosystem services are especially scarce. The socio-economic and environmental data required to build these indicators maybe available but these are not commonly integrated and made operational presumably because there is little agreement on how to do this (Norton et al. 2012). This situation reflects the youthfulness of the underpinning science and the motivating policy framework, and the complex nature of these services which in turn require novel

cross-disciplinary working to increase understanding (Fish et al. 2011). Synthetic descriptions of landscapes and ecosystems may also exist in non-spatial forms but can still provide vital additional context for planning decision-making. For example, the National Character Area (NCA) profiles for England are a rich source of local detail describing the mosaic of habitats that make up each character area, prevalence of designated sites and national importance, ecological relationships to surrounding NCA, summaries of recent change in habitats and ecosystem services plus a forward look to opportunities for achieving integrated delivery of ecosystem services

While many of the issues surrounding data availability for sDST analysis offer ongoing challenges, access to environmental and ecological data has undoubtedly increased in the last 10 years. On-line resources now allow free and simple access for all to a vast range of resources many of which are listed in Biodiversity 2020 and in guidance on Neighbourhood Development Planning. Facilitating wider access for all to local information is an obvious step toward empowering people and encouraging them to take a greater role in developing local visions for land-use, conservation and development. A significant new contribution will be the release of the ‘My Environment’ portal for England due in 2012/’13. These new on-line tools can be considered simple sDST which support the Localism agenda (Table 7).

Table 7: Examples of web-based resources to support Localism and local needs for information on the natural environment

<table>
<thead>
<tr>
<th>Resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural England</td>
<td>Website provides a wealth of information through its Nature on the Map application <a href="http://www.natureonthemap.org.uk/">www.natureonthemap.org.uk</a>. Visitors can view maps of their local area and identify its natural resources, including nature reserves, country parks, habitats, and biodiversity. For example users are directed to the MAGIC website where detailed 1:50,000 maps of priority habitat areas are available in England.</td>
</tr>
<tr>
<td>Environment Agency</td>
<td>“What’s in your backyard?” online service <a href="http://www.environment-agency.gov.uk/homeandleisure/37793.aspx">www.environment-agency.gov.uk/homeandleisure/37793.aspx</a> provides interactive maps of local areas, with information on air pollution, flooding, bathing water quality, pollution, river quality and landfill sites.</td>
</tr>
<tr>
<td>Forestry Commission</td>
<td>Has recently launched ‘ForestXplorer’. This mobile app enables people to use their iPhone, iPod or iPad to locate their nearest Forestry Commission woodland and quickly find out what they can do, see and discover. They can download handy trail maps, find out what events are on and even use the app to identify trees from their bark, seeds or leaves.</td>
</tr>
</tbody>
</table>

30 [http://publications.naturalengland.org.uk/category/587130](http://publications.naturalengland.org.uk/category/587130)
31 See also data.gov.uk
The Open University’s iSpot tool [www.ispot.org.uk](http://www.ispot.org.uk) helps people identify wildlife and plant species. Members of the public can get involved by taking part in the national biodiversity survey and by joining the online nature community which helps identify species.\(^3\)

### 5.3.3 Review of Localism; identifying user groups and the case for sDST

#### Target groups

The current policy landscape provides much greater opportunities for local engagement in decision making by transferring greater power to local authorities and local communities. The Natural Environment White Paper and National Planning Policy Framework describe how this may be achieved for two key sectors; nature conservation and planning. Together, these two documents establish a variety of different bodies and mechanisms by which environmental and planning decisions will be made. Local authorities will be crucial drivers of this process as they have increased decision making power and will drive the production of Local Plans where strategic priorities will be established. The establishment of NIAs for ecological restoration will provide additional strategic guidance for the areas where they are established, thus providing a key mechanism for taking forward the recommendations of [Making Space for Nature](http://www.bnhc.org.uk/home/bioblitz.html). More widely, LNPs will provide strategic guidance on the natural environment within particular areas, supported by a network of Natural Value Ambassadors. Both NIAs and LNPs will require partnership across a range of organisations from statutory bodies, conservation organisations, local businesses, land owners and members of local communities, and should also feed into the production of Local Plans. Individual communities may then translate the locally strategic guidance from Local Plans and LNPs into Neighbourhood Plans and the action of local community groups, thus providing an additional tier of local input and involvement in the decision making process that is democratically accountable.

#### User needs and benefits derived from the use of sDST

From this brief review, it is possible to identify a number of likely key audiences and mechanisms through which environmental information and evidence should be delivered in order to support the localism agenda. Scoping these is an important consideration for the future development of a Spatial Decision Support Tool (sDST).

Firstly, it is clear that local authorities are critical to the whole process. Given the excellent response to the questionnaire from local government, the report of the questionnaire consultation provides a good characterisation of the needs of this group, although possibly with a slightly skewed sample of respondents towards those most interested in biodiversity-relevant decisions. At present they employ a range of relevant environmental expertise from local biodiversity officers and county ecologists to planners and other environmental specialists. Many of these already have access to local-specific information, through contacts with the appropriate statutory authorities, conservation organisations and national datasets, such as through the National Biodiversity Network and Magic 33

[^3]: The rising popularity of Bio Blitz is also testament to the enthusiasm for recording and experiencing the diversity of nature, and where the richness of the experience is increased by bringing together experts and non-experts to work together [http://www.bnhc.org.uk/home/bioblitz.html](http://www.bnhc.org.uk/home/bioblitz.html).
portal. The production of local plans will require consideration of potential future drivers of change over a medium-length time frame of about 15 years. Crucially, these plans should be based upon adequate, up-to-date and relevant evidence about the environmental characteristics and prospects of an area. Localism is likely to result in an increased role and workload for these staff, with increased responsibility for local strategic planning and decision making. Therefore, the production of a tool which were to make such decision making easier and more rapid would be likely to be well-used. This could involve the stream-lining of information and data access, thus making the initial data and information gathering required for such exercises more efficient. Given the well-established structure within authorities and professional bodies overseeing particular specialities across the sector, such as the Association of Local Government Ecologists or national planning bodies (e.g. Office of the Deputy Prime Minister, The Planning Portal, Royal Town Planning Institute), engaging with this potential audience should be relatively straight forward.

The establishment of LNPs, and where appropriate, NIAs, provide an additional mechanism for strategic consideration of environmental planning issues. Precisely how these will operate remains unclear, but they are likely to comprise partnerships of local land owners, members of local communities, local authorities, local business and conservation organisations and statutory organisations. The provision and advice to these groups will be critical in order for them to operate effectively but there is also a recognition that stakeholders within these groups will also generate new datasets by virtue of their own activities. The NEWP identifies the need for the Government’s environmental bodies to provide coherent advice to local partners while LNP/LEP and NIA are likely to require and generate new spatial environmental information, which could be readily assembled and analysed on an sDST platform. In many cases such platforms will already be in use. Indeed the issue may well be fostering analysis of common datasets and problems across a range of GIS systems and tools already in use among partners rather than introducing tools where none exist. These new partnerships are likely to require access to as much environmental and biodiversity data from the area of interest as possible, in order to produce strategic guidance and target ecological restoration. In order to make maximum use of restoration opportunities, such information should be presented within a wider regional or national context, although this was not particularly reflected in the local government responses to the questionnaire consultation\(^{34}\), but was better reflected in responses from conservation and statutory organisations and in discussion (Appendix 3). Thus, if particular elements of local biodiversity are of particular importance within a regional or national context, that should be readily identifiable as a priority for that local area. The new National Character Area profiles for England are likely to be increasingly useful in this respect. Of course, many data-sets are not available at very local scales, and are likely to become increasingly inaccurate when applied at those scales. These limitations should be considered in the potential development of tools able to operate at the finest spatial scales, for example Natural England’s in-house GIS tool is automatically configured to exclude certain datasets depending on the scale of the viewing session (Nick Dales pers comm).

