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Developing and Testing an Environmental Sensitivity Mapping Webtool to Support Strategic Environmental Assessment in Ireland

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Rialtas na hÉireann
Government of Ireland

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

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We regulate the following activities so that they do not endanger human health or harm the environment:

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- large scale industrial activities (*e.g. pharmaceutical, cement manufacturing, power plants)*;
- intensive agriculture *(e.g. pigs, poultry)*;
- the contained use and controlled release of Genetically Modified Organisms *(GMOs)*;
- sources of ionising radiation *(e.g. x-ray and radiotherapy equipment, industrial sources)*;
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- Office of Environmental Sustainability
- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet regularly to discuss issues of concern and provide advice to the Board.

EPA RESEARCH PROGRAMME 2014–2020

Developing and Testing an Environmental Sensitivity Mapping Webtool to Support Strategic Environmental Assessment in Ireland

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EPA Research Report

Prepared for the Environmental Protection Agency

by

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Executive Summary

Environmental sensitivity is a critical consideration in natural resource management. In the context of the legislative requirements for impact assessment, environmental sensitivity (or vulnerability) assessments present a framework for systematically determining the potential for significant adverse impacts. This is reflected in the Strategic Environmental Assessment (SEA) Directive's requirement to take account of the *vulnerability* of the area likely to be affected when identifying and characterising potential impacts (EC, 2001, Annex II, 2), as well as in the Environmental Impact Assessment (EIA) Directive's cautioning on the potential for significant effects when proposing developments in *environmentally sensitive* locations (EC, 2014, Article 28). Assessing environmental sensitivity provides further insight into the baseline environment by contributing an additional dimension to the purely technical consideration of environmental characteristics. It can serve as an empirical and systematic approach, and as a more objective critical foundation to promote evidence-based impact assessment and environmental planning.

In light of the potential contribution of environmental sensitivity assessments, an Environmental Sensitivity Mapping (ESM) webtool has been developed to support SEA processes in Ireland. The webtool centralises publicly available SEA-relevant spatial datasets and includes a novel widget that enables instant generation of context-specific environmental sensitivity maps. The ESM widget is based on a multi-criteria spatial assessment method to measure the intrinsic sensitivity of the receiving environment. It also facilitates public engagement by allowing user-defined selection of environmental criteria as well as weights that reflect the relative importance of the criteria brought into the assessment.

Extensive stakeholder consultation has been undertaken to guarantee the development of a focused, participative, interactive and user-friendly webtool. Sectoral testing has validated its applicability. All feedback suggests that the webtool provides an invaluable resource for SEA by facilitating access to multiple spatial datasets and by generating maps that graphically and meaningfully highlight potential sensitivities, pointing to where development would need to be carefully considered and sensitively planned. The mapped outputs aim to highlight the relative environmental sensitivity of different areas and are to be used to provide early warning, inform on the potential for land use conflicts and, in this way, provide a critical evidence basis for sectoral planning discussions and for developing alternatives that avoid or minimise potentially incompatible or unsustainable zonings.

The ESM webtool has been piloted within real-life SEAs of live plans. Following the live testing of the ESM webtool, stakeholder feedback indicates that it has made a positive contribution to (1) the development of the National Planning Framework (NPF) and associated SEA and (2) the early and formative stages in the development of the Regional Spatial and Economic Strategies (RSESs) and associated SEAs for the Eastern and Midland Regional Assembly (EMRA), the Southern Regional Assembly (SRA) and the Northern and Western Regional Assembly (NWRA). In fact, all of the stakeholders who responded to an online questionnaire on the application of the ESM webtool unanimously agreed that it improved the SEA process and confirmed that they would use the webtool again in supporting SEA.

In response to stakeholder feedback during the pilot testing, the webtool has been further enhanced with additional datasets and more detailed user guidance. At the time of writing, the webtool contains 107 SEA-relevant spatial datasets, a step-by-step user manual and a video tutorial. This proves that the webtool has the flexibility to respond to evolving demands and practice over time. Key recommendations on future hosting and maintenance arrangements for the ESM webtool are put forward. These include having regard to the positive stakeholder feedback and ensuring the long-term sustainability of the ESM webtool by securing organisational and financial support for its ongoing maintenance and real-life implementation.

1 Introduction

The Environmental Sensitivity Mapping (ESM) project has delivered a novel webtool to support Strategic Environmental Assessment (SEA) processes in Ireland. The ESM webtool now includes over 100 SEA-relevant, up-to-date spatial datasets for simultaneous visualisation and querying. More importantly, it contains a geoprocessing widget that enables instant generation of plan-specific sensitivity maps, aiming to provide early warning of potential land use conflicts to inform the scoping and impact assessment stages of SEA in particular, and to contribute to cumulative effects assessment to ultimately contribute to evidence-based planning and decisions.

The purpose of both the webtool and the widget is to support practitioners (e.g. government departments, regional assemblies, local authority planners, consultants) when undertaking SEA by enabling a systematic spatial examination of environmental considerations and their vulnerability or sensitivity, as required under the SEA Directive (EC, 2001). Underpinning this function is the aim to enhance consistency and transparency in environmental assessment across planning hierarchies and sectors, as well as to facilitate evidence-based decision-making. Visualisation of the geographical distribution and overlay of environmental criteria in a dedicated interface assists exploration of the relative degrees of environmental sensitivity and the potential for cumulative effects in specific plan/programme areas. To ensure that context-specific considerations are factored in, end users are prompted to select environmental criteria relevant to the plan/programme under preparation and assessment, and to assign weights to such selected criteria on the basis of their relative importance.

The project started in February 2014 and was awarded a cost extension in May 2017 in order to, among other things, pilot and refine the application of the ESM webtool. The performance of the geoprocessing capabilities of the webtool was tested using real-life SEAs linked to live sectoral land use plans. The focus on land use planning was justified on the basis that the large majority of SEAs undertaken in Ireland (approximately 75%) relate to this sector. Following extensive stakeholder engagement as part of the piloting and ongoing development of the ESM webtool, a range of improvements have been incorporated into the webtool to ensure better usability and functionality. Although some limitations still exist in terms of regular maintenance and updates, technical guidance in the development of the ESM webtool is provided with specific details on its main operational components. This will help to guide and assist the technical handover of the final ESM webtool as part of its future direction.

This final report is divided into two parts: the first (Chapters 1–8) describes the development of the ESM webtool, including the theoretical and methodological approach and the stakeholder consultation, and the second (Chapters 9–12) reports the results of the piloting of the ESM webtool within real-life case studies and the changes and adjustments made to both the content and the functionality of the webtool to maintain it and to address stakeholder feedback. Recommendations are put forward on potential future hosting and maintenance arrangements for the ESM webtool and future directions. A number of appendices are included, providing additional information on consulted organisations, stakeholder comments, the user manual and other relevant information.

2 Environmental Sensitivity

Environmental sensitivity or vulnerability is a critical consideration in natural resource management, particularly in the analysis of interactions between society and ecosystems. In the context of the legislative requirements for impact assessment, the terms “sensitivity” and “vulnerability” are often referred to interchangeably when describing susceptible natural resources (e.g. protected habitats, water bodies) that could be significantly affected (e.g. disturbed, degraded) by anthropogenic stressors associated with the implementation of a plan, programme or project. Environmental sensitivity assessment is not a requirement per se under either the SEA (EC, 2001) or the amended Environmental Impact Assessment (EIA) (EC, 2014) Directives. However, it provides further insight into the baseline environment and a framework for systematically determining the potential for significant impacts. Indeed, the SEA Directive refers to the vulnerability of the area likely to be affected when identifying and characterising potential impacts (EC, 2001, Annex II, 2) and the EIA Directive warns about the potential for significant effects when proposing developments in environmentally sensitive locations (EC, 2014, Article 28). It has been argued that impact assessments that account for sensitivity are generally less subjective than those that do not (Kværner *et al.*, 2006). Moreover, sensitivity assessments provide an additional dimension to the purely technical factoring of characteristics. Therefore, they can serve as an empirical and more objective critical foundation for sectoral planning discussions to promote evidence-based impact assessment and environmental planning.

3 Measuring Sensitivity

There are three generic ways to conceptualise and measure sensitivity (Adger, 2006): (1) analyse a system's or region's characteristics that make it susceptible to change, i.e. starting point (e.g. González *et al.*, 2011a); (2) analyse resulting impacts, i.e. focus on the endpoint (e.g. Antunes *et al.*, 2001); and (3) analyse exposure, sensitivity and adaptive capacity, i.e. a systems approach that addresses interactions between all components (e.g. Yoo *et al.*, 2014). Nevertheless, given common data and resource limitations, the majority of environmental assessments tend to focus on either the starting or the endpoints, as the system's interactions and adaptive capacity are complex and often difficult to measure.

In practice, environmental sensitivity assessment is commonly centred on biophysical components, examining the capacity of a given environmental factor or set of factors to absorb anthropogenic change and remain in the same state (Carpenter *et al.*, 2001; Adger, 2006; González *et al.*, 2011a; Toro *et al.*, 2012). The higher the natural or acquired sensitivity of an environment or environmental factor, the less resilient it is, i.e. the less capable to cope with human-induced change. For example, a water catchment containing a sensitive species (natural sensitivity), such as the protected freshwater pearl mussel (*Margaritifera margaritifera*), would be susceptible to changes in water quality. Similarly, a poor-quality-status water body would have acquired sensitivity to further point source pollution; it would be harder to maintain or improve its status while coping with additional stressors. In practical terms, environmental sensitivity can be associated with (1) quality status of a given environmental factor (as per above, the poorer the water quality, the higher the acquired sensitivity), (2) presence of a protected species or designation (e.g. European sites) or (3) risk (e.g. flood risk areas would be unable to absorb additional urban development without mitigation). In general terms, the lower the quality status of an environmental factor or the greater the degree of protection assigned to it, the greater the potential for land use conflicts. Similarly, the higher the risk, the less suitable the land may be for certain developments. However, there are currently no established legislative thresholds/ targets or statutory protection measures for certain environmental factors, such as landscape or soils, making it difficult to the determine the sensitivity on the basis of the above considerations. To address this, expert and/or stakeholder value judgments may be applied to determine sensitivity (Hegmann and Yarranton, 2011).

Sensitivity is context and spatially specific (Brooks *et al.*, 2005; Wang *et al.*, 2008; Tran *et al.*, 2010; González *et al.*, 2011a). The relative environmental sensitivity of an area can be considered to directly relate to the number of relevant environmentally sensitive factors that overlap at that location (Antunes *et al.*, 2001; Marull *et al.*, 2007; González *et al.*, 2011a). The more environmentally sensitive features that occur in a given area, the higher the overall sensitivity of that area and the higher the likelihood for adverse effects, including cumulative adverse effects. The simultaneous occurrence of multiple sensitive factors (such as poor water quality, presence of a Red List species and a high amenity landscape) at one location will render the environment more susceptible to change than if only one of those factors were present, as a result of accumulated sensitivity.

In the context of SEA, environmental sensitivity assessment should aim, at least, to identify areas that have a higher probability of being susceptible to change (i.e. starting point or baseline environment). It should provide an early warning of potential land use conflicts and identify the location and extent of probable adverse effects in order to inform planning and decision-making. Such sensitivity assessment is supported by geographic information systems (GIS). In fact, impact assessment methodologies are increasingly moving towards greater use of spatial data and GIS (Atkinson and Canter, 2011; González, 2012). They increasingly include environmental sensitivity assessment (e.g. Kværner *et al.*, 2006; Marull *et al.*, 2007; Wang *et al.*, 2008; Toro *et al.*, 2012; Pavlickova and Vyskupova, 2015) and attempt

to determine the potential for cumulative effects (e.g. Antunes *et al.*, 2001; Geneletti *et al.*, 2007; González *et al.*, 2011a; Skondras *et al.*, 2011). Although no standardised approach to sensitivity assessment exists, common approaches integrate multi-criteria assessment and GIS for the combined spatial analysis of multiple environmental considerations through aggregation methods.

