JNCC Report 815

Review of Land Use Decision Support Tools

Summary Report

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This Report provides a summary of JNCC Report 815: *AReview of Land Use Decision Tools: An assessment of spatial prioritisation and optimisation tools for ecosystem services and benefits*.

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Evidence Quality Assurance:
This document is compliant with JNCC's Evidence Quality Assurance Policy.

Project background

Land use decision-making is a complex process that involves navigating multiple and often competing pressures. Striking a balance among demands such as food production, biodiversity and infrastructure development is essential for sustainable and responsible land use planning. A wide range of land use decision support tools have been developed, each with different processes, different focuses and using a range of analytical methods to prioritise potential management interventions.

Aims and objectives of the project

The aim of the project was to develop an understanding of the technical approaches used by existing land use decision making tools that spatially prioritise or optimise interventions to achieve multiple ecosystem services (ES) and environmental benefits. The key objectives for the project were to:

- Critically review and describe the analytical methods used by decision support tools to prioritise or optimise interventions to deliver environmental benefits.
- Describe the relative strengths and limitations of these tools to inform future analytical processes to spatially prioritise land management interventions.

Tools reviewed in this report:

- Artificial Intelligence for Environment and Sustainability (ARIES)
- ASSIST E-Planner
- Ciriabest
- EcoservR
- HydroloGIS
- Integrated Valuation of Ecosystem Services and Trade-Offs (InVEST)
- Land Utilisation Capability Indicator (LUCI)
- Land Use Choices Tool (LUCT)
- Systematic Conservation Planning (SCP) and Marxan
- Natural Environment Valuation Tool (NEVO)
- Nature Assessment Tool for Urban and Rural Environments (NATURE)
- Environmental Benefits for Nature (EBN)
- Restoration Opportunities Optimization Tool (ROOT)

Methods

Building on previous work by JNCC, this review investigates 13 tools that met identified criteria; where the tool:

1) explores ES/benefits relevant to land use decision making in the UK,
2) performs prioritisation/optimisation, and
3) includes three or more ES/benefits.

Evidence was gathered on these tools through examining user guidance documents, published literature and by direct engagement with tool developers where required. This review examines analytical methods used by the tools, strengths and limitations, and other criteria such as scale and usability. Tools were reviewed individually and comparatively.

Prioritisation and optimisation – context for this report

Within the report the terms ‘prioritisation’ and ‘optimisation’ are used, sometimes interchangeably. For optimisation, it is important to note that models are unlikely to be able to capture all variables and results are not necessarily a real-world ‘optimal’ outcome. Prioritisation tools rank outputs, some of which could be similar, giving multiple results, but with less surety regarding whether the first result is significantly better than the others. This can give more of a balanced view of the options due to the presentation of multiple possible outcomes rather than one ‘optimal’ solution.

Tool review

The review categorised the 13 tools in numerous ways to help identify their key features, these have been described below in more detail.

Modelling versus Scoring

The 13 tools fall into two broad categories of those that undertake ES modelling and those that use relative scoring of ES values, land use benefits and costs:

Modelling

These tools undertake complex ES provision modelling, allowing the quantification and spatial mapping of ES. Modelling allows for consideration of interrelationships between ES and can capture more dynamic aspects of ES compared to scoring. Reviewed tools: ARIES, EcoservR, InVEST, LUCI and NEVO.

Strengths:

- Models are able to predict change over time and how this may impact ES provision.
- Modelling tools can use socioeconomic data to simulate both supply of ES and also where the demand for ES is located.

Limitations:

- There are varying degrees of uncertainty within the models, limiting the reliability of outputs.
- Processing times can be long depending on the project, and some models require high computational power.

Scoring

These tools assign a rank, value or score depending on what land cover/habitat is present (or would be present if an intervention is carried out). The tools do not model ES service flows and deal with each area or ES within its own 'box'. Scores and values are generated in different ways according to the tool. Reviewed tools: Ciriabest, EBN, HydroloGIS, LUCT, NATURE, ROOT and Marxan.

Strengths:

- Tools require less computational power and are less resource intensive than modelling tools.
- Tools do not infer information from complex ecosystem variables, so outputs may offer more transparency and reliability.

Limitations:

- Clarity and accuracy of some of the 'scores' can be questionable, particularly if source information has not been published.

Methods of spatial prioritisation

The methods of spatial prioritisation or optimisation can be divided into three main categories: analytical methods, post-hoc analysis, and simple mapped presentation of priorities:

Analytical methods

The tools in this category conduct prioritisation within the tool methods themselves, focussing mainly on the prioritisation/optimisation of interventions, locations, and co-benefits. They offer the user clear suggestions or choices on land use change, supported by quantified recommendations.

Linear programme algorithms

This method finds the best solution for interventions which are defined and fixed in quantity, looking at linear relationships. Multiple objectives or 'targets' can be considered within the model in order to explore solutions. Tool reviewed: ROOT.

Strengths:

- The algorithm synthesises ES objectives spatially to identify priority areas within the landscape.
- Linear Programme algorithms can handle large scale datasets with complex and extensive constraints.

Limitations:

- Performance and reliability is limited by computational strength of the device/system being used.
- The algorithms assume that relationships between variables (ES) are linear, which is not the case in reality.

Simulated annealing algorithms

This method uses random perturbations to iteratively improve a solution for ES optimisation until the 'shortest path' is generated. This is where the best objectives/goals are optimised with the lowest amount of negative impacts on other benefits or objectives. Tool reviewed: Marxan.

Strengths:

- Suitable for complex systems and real-world scenarios (not restricted to linear relationships).
- The algorithm can find many near optimal solutions to complex problems in a relatively reasonable time.