\(^{34}\) However, discussion with the county ecologist for Cumbria showed that she had a pressing demand for the results of spatial biodiversity opportunity mapping that would highlight areas with the greatest potential for reducing habitat fragmentation and increasing ecological resilience. Such requirements are consistent with the NPPF text and the North West Regional Spatial Strategy (J. Palmer pers comm).
Given the significant pressures on our environment identified by the Foresight report on *The Future of Food and Farming*, current or historical information may not be adequate for some strategic decisions and planning. The presentation of likely impacts of different future scenarios of change, such as climate change or demographic change, upon key environmental measures would provide useful additional context for this future planning. Local Plans in particular will not only require a clear collation of current environmental information, but also an informed and evidence-based consideration on how relevant environmental features may change over an appropriate timeframe. As with the use of large-scale data in a local context, the presentation of such future scenarios should be alongside clear caveats and guidance. In fact, the use of future projections and scenarios is likely to be associated with a greater degree of uncertainty than existing data, and therefore may require an additional level of expertise to interpret and use effectively. This level of support should exist within both LNPs and NIAs, either through statutory agency or local authority support or membership, although there appeared to be less recognition of the importance of future scenarios in these organisations than at national government. This same information is also likely to be of value for conservation organisations and statutory authorities for their own purposes.

At the finest scale, localism is likely to empower individual communities and neighbourhoods to produce their own Neighbourhood Plans or establish specific Community Action Groups. Unfortunately, because of the difficulties in reaching this diverse audience in a simple way, there was a poor response from community organisations and the voluntary sector to our questionnaire. They will require information to assist with decision making, although they are likely to be heavily reliant upon the strategic priorities identified by LNPs, NIAs and local authorities in their Local Plans. It is possible that much of the local information used to produce Neighbourhood Development Plans and guide action groups will come from individuals within the local communities and groups themselves, although undoubtedly groups and communities would probably benefit from greater access to centrally held data, such as through the development of a new tool. If it were possible to present future scenarios in a relatively simple and accessible way to this audience, this could provide a good way for decision makers to develop and support wider local engagement with Local Plans, LNPs and NIAs. Often people initially resist change, but by presenting information about how the future may change, and the need to adapt to changing environmental pressures and circumstances, more effective and inclusive local decision making may result.\(^{35}\)

Many national datasets have considerable error or poor coverage at local resolutions. The presentation of data with perceived errors in it when presented to local communities and applied to a local scale may undermine the development and use of a particular tool to inform decision making before the process has begun. The potential to add and update the information for a local area based on specific local knowledge and data may therefore be an important step to maximise local support for a particular decision-making process, and was identified as a priority by potential users.

\(^{35}\) Again, visualisation techniques and the use of participatory BBN can be an effective way to establish common understanding among specialists, decision-makers and local stakeholders. The Forestry Commission have also established an effective toolkit of techniques for facilitating public dialogue; [http://www.forestry.gov.uk/forestry/INFD-5XMD58](http://www.forestry.gov.uk/forestry/INFD-5XMD58)
For example, the inclusion of such local knowledge has been found to be an important element in improving the credibility of models used for decision making about flood risk\textsuperscript{36}. 

**Figure 6.** Priority Habitats in the Forest of Bowland edge just east of Lancaster from the NBN (a) and MAGIC (b) web portals. Polygons assigned to Upland heath, woodland and fen Priority Habitats are shown.

a) 

b) The inset on the right shows attributes attached to the fen polygon highlighted in red.

\textsuperscript{36} Models, decision-making and flood risk: doing simulation modelling differently. RELU Policy and Practice Note 22. October 2010. On-line at www.relu.ac.uk/news/policyandpracticenotes.htm
Increasing the contemporary accuracy of key datasets: an example of the live updating of Priority Habitat data in England

When asked about data needs, user groups prioritised up-to-date and finely resolved data on conservation designation, habitat quality and species distributions. Maps showing the extent of Priority Habitats are available from the Nature on the Map, NBN and MAGIC portals. These provide access to finely resolved data but the resulting coverage is based on compilations of survey datasets of varying age and reliability (Fig 6a,b)\(^37\).

The metadata available is comprehensive but indicates wide variation in temporal coverage and quality. For example the Fen dataset comprises surveys from between 2001 and 2011. Although GIS data capture methods are outlined no details are provided on data quality except that for the West Midlands and Lancashire more detailed coverage was available derived from an NE pilot study. Metadata for the Lowland Meadows dataset provides more detail. Temporal coverage ranges from 1974-2007 and 49% of the mapped areas are considered accurately identified and 12% accurately identified \textit{and} precisely mapped. 46% of the data is also from the last 10 years.

Because of the variation in survey dates, the need to ground truth the habitat data in any one area is obvious especially if precise information is needed for assessing a planning application. In many situations a local site visit may well establish the current situation but, with no obvious means or incentive to update the online database, the online map will become increasingly out-of-date. If dealing with a modest sized area, ground truthing might be achievable by staff on the ground. Combining existing data coverage with the ability to upload map updates qualified by acceptable validation checks, would be highly beneficial (Fig 7a,b).

\textbf{Figure 7.} Screenshots from the NE pilot interactive tool. Existing Priority Habitat boundaries (a) (purple boundary) and crowd-sourced updates (a) (red boundary). Submitted updates are then moderated for their accuracy and plausibility and the record accepted or rejected (b).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure7.png}
\end{figure}

\(^{37}\) Natural England intend to publish a single habitat data layer in April 2013 that will bring together the most up to date information available on broad and priority habitats plus designated site boundaries.
b)

A Natural England pilot project has recently sought to develop a prototype online interactive tool to allow ‘crowd sourcing’ of updated information on species observations and habitat polygon assignments. This is a simple PPGIS system that exposes the existing Priority Habitat inventory maps, allows users on the ground to submit an update from their Smartphone and the submission is then moderated before being incorporated with additional metadata, into the geodatabase (Fig 7a,b). The incentive for employing such technology would be an improvement in the accuracy and effectiveness of local planning decisions and regional spatial analyses.

Spatial analyses and uptake at the local level

The most complex options for sDST development involve the potential development of tools to examine trade-offs and optimisations between competing cross-sectoral demands, for example between biodiversity and other ecosystem services. Whilst some tools are starting to become available and be used for such decision making, they may be most likely to be effective at the national and regional level. Given the greater uncertainties and errors associated with the presentation of information and data at the finest resolutions discussed, providing accurate but widely applicable sDST for use at local scales is likely to be difficult. There are therefore likely to be some significant obstacles to the use of the most sophisticated sDST to inform the localism agenda at the finest scales. Given the technical expertise likely to be required to use such tools effectively, they are most likely to be used by specialists within local authorities or statutory agencies, and it is likely to be through those individuals that the information may then be made available to LNP s and NIAs. However, this was not amongst the highest priorities for a potential sDST for local government or statutory agencies. Capacity for the use of such tools also exists within Defra family bodies, non-Governmental environmental agencies and conservation organisations, and ecological consultancies, potentially providing an alternative mechanism for such information to be used and fed through to local communities.

It is unlikely that most individual landowners or members of communities would have the expertise to make the most of sophisticated tools with complex modelling options and capabilities on their
own. However, the use of such tools to engage such individuals within a workshop-type framework can be extremely successful to facilitate collective decision making\(^{38}\). Visualisation techniques and novel ways of presenting data and uncertainty are becoming increasingly important elements in such participatory processes\(^{39}\).

An important issue in supporting Localism with data, participatory processes and sDST is the use of language. Research commissioned by Defra\(^{40}\) investigated public understanding of much of the terminology surrounding biodiversity, conservation and ecosystem services. The work was based on a UK-wide focus group study stratified by socio-economic group, age and tendency to support green issues. Clear messages emerged. Biodiversity was poorly understood while the term ecosystem services was wholly unfamiliar, confusing and usually misinterpreted. Yet at the same time, groups expressed clear support for concepts that demonstrate widespread value for nature and the cost of its degradation, for example the interdependency of nature, the precautionary principle, that prevention is better than cure and that we often treat nature as a set of free goods and so end up damaging it. So, while there is substantial public appreciation of the natural environment there is an obvious danger that reliance on the use of complex parlance in tools and information will result in confusion, low perceived relevance and low engagement. The DEFRA (2007) study also showed wide public recognition of the role of the natural environment in increasing quality of life and providing natural life-support services such as clean air/water and food. Clearly, the usage and usefulness of the term ‘ecosystem services’ is greatest by those closest to its intellectual origins and for whom the concept most resonates with their scale of operation; decision-makers at national or regional level. While the term is generative of ideas (Fish 2011) and is increasingly pervasive it may be less helpful and even obfuscatory for the lay public if not carefully explained.