4 Methodological Framework

The ESM widget focuses on the conceptual starting point, measuring the intrinsic sensitivity of the receiving environment. It builds on current practice (González *et al.*, 2011a) and adopts a GIS-based multi-criteria assessment method based on the weighted linear combination algorithm that avoids normalisation – a widely applied decision rule (Malczewski, 2000):

$$ES = \sum_{j=1}^{n} WjVj \qquad (4.1)$$

where ES is environmental sensitivity; Wj is the susceptibility of factor *j* defined by scientifically grounded considerations; and Vj is the significance of factor *j* according to public/stakeholder opinion.

This method combines all environmental factors co-occurring in a given area and, in this way, enables the identification of its overall environmental sensitivity. More importantly, it enables the inclusion of legislative thresholds/targets, statutory protection measures and risk considerations in the form of scientific scores (i.e. scientifically grounded sensitivity of environmental factors – see section 4.1) and subjective weights (i.e. public perceptions or values on relative significance – see section 4.2). Therefore, the ESM widget undertakes an aggregated analysis of plan/programme-specific spatial datasets that illustrate not only the location and spatial correlation of environmental features on the landscape, but also their baseline status (e.g. environmental quality indicators) and the importance ascribed to them by stakeholders.

4.1 Harmonising Sensitivity Values

A scientific score has been associated with each dataset in the ESM widget; the scores aim to capture the relative susceptibility of the environmental factors to change. To enable a combined assessment and comparable representation of individual factors, relative values need to be standardised (Antunes *et al.*, 2001; Wang *et al.*, 2008; González, *et al.*, 2011b; Yoo *et al.*, 2014). As noted in Chapter 3, in the context of the ESM, the susceptibility of individual factors is captured by their quality, protection status or risk and, when these are not applicable, using value judgments. This permits the combination of multiple harmonised indicators into a single environmental sensitivity index. The overall degree of sensitivity of an area is obtained through aggregation of harmonised individual indicator values co-occurring in that area.

In developing the widget, the harmonisation of relative degrees of sensitivity of environmental factors was initially based on statutory thresholds and targets using a scale from 1 (meaning “low”) to to 3 (meaning “high”). These preliminary “scientific scores” were subsequently adjusted in consultation with national SEA and environmental topic experts, and representatives from governmental bodies and environmental consultancies (see section 8.1). The applied harmonisation rules assume that the greater the sensitivity of an environmental factor, the higher the scientific score assigned to it.

4.2 Sensitivity Perceptions

It is widely acknowledged that the evaluation of impacts and any decisions based on impact assessment results always has a subjective dimension associated with the varying values, knowledge and perceptions of those involved in the process (Lawrence, 2007; González *et al.*, 2011b; Hegmann and Yarranton, 2011; Toro *et al.*, 2012). For example, experts may have a knowledge-led bias (e.g. ecologists favouring biodiversity conservation or hydrologists prioritising the protection of water quality), whereas the subjectivity of public input (a mandatory requirement in both plan-making and SEA under the Aarhus Convention and Directive 2003/35/EC – EC, 2003) is linked to awareness levels and/or personal values or concerns (Cox, 2013).

Adger (2006) argues that sensitivity assessment must reflect social values and contexts in order to capture differences in local sensitivity perceptions. This is commonly carried out by incorporating value judgments on significance/importance (González *et al.*, 2011a; Hegmann and Yarranton, 2011). The ESM widget enables this by means of significance weights

applied to each environmental theme selected. As per selection of environmental criteria, weights can be established by the end user but, ideally, they should be agreed among stakeholders during SEA scoping and public consultation (as the widget enables the incorporation of a single weight per environmental theme by the user, study team or stakeholders). Alternative weighting scales were presented and discussed with stakeholders (see section 8.1). For simplicity and user-friendliness, the provision of two weighting options was agreed, (1) to maintain the scientific scores as they are and (2) to emphasise the significance of a given theme in comparison with others included in the assessment. This "emphasis" weight doubles the scientific scores of environmental criteria within the selected theme, intensifying or increasing the overall sensitivity of the related areas.

The inclusion of weights not only enables the incorporation of local sensitivity perceptions, it also facilitates the creation of context-specific maps that capture differing degrees of public/stakeholder concern associated with different planning alternatives. However, when different public/stakeholder groups are consulted, variations in the importance assigned to each environmental theme could result in diverging maps for a single assessment. In this regard, careful consideration must be given to personal and/or sectoral bias. Nevertheless, weights can be changed to examine how different perceptions may alter the resulting sensitivities across a region (e.g. Chen *et al.*, 2010). Although possible variations in the resulting maps are acknowledged, the objective of this approach is to ensure that key issues/concerns are captured in the assessment and that public/stakeholder values are factored in the various maps to inform the SEA and plan-making processes. Interpretation of the mapped outputs must have due regard to the selected environmental themes and criteria, as well as to the assigned weights, which are all recorded in the output maps (see Figure 6.2).

4.3 Webtool and Widget Inputs and Outputs

The spatial datasets in the ESM webtool are incorporated in vector format (illustrating discrete point, line or polygon features) and can be viewed and queried by the end users (Figure 4.1). Vector datasets enable detailed resolution of discrete boundaries and linear features when zooming in close to the relevant areas.

Environmental sensitivity index

Figure 4.1. Categorisation of the ESM outputs. The numbers in parentheses refer to the aggregated sensitivity, resulting from adding up the scientific scores and the applied weights.

To enable map algebra (necessary to combine overlaying datasets in the widget for calculating the aggregated sensitivity), vector datasets are converted to raster datasets (pixelated graphics). Such raster datasets sit in a server and are activated in the widget when the end user selects the environmental criteria and weights for the assessment (see section 4.4). A spatial resolution or pixel size of 100 m × 100 m has been adopted for ESM assessments and raster outputs. This cell size preserves sufficient detail for regional- and county-level assessments and reasonably represents environmental and land use processes and patterns at the landscape scale (Antunes *et al.*, 2001; Geneletti *et al.*, 2007; Marull *et al.*, 2007; González *et al.*, 2011a).

The ESM outputs are presented in raster format. The output map is a static PDF image depicting the relative degrees of environmental sensitivity within the plan/programme area (Figure 4.1). For standardisation, as well as to facilitate comparability of results, the environmental sensitivity is ranked according to the scale presented in Figure 6.2. The overall index reflects the number of overlapping environmental considerations, where "very low" indicates occurrence of a single sensitive dataset or three non-sensitive datasets (see also section 4.1) and builds gradually to encompass a higher number of co-occurring environmental considerations.

The output map includes the list of pre-selected environmental factors (i.e. all the datasets ticked and, therefore, brought forward into the assessment) and the weights assigned to each environmental theme by the end users (see Figure 6.2). The purpose of this is to ensure transparency and facilitate a contextualised interpretation of mapped outputs. For example,

as noted in section 4.2, the application of different environmental criteria and weights to explore different scenarios or to examine the effect of different concerns on assessment outputs can be duly interpreted with the help of the aspects listed in the output map.

4.4 Environmental Sensitivity and Cumulative Effects

The ESM focuses on the spatial dimension when assessing the potential for cumulative effects. This entails consideration of individual actions concentrated in space affecting the capacity of that environment to absorb change (see Chapter 3). In the context of the ESM, and given the focus on the receiving environment (i.e. starting point), the potential for cumulative effects is determined on the basis of the spatial concentration of environmental criteria. This relates to the aggregated sensitivity of the receiving environment (and hence the potential for cumulative adverse effects) being directly linked to the number of overlapping environmental sensitivities. For example, a proposed land use zoning for the future development of industrial and commercial facilities sitting on a highly vulnerable aquifer and poor surface water quality catchment, with areas likely to contain Annex I habitats (designated under the Habitats Directive) and entries in the Record of Monuments and Places (RMP), would potentially lead to cumulative adverse effects on biodiversity, water, human health and cultural heritage. Nevertheless, double counting should be avoided when selecting datasets for examining potential cumulative effects. For example, selecting ancient woodlands, Annex I habitats and woodland habitats would overemphasise the accumulated sensitivity of certain woodlands, yet such woodlands may be included in all three datasets. Similarly, selecting aquifer vulnerability, Water Framework Directive (WFD) groundwater status and groundwater source protection areas would overstate the sensitivity of this natural resource. At the strategic level, development pressures or drivers of change are not only influenced by proposed plan/programme actions, but also by external factors such as national, European and global policies. Although not incorporated into the webtool, these must also be considered when analysing the potential for significant cumulative effects.

The ESM outputs provide an overall sensitivity index, representing a categorisation of the relative environmental sensitivity of the different areas (see section 3.5), which entails an aggregation of all selected and overlapping environmentally sensitive criteria in a plan area. The sensitivity index provides a composite illustration of the accumulated sensitivity, facilitating the analysis of the potential for adverse spatial cumulative effects of different planning alternatives. Such an aggregated index may, in principle, result in individual environmental criteria being obscured. However, the ESM webtool allows the environmental criteria that co-occur at a given location to be identified and queried, and thus enables scrutiny of all underlying sensitivities (see Figure 4.1). Similarly, the effects that significance weights (see section 4.2) may have on the overall sensitivity index need to be considered, as the weights assigned may emphasise/magnify a less sensitive environmental criterion and thus dilute highly sensitive factors. In order to address this, an evaluation of the effects that significance weights may have on the ESM outputs is recommended (see also section 4.2).

5 ESM Webtool Interface

The ESM webtool is designed to facilitate the exploration of multiple datasets. Its purpose is to enable geographical exploration of environmental considerations onshore. It contains a widget that enables relevant environmental datasets to be combined, producing environmental sensitivity maps for informing SEA processes (see Chapter 6).

The webtool centralises publicly available SEA-relevant data, providing access to over 100 spatial datasets for viewing and querying (Appendix 1). These datasets are grouped by SEA themes, namely population and human health; biodiversity, flora and fauna; water; soils and geology; air and climatic factors; cultural heritage; landscape; and material assets. Their spatial inter-relationships can also be explored. As shown in Figure 5.1, all of the included environmental datasets can be interrogated, i.e. end users can turn on/off datasets for their individual or combined visualisation and print them out, as well as click on a given area to obtain information on its main characteristics (e.g. description, typology and status of environmental factors at that location).

The webtool contains a number of functional tools to facilitate data visualisation and exploration (refer to the user manual in Appendix 2 for details).

Figure 5.1. The ESM webtool interface illustrating the spatial datasets available in the viewer (right), the query tool (centre) and the widget (left), where themes/criteria and weights can be defined for their combined assessment.

6 ESM Widget Interface

The ESM webtool contains a novel geoprocessing tool or widget that includes a subset of the webtool's datasets for incorporation into the sensitivity assessment. The widget prompts the end user to select SEA themes and criteria (i.e. spatial datasets) that address plan programme considerations, together with their relative importance or significance in the form of weights (Figures 5.1 and 6.1). In this way, the widget generates context-specific environmental sensitivity maps for a given sectoral plan or programme (Figure 6.2).

6.1 Running the Widget

The following is a descriptive summary of the steps undertaken to run the widget and produce context-specific environmental sensitivity maps (see Figure 6.1). Refer to Appendix 2 for the user manual.

6.1.1 Select study area

The widget includes administrative boundaries (e.g. regional authorities and counties) as well as river basin districts as possible study areas (Figure 6.3). The plan/programme area is to be manually selected by the user from the widget's "select local area" list prior to the assessment. To incorporate feedback from the consulted stakeholders, and to address potential transboundary sensitivities, a 10-km buffer area is automatically applied to the selected study area. Therefore, the assessment and the mapped outputs reflect the geographical extent of the buffer zone. The webtool enables the uploading of external shapefiles into the viewer, so uploading an alternative plan-specific study area is also possible. Although the widget currently does not recognise external datasets for computation, the user can select a wider geographical area (e.g. administrative boundary) and subsequently zoom in to the uploaded study area (e.g. town boundary) to explore ESM outputs at a local level.