Limitations:

- It can be difficult to incorporate constraints into the algorithm framework, particularly if they are complex.
- The 'set speed' of the algorithm can impact the outputs. If set too 'slow' it may not be able to find an optimal outcome.

Cost-benefit analysis

This method generates a mathematical 'best' use for land, calculating the financial costs of implementation of specific interventions, and the ES benefits that will be generated. Tool reviewed: LUCT.

Strengths:

- The method provides comparative numerical data that allows decision-makers to make informed decisions.
- Decision-makers can consider levels of uncertainty and economic risk of certain interventions.

Limitations:

- Cost values could change within a matter of weeks or days (e.g. fertiliser costs), requiring frequent updates in the tool.
- With set objectives, the cost-benefit analysis may play down or ignore other important ES changes.

Trade-offs/synergies

Tools within this categorisation cross compare multiple ES outcomes to identify where services conflict or complement each other, with 'win-win' scenarios. Tools reviewed: LUCI, HydroloGIS, NEVO.

Strengths:

- Trade-offs allow decision-makers to explore a range of outcomes and options and can be targeted to specific objectives.
- 'Win-win' outcomes can be easily identified and explored.

Limitations:

- There is complexity with analysing multiple, often conflicting objectives that the tools may not be captured accurately.
- 'Win-win' outputs potentially offer a false sense of security and may not be a reflection of real-world outcomes.

Post-hoc analysis

The tools in this group provide outputs for a specific intervention or scenario and then present the data either as a spatial pattern of services output or tabulated scoring values. The user then undertakes post-hoc comparisons either within the tool (e.g. NATURE Tool) or through another programme (e.g. InVEST).

Spatial pattern of services outputs

Tools provide mapped outputs for ES that can then be interpreted visually and compared by the user. Tools reviewed: InVEST, ARIES, EcoservR.

Strengths:

- Visualised outputs are very useful for interpretation by the end user and for stakeholder engagement.
- Outputs are potentially more reliable than algorithm models which have varying degrees of certainty and confidence.

Limitations:

- In most cases the end user is required to process outputs further to conduct analysis, requiring additional resources.
- Post-hoc analysis can be biased by the limited number of interventions and scenarios which have been generated.

Tabulated scoring value outputs

Tools provide tabulated and graph outputs for ES that can then be interpreted in the tool/Excel and compared by the user. Tools reviewed: NATURE, EBN, ARIES, Ciriabest.

Strengths:

- Tabulated outputs and graphs/charts are very useful for interpretation, particularly where there are set targets and goals.
- Numerical data outputs are particularly useful for planning scenarios such as Biodiversity Net Gain and Natural Capital.

Limitations:

- The analysis is non-randomised.
- A lack of mapped outputs can be difficult for interpretation and may require additional work to visualise results.

Simple mapping

This method does not provide any prioritisation/optimisation but can be interpreted to make land use decisions. ES opportunities and information on priorities are visualised through online maps. Tool reviewed: ASSIST E-Planner.

Strengths:

- The tool provides clear visual interpretation of ES opportunities through a traffic light system.
- Mapped opportunities are relevant to a range of environmental stewardship interventions within the UK.

Limitations:

- There is no optimisation or prioritisation capabilities, or post-hoc analysis.

Detailed tool reviews can be found in Appendix 1 of the full report. Reviewed criteria includes method of prioritisation/optimisation, use of mapped outputs, spatial scale, relevance to sectors, cost-effectiveness, ease of use, data requirements, tool adaptability, performance and reliability.

Key considerations

The report provides some suggestions of appropriate tools to use in specific scenarios; however, it cannot inform which is best to use for overall land use decision making. Depending on the aims and objectives of a specific project, tool methodologies would need to be further reviewed to 'match' the scenario. The capabilities of the user and complexities of the site or project will also affect suitability and usefulness of tools.

The review identifies several key factors that future tool developers could consider for future spatial prioritisation of land use decisions tools. Simulated annealing algorithms combined with cost-benefit analysis may be methodologies to explore further, particularly considering the tools Marxan and LUCT. The following points could also be considered for any future tool development:

- The tool needs to be accessible and free. Combining the tool with existing landowner government interfaces and platforms (such as the Rural Payments Agency) could increase efficiency and accessibility for landowners.
- Data sets for any tool need to be transparent, updated and from a trusted, evidenced source or there may be issues with reliability and accuracy of outputs.
- Tools must address habitat heterogeneity, a common issue amongst datasets. This is where the same value is given for the same habitat across a spatial area even if there are differences in elevation, slope, condition, etc.
- Tools should be relevant to ELM, potentially with the ability to select inputs with clear interventions (stewardship options). This will make them more relevant and easier to use by private land managers across the country who are already engaged in environmental stewardship.
- Compatibility of outputs and digitisation of spatial data will be vital for efficiency and future collaboration.
- For prioritisation/optimisation, models should overlay and combine individual ES to highlight win-win scenarios, trade-offs and negative impacts. An easy to understand traffic light system would make interpretation of results easier for the user.
- To assess and prioritise a wide range of ES or actions, a tool may need a nested modelling framework. This could combine multiple single ES models with additional processing models to conduct prioritisation.
- Modelling speed and computational requirements will differ depending on how complex the tool is. For general use by private landowners there may need to be a limit to software requirements so that the tool is accessible and useable.
- A two-tier system of data input requirements would be beneficial for end users. A tool that works with minimal, simple input data with an opportunity to add more detailed information would increase the inclusivity of the tool but allow for more technical application.
- For tool accuracy, reliability and relevancy, the finer the spatial scale the better. This will depend on the project and the end user, however for a typical land manager a sub-field level of detail would be useful for prioritising land use decisions.