To conclude, there is considerable potential for sDSTs to inform the localism agenda. The greatest capacity for the use of such tools probably exists within local authorities, statutory bodies and some conservation organisations and other NGOs. LNPs and NIAs are likely to benefit from the use of such tools, and indeed provide an important audience for tools to inform local planning and decision making. This is likely to be achieved through the provision of specific advice and expert knowledge from local authorities and other bodies involved in LNPs and NIAs, but they may alternatively require specific engagement with the development of a tool. The capacity for specific neighbourhoods and communities to use a tool in isolation is likely to be limited to the tool providing a means for the simple presentation of local environmental data, for which there would probably be a high demand.

### 5.3.4 Review of Decision Support Tools

The objective was to undertake a brief review of existing spatial decision support tools (sDST) including applications relevant to terrestrial and aquatic systems and with a focus on ecosystem

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\(^{38}\) Pagella, T. *pers. comm.*

\(^{39}\) See for example Slingsby et al (2011) for new interactive graphic techniques. Also [www.ccg.leeds.ac.uk/teaching/wilderness/](http://www.ccg.leeds.ac.uk/teaching/wilderness/) for PPGIS modelling of wilderness areas in GB

\(^{40}\) Defra (2007) *Public understanding of the concepts and language around ecosystem services and the natural environment.* Defra project code: NR0115 (J278742)
services. The results are summarised in Table 8 and also see 5.3.5. See Appendices 5 and 8 for detailed assessments and descriptions of the tools.

The assessment of user needs indicated that while there were fundamental needs for improved access to more finely resolved up-to-date datasets, different groups of users demonstrated differing levels of interest in sDST that could perform more complex analyses of spatial data. Respondents within National government, Statutory Advisory Bodies and Industry/Agriculture ranked features of more complex tools very highly although interest often focussed on the outputs of these analyses rather than a desire to carry out the analysis themselves. These additional functionalities, ranked no lower than third most desirable by at least one sector, were:

- The ability to evaluate trade-offs between information layers and competing decision solutions
- The flexibility to incorporate user-defined rules for evaluating those trade-offs
- The ability to include scenarios of future impacts of drivers such as land-use and climate change

National government respondents were particularly interested in the functionality of being able to run scenarios. Modelling their impacts at small scales and across drivers and sectors presents the most complex technical challenge but the analytical difficulty reduces the more that users’ interests are focussed on capturing broad spatial patterns with less interest in accurate prediction at fine resolution (Verboom et al. 2007; Alkemade et al. 2009). By analogy with the type of decisions that respondents currently use tools for, there is also the requirement for users to parameterise their own decision-cases in the form of scenarios that are contingent on local conditions. As discussed previously, these requirements can be addressed using participatory processes coupling GIS systems, visualisation and BBNs.

Industry/agriculture and Local Record Centres were also interested in the ability to evaluate trade-offs between information layers, including the flexibility for user-defined rules to explore these trade-offs. At the county and district scale there was also interest in opportunity mapping to assess the potential for joining up habitats in order to support the new emphasis on resilient biodiversity networks included in Biodiversity 2020, in the text of the NPPF and promoted by regional spatial strategies. There remains a clear distinction between the need for these kinds of new analytical outputs to facilitate decision-making versus the willingness to actually carry out the analyses. Because of lack of resources and technical skills, consumers of the outputs of sDST are in many cases unlikely to be the producers of those outputs even if the tools could be made available to them.

These findings illustrate some basic tensions between the perceived needs of different user groups; primarily the conflict between the need for a tool that is easy and cheap to use with the requirement for flexibility, the ability to parameterise your own decision-making context, and dynamic modelling which necessitate a complex tool and the attendant technological and resource overheads. A second distinction is drawn out from the requirements for decision making in the questionnaire study.

For example, Policy EM1(B) in the North West Regional Spatial Strategy (http://www.cumbria.gov.uk/elibrary/Content/Internet/538/755/1929/1982/3972715317.pdf) expects Local Authorities to “develop functional ecological frameworks that will address habitat fragmentation and species isolation, identifying and targeting opportunities for habitat expansion and reconnection”.

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Industry and agriculture respondents were interested in a tool to provide them with ‘the answer’ while national and local government and statutory advisory bodies ranked this facility lowest of all and were interested in a tool that provided them with the information they needed in order to take an informed decision themselves.

**Summary of findings**

Decision support tools are undergoing rapid development driven by changes in the policy landscape, from the rapid uptake of the ecosystem services paradigm and new cross-disciplinary research agendas that seek to better understand the functioning of social-ecological systems. New technological advances in data storage, data processing algorithms and software development have led to the emergence of a range of new applications and approaches but these are generally so new that no stable, flexible and well-used set of tools exists. In many ways, the UK is slightly behind other European countries and the USA. Consequently there are very few examples of application of major decision support tools in the UK, and, at the time of writing, none regarding the larger ecosystem service tools such as Aries and InVEST. There is therefore considerable groundwork to be done with respect to developing and applying some of these tools in case studies. On the other hand, the UK has some sophisticated biodiversity information tools and a number of different information gateways which provide access to biodiversity and other environmental data (e.g. GiGL, EASIMAP, Nature on the Map, MAGIC, NBN). Of increasing importance are also recording initiatives which rely on public reporting of biodiversity and environmental data, often using mobile phone applications. Examples include the OPAL biodiversity survey and iSPOT.

Within the UK, development and application of ecosystem service tools is making progress: LUCI (formerly Polyscape) is being run as a new case study for the Bassenthwaite catchment (several case studies using the older version Polyscape have been run in Wales), and there are plans to apply InVEST in the BESS project focussed on lowland multifunctional landscapes in Wessex (Tom Oliver pers comm). Large-scale modelling of proxies for some ecosystem services was also conducted in the Countryside Survey Integrated Assessment. This work demonstrated how statistical models of ecosystem service indicators could be developed and used for future projection and scenario testing (Smart *et al.* 2010; 2011). In addition, the advent of cloud computing provides new online platforms where multiple tools can be accessed and run with varying degrees of dynamic linkage between them. Two such possible platforms are the Environmental Virtual Observatory (EVO)42 and the My Environment portal soon to be rolled out for England.

**Table 8:** Key features of the principal sDST used for ecosystem service analysis. See Appendices 5 and 8 for supporting detail. Indication of the sophistication with which each tool can analyse trade-off and risk between competing requirements is based on the review in Appendix 8, summarised in section 5.3.5.