6.1.2 Select environmental criteria

The webtool provides a comprehensive set of publicly available SEA-relevant environmental datasets for viewing and querying (see Appendix 1). A subset of these datasets, representing the most relevant considerations for sensitivity assessment, is available in the widget for selection and incorporation into the sensitivity mapping.

The end user selects a given environmental theme and all associated datasets are displayed, enabling further focusing of the assessment on relevant environmental criteria under that theme (Figure 6.4). As noted in the user manual (Appendix 2), the onus is on the end user to ensure that the selection of environmental datasets is appropriate. For meaningful environmental assessment, selection of criteria should never be arbitrary. Criteria can be individually identified by the

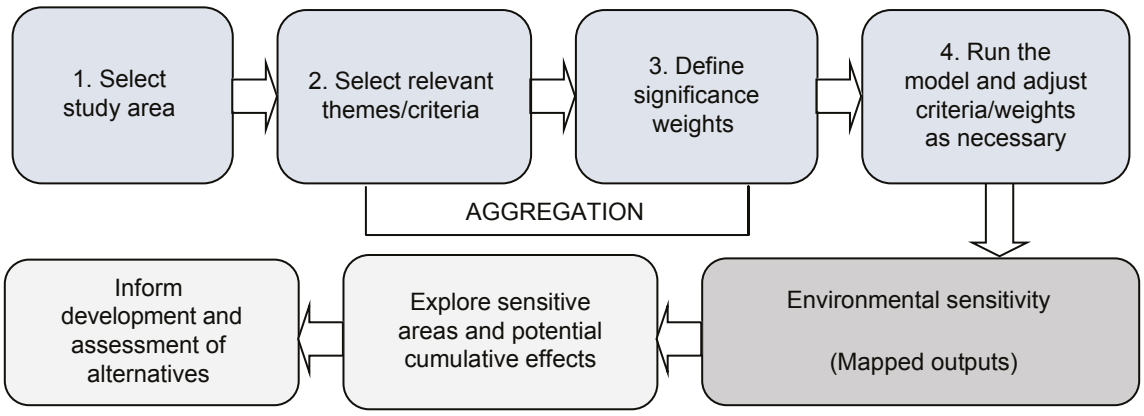
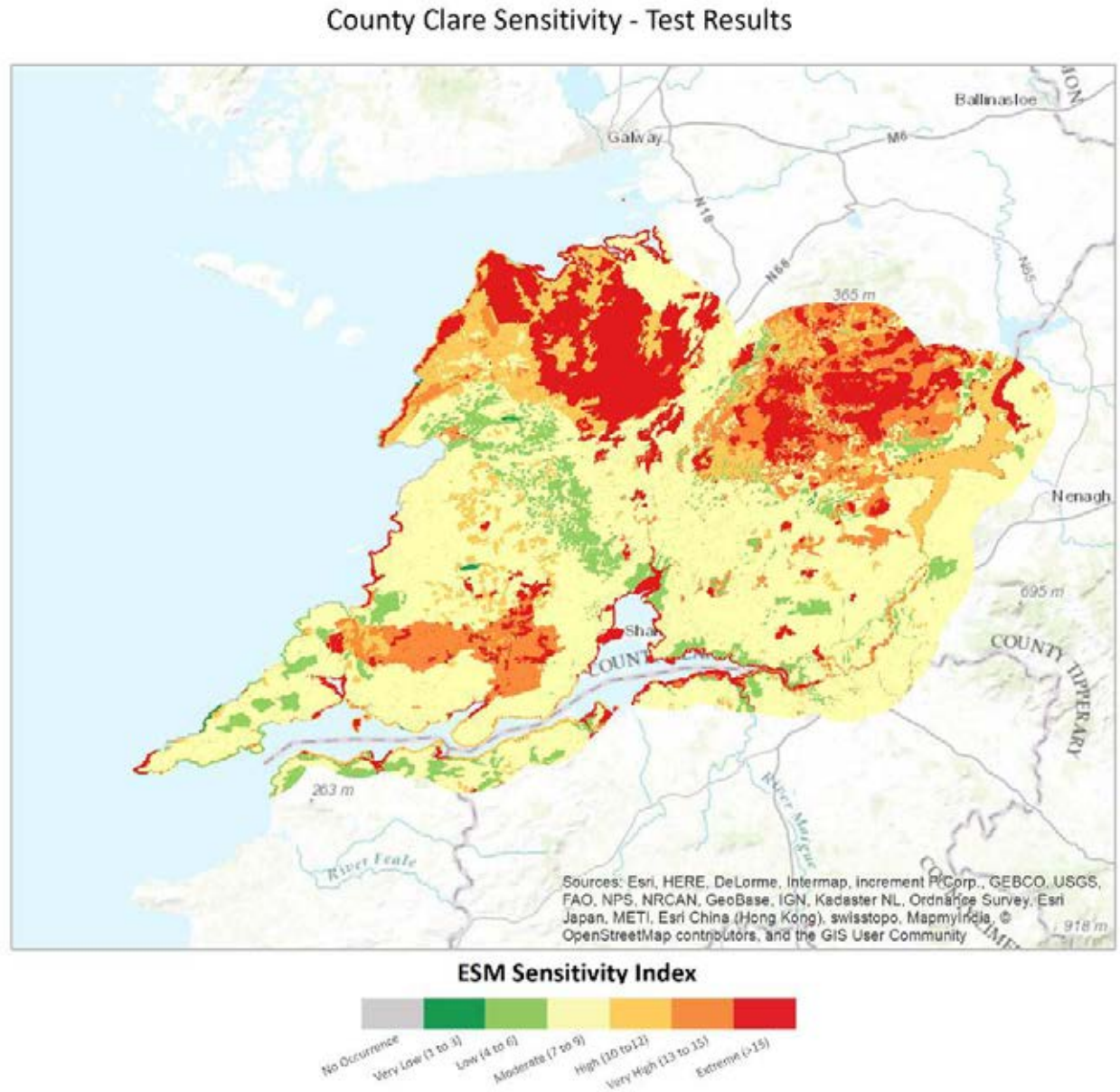


Figure 6.1. Schematic diagram of the ESM widget steps. The potential for cumulative effects and assessment of alternatives are to be undertaken outside the ESM webtool process.



Date: 13/12/2016 Time: 16:02:29 Author: AG

*This map is an aggregate result based on the variables and user defined weights listed below.
Warning: Please note that weights are only to be used to emphasize the relative significance of an environmental aspect - applying weights to more than two themes would magnify, and possibly overstate the overall sensitivity.

Air & Climactic	*Weight: 1*	*Variables:*	*Historical Flood Extents*
Biodiversity, flora and fauna	*Weight: 2*	*Variables:*	*Margaritifera Sensitive Areas, Natural Heritage Areas, Proposed Natural Heritage Areas, Candidate Special Areas of Conservation, Special Protection Areas*
Cultural Heritage	*Weight: 1*	*Variables:*	*Record of Monuments and Places*
Population and Human Health	*Weight: 1*	*Variables:*	*WFD RPA Groundwater Drinking Water*
Soils and Geology	*Weight: 1*	*Variables:*	*Geoparks and Geosites, Peat Bogs*
Water	*Weight: 2*	*Variables:*	*Aquifer Vulnerability*

Figure 6.2. Sample environmental sensitivity output map.

Figure 6.3. Screenshot of the ESM widget illustrating study area selection options.

Figure 6.4. Screenshot of the ESM widget illustrating environmental themes, associated datasets/criteria and weight selection options.

end user (e.g. environmental assessor) or identified jointly during scoping (e.g. through a consensus-based approach via a scoping workshop). In all cases, they should be informed and contextualised, that is, tailored to the level in the planning hierarchy and sector under consideration. This selection of environmental themes/criteria is necessary for a focused assessment (Therivel, 2004; Jones *et al.*, 2005). The selection will result in the creation of "tailored" environmental sensitivity maps for a given sectoral plan or programme (see Chapter 7).

6.1.3 Define weights

To facilitate input of public/stakeholder perceptions, and thus comply with SEA public consultation requirements, the proposed approach enables weights to be assigned to the selected environmental themes (section 4.2). This prioritisation, through the inclusion of relative importance values, can be used to highlight significance of issues or concerns (e.g. where the conservation of biodiversity is perceived to be more important than cultural heritage protection) for the specific plan area. Once an environmental

theme is selected, relative importance weights can be assigned by the environmental assessor/s (Figure 6.4). As with selection of environmental criteria, weights can be assigned by the end user. Ideally, these should be agreed among key stakeholders during scoping or agreed with the general public during public consultation (as the webtool enables the incorporation of a single weight per environmental theme).

6.1.4 Run the model

Once the relevant criteria and weights are defined, the user can run the widget. This will utilise the pre-processed raster files (see section 4.3) and launch the weighted linear algorithm geoprocessing tool to produce a context-specific environmental sensitivity map for the plan area, which is displayed on the viewer (Figure 6.5).

The tool generates static outputs in the form of PDF maps (see Figure 6.2). The maps are temporarily saved in the session (and the user can open them in a new tab and save them in the local drive for future reference). The widget can then be re-run with an alternative set of criteria or weights to generate new context-specific maps. This enables the examination of how different criteria and weights, or indeed planning scenarios, may result in different sensitivities across a region (see section 4.2).

6.2 Benefits

The webtool and widget provide a number of direct benefits, which have been emphasised by the stakeholders involved in the project (see sections 8.2 and 8.3). These include:

- **Rapid access to SEA data**. Centralisation of SEA-relevant datasets in a single interface facilitates their use, reducing time and resource requirements for data gathering and preparation.
- **User-friendly interface for generating context-specific maps**. The interactive widget enables the instant generation of environmental sensitivity maps, which are specific to the plan/programme area, without the need for specific GIS technical skills.
- **Systematic and flexible methodology**. Multiple maps can be generated to capture different considerations (i.e. environmental criteria specific to the plan/programme under assessment) and values (i.e. relative importance assigned to the selected criteria); these maps are transparently generated through the systematic application of a simple data combination approach.
- **Cross-county comparison and transboundary assessments**. Adopting the same criteria and weights across counties and regions facilitates their comparability. This, in turn, can help address some of the existing inconsistencies and conflicting approaches between plan areas, and

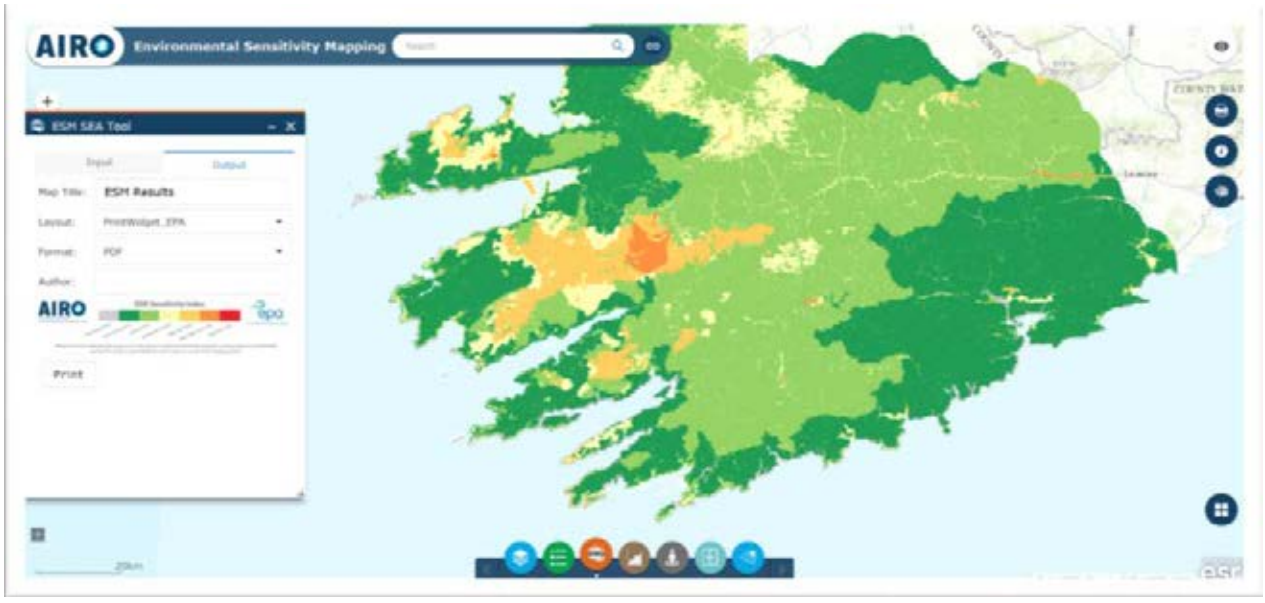


Figure 6.5. Screenshot of the ESM widget illustrating the output environmental sensitivity raster file.

contribute to harmonising methods for assessing potential transboundary impacts, as well as developing a consistent approach to developing sustainable strategies across regions.