<table>
<thead>
<tr>
<th>Spatial Decision Support Tool (sDST)</th>
<th>Trade-off &amp; Risk analysis</th>
<th>Ecosystem services modelled</th>
<th>Scenarios</th>
<th>Inputs/user parameterisation</th>
<th>Scale of application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INVEST</strong>&lt;br&gt;<a href="http://ncp-dev.stanford.edu/~datatoolbox/invest">http://ncp-dev.stanford.edu/~datatoolbox/invest</a>&lt;br&gt;Good</td>
<td>biodiversity: habitat quality and rarity, carbon storage and sequestration, reservoir hydropower production, water purification, nutrient retention, sediment retention, water quality regulation, managed timber production, crop pollination</td>
<td>Developed externally with stakeholders and introduced as GIS layers or data tables</td>
<td>Models require parameterisation and in some cases modification for new regions. A global model is under developed but will operate at coarse resolution. At its simplest, input data are land cover maps (past, present, possible future) and a Digital Elevation Model plus other input parameters for valuation.</td>
<td>Can be applied at any scale dependent on data availability. Case studies available from Americas and Africa eg. policy and conservation planning in the Willamette basin, Oregon, USA</td>
<td></td>
</tr>
<tr>
<td><strong>ARIES</strong>&lt;br&gt;<a href="http://www.ariesonline.org/">http://www.ariesonline.org/</a></td>
<td>Good</td>
<td>carbon sequestration &amp; storage, open space proximity, aesthetic viewsheds, flood regulation, sediment regulation, water supply, coastal flood regulation, subsistence fisheries, recreation, nutrient regulation</td>
<td>Input as separate data layers. Some modules have built in scenario editing functions.</td>
<td>Application to new case studies or situations requires consultation with the ARIES development team to discuss the fit to existing models; largely Bayesian networks. Partnership opportunities and training are available for new development.</td>
<td>Can be applied at any scale dependent on data availability. Case studies available from tropics and temperate landscapes.</td>
</tr>
<tr>
<td><strong>ECOMETRIX</strong>&lt;br&gt;<a href="http://www.parametrix.com/cap/nat/EcometrixEcosystemSOQ_11.pdf">http://www.parametrix.com/cap/nat/EcometrixEcosystemSOQ_11.pdf</a></td>
<td>Basic</td>
<td>water provisioning, water regulation, climate regulation, a range of cultural services</td>
<td>Data sets are created for a baseline condition and anticipated future condition. Ecosystem function scores are calculated using these as inputs.</td>
<td>Major new applications are directed in collaboration with the developers. Base data are collected and entered by the user, stratified by pre-set land-use types. Service provision is calculated from these according to in-built algorithms. An early web-based prototype is available.</td>
<td>Limited information available. Most examples are run for commercial clients. An example in development involves EcoMetrix as a base with addition of a Bayesian spatial DST for Spatial Marine Planning (with US BOEMRE), but no further information is available.</td>
</tr>
<tr>
<td>Application</td>
<td>Type</td>
<td>Description</td>
<td>Applications</td>
<td>Notes</td>
<td></td>
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<td>-------------</td>
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</tr>
<tr>
<td>LUCI/Polyscape (no website available)</td>
<td>Basic but undergoing development</td>
<td>Agriculture, water regulation, erosion and sediment control, carbon sequestration, habitat connectivity, N and P water quality (under development). Scenarios can be constructed by modifying input parameters and/or input land use data. Users can modify base data, parameters and define questions of interest using GIS toolboxes.</td>
<td>Has been applied at farm-scale up to landscape/catchment scales (up to approximately 10,000 km² and with the capability to handle larger areas). Case studies have been applied within Wales, New Zealand, Ghana, Greece and England (the Bassenthwaite catchment and the Loweswater catchment).</td>
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<tr>
<td>SIAT <a href="http://www.sensortijp.org/">http://www.sensortijp.org/</a></td>
<td>Good</td>
<td>Around 60 environmental, social and economic indicators were modelled, aggregated to nine higher level Land Use Functions. Scenarios were pre-defined, and indicator model outputs calculated for all combinations of scenarios. Entirely new scenarios would be very costly to construct and parameterise. The policy user could alter a range of settings, e.g. subsidy level for biofuel within a series of set menus. No other changes were possible.</td>
<td>Applicable at EU scale, down to regional (European NUTS2 regions). Policy cases looked at CAP reform, subsidy of biofuels, and strengthening Biodiversity protection.</td>
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<tr>
<td>NatureServe Vista <a href="http://www.natureserve.org/index.jsp">http://www.natureserve.org/index.jsp</a></td>
<td>Basic/Good</td>
<td>The primary role is mapping of conservation, land-use and other information layers, with the aim of exploring synergies and conflicts. It does not aim to model ecosystem services. However it can calculate marginal values for land parcels based on how unique the parcel's biodiversity, how threatened it is, and the cost to conserve it. These can be ranked and evaluated against Can be imported as GIS layers. Each case study is a unique application of a question/problem. It is an iterative process, building data and information layers with technical support. Internal weights, e.g. rarity weighting for a conservation element, NatureServe Vista is freely downloadable. Technical support is available at a cost. Applications in the USA include sustainable forest management in Potlatch, Arkansas and sustainable agriculture assessment in the</td>
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<tr>
<td>Napa Valley, California. A case study on conservation and land management is ongoing in Peru.</td>
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</table>
The main findings from the review are as follows:

- Most tools can in principle operate at any scale, but some are more suited to particular scales due to their data requirements and algorithms/models.
- For all tools, the biggest limitations to their use are data availability. In essence no matter how good the modelling algorithm, attempts to substitute fine resolution data for model estimates will incur uncertainties that need careful communication. This is especially so when modelling at small scales were expectations can be readily matched with observations.
- A secondary limitation is the algorithms/models required for new features e.g. mapping ecosystem services. This is an area of rapid scientific development.
- There are few or no applications of large complex tools in the UK context, with the exception of current/imminent pilots involving LUCI/Polyscape and InVEST (Table 8).
- Tools vary in their complexity and user-friendliness. Increased functionality usually comes with increased complexity and the associated overheads of technical time and expertise required to run those tools.
- Different user groups have different sets of requirements from tools.
- No single tool or toolkit seems likely to satisfy all possible requirements in terms of scale of application, data demands, simplicity of use, trade-off analysis and ecosystem services assessment.
- Of the tools designed to support ecosystem service analysis only InVEST explicitly includes a biodiversity model, based on habitat rarity and quality, linked to distance from potential threats (infrastructure, inappropriate land-uses, etc.). LUCI/Polyscape includes biodiversity indirectly via habitat connectivity but researchers could build in further capability in collaboration with the LUCI/Polyscape team.

Based on these findings a number of suggestions for further development are set out.

- An important next step is to scope the feasibility of implementing a range of tools within the hierarchy of functionality set out in the next section.
- Use existing expertise and systems already in use, such as Planning Screening Tools, as a foundation ensuring development is oriented toward real practical problems faced by end-users.
- Trial a selection of more complex tools in the same case-study area to identify issues such as knowledge and data demands versus acceptable accuracy at operational scales, associated with implementing these tools. A similar approach applied in the USA is shown in the full review report (Appendix 5), comparing ARIES, InVEST and other ecosystem service tools.

A simple hierarchical framework for sDST development is presented below. This could comprise a diverse range of tools, providing functionality within one level, or one or two tools with the flexibility to operate at different levels.

**Level 1:** A comprehensive repository for data and spatial layers. The simplest approach would be a one-stop shop for data and information layers. Simple routines could allow users to specify or
explore rules for trade-offs between data layers and their outcomes. Predicted future land-use/climate impacts under different scenarios may be incorporated by addition of fixed data-layers, but there would be limited flexibility to explore these without algorithms to derive new data layers based on manipulating data from a variety of sources. It may be possible to add valuation functionality by linking to databases for value transfer. In principle it may be possible for users to add their own data layers, but the majority of technical users would be more likely to extract data-layers for use in their own software systems.

Level 2: sDST to undertake ecosystem service analysis and land-use optimisation. A more functional approach would build on level 1 to add models or algorithms to quantify ecosystem services and other parameters of interest based on a wider array of input data. Options include novel application of existing tools such as InVEST, ARIES or LUCI/Polyscape, parameterised for the UK or for a region of interest. The advantage is that these tools are specifically designed for spatial ecosystem service analysis and optimisation. Using these tools would require specialist expertise to parameterise and set them up, and be responsible for upgrades. The most useful system would be one that retained a modular structure so that additional datasets and functionality could be continually incorporated (e.g. mapping of new ecosystem services, improvement of existing models, additional layers based on habitat connectivity analyses, other static layers for GHG emissions, ecological water quality, diffuse pollution with and without mitigation measures). Many of these layers might well originate from models and analysis run externally (e.g. Catchpole 2006, 2007).

To achieve greater uptake among a greater range of end users, a parsimonious approach would be to augment existing platforms already well known to users. The approach here would be to survey the usage of existing tools across scales and sectors and assemble the best of the functionality and outputs into a toolbox of ‘add-ins’ that can be simply installed on existing systems. This is an attractive option since it likely to be less costly, avoid duplication of effort and impose far fewer overheads in terms of training and migrating datasets from one platform to another. This approach is likely to involve greater technical challenges in software development, installation and maintenance but these are not likely to be insurmountable. This option would also still require a high level of input from ecologists and planners to maximise data quality and quantity, local realism in the operation of the toolkit and the inclusion of the best scientific understanding in the methods adopted.

Level 3: Dynamic modelling and projections of future impacts. Most comprehensive, here the aim would be to build further on level 2 by including more sophisticated dynamic modelling to explore future states, impacts of climate change (incorporating changing processes, socio-economic drivers as well as future climate as static input), and changing land use under other policy scenarios. At level 3, the ability to dynamically model multiple impacts would be included within the tool unlike level 2 where only the static output layers are incorporated. The technical challenges are greatest at this level. Dynamically linking complex models requires considerable expertise while the demand for realistic ranges of parameter values as well as sensitivity and uncertainty analyses will be significant. Hence, progressing level 3 will need to be based on clearly identifying users’ needs and then matching these to developments that are most likely to achieve robust analytical outputs with the least uncertainty at the scale of interest.
Particular models and tools will be harder to integrate into level 2 and 3 architecture than others. For example where existing tools carry accreditation that offers the possibility of a market edge, then multiple ecosystem service modelling platforms will need to be compatible with these existing tools or seek to acquire accreditation themselves. The most efficient route may be to include the outputs from these tools as analytical metamodels that for example quantify the correlative relationships between say GHG emissions and various mitigation options but without the dynamic complexity included in the stand-alone tool. Metamodels for other ecosystem services such as biodiversity, flood protection and recreation could be included and jointly analysed. The metamodel approach may be a disadvantage in situations where sensitivity to local conditions and realistic dynamic behaviours are sacrificed in favour of increased generality, low data requirements and ease of use. The least desirable outcome would be a complex sDST that still fails to robustly forecast the dynamic interactions between parts of the social-ecological system under various scenarios and management interventions. The vital issue here is in tailoring the tool to the users’ needs, their sectoral and policy priorities, their scale of interest and their capabilities in terms of time and technical skill.

Some sector-specific tools such as FARMSCOPER and Carbon footprinting methods, aim to achieve high local realism by incorporating detailed data for each specific farm holding. This offers the prospect of feeding high quality, high resolution data into a larger scale analysis but just for these specific locations embedded within a larger regional domain most of which would be modelled based on more widely available lower resolution input data. For the small number of data rich areas, the outputs of the more general level 2 tool could be compared with the optimally modelled outputs from the sector-specific tool. Case study applications of this sort would allow quantification of any increase in uncertainty, bias and loss of local predictive accuracy resulting from analysis using more generalised, less sophisticated and less parameter-hungry tools. The aim here would be to provide robust guidance on the consequences of using simpler and more generalised versus more complex and locally sensitive tools.

5.3.5 Review of risk-assessment and trade-off methods

Risk and trade-off analysis is a fundamental requirement for ecosystem service analysis where gains in one service may fundamentally reduce supply of another, for example soil Carbon storage versus drainage, cultivation and food production on lowland peats. Searching for optimal management strategies that simultaneously maximise a range of services has a strong spatial component. Hence trade-off techniques need to be embedded within a GIS framework where they can be applied at differing scales (Eigenbrod et al. 2010; Anderson et al. 2009). Formal methods exist for managing risk and trade-off in information sciences. These jointly analyse the benefits and disbenefits of opting either for one attribute or another versus combining both attributes. Trade-off functions weight the direction and magnitude of the co-dependence between the attributes of interest. Within an sDST these trade-off methods will be applied to combined spatial data layers where the sophistication and choice of methods and weights, reflecting knowledge and uncertainty, will affect the result.

43 For example the PAS2050 accreditation given to some Carbon footprinting calculators (Little & Smith 2010).
44 A metamodel is a simplified description of a more complex model. For example the relationships between variables in a dynamic model could be captured by a static regression model that is easier to run and less data hungry but will lack the flexibility and sensitivity of the more complex model whose essential behaviour it describes.
This review considered the following methodological and conceptual issues:

1. How are trade-offs analysed from a GIS perspective (section 2)
2. What practical considerations are there from the point of view of data needs associated with the different methods (section 3)
3. Critically review existing sDST for ecosystem service analysis against those methods (section 4).

The aim of structuring the review in this way was to shed some theoretical light on the capabilities and capacities of sDSTs and the way that they accommodate risk and trade-off. The review considered a suite of approaches for combining spatial data that demonstrate an increasing complexity of methods from the perspective of risk and trade-off in decision making. The review then ranked the risk and trade-off capabilities of the sDST considered in Appendix 5 and section 5.3.4. The results are summarised in Table 8.

Summary of findings

The key findings to emerge from this review were:

1) The over simplicity of standard Boolean Multi Criteria Evaluation (MCE) approaches. These approaches classify boundary or threshold exceedance into either a 0 or 1. Such an approach takes no account of the changing risk involved in moving gradually nearer to a boundary or threshold, or the difficulty of moving back across it given the resistance and non-linearities inherent in social-ecological systems.

2) The importance of defining layer or factor weights. Essentially, this is where prior knowledge is introduced to progressively add realism and accuracy into evaluation rules. An example would be where the best scientific knowledge is used to continually update ecological criteria applied in a Planning Screening Tool (PST) about the potential risks to nearby habitats and species. A coarse rule for Great Crested Newt might just indicate that there was or was not potential habitat within 100m. This is a binary rule with high uncertainty. A better rule would combine ecological knowledge and local information to estimate whether a nearby pond was highly favourable habitat and also very likely to contain a population. This rule could be based on output from a species model.\(^{45}\) Such methods could also incorporate the risks associated with non-linear and step changes. Despite the scientific popularity and likely importance of such phenomena, the data and knowledge required to predict such dynamics will be limited in many cases.

3) Order Weighted Averaging (OWA) is a useful method for managing tradeoffs in a transparent way where the degree of tradeoff and risk are specified in advance of the analysis, especially in the context of stakeholder or public consultation. This approach is therefore well aligned with the preference expressed among some potential users for an ability to define their own thresholds and weightings when analysing trade-offs (see Table 3).

4) Analytical Hierarchy Processing (AHP) is a useful method for managing tradeoffs in the context where domain experts may understand the problem but not the informatics/sDST context.

5) None of the tools covered in the sDST review deal formally with risk and trade-off though many claim to and most could do but require further development.

6) Few GIS systems have the built-in modules required to deal with risk and trade-off while many users currently employ different tools at differing scales suited to their own sectoral and policy interests.

7) This suggests that rather than develop a new sDST tool to work at all scales, for all ecosystem services and for all users, a better approach would be to develop bespoke, universally compatible ‘add-ins’ using environments such as IDRISI\(^{46}\) or QGis freeware\(^{47}\). These universally-compatible analytical GIS components could then be downloaded and utilised within existing systems.

6. Synthesis of user group needs assessment and reviews

There appear to be few technical obstacles to creating sDST that could provide novel analyses to underpin integrated, ecosystem-based, multi-functional land use planning at multiple scales in England. The main constraints are data availability and matching tool developments to users’ current and longer term needs. The principal requirements are as follows;

1. **Increasing data and knowledge availability.** Making progress in modelling changes in ecosystem services and biodiversity is strongly limited by scientific understanding of social-ecological system dynamics and by fundamental data that measure key properties, including model parameters and indicators of ecosystem service supply and demand. New datasets are increasingly required that measure potential ecosystem service supply yet there are also severe demands simply for more finely resolved and up-to-date biodiversity information\(^{48}\). These constraints lessen with the increasing acceptability of results at coarser scales with less focus on local accuracy. Unfortunately many end-users face decision-making at fine spatial resolutions in specific areas and call for more, better quality data at these resolutions.

2. **Clearly matching tools to user needs.** Many tools already exist or are under development yet many users have problems that could be tackled by better use of sDST. Future development should take care to avoid developing tools that are solutions to non-existent problems but instead focus on the real challenges confronted by decision-makers. This involves not re-

\(^{46}\) [http://clarklabs.org/products/](http://clarklabs.org/products/)

\(^{47}\) [http://www.qgis.org/](http://www.qgis.org/)

\(^{48}\) For example, Cumbria County Council would like spatial information that translated the presence of peatland into a new ecosystem service map that estimated the likely contribution of each area to flood prevention. However, the main priority would simply be for an updated map of peatland Priority Habitat (J.Palmer pers comm.).
inventing wheels and where possible, integrating new analytical outputs with existing local tools rather than expecting end users to universally adopt new platforms and software.