- **Recreating in-house assessments**. The sectoral testing of the widget has validated its applicability and the outputs reflect and, in some cases, improve environmental sensitivity assessments undertaken in-house (see section 8.3 for further detail).
- **Easy to analyse outputs**. The printout maps (see Figure 6.2) provide a detailed account of datasets and weights incorporated into the assessment, facilitating an easy interpretation of the assessment outputs.

6.3 Data Gaps and Limitations

During the development of the webtool, it has become apparent that a number of key SEA-relevant spatial datasets are currently unavailable at the national level. Existing data gaps and limitations have led to certain thematic areas being under-represented or incomplete in the webtool.

The absence of comprehensive, nationwide datasets for some thematic areas, such as biodiversity, flora and fauna (e.g. habitats and ecosystem services mapping, ecological corridors), landscape (e.g. landscape character areas, scenic views and prospects), cultural heritage (e.g. the Record of Protected Structures), and geology and soils (e.g. soil productivity), has inevitably resulted in their omission from the ESM interface. The recognised methodological inconsistencies in some of the datasets and information gaps (e.g. landscape character areas) also affect the ability to comprehensively consider all SEA-relevant themes and criteria. During the project, significant efforts were made to address some of the identified gaps. For example, the landscape theme was initially omitted from the webtool because of the lack of a national landscape dataset. To address this, landscape character areas prepared at county level were collated and harmonised, in consultation with the local authorities, to resolve existing categorisation divergences. Despite this, landscape character areas are yet to be prepared for certain counties, rendering the amalgamated and harmonised landscape dataset incomplete (i.e. the dataset does not have full national coverage). Because of this, the dataset is displayed in the webtool for visualisation and querying but it is not included in the widget. Efforts were also made to expand cultural heritage (i.e. the Record of Protected Structures) but the inclusion of this dataset has been hindered by the fact that it is incomplete.

The above, and the following aspects, need to be considered when applying the ESM webtool:

- The quality of the ESM outputs (i.e. sensitivity maps) is dependent on the quality of the data entered into the assessment. The ESM webtool is fully reliant on existing and publicly available spatial datasets from third-party sources. As a result, existing data gaps (e.g. omission of the Record of Protected Structures in the ESM webtool as a result of data availability and access constraints), and any scale and quality/ completeness issues associated with the included datasets (e.g. geographical coverage and detail of landscape areas), can affect the comprehensiveness and detail of the sensitivity analysis.
- The reliability of the environmental sensitivity index depends not only on data availability and quality, but also on the parameters selected for inclusion in the assessment. The availability of more data for certain SEA themes (e.g. a large number of water-related spatial datasets because of WFD requirements) could cause an unintended imbalance of environmental sensitivity towards a given theme if all datasets were selected. As this has implications for the assessment outputs, a sensible number of criteria should be selected to avoid unintended bias (unless a particular environmental consideration is specifically intended to be emphasised).
- Scientific scores determine the intrinsic susceptibility of each environmental dataset and are the basis by which datasets are aggregated for the sensitivity analysis. Scientific scores range from 1 (low, e.g. coniferous forests, unrestricted coal areas) to 3 [high, e.g. Special Areas of Conservation (SACs), geoparks, groundwater source protection areas] and have been defined for each dataset in consultation with stakeholders. Refer to the Annex of the user manual in Appendix 2 for more detailed information on scientific scores. These should be taken into consideration when interpreting the ESM outputs.

- Weights applied to the SEA themes affect the ESM outputs. Significance weights can be determined by the end user or by a stakeholder group. In all cases, significance weights are subjective but not arbitrary (i.e. they should be based on evidence). For an effective assessment, a range of relevant experts should be consulted to determine appropriate weights for specific themes and the effect that weights have in the relative sensitivity outputs should be examined.
- The sensitivity maps have a resolution of 100 m × 100 m. This resolution has been adopted as it provides sufficient detail for regional- and county-level assessments, a common geographical extent in SEA studies. All vector datasets have been converted to 100 m × 100 m resolution rasters and, in doing so, detail is lost at the local level. Therefore, it is advised that mapped outputs are not examined/scrutinised by zooming in tight to local areas, as the 100 m × 100 m resolution does not enable fully representative considerations/issues at that level.

Given the above considerations, the ESM outputs should be treated as indicative rather than definite. The maps aim to highlight the relative environmental sensitivity of different areas and are to be used to provide early warning, advise on the potential for land use conflicts and, in this way, promote evidence-based planning. They should not be used to identify no-go areas or provide a green light for development.

7 Pilot Testing the ESM Webtool

The ESM webtool was tested to validate its applicability by illustrating the effect of value judgments (i.e. assigning subjective weights) on environmental sensitivity. They are presented as examples of how varying stakeholder perceptions may shape the mapped outputs. County Clare, Ireland, is used as a case study to exemplify the effect that user weights of 1 (i.e. maintaining the scientific scores as they are) and 2 (i.e. emphasising the significance of a given theme and thus intensifying the relative sensitivity of the relevant areas) have on the results (Table 7.1 and Figure 7.1).

The maps in Figure 7.1 contain the same environmental criteria as per Table 7.1. However, the map on the right presents the results of the second

Table 7.1. Environmental themes, factors and weights applied in testing the webtool

Selected environmental themes and factors	Scientific score	Weights, scenario 1	Weights, scenario 2
Biodiversity, flora and fauna			
SPAs	3	1	2
SACs	3	1	2
NHAs	3	1	2
pNHAs	2	1	2
Annex I habitats	3	1	2
Margaritifera-sensitive areas			
Catchments of SAC populations listed in S.I. No. 296/2009	3	1	1
Catchments of other extant populations	3	1	1
Catchments with previous records but current status unknown	2	1	1
Air and climate			
Historical flood events	3	1	1
Water			
Aquifer vulnerability			
High/extreme/rock near surface	3	1	2
Moderate	2	1	2
Low/water	1	1	2
Groundwater source protection areas	3	1	2
WFD lake status			
High	2	1	2
Pass/good/moderate	1	1	2
Poor/bad	2	1	2
WFD river status			
High	2	1	2
Pass/good/moderate	1	1	2
Poor/bad	2	1	2
Cultural heritage			
RMP	3	1	1
NIAH	2	1	1
Geology and soils			
Peat bogs	2	1	1

NHA, Natural Heritage Area; NIAH, National Inventory of Architectural Heritage; pNHA, proposed Natural Heritage Area; S.I. No., statutory instrument number, SPA, Special Protection Area.

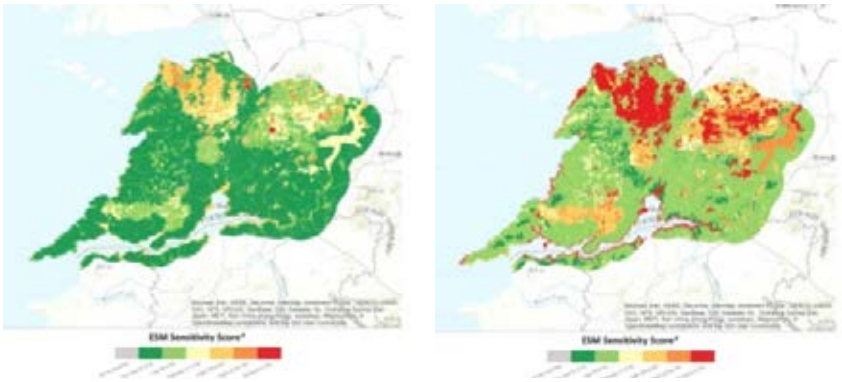


Figure 7.1. Weight scenario 1 (left): environmental sensitivity of County Clare with a neutral weight (i.e. all criteria have a weight equal to 1). Weight scenario 2 (right): environmental sensitivity of County Clare where biodiversity and water criteria are assigned a weight of 2.

testing scenario in which the weights were adjusted to emphasise the significance of protecting both biodiversity and water resources in the county. As evident in the map, the relative sensitivity of areas containing ecological designations and vulnerable water resources significantly increases. This gives rise to an increase in the sensitivity category across all areas as a result of the underlying aquifer vulnerability in particular, and across the Burren, Lough Derg and Shannon estuary shorelines because of ecological designations at those locations.

8 Consultation Outcomes

Stakeholder input has been critical in developing a robust, user-friendly and interactive ESM webtool. A total of 43 stakeholders, representing over 30 public and private organisations (e.g. governmental agencies, local authorities and private consultancies), participated in four stakeholder workshops, informing the development and subsequent testing of the functionality of the ESM webtool (Appendix 3). All workshops provided opportunities for multi-disciplinary debate on the user needs and interface requirements of the ESM webtool and ESM widget.

The first ESM stakeholder workshop (on 12 March 2015) focused on (1) the proposed methodological approach on which the ESM webtool is based, (2) its content with regard to both spatial data and geoprocessing tools, (3) the standardisation of scientific scores attached to each of the incorporated datasets and (4) its user interface. The purpose of the second stakeholder workshop (on 16 March 2016) was to review and finalise the scientific scores associated with the spatial datasets included in the webtool (partially agreed at the first workshop) and, more importantly, to test the applicability of the ESM widget in producing meaningful environmental sensitivity maps.

The sectoral workshops on renewable energy (on 14 May 2016) and on land use planning (on 1 June 2016) aimed to test the applicability of both the visualisation and the information capabilities of the ESM webtool and the reliability and usefulness of environmental sensitivity maps produced through the application of sector-specific widgets.

8.1 Defining Scientific Scores

The first and second stakeholder workshops aimed, among other things, to define and agree scientific scores, with the objective of harmonising the relative susceptibility of the various environmental factors. A semi-structured approach was adopted to conceptualise sensitivity and to accordingly assign relative scores to the environmental spatial datasets. This enabled statutory measures and thresholds (e.g. quality, protection status) and risk, as well as expert opinion, to be considered.

At the first workshop the importance of reaching consensus on the harmonised sensitivity values was considered and the adoption of a sensitivity scale was agreed. Preliminary scores for the relative degrees of sensitivity for 38 publicly available environmental datasets were then put forward by the project team to the workshop participants (Table 8.1). The preliminary scores were based on statutory thresholds, targets, designations and risk, where applicable. The applied harmonisation approach assumes that the greater the sensitivity of an environmental criterion, the higher the score assigned to it. The spatial datasets for which legislative measures were not available to capture intrinsic sensitivity were not assigned preliminary scores and, therefore, were fully open to discussion. Stakeholders were asked to revise these preliminary scores and provide expert input for their adjustment. The revised scores, together with value judgments for the remainder of the datasets, were gathered and revisited at the second workshop.