3. **Disseminating the results of complex multi-scale analyses.** Users require simple, cheap, tools that are easy to use but also recognise that emerging policy requirements and the emphasis on an integrated, cross-sector planning paradigm will require more complex spatial analyses. Future developments should therefore facilitate end users in their need for the outputs of new policy-relevant analyses but without foisting on them the technical burden of performing the analyses themselves.

4. **Adding to existing functionality.** Where there is an appetite for users to engage in their own analytical work, this is more likely to be facilitated by providing the technical means for new analyses to those who need them without requiring a major shift to different software systems. Bespoke, universally-compatible, problem-specific and free GIS ‘add-ins’ may be a way forward.

5. **Progressing complex ecosystem services analysis and impacts modelling.** The more technically and scientifically challenging work still needs to be done. Those with the technical expertise should continue to develop and apply tools that analyse cross-sector and cross-scale relationships and trade-offs so that vertical tensions (for example between local planning and conservation objectives and larger scale constraints and opportunities), and horizontal tensions (for example between different sectors such as agriculture, nature conservation, housing and flood defence), can be quantified and options determined for resolving them. Resolving these tensions is at the heart of a hierarchic ecosystem approach to planning (Vasishth 2008). Particular issues to be tackled include drawing explicitly on local knowledge and interdisciplinary working between social scientists and ecologists (Pagella 2011).

7. **Suggestions targeting six main areas for development under a possible Phase 2**

Draft options are set out for further sDST scoping and development based on the results from the users’ needs assessment, the policy context and the series of mini-reviews plus consideration of the needs of the Localism agenda. These sources of evidence provide a comprehensive and robust sense of users’ needs and current capacity and have been synthesised to produce the following suggestions for further development under six headings;

1. Work on improving sDST.
2. Work on improving and providing scenarios for impact assessment.
3. Work to improve data sources and accessibility.
4. Further engagement with user groups.
5. Address user needs to assist Localism.
6. Develop the organisational context within which 1 to 5 can be efficiently delivered to address users’ needs and to advance implementation of an ecosystem approach to integrated cross-sectoral spatial planning.
**Decision Support Tools**

**Suggestion 1.1: Develop existing capability where possible.**

Improve or combine the functionality of the best tools already being used at the scales relevant for decision-making for current biodiversity and land-use planning, for localism and for future policy needs.

An essential aspect of a Phase 2 project would be to locate and establish the applicability of the wide variety of sDST already being used. This would a) reduce the need to gather new data, b) avoid duplication of effort, c) reduce costs. The scope of such an exercise would need to be clearly defined so as to remain manageable. For example focussing on a particular set of catchments or NIA in a Phase 2 pilot would constrain the geographic domain, range of land-use and ecosystem services and the number of participants and stakeholder organisations involved.

**Suggestion 1.2: Support the development and wider use of Planning Screening Tools (PST) as an entry-level option.**

These are already being developed and trialled in a number of counties. Because they are explicitly targeted at helping to solve local biodiversity and planning issues they provide an effective point of entry into the task of facilitating local decision-making faced with new policy initiatives and future environmental change. These provide the first level of functionality of decision tools which could be provided within a national tool, as well as, or in addition to local and more specific tailored examples which are being developed currently around the UK. Given that planning decision-making is so widespread, increasing the effectiveness of PST in the planning process could be an efficient way of helping achieve the primary objectives in Biodiversity 2020 of site and species safeguard and no loss of Priority Habitats.

Two key developments seem desirable, a) Increasing the extent to which PST implement ecological rules for planning screening, b) Ensuring that the map-based results from technically challenging but policy relevant analyses listed in Option 6.2, can be readily loaded, viewed and analysed within the developing PST. Our review suggests that add-ins for existing widely used GIS platforms such as MapInfo, could be written in IDRISI or freeware such as QGis. Functionality such as the FME transformer suite can be used to ensure many types of output are GIS compatible while simple dissemination and viewing of spatial layers for non-GIS users can be readily achieved using geospatial PDF files.

It would be essential to involve those developers and staff that are already in the process of designing and implementing local PST/sDST capability (see for example [http://www.archnature.eu/activity2.html](http://www.archnature.eu/activity2.html)). Building on existing local capability is resource efficient,

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49 Over 60% of questionnaire respondents used some form of sDST at least once a week (Appendix 3, Fig 5).

50 For example in an unpublished report from the Norfolk Biodiversity Information Service written in Aug 2010, of 27 Local Record Centres contacted, 10 were using or trialling automated Planning Screening Tools.

51 England Biodiversity Strategy. Pg 12, Outcomes 1a, 1b.

52 The Feature Manipulation Engine (FME) allows easy translation of datasets between formats and coordinate systems fostering sharing and joint analysis of disparate datasets on a common platform of choice. See [http://www.gis.unbc.ca/help/software/fme/FunctionsFactories.pdf](http://www.gis.unbc.ca/help/software/fme/FunctionsFactories.pdf)
ensures that solutions will be aimed at real problems and maximises the speed from development to deployment.

**Suggestion 1.3:** The evidence from the user needs questionnaire survey (pgs 9, 10 & 11) suggests that users are interested in the following functionality from sDSTs (in decreasing order of importance):

1. Handling and expressing uncertainty in tool outputs and inputs.
2. Ensure that tools are quick, cheap and simple to use.
3. The ability to provide maps as output or otherwise allow easy visualisation of results.
4. Present information at a range of scales but with a clear focus on fine resolution applications if supported by adequate data. For example 80% of respondents needed to make decisions at the habitat patch scale (<1 hectare).
5. The facility for users to add their own data/knowledge to the analytical process.
6. That tools output results in a number of formats for use in other software.

**Suggestion 1.4:** Develop sDST functionality for policy-relevant yet technically complex novel analyses.

There are other elements of functionality which should also be supported. These were identified as highly important in the questionnaire survey, but by specific user groups: primarily national government, statutory bodies and industry/agriculture. They are likely to be growth areas even at the local level but because the policy drivers (NEWP, Biodiversity 2020) are recent, the response in terms of action on the ground has yet to build maximum momentum. Potential users recognised that these additional issues would be a growth area for sDST in the future. The additional functionality elements are:

- That the tool allows evaluation of trade-offs between information layers or competing decision solutions. One set of users (policy makers) preferred to make the final decision themselves, while industry users preferred the tool to suggest the optimal solution.
- The flexibility to allow user-defined rules for combining information and evaluating trade-offs
- The ability to explore scenarios of future impacts of drivers such as land-use and climate change
- Spatial connectivity and network analyses

**Suggestion 1.5:** Ecosystem-service modelling tools such as InVEST, ARIES or LUCI/Polyscape should be developed for application and testing at the England-wide scale with the objective of providing analyses and outputs that provide new policy-relevant context for local needs.

In parallel with 1.2, research and development should be carried out to explore the applicability of existing tools in producing large-scale analyses that are aligned to policy objectives for resilient habitat networks, the ecosystem approach and socially and ecologically optimal land-use options. Key developments would focus on parameterising these tools for application at larger regional or England-wide scale to allow a full range of spatial analyses as listed under Option 6.2. This would involve further development of ecosystem service modelling and mapping. Tool development work would also focus on means of efficiently incorporating high quality biodiversity datasets from LRC and other local data providers. Developments envisaged here and for Option 1.5 would ideally progress a common platform and common tools. In reality this may mean developing a common set
of add-ins that can be used within different applications, MapINFO and LUCI/Polyscape, or at the very least, ensuring dataset compatibility. The need for these parallel agendas reflects the tension between policy demands for more complex landscape-scale analyses and the growing requirement for the outputs by end users versus the lack of time, data and in-house technical skills to execute the analyses. The wider implications of this are discussed in 6.1 to 6.3.

**Suggestion 1.6:** Tool development should focus on web-mounted applications to ensure the widest use by end users. For example the developing potential of the Environmental Virtual Observatory or the My Environment portal may provide a future platform for issuing requests to, and linking the outputs from, more complex sDST to PST or GIS platforms used by locally based end-users ([http://www.evo-uk.org/evo-cloud-services-portals/local-community-tools](http://www.evo-uk.org/evo-cloud-services-portals/local-community-tools)).

**Scenarios**

**Suggestion 2.1:** Improve access to and understanding of scenarios.

Users recognised that the twin pressures of land-use and climate change are likely to increasingly affect their decision-making (Appendix 3, pg 15). There is a clear requirement for easier access to scenarios and to simplify their use and interpretation (Appendix 3, pg 11). Sectors of particular interest to users are water resource management & flooding, biodiversity & conservation, agriculture, woodland & forestry, recreation.

**Suggestion 2.2:** sDST development should include translation of non-spatial scenarios into plausible local impacts of future change on biodiversity, land-use and ecosystem services.

Most scenarios are non-spatial. Even UKCP09 is essentially a series of spatially explicit modelled impacts driven by non-spatial emissions scenarios. Hence there is a pressing need for better ways of translating non-spatial storylines of plausible environmental change across England into plausible local impacts. Biodiversity models as components of new sDST capability have a clear role to play. These could be inputs to or outputs of sDST. The RegIS and RegIS2 models are examples of attempts at regional impacts modelling where metamodelling was used to reduce parameter richness and data demands whilst maintaining acceptable local realism in its outputs53.

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**Suggestion 2.3:** Use of visualisation tools to help local communities discuss and imagine local impacts of demographic, land use or climate change should be considered.

The novelty is using them in such a way that such participatory sessions can generate possible impacts that are captured and returned to systems such as InVEST, ARIES and LUCI/Polyscape as new datasets of variables that then set new boundary conditions for carrying out a new habitat connectivity or ecosystem service trade-off and land-use optimisation analysis.

**Suggestion 2.4:** Focus on impacts modelling on the effect of extreme weather events.

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At smaller scales, it may well be the rare but increasingly probable extreme weather events that stimulate changes in local planning and ecosystem management. People are more likely to be affected by drought or flood than annual rise in mean temperature *per se*. Therefore visualisation and estimation of climate change impacts might beneficially focus on prediction of weather extremes and on their impacts. The two are separate. Extremes may be hard to predict but increasingly likely while the severity of their impact is high. So even if extremes cannot be usefully forecast then it may still be worth envisioning their impact given their increasing likelihood in the future. Modelling and visualisation tools have a clear role to play here (see 3.3).

**Datasets**

**Suggestion 3.1:** *Within sDST, develop functionality for estimating the impact on decision-making of using input data at different scales.*

User needs were clear regarding the kinds of data needed, barriers to using datasets and the desire for more finely resolved data. Thus Phase 2 development should explicitly include testing of the impact on decision making and ecological analyses of using coarse to more finely resolved input data. Developments could for example include an alert system that warns the user that the resolution of the data is potentially too coarse to firmly implement an ecological rule in a PST. An example might be where a species record is resolved at only the 10km square level and so applying a rule that a development should not be within X metres or that neighbouring favourable habitat needs to be within Y metres to maximise ecological connectivity cannot be achieved using the input data. At this point the facility for updating the system with newly gathered data could be flagged.

**Suggestion 3.2:** *Develop guidance on application and interpretation of modelled data at different scales.*

Where modelled data layers are either input or output then the communication of uncertainty requires careful handling especially if tools are applied at the optimum scales for users (<1 ha or <1km square, Appendix 3, Fig 6). At these scales incorrect model predictions will be more obvious. This emphasises managing expectations from modelled data.

**Suggestion 3.3:** *Prioritise increasing the quality and quantity of ecosystem service datasets for particular services.*

When asked about their requirements for ecosystem service data, users were principally interested in species and habitat related services (over 75% of users classed these as important, Appendix 3, Fig 13). However over 50% also indicated that freshwater provision, flood and climate regulation, recreation, tourism and cultural values were important. Future work should focus on increasing the quality and quantity of data on these services via either modelling or observation as important inputs to sDST.

**Suggestion 3.4:** *Support a web-based, one-stop-shop for access to key datasets or access to points of contact for key datasets.*
A clear message from the User Group Workshop and the questionnaire survey was that a single clearing house for datasets is desirable. Since many useful repositories and web-bases exist a key step forward would be to maintain one single database of databases and web links.

**Suggestion 3.5:** Develop a common standard measure of data quality to enable quicker and easier assessment of available datasets.

For example, consider extending the IPCC Tiered classification of evidence and data to a wider range of models and analyses.

**Suggestion 3.6:** Scope wider roll out of on-line tools to increase the currency and resolution of habitat and species data uploaded from front-line users.

This could employ functionality such as that recently piloted by Natural England (see Figs 6 and 7). The incentive for this would be better, more accurate planning screening as well as more robust wider spatial analyses such as network opportunity mapping and ecosystem service analysis.

**Further engagement with potential user groups**

**Suggestion 4.1:** Further engage with the farming sector and other user groups at the start of Phase 2.

Although the e-questionnaire was circulated to the farming community via contacts in three relevant organisations (Table 2), very few responses were received. This could either be interpreted as lack of interest in sDST or that we were not successful in reaching a larger number of farmers who did have an interest. The Integrated Advice Pilot project (ADAS 2012) also reported considerable difficulty in engaging the farming community. Their work on uptake of the FARMSCOPER tool suggested that farm advisers rather than farmers were more likely to use the tool. They would then disseminate and interpret the results to their clients. Since many farmers in the Integrated Advice pilot sought and paid for advice based on established and trusted relationships, engaging farm advisors may be a more effective point of entry than targeting farmers directly. Because of the importance of agricultural land use in England and the significance of agri-environment scheme implementation as a delivery mechanism for biodiversity objectives, it is suggested that Phase 2 includes further efforts to engage with this potential user group.

**Suggestion 4.2:** Further assess the needs of Local Nature Partnerships (LNP)/Local Enterprise Partnerships (LEP) once they have bedded in i.e. early in Phase 2.

Collaboration between the new LNP and LEP appears to be a central plank of the Biodiversity 2020 vision for growing a green economy. Therefore LEP and LNP may constitute an important new user group that could benefit hugely from sDST to help reconcile multiple objectives for development.

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54 Natural England is currently involved in piloting an approach to help LEP build an environmental dimension into their local economic development visions. Linkage of those project outcomes to a possible Phase 2 would seem desirable (Nick Dales pers comm.)
land and space for nature. Therefore consultation should be undertaken as a first part of any Phase 2 since by that time these partnerships should have bedded in.

**Suggestion 4.3: Engagement with other government departments for Communities and Local Government**

Bringing the Department for Communities and Local Government on board in any further scoping and development would seem essential to effectively cover Localism issues and as a potential further funding source. Similarly phase 2 should seek to foster links with the Department of Business, Innovation & Skills and the Department of Energy & Climate Change.

**Localism**

**Suggestion 5.1: The review of needs for Localism highlighted a number of key elements which any sDST would require to help usefully inform the localism agenda.**

Some of these issues and desirable attributes also feature in the suggestions previously listed. Key features of a tool to work at the local scale would also include the attributes of sDST listed in 1.3 as well as the following:

1. **Provide a simple one-stop location** for access to local environmental information.

2. **Be underpinned with relevant data at a local level** or have the provision for local information to be input if existing information is out of date or inaccurate.

3. **Present information about relevant national or regional priorities** in order to contextualise the local information.

4. **Present future scenarios in an accessible way so they may be widely understood.** This information will provide an important mechanism to help local communities understand the sorts of changes which may be required to adapt to the future.

5. **Provide sophisticated capability** to examine trade-offs and synergies between the provision of different ecosystem services, biodiversity and other considerations is desirable. This will require use by experts but may be used to facilitate greater engagement of local people in decision making through the use of workshops. This desirable feature conflicts with the need for simple, quick and easy to use tools. This fundamental tension is a key reason for tabling the hub and spoke model discussed in option 6.2.

6. **Avoid a rural/urban divide.** Most people live in large urban centres where green space is at a premium yet many of those who consume recreational ecosystem services in the countryside travel there from urban centres. Approaches to Localism should therefore recognise urban issues of green space planning and that those who express strong values for rural landscapes and contribute to the buoyancy of the rural green economy, live in towns and cities.