Although agreement was reached among stakeholders on the majority of environmental themes, consensus was easier to reach on some themes (e.g. biodiversity, water and cultural heritage) than others (e.g. population and soils). This is possibly because of the presence/absence of statutory measures and designations under European and national legislation influence perceptions, leading to coupling sensitivity with protection and conservation requirements. Overall, the lack of specific statutory measures for certain datasets rendered them less sensitive than those that are protected/designated. However, in a number of cases, expert opinion was observed to ultimately determine the relative sensitivities assigned rather than existing statutory thresholds or targets. In total, 45% (i.e. 15 out of 33) of the preliminary scores assigned by the project team on the basis of the proposed conceptualisation framework remained unchanged following discussion.

Table 8.1. Environmental criteria reviewed and sensitivity scores agreed during the stakeholder consultation process

Criteria	Final sensitivity scores (1 = low, 2 = moderate, 3 = high)	Basis of the score/comments
Population and human health		
Percentage population change (2006–2011)		
Decreasing	[a]	Omitted as sensitivity criteria
Increasing		
Population density per square km (2011)		
High	[a]	Omitted as sensitivity criteria
Low		
Total population (2011)	[c]	Omitted as sensitivity criteria
WFD RPA ground drinking water	3[a]	Statutory: protection priority
WFD RPA lakes drinking water	3[a]	Statutory: protection priority
WFD RPA river drinking water	3[a]	Statutory: protection priority
Biodiversity, flora and fauna		
Ancient woodlands		
Ancient woodland	3[a]	Value judgment: protection priority
Possible ancient woodland	3[a]	
Long-established woodland	2[a]	
Annex I habitats (Habitats Directive)	3[b]	Statutory: legal protection and indicator of environmental quality
Coastal habitats (saltmarshes)	2[a]	Statutory: protection priority and environmental quality
Forest inventory and planning system		
Deciduous	2[c]	Value judgment: environmental quality
Coniferous	1[c]	
Margaritifera-sensitive areas		
Catchments of SAC populations listed in S.I. No. 296/2009	3[b]	Statutory: legal protection and indicator of environmental quality
Catchments of other extant populations	3[b]	
Catchments with previous records but current status unknown	2[b]	
NHAs	3[a]	Statutory: legal protection
pNHAs	2[b]	Statutory: protection priority
Salmonid rivers	3[b]	Statutory: legal protection
SACs	3[b]	Statutory: legal protection
SPAs	3[b]	Statutory: legal protection
Woodland habitats	2[a]	Value judgment: environmental quality
Water		
Aquifer vulnerability		
High/extreme/rock near surface	3[b]	Value judgment: environmental quality
Moderate	2[b]	
Low/water	1[b]	
Aquifer categorisation		
Pure limestones that are designated as karst aquifers	3[c]	Value judgment: environmental quality
Pure limestones that are not designated as karstic aquifers, impure limestones and Precambrian marbles	2[c]	
Non-carbonate rocks	1[c]	

Table 8.1. Continued

Criteria	Final sensitivity scores (1 = low, 2 = moderate, 3 = high)	Basis of the score/comments
Groundwater source protection areas	3[a]	Statutory: protection priority
RPA nutrient sensitive areas (lakes)	3[b]	Statutory: protection priority
RPA nutrient sensitive areas (rivers)	3[b]	Statutory: protection priority
RPA recreational waters (lakes)	3[a]	Statutory: protection priority
RPA recreational waters (coastal/rivers)	3[a]	Statutory: protection priority
RPA water-dependent habitats (SACs)	3[b]	Statutory: protection priority
RPA water dependent habitats (SPAs)	3[b]	Statutory: protection priority
Wetlands	2[a]	Statutory: protection priority
WFD groundwater status		
Good	1[a]	Statutory: environmental quality
Poor	2[a]	
WFD lake status		
High	2[a]	Statutory: environmental quality
Pass/good/moderate	1[a]	
Poor/bad	2[a]	
WFD river status		
High	2[a]	Statutory: environmental quality
Pass/good/moderate	1[a]	
Poor/bad	2[a]	
Soils and geology		
Bedrock geology	[c]	Omitted as sensitivity criteria
Land cover (CORINE 2012)	[c]	Omitted as sensitivity criteria
Geoparks and geosites	3[b]	Statutory: international importance
Outcrops	2[a]	Value judgment: protection priority
Peatlands	2[b]	Statutory: protection priority
Soils	[c]	Omitted as sensitivity criteria
Well-drained soils	2[c]	Value judgment: environmental quality
Poorly drained soils	2[c]	Value judgment: environmental quality
Air and climatic factors		
Air quality	[c]	Omitted as sensitivity criteria
Air zones		
Dublin/Cork/cities	1[c]	Value judgment: environmental quality. Omitted as a sensitivity criteria
Rural areas	1[c]	
Coal-restricted areas		
Restricted	1[c]	Value judgment: environmental quality. Omitted as a sensitivity criteria
Unrestricted	1[c]	
Historical flood extents	3[a]	Statutory: risk status
Landscape		
Landscape character areas	[c]	Omitted as a result of current inconsistencies in the dataset
Scenic views and prospects	[c]	Omitted as a result of current inconsistencies in the dataset

Table 8.1. Continued

Criteria	Final sensitivity scores (1 = low, 2 = moderate, 3 = high)	Basis of the score/comments
Cultural heritage		
NIAH	2[b]	Statutory: protection priority
RMP	3[b]	Statutory: legal protection
Material assets		
Discharge licences	[c]	Omitted as sensitivity criteria
IPPC licences	[c]	Omitted as sensitivity criteria
Landfill sites	[c]	Omitted as sensitivity criteria
Licenced waste facilities	[c]	Omitted as sensitivity criteria
Quarries	[c]	Omitted as sensitivity criteria
Wastewater treatment plants and status	[c]	Omitted as sensitivity criteria
Water boreholes and source	[c]	Omitted as sensitivity criteria
Wind farms	[c]	Omitted as sensitivity criteria

CORINE, Coordination of Information on the Environment; IPPC, Integrated Pollution Prevention and Control; NHA, National Heritage Area; NIAH, National Inventory of Architectural Heritage; pNHA, proposed National Heritage Area; RPA, Record of Protected Areas; SPA, Special Protection Area.

[a]The preliminary score was maintained.

[b]The preliminary score was adjusted.

[c]No preliminary score was provided.

8.2 Stakeholder Feedback on the Webtool and Widget

Feedback on the testing of the ESM widget was, overall, positive; all participants considered the user manual (Appendix 2) easy to follow and the large majority indicated that the ESM webtool was user-friendly and use of the widget was intuitive. Participants highlighted the potential to apply the ESM webtool and ESM widget in the assessment of plans/programmes within their organisation. It was considered an excellent resource that allowed access to multiple datasets using one platform; in particular, the webtool could reduce time requirements for data gathering within the already short time generally available to make decisions, and it was considered a useful and robust tool to obtain a first-hand sensitivity overview at regional level.

A number of suggestions were made to improve the user manual, as well as the ESM webtool content and interface. These suggestions included adding new functionality (e.g. swipe tool and shapefile upload options), expanding data content and enhancing their visual representation (e.g. inclusion of new datasets and enhancing colour-coding) and improving the layout of the printed output (e.g. inclusion of a disclaimer, date and author and a wider geographical envelope). The suggestions have been incorporated and have significantly contributed to the improvement of the webtool.

8.3 Pilot Testing the Webtool: Sectoral Case Studies

The ESM webtool and ESM widget were piloted in two sectoral workshops relating to renewable energy and land use planning. The purpose of these sectoral workshops was to test the applicability of the visualisation and information capabilities of the ESM webtool and the reliability and usefulness of environmental sensitivity maps produced through the application of the widget for different sectors.

A sector-specific widget was developed for the workshops in order to include specific datasets relevant to each sector. For example, wind energy planning needs to take account of wind speed and distance from dwellings, whereas solar and biomass require due consideration of slope and aspect, among other factors. This sector-specific widget contains

relevant environmental datasets, buffer distances and scientific scores that have not been subject to consultation. For this reason, it is not included in the published webtool.

Participants applied the ESM widget to create environmental sensitivity maps for the counties of Clare and Kildare on the basis of a number of case studies developed to facilitate user testing. Feedback was sought from participants on the meaningfulness and usefulness of the produced maps. All feedback suggested that:

- the environmental sensitivity categories adopted in the mapped outputs (i.e. legend) are appropriate;
- the maps meaningfully highlight potential sensitivities, pointing to where development would need to be carefully considered and sensitively planned; and
- the maps provide additional insight that may be useful in the SEA process.

More importantly, the Environmental Assessment Officer from Clare County Council indicated that the ESM output compares very well with, and may actually be better than, the process undertaken by Clare County Council in December 2015 when undertaking the SEA of the County Development Plan (CDP) (CCC, 2015).

During the preparation of the Clare CDP and the associated SEA, an environmental sensitivity analysis was undertaken. The analysis was based on the approach and methodology presented in the GIS for SEA Manual (EPA, 2015), which also forms the basis for the preparation of sensitivity maps in the ESM widget. The Clare CPD SEA considerations were mimicked as far as possible during the sectoral workshop (i.e. certain datasets are not available in the ESM widget, such as nature reserves, and the level of detail in others differs, e.g. flood zones A and B are not available in the sectoral widget and historical flood events were used instead as a proxy). The assigned weights (or scientific scores) in the ESM also differed from those in the approach adopted by Clare County Council, thus influencing the results. Nevertheless, overall, the Clare County case study validates the applicability of the ESM webtool and ESM widget (subject to the differences in the available datasets and agreed scores).

Despite the differences in incorporated datasets and weights, the mapped outputs largely correlate in capturing the generic areas of sensitivity, particularly the higher sensitivity areas in the northern part of the county and along the river corridors (Figure 8.1). The map generated at the workshop using the ESM widget was perceived to be a more appropriate consideration of environmental sensitivities as it captures, among other areas, the highly sensitive zones along the coast/estuary and on the shores of Lough Derg, which are not identified in the map prepared by the county council.

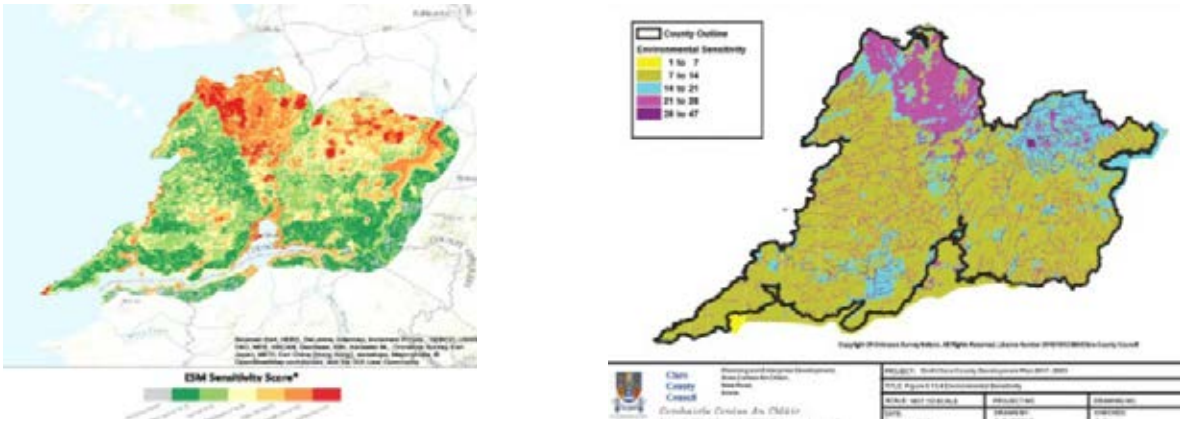


Figure 8.1. Environmental sensitivity of County Clare, prepared as part of the CDP SEA (left) (source: CCC, 2015) and environmental sensitivity of County Clare as per the sectoral workshop scenario (right).