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55 Natural England are running a number of pilot schemes with LEP involving the inclusion of better environmental information within local development planning (Gary Kass pers comm.)
Developing the organisational context within which new sDST could work to deliver biodiversity policy in England

**Suggestion 6.1: Include Local Record Centres and the county recorder network in Phase 2.**

Local Record Centres (LRC) and the county recorder network are likely to be central to the development of Phase 2. They are an essential part of local mechanisms for delivering biodiversity information needed to facilitate multi-functional land-use planning and an ecosystem approach. LRC have also played a major role in developing PST because a) they best understand local needs for biodiversity data in response to enquiries from planners and other sectors and b) receive, validate, manage and disseminate the most up-to-date biodiversity data for their county. LRC also provide linkage through to the capabilities and needs of other providers and users of data including scholarly amateur societies, Bioblitzes and recording activities run on nature reserves.

**Suggestion 6.2: Allocate sDST development efforts in ways that link the best science and policy-relevant landscape-scale analyses with the increasing needs of front-line users.**

Our analysis of user needs showed that there is a tension between the demands of new policy for technically challenging analyses of land-use options, ecosystems and biodiversity and the ability of end users to carry out these analyses. While there is a growing demand for these more complex outputs of sDST, front-line users often do not have the time or technical capacity to meet the analytical challenge even though they are capable of interpreting and applying the outputs and see a growing need for them in their decision-making. Therefore a hub and spoke model should be explored that would deliver technically challenging but policy and problem-relevant analyses to end-users. A two-way information flow is envisaged where high quality biodiversity data flows from the LRC to the competent analytical hub and where easily interpretable maps and other outputs are disseminated to end-users, such as county ecologists, district planners, wildlife trusts and LNP/LEP consortia.

Pilot schemes for developing capability in Phase 2 should recognise that LRC currently provide data and in some cases, simple yet highly relevant PST outputs to District Councils and County Councils on a reactive basis as planners submit applications for development. However, new policy initiatives such as Localism and the Neighbourhood Development Planning (NDP) process, NIA (Nature Improvement Area) and LNP conservation plans are likely to pose greater needs for strategic, more complex analyses over larger areas but still dependent on high quality finely-resolved data. These more complex analyses will include some of the following:

1. requirements for ecosystem service trade-off analyses and risk assessment,
2. habitat network planning and connectivity analyses,
3. optimisation of land-use planning,
4. translation of non-spatial scenarios of future environmental change into model-based forecasts and visualisations of local impacts on biodiversity and land-use
We suggest exploring options whereby these policy-relevant but technically challenging analyses are carried out by a competent technical centre as part of a strategic focussed work program to deliver the kinds of analyses listed above at regional and national scales. The size of the domain analysed would cover the whole of England providing maximum scope for exploring spatial trade-offs and distributing optimal configurations of land-use to places across as large an administrative and ecological area as possible. This larger perspective would provide the context in which finely resolved local analyses and decision-making were embedded (Wong et al. 2012). Simple maps and other outputs would then be disseminated to end-users via LRC, NIA partnerships, Wildlife Trusts and any other interested parties. However for the larger scale analyses to achieve maximum accuracy and realism the hub would need to be ‘fed’ by the most up-to-date, finely resolved biodiversity information. Hence a two-way information flow would need to be put in place between the analytical hub and county LRC. LRC would then feed data to the hub and the hub would feed analytical results to the spokes to be considered alongside other local datasets relevant to the particular question at hand.

A technically competent central hub would have many advantages:

1. They could deal centrally with licensing and confidentiality issues surrounding use of essential datasets so that for example the end-user would see an analytical output that involved overlay and manipulation of IACS or June census data but where the user was not privy to, and could not extract, the confidential aspects of the input data. Having a central hub resolve and manage the licensing issues and data masking technicalities would be more efficient than each end-user attempting to do so.

2. They could focus on the science-side of the problem, assembling, synthesising and disseminating best practice from the literature and emerging experiences and outputs from the latest research and NIA activities. This could be achieved via a periodic policy & practice meeting or/and via webinars and web-posts. A clear objective for this work would be to synthesise the scientific evidence both published and based on local knowledge, to produce agreed ecological rules and weightings for PST and trade-off/risk assessment analyses (see Review of Risk Assessment & Trade-Off Tools). These priorities would be defined on a habitat and species basis according to local needs.

3. The technical capability and applied research focus of a central hub would enable trialling and implementation of state-of-the-art ensemble approaches to risk-assessment and trade-off analyses as well as models used to estimate local impacts of scenario-driven pressures on biodiversity and ecosystem services. Thus end-users would have confidence that the technical outputs, while simple to interpret and map-based, would have been generated using the best possible treatment of uncertainty and available knowledge.

Suggestion 6.3: Devise and fund a pilot hub-and-spoke project.

Scoping a hub and spoke model for joint working raises many practical issues and the possibility of substantial costs. In order to tackle these issues a step at a time we suggest the option of funding a pilot, consisting of a focussed research program of central sDST development and analysis based on a single analytical hub, whose consortium composition and location would be open to tender, in equal partnership with one or two Local Record Centres who in turn have an existing role in servicing Local Authority needs, which would include the provision of data and advice to those preparing
NDPs under Localism, as well as the likely information requirements of one or two NIA. Such a partnership is likely to include bodies such as Natural England, Environment Agency and the Forestry Commission all of whom have experience and competence in generating and applying the requisite science and technology to their relevant statutory duties.

A new hub and spoke model is likely to require a new organisational structure and research specification. A major part of this will be supporting the development of PST/sDST at local levels as well as applying and developing tools for larger scale analyses. While the costs of such a new partnership could be significant it is noted that the pressing need for greater trans-disciplinary working surrounding biodiversity and ecosystem service valuation and decision-making led to Rafaelli et al. (2009) 56 to moot the idea of a new national centre for inter-disciplinary biodiversity science. In light of the policy context under consideration here a better name would be a national centre for biodiversity and spatial planning.

A three-stage plan for further work

**Suggestion 7.1:** Develop a one-stop-shop database of databases for information and datasets to support application of existing and future sDST at larger and smaller spatial scales.

This could be as simple as a website that would act as a first port of call. The plethora of ever increasing data sources spread across disparate sites suggests that a single portal if maintained and comprehensive, might save users much time and frustration and reduce the chance of missing vital information.

**Suggestion 7.2:** Develop and apply methods for translating non-spatial scenarios of environmental change into narratives and visions of plausible local impacts on ecosystems and land-use.

This would involve a modelling component targeted at biodiversity and ecosystem services as well as participatory work that sought the input of local people into envisioning different aspects of future change that mattered to them.

**Suggestion 7.3:** Scope further options for collaborative delivery of new analyses to end users. This would include scoping the desirability of a pilot project to implement the hub-and-spoke model as well as other models for delivery.

56 “LWEC initiatives may provide opportunities for consolidation and cohesion ... but this is probably better achieved through a focused concerted action by NERC and its partners, such as the establishment of a national centre for inter-disciplinary biodiversity science. History shows that the major breakthroughs in issues which have an urgent strategic goal have come from bringing together, within a focussed and co-ordinated environment, researchers from across a range of disciplines who had not traditionally worked together (National Academy of Sciences 2004).”

Pg 86 In Valuation of Biodiversity – A NERC Scoping Study (Rafaelli et al 2009).

Depending on available resources, agree and develop an R&D specification for a pilot hub-and-spoke model. The aim would be to scope an applied science, policy and practice partnership that would develop SDST to support a two-way information flow between an analytical hub, comprising a consortium of technical specialists, ecologists and social scientists, and a local network of end-users and biodiversity data-providers. This model addresses;

1. The clear need for novel landscape-scale analyses to be aligned with a new cross-sectoral paradigm for integrated and ecosystem-based planning.
2. The increasing requirements of front-line users to apply these outputs in their decision-making; likely to include NIA, LNP and NDP.
3. The limitations on time and resources that prevent local users from executing these analyses themselves.
4. The potential for harnessing the functionality of tools already in use by different sectors.
5. The need to improve the quality and resolution of data used to drive the spatial modelling, planning screening and ecosystem services assessments.

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9. References


Defra (2007) *Public understanding of the concepts and language around ecosystem services and the natural environment*. Defra project code: NR0115 (J278742)