9 Real-life Piloting of the ESM

9.1 Background

Sectoral testing of the ESM validated its applicability and illustrated the usability of mapped outputs in supporting systematic, transparent and evidence-basis SEA processes. Since project commencement, there has been strong practitioner and stakeholder interest in using the webtool. At project completion, a cost extension was granted to respond to this demand and pilot the application of the webtool (and widget) using Irish case studies to test and further refine the tool and ultimately make it publicly available. A number of improvements resulting from the real-life testing have further enhanced the usability of the webtool and ensure its future application. In this context, it has been a key objective of the cost extension to also explore options for long-term hosting of the ESM webtool and to make it publicly available for use by environmental authorities, including the Environmental Protection Agency (EPA), SEA practitioners, local authorities and key sectors. These options are discussed as part of the conclusions and recommendations of the real-life testing.

Extensive stakeholder engagement has been undertaken as part of the piloting to guarantee the development of a focused, participative, interactive and user-friendly webtool. Cross-sector government representatives, agencies, consultants, SEA practitioners and planners have been actively engaged throughout the project. All feedback suggests that the webtool provides an invaluable resource for SEA by facilitating access to multiple datasets and by generating maps that graphically and meaningfully highlight potential sensitivities, pointing to where development would need to be carefully considered and sensitively planned. The instant generation of context-specific maps without the need for specific technical skills overcomes GIS skill barriers and reduces the time required to gather and analyse data within the short time limits generally available to make planning decisions.

9.2 Scope of Pilot Tests

The objectives of the cost extension were two-fold, as described in the following subsections.

9.2.1 Piloting and refining the application of the ESM webtool

Applying the webtool and widget to a real-life SEA of a live sectoral land use plan will facilitate testing of the performance of the geoprocessing capabilities of the tool. This also includes reviewing the content, updating currently included spatial datasets as appropriate and adding new relevant datasets as far as possible, and adjusting the webtool's functionality. The focus on a land use plan reflects the fact that the large majority of SEAs undertaken in Ireland (approximately 75%) relate to this sector. Moreover, recent and current work on the National Planning Framework (NPF) and Regional Spatial and Economic Strategies (RSESs) provided an ideal live platform to test its applicability.

This objective can be divided into the following distinctive targets:

- Liaise with the selected live sectoral plan SEA and planning teams to define the scope of the SEA and GIS mapping needs, brief them on the benefits and limitations of applying the webtool and widget, and provide a working workshop to train the team on the use and applicability of these support tools.
- Identify potential data deficiencies (national, regional or local authority datasets) that may need to be integrated to further enhance the capability of the webtool and better support the live SEA and planning process. This also means integrating such datasets within the relevant SEA themes and assessing the effects they may have on webtool outputs.
- Verify and validate the scientific scores that were agreed during the project consultation process, which are embedded into the data in the webtool. This will entail active engagement with

the individuals involved in the live sectoral plan case study to review, and adjust if necessary, the current scientific scores and to examine the effects that any adjustments may have on webtool outputs.
- Review existing functionality within the webtool and identify additional improvements that can contribute to further enhancing its applicability.
- Assess the performance of the webtool in a real-life setting, particularly in relation to server performance because of simultaneous use by multiple agencies. Applying the ESM to a live SEA and planning process will enable the identification of any server capacity limitations and contribute to determining the system requirements for its long-term hosting and maintenance.
- The above tasks also include communication with the appointed SEA consultants; the feedback and comparison with professional GIS analysis will contribute to verifying the applicability of the webtool and the validity of its outputs.

9.2.2 Exploring options for long-term hosting of the ESM webtool

The extensive engagement and consultation with various stakeholder groups throughout the project to date and the resultant awareness of the developed outputs from the project have garnered significant interest from a number of government departments in the application of the webtool, including the Department of Culture, Heritage and the Gaeltacht (DCHG), the Department of Communication, Climate Action and the Environment (DCCAE), the National Parks and Wildlife Service (NPWS), the Marine Institute and the Sustainable Energy Authority of Ireland, as well as regional and local authorities and private consultancies. Given the significant interest in the webtool and its potential to enhance SEA practice, it is crucial that it is made publicly available for practical use and application. Hence, a further critical activity, planned as part of the proposed extension period, is the exploration of available options for long-term hosting/co-hosting and updating of the ESM webtool to enable ongoing access and use by environmental authorities, SEA practitioners, local authorities and key sectors.

This objective includes the following targets:

- Explore possible linkages with other currently available GIS mapping tools, including EPA links to the SEA search and reporting tool via Eden (https://gis.epa.ie/EIS_SEA/), the Department of Housing, Planning and Local Government's (DHPLG) MyPlan.ie (http://www.myplan.ie) and Ordnance Survey Ireland's (OSi) GeoHive (http://www.geohive.ie/), as well as potential options with the DCCAE. Hosting the ESM webtool and ESM widget on any existing web platform will take account of the operating system and programming language requirements, as both the webtool and widget have been developed using the most up-to-date Environmental Systems Research Institute (Esri) technology based on the ArcGIS application programming interface (API) for JavaScript.
- Migrate the webtool and widget to their new hosting. When a suitable website has been identified and a hosting agreement reached, the ESM project team will provide all relevant files, including the geodatabases and modelling flows that make up the ESM widget, and provide technical documentation and support to facilitate the transfer. This also includes basic training on the maintenance of the webtool.

The delivery of these aims and objectives as part of the cost extension are discussed in the following chapters.

10 Case Study 1: National Planning Framework

The NPF is the government's high-level strategic plan for shaping the future growth and development of Ireland until 2040. It is a framework to guide public and private investment, to create and promote opportunities for people and to protect and enhance the natural and built environment. The government published the finalised NPF together with a 10-year national investment plan as one vision (Project Ireland 2040) on 16 February 2018.

10.1 Planning Context

The NPF sets a new strategic planning and spatial development context for Ireland for the period between now and 2040. The NPF defines a high-level framework for the co-ordination of a range of national, regional and local authority policies and activities, planning and investment. These include the goals of sustainably accommodating population growth, strengthening urban and rural places through proportionate provision of housing, community services and employment, and releasing the potential of marine and terrestrial resources. The delivery of national policy objectives is to be driven forward by national investment and implemented regionally through RSESs (currently in preparation) and locally through CDPs.

The NPF has been subject to SEA, under the requirements of European Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment (the SEA Directive), as implemented in Ireland through the European Communities (Environmental Assessment of Certain Plans and Programmes) Regulations [statutory instrument (S.I.) No. 435/2004] (Office of the Attorney General, 2004a) and the Planning and Development (Strategic Environmental Assessment) Regulations 2004 (S.I. No. 436/2004) (Office of the Attorney General, 2004b), as amended.

The NPF process was led by the DHPLG and overseen by a high-level cross-departmental steering group, chaired by the Minister for Housing, Planning and Local Government and consisting of senior personnel across government departments.

An advisory group was also set up to facilitate the participation of a range of interests under the broad umbrellas of economic, environment, social and knowledge sectors. An environmental steering group (RPS Group consultants) was also established to oversee the integration of environmental requirements in the preparation of the NPF, i.e. SEA, appropriate assessment (AA) and Strategic Flood Risk Assessment (SFRA). See www.npf.ie for further information.

10.2 Webtool Application

The ESM project team held an initial meeting with the DHPLG planning team in charge of leading the preparation of the NPF to discuss the application of the webtool to the NPF SEA process. It was agreed that the webtool could be used as a support tool.

As part of the SEA consultation process, an alternatives workshop was organised to inform the preparation of the NPF. The workshop was the first step in examining the range of high-level options available as part of a long-term growth strategy for the NPF, with a view to developing a number of scenarios and potential viable combinations for evaluation, final testing and recommendation. The workshop engaged over 40 governmental, industry and academic representatives.

The ESM project team took part in the workshop, providing an outline of the ESM webtool and demonstrating its functionality, including the method, content and outputs of the widget, to participants. The objective was to provide participants with an understanding of what ESM can do and how it can be applied. During discussion of alternatives, numerous references to the webtool were made, which supported discussions. Nevertheless, the high-level nature of the options considered restricted the direct applicability of the webtool in informing the development of the NPF alternatives.

The ESM project team liaised with the SEA team during the assessment of the preferred alternative and the preparation of the Environmental Report (ER). The project team provided spatial analysis support as

required, as well as contributing to the assessment of NPF policies and actions that had a spatial component by making use of the widget.

10.3 Results and Outputs

The NPF SEA ER contains a section on ESM (refer to section 5.3 of the NPF SEA ER for full details – RPS Group, 2017). This section introduces the ESM webtool as a useful method for "presenting a visual overview of the relative sensitivity of areas, particularly where they overlap, in order to provide a more strategic and informed approach to planning" (NPF SEA ER – RPS Group, 2017, p. 115). It includes sensitivity maps for each of the five metropolitan city areas and their associated hinterlands, as well as a national sensitivity map, generated based on a set of defined and justified variables that specifically address NPF-related considerations (Figure 10.1).

In addition, the ESM webtool was further applied to support the assessment of key enablers for all five cities. For Dublin enablers, for example, greenfield areas for housing have been identified in order to progress the sustainable development of Adamstown, Cherrywood, Clonburris and Clongriffin. However, this requires consideration of the intrinsic sensitivity of the receiving environment at the various planning tiers. This consideration was captured by examining the strategic areas in the context of the ESM webtool outputs (Figure 10.2). The results of the environmental sensitivity mapping illustrates that the general area of Adamstown has moderate sensitivity, mainly as a result of groundwater resource protection considerations (Figure 10.2a). Greenfield areas to the north of the current urban area contain pockets of higher sensitivity associated with cultural heritage, and to the south of the railway line the potential for cumulative effects increases along the Grand Canal as a result of its ecological significance. Aquifer vulnerability considerations render the general area of Cherrywood moderately sensitive in environmental terms (Figure 10.2b). The potential for cumulative effects increases in areas of high and very high sensitivity, resulting from the overlapping occurrence of susceptible biodiversity (woodland habitats), drinking surface water and cultural heritage features on the landscape. The area around Clonburris is characterised by low environmental sensitivity on account of its urbanised nature (Figure 10.2c). Aquifer vulnerability considerations result in the lands north and south of the currently urbanised area to increase in sensitivity. The vicitinity of the Grand Canal is characterised by high sensitivity due to ecological considerations. The lands around Clongriffin are generally environmentally robust, with some areas having moderate sensitivity as a result of groundwater protection considerations and discrete pockets of high sensitivity where cultural heritage features occur (Figure 10.2d). Changes to the quality of water resources as a result of development in this area have the potential to result in secondary cumulative effects on the highly sensitive coastal environment.

The SEA ER includes mitigation measures that specifically refer to ESM. For example, the "Policy Area – A New Way Forward" (Chapter 2 of the draft NPF) includes a general mitigation that states that "The EPA-funded Environmental Sensitivity Mapping (ESM) Webtool which has been used in the assessment of the NPF will be applied at the lower tiers of planning to inform planning decisions in terms of zoning and provision of services. Future plans e.g. RSESs and CDPs, should look to investigate the potential application of the Webtool to strategically inform integrated land use management to better plan and address cumulative analysis of impacts on the environment" (NPF SEA ER – RPS Group, 2017, p. 142). Similarly, specific policies have proposed SEA mitigation measures linked to the ESM, such as policy 10 of the "Policy Area: Making Stronger Urban Places", where it is proposed that "Many existing urban areas already located in close proximity to European Sites. Overall, although densification of the existing urban space is desirable, any urban growth and development should be supported by a quality site selection process that addresses environmental concerns such as landscape, cultural heritage and biodiversity as a minimum. The Environmental Sensitivity Mapping Tool should be utilised to support such a study" (NPF SEA ER – RPS Group, 2017, p. 145). The consideration of the ESM webtool in the proposed SEA mitigation measures provides a solid foundation for the application of the webtool in other planning tiers.

On 16 February 2018, the government published the finalised NPF, which, together with the National Development Plan, form Project Ireland 2040 (https://www.gov.ie/en/campaigns/09022006-project-ireland-2040/), the government's vision for development in Ireland over the next 20 years.

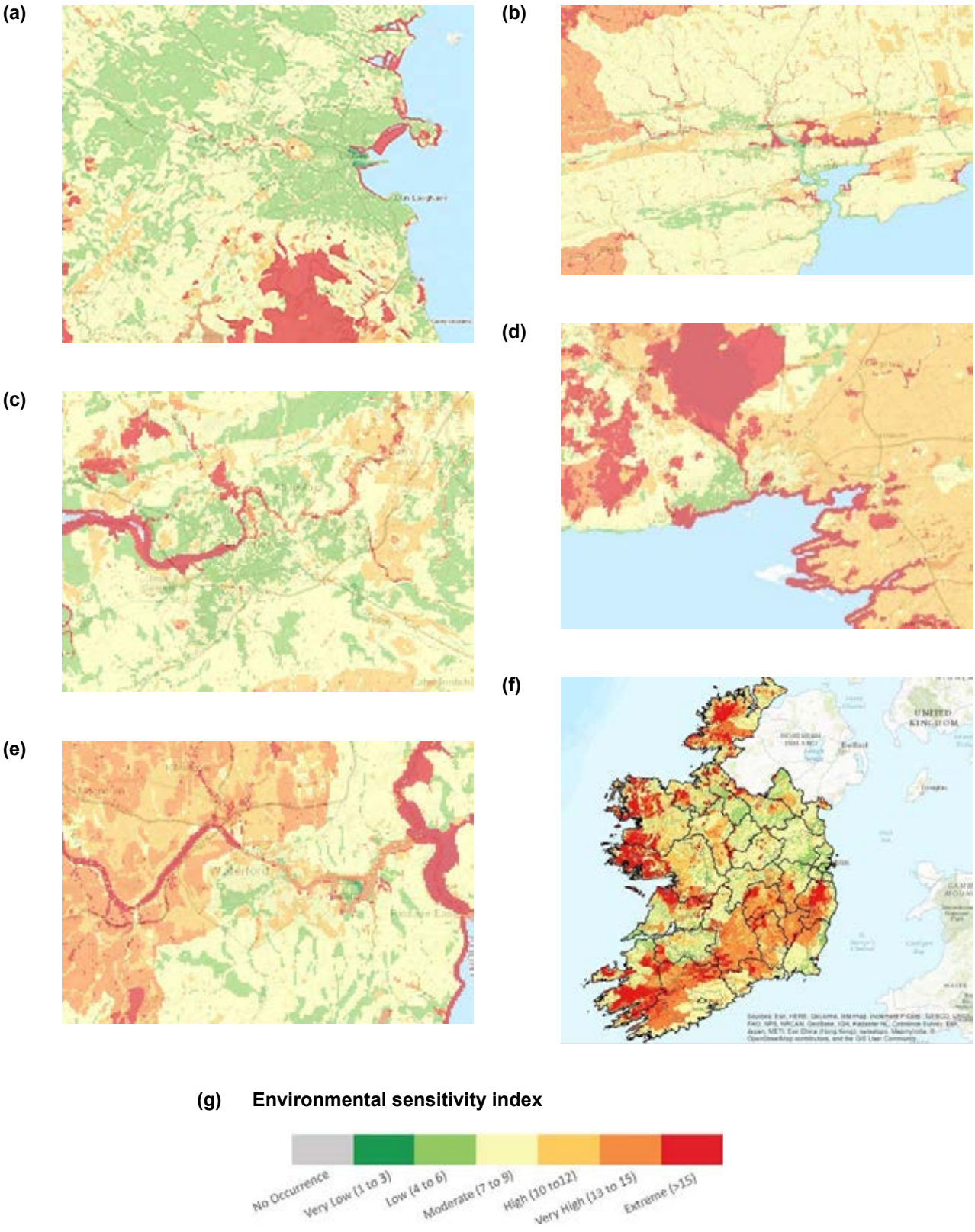


Figure 10.1. Environmental sensitivity maps produced through the ESM webtool to support the baseline section of the SEA ER. (a) Dublin city area; (b) Cork city area; (c) Limerick city area; (d) Galway city area; (e) Waterford city area; (f) Ireland; (g) ESM Sensitivity Index. Source: NPF SEA ER prepared by RPS Group plc (2017).

Figure 10.2. Environmental sensitivity maps produced through the ESM webtool to support the assessment of city enablers in the SEA ER. (a) Adamstown; (b) Cherrywood; (c) Clonburris; (d) Clongriffin. Source: NPF SEA ER prepared by RPS Group plc (2017).

In Chapter 11, "Assessing Environmental Impact", specific reference is made to the ESM webtool as follows:

> In preparing the NPF, an Environmental Sensitivity Mapping (ESM) tool was used in the SEA and environmental assessments. ESM is a method for identifying at a strategic level, environmentally sensitive areas and to help inform cumulative and in-combination effects on the environment. It also provides a visual overview of the relative sensitivity of areas, particularly where they overlap, in order to provide a more strategic and informed approach to planning. (DHPCLG, 2018)

This recognition of and support for the ESM webtool reflects the value and usability of the tool in assisting with the SEA process. This will be an important consideration for the future application of the tool in other SEA and environmental assessments, including as part of the preparation of the RSESs, CDPs, local strategies and future marine spatial planning frameworks.

10.4 Stakeholder Feedback

Feedback on the applicability and limitations of the webtool was gathered by the project team immediately after the alternatives workshop. This was based on observations as well as direct comments from the participants and the NPF SEA team. Overall, the feedback was positive and participants were interested in applying the webtool (a few wanted to know when it would be publicly accessible). Nevertheless, SEA consultants highlighted that the NPF policies and considered alternatives are too strategic (i.e. little detail given regarding where and how) for the ESM to be useful for informing the preparation of the framework and supporting the SEA process. Despite this, there was overall support for the potential benefits of environmental sensitivity analysis. The

Marine Institute noted that marine spatial planning needs to communicate and integrate with terrestrial planning and, therefore, the ESM would benefit from the inclusion of offshore data. The Marine Institute is developing sensitivity maps and opportunities/ constraints mapping, so the representative suggested that efforts could be co-ordinated to provide a comprehensive national offshore and onshore overview of environmental assets and sensitivities, as well as an overall assessment tool.

On the technical side, a participant observed that the ESM colour ramp seems to indicate that red areas are no-go areas and suggested changing the colour ramp of the ESM index. In addition, the ESM project team observed that the connectivity issues (i.e. poor Wi-Fi speed) during the workshop affected the usability of the ESM; in particular, some layers did not display or took a long time to display, and running the widget did not render any results in some cases.

The initial feedback was followed by a more formal online survey, which targeted the NPF planning and SEA teams. It was considered that the workshop participants did not get an appropriate opportunity to individually explore and apply the webtool, and that NPF planning and SEA teams could provide more valuable feedback on the basis of their experience. Feedback was gathered on the perceived contributions and limitations of the ESM webtool with regard to the drafting of the NPF and the associated SEA ER (see Appendix 5).

10.5 Results from the Online Survey

The survey was distributed to five NPF stakeholders for completion and two responses were received. From the completed survey responses, it is evident that the ESM webtool was considered useful when applied at the national planning level, with both respondents agreeing that “the Webtool improved the SEA process”. When the stakeholders were asked how the ESM webtool enhanced the SEA process, the following answers were selected:

- Centralised access to spatial datasets in a single web interface facilitated rapid and combined exploration of issues.
- Exploration of environmental sensitivity outputs facilitated identifying potential land use conflicts.
- The sensitivity maps informed the development and assessment of alternatives.
- The sensitivity maps enabled exploration of potential cumulative effects.
- The ESM webtool contributed to assessment transparency.

When the stakeholders were asked if they would use the ESM webtool again, they replied positively, stating that it was useful in supporting the SEA process.

The two respondents concurred with the harmonised scores assigned by experts in the SEA/environmental field during the tool development workshops; furthermore, in terms of functionality, they agreed that the ESM webtool is easy to use and very intuitive. In terms of recommendations, when the stakeholders were asked if there were any important SEA-relevant spatial datasets missing in the webtool, one of the respondents felt that the addition of “flooding datasets would greatly enhance the tool; ecosystem services mapping would also assist when available; and maritime spatial planning in due course”.

When the stakeholders were asked if the webtool could benefit from any additional functionality, one respondent felt that it did not require anything at this stage but hoped that it would be flexible enough to respond to evolving practices over time.

Regarding technical difficulties, the stakeholders were asked if they had experienced any problems applying the ESM webtool or ESM widget. One of the two respondents noted that the tool can take time to run but felt that this was to be expected.

With regard to final comments and recommendations, the following responses were received:

- The webtool is a beneficial tool but it is reliant on the baseline datasets available which can be a key limiting factor. (Respondent no. 1)
- Very good tool to assist plan makers and has great potential around alternatives. (Respondent no. 2)

From the feedback received from the NPF case study stakeholders, it is clear that the ESM webtool is considered useful in supporting the SEA process. Future improvements required relate to the availability of spatial datasets such as flooding, ecosystem services and marine spatial planning information (flood

and ecosystem services have been included as a result; marine spatial datasets are beyond the scope of the project). As data have become available during the project and the cost extension, they have been reviewed by the ESM project team and incorporated into the webtool when relevant. For example, predicted flood extent mapping was incorporated as soon as it was publicly available. In terms of functionality, the webtool and widget have been reviewed since the survey was circulated and capabilities have been improved to ensure that less time is required to run the tool effectively. All recommendations have been duly considered and detailed responses are provided in section 11.3 and summarised in Appendix 5.

11 Case Study 2: Regional Spatial and Economic Strategies

For each of the three regions, the regional assemblies are in the process of preparing their own strategies, known as RSESs, in accordance with the framework set out by the NPF. County and city development plan review cycles will align with their respective regional strategies, ensuring that the shared vision is carried through to the local planning level.

11.1 Planning Context

The objective of the RSESs of the three regional assemblies is to provide long-term planning and economic frameworks for the regions, which will be consistent with the NPF and the economic policies or objectives of the government.

The invitation to tender for professional services for SEA of the Eastern and Midland Regional Assembly (EMRA), the Southern Regional Assembly (SRA) and the Northern and Western Regional Assembly (NWRA) RSESs includes a note in the "Terms of Reference" stating that:

> The All-Island Research Observatory in Maynooth University (AIRO) is working closely with the Department of Housing, Planning and Local Government on production of the National Planning Framework (NPF), part of the SEA of this process has been using the EPA funded Environmental Sensitivity Mapping (ESM) Webtool. The contracting authority requests that Tenders include the use of this Environmental Sensitivity Mapping Webtool for environmental sensitivity analysis purposes. (EMRA, 2017, p. 6)

Each of the three regional assemblies is preparing its own RSES, which are expected to be completed in 2019. The initial draft deadline of May/June 2018 would have facilitated the use of the ESM webtool through the various SEA stages. The preparation of the RSESs involves the relevant local authorities, working together with relevant stakeholders, including the Minister and DHPLG, the Department of Public Expenditure and Reform, and other interests, to put in place a regional co-ordination framework for the relevant statutory development plans at local authority level.

The preparation of the RSESs is subject to SEA under the requirements of the European SEA Directive as implemented in Ireland through S.I. No. 435/2004 and S.I. No. 436/2004 (Office of the Attorney General, 2004a,b). RPS Group consultants were commissioned to provide professional services for the SEA of all three RSESs.

11.2 ESM Webtool Application

11.2.1 Training for RSES-SEA consultants

Prior to applying the ESM webtool and ESM widget in the second case study, the ESM project manager conducted an in-house training exercise with one of the RPS Group SEA team's GIS consultants. This was to provide the consultant team with an overview of recent developments and data updates within the ESM webtool and ESM widget since its application as part of the SEA of the NPF, as well as to explain how it could be used to assist with the SEA of the RSESs. This proved to be a useful two-way exercise as the consultant was able to highlight data gaps within the tool, which became apparent during the pre-draft issues stage of the RSESs. For example, additional socio-economic spatial data on health, housing stock and labour force, as well as information on rail and road networks, airports, ports and broadband provision, have all since been included in the ESM webtool, ensuring more comprehensive datasets for the SEA themes "population and human health" and "material assets". Following the exercise, the RPS Group GIS consultant was able to provide training to her colleagues involved in providing SEA assistance to each of the three regional assemblies.

11.2.2 Demonstration of the ESM webtool at a RSES-SEA scoping workshop

On 13 March 2018, the RPS Group hosted a SEA scoping workshop in Dublin to assist with the preparation of the RSESs. The aims of the workshop were to understand key environmental issues for

each of the three regions and to discuss tools that could assist with the SEA of the RSESs. The workshop was designed around four key aspects: discussing environmental issues; the development of environmental guiding principles; the development of alternatives; and the potential of applying the ESM webtool to the RSES SEA process. The workshop was attended by 32 governmental, regional assembly, public body and academic representatives.

As part of the workshop session on the ESM webtool, a presentation was given on its functionality, including the methods, content and outputs of the widget. In addition, the presentation reflected on particular environmental issues arising from the initial RSES consultation stage [the ESM demonstration was applied to key specific aspects included in the EMRA issues paper (https://emra.ie/regional-strategies/issues-paper/)]. These issues related to biodiversity, climate change, urban and rural growth settlements, water quality and infrastructure developments. The ESM webtool and ESM widget were applied in hypothetical regional scenarios to consider these issues and help identify potential spatial conflicts, opportunities and development alternatives.

Feedback on the application of the webtool was gathered by the project team during the RSES-SEA workshop. This was based on observations as well as direct comments from the participants and the SEA team. Overall, the feedback was positive and participants were interested in applying the webtool to their own plans/programmes (a few wanted to know when it would be made publicly available). In particular, some of the participants proposed using the webtool and widget in the development and evaluation of alternatives as part of the SEA process. One of the SEA consultants also suggested linking the ESM with the government's website, Myplan.ie, and incorporating some of the zoning data from local authority development plans; however, given that zoning is temporal (i.e. subject to the local development plan period), this may require regular updating.

The demonstration was well received by the stakeholders at the workshop, and a number of regional assembly representatives/planners expressed an interest in receiving further information, guidance and one-to-one training on the application of the ESM webtool. The ESM project team therefore offered to visit and provide one-to-one training sessions to each of the regional assemblies. Nevertheless, only the EMRA accepted this invitation.

11.2.3 Eastern and Midlands Regional Assembly SEA workshop

A subsequent training session was held at the offices of the EMRA on 24 April 2018. The session was attended by five EMRA-RSES staff and two members of the ESM project team, who facilitated the demonstration and training exercise. In terms of the potential of the ESM webtool, the EMRA planners discussed the applicability of the webtool in assisting with the identification of growth centres and settlements. It was noted that the EMRA team were in the process of exploring potential development options based around new policy and catchment boundaries, including the metropolitan area. The EMRA planners believed that the ESM webtool would be particularly useful for investigating capacity issues as part of its growth strategy, namely examining potential theoretical urban forms such as monocentric, polycentric, dispersed, economic and low carbon/climate resilient. The planners acknowledged that they were working with Irish Water, the National Transport Authority and the Office of Public Works (OPW) around water, wastewater, transport and flood risk management issues and capacity. The ESM webtool could assist with environmental sensitivities and capacity issues as part of this planning process. In particular, the EMRA team thought that the ESM webtool could support the development of a regional green infrastructure strategy. The EMRA planners also acknowledged that RPS Group consultants had specifically recommended the use of the ESM webtool to explore environmental as well as socio-economic sensitivities as part of the RSES-SEA process.

With regard to the recording of the ESM analyses, one of the EMRA planners suggested that it would be important to keep a record of the various ESM scenarios examined and produced throughout the planning process. The tracking of geographical extents and the variables used to generate environmental sensitivity maps could help inform decision-making and the consideration of alternatives as part of the plan-making process. The planner believed that this would be particularly important when communicating

progress and outcomes to stakeholders, including elected members, throughout the key planning stages.

In relation to data requirements, two of the EMRA members noted that they expected offshore/marine data to be included in the webtool to assist with the plan-making process, particularly in relation to integrated coastal management, which was a requirement of the RSES. The ESM project manager explained that offshore data were beyond the original scope of the ESM project. However, it was acknowledged that marine data would provide useful contributions to existing datasets and should be explored as further iterations of the project. It was also noted that comprehensive offshore data were available in Ireland's Marine Atlas (https://atlas.marine.ie) and would be used as part of the marine spatial planning process, currently ongoing. Additional specific data requirements identified by the EMRA staff included:

- a network of canal and river pathways/walks;
- United Nations Educational, Scientific and Cultural Organization sites, i.e. Dublin Bay Biosphere (note that the viewer already includes data for World Heritage Sites and Tentative World Heritage Sites);
- Record of Protected Structures;
- marine archaeology, i.e. shipwrecks; and
- offshore renewable energy resources.

Since this workshop, the ESM webtool has been updated to include data on the Grand and Royal canals and Dublin Bay Biosphere. As data on the Record of Protected Structures are under review (at the time of writing this report), it has not been possible to include this information; however, it will be recommended for incorporation in future iterations. Offshore data are beyond the remit of this project; however, this will also be recommended for inclusion as part of the ongoing development of the ESM webtool. As noted previously, all recommendations have been duly considered and detailed responses are discussed in section 11.3 and summarised in Appendix 5.

Survey results

At the time of finalising this cost extension (July 2018), the preparation of the RSESs for each of the regional assemblies was still ongoing. To date, no draft RSES or ER has been published and, consequently, it has not been possible to determine exactly how the ESM webtool assisted with the plan-making and SEA processes. However, the feedback from the RSES-SEA consultants and EMRA respondent does suggest that the ESM webtool is being used and is considered useful in informing both SEA and planning processes.

The five EMRA planning team representatives who attended the ESM session were asked to respond to the online questionnaire; however, one of them responded on behalf of all EMRA planning team members. The respondent confirmed that he had applied the webtool to the RSES and that it had improved the SEA process, agreeing that:

- The ESM outputs reduced screening/scoping time.
- Centralised access to spatial datasets in a single web interface facilitated rapid and combined exploration of issues.
- Exploration of environmental sensitivity outputs facilitated identification of potential land use conflicts.
- The sensitivity maps informed the development and assessment of alternatives.
- The ESM webtool enabled examination of the effect that stakeholder values can have on the overall sensitivity of different areas.
- The sensitivity maps enabled exploration of potential cumulative effects.
- The ESM webtool contributed to assessment transparency.
- The ESM webtool contributed to assessment consistency (e.g. comparability across regions).

The respondent agreed that this was a very useful tool to inform SEA and planning and concurred with the harmonised scores assigned by experts in the field. With regard to exploring different sensitivity scenarios, the respondent confirmed that he had tried this by selecting different criteria (using different spatial data layers). He also explored different sensitivity scenarios by adjusting the weights applied to different SEA themes.

In relation to functionality, the respondent agreed that the webtool was easy to navigate and use, but he had to read the user manual to learn how to apply the webtool. In terms of data gaps, he noted that "Not all the layer list datasets are available for input into the tool" and that the availability of a "graph widget" would benefit the webtool. He confirmed that he had not

encountered any technical difficulties when applying the webtool and found the ability to add shapefiles "an excellent feature".

Since the workshop and circulation of the online survey, RPS Group consultants have been asked by the EMRA to use the ESM webtool to assist it with the spatial analysis of 37 towns as part of its growth strategy. The ESM project team have assisted by exploring one potential town expansion scenario and producing ESM outputs. These will guide and assist the SEA consultants with the exploration of the remaining 36 town examples. These output maps will be significant in helping the EMRA to record and document the geographical extents and the variables used to generate environmental sensitivity maps as part of its growth strategy, which will, in turn, help to inform the consideration of alternatives in the plan-making process and, ultimately, decisions.

11.2.4 ESM webtool application by RSES-SEA consultants

The RSES-SEA consultants were invited to participate in the online survey to provide more specific and valuable feedback on the basis of their experience. Three out of the four consultants completed and returned the questionnaire. Despite the limited responses, all agreed that the webtool improved the SEA process, giving a range of reasons, including:

- identifies potential land use conflicts;
- the option to weight environmental themes enabled factoring in scoping priorities and/or concerns;
- enables exploration of potential cumulative effects;
- contributes to assessment consistency (e.g. comparability across regions); and
- the provision of an audit trail of the information used to support assessments.

All three consultants also concurred that the webtool was a useful support tool for SEA. In terms of the scientific scores, two of the consultants agreed with the harmonised scores assigned by experts in the field, but the third consultant found (some of) the assigned scores inadequate and adjusted them by applying a higher weight to the related theme. This consultant suggested that further guidance should be provided in the user manual on the scientific scores.

The three consultants confirmed that they explored different sensitivity scenarios by selecting different criteria (using different spatial data layers). One individual recommended the inclusion of worked examples to help illustrate how the tool can be applied to a broad range of programmes/plans and scenarios. Two consultants also confirmed that they explored different sensitivity scenarios by adjusting both environmental criteria and weights; the other adjusted weights only.

With regard to the user interface, two of the consultants found the functionality of the ESM webtool to be intuitive, with one confirming that they had read the user manual and watched the demonstration video to learn how to apply the webtool. The third consultant stated that the webtool interface was not user-friendly as it was "sometimes confusing why certain layers are not switching on until you realise the parent layer also needs to be on".

In terms of data gaps, the consultants suggested the inclusion of CFRAM data; historical landfills; EPA/ Geological Survey Ireland (GSI)/Forest Service 2006 soil mapping at 50,000 scale with soil types; County Geological Site/Geological Heritage Areas; and the locations of water treatment plants. For additional functionality, one consultant recommended incorporating additional zoom levels and an option to zoom to the study area.

When asked if any technical difficulties were experienced, only one consultant remarked that "sometimes the large national datasets take time to load, but this is expected".

All of the recommendations have been considered and are addressed collectively in section 11.3 and Appendix 5.

11.2.5 ESM webtool demonstration at the National SEA Forum workshop

A demonstration and training workshop was organised for the members of the National SEA Forum on 23 May 2018. At the beginning of the workshop, the ESM project manager demonstrated how to use the ESM webtool viewer and ESM widget. The workshop members were asked to participate in a specifically designed exercise requiring them to apply both the webtool and the widget and then answer questions

on its usability. Given the practical nature of the exercise and workshop, a number of comments and observations were recorded by the project team during the event. Following the workshop, the exercise and questionnaire were re-circulated to the participants to provide them with another opportunity to offer their feedback on the webtool not captured during the event.

Overall, the forum members agreed that the ESM webtool was useful in bringing a wide range of environmental and socio-economic data together and would make a positive contribution to the SEA process. Many of the more focused comments related to user and technical improvements. These included suggestions on the provision of additional guidance on how to use the webtool, such as links to a video tutorial; instructions and/or indication regarding the length of time required for geoprocessing and rendering results (i.e. visual timer); and indicating where the produced sensitivity maps should be "printed" (i.e. in the widget) for clear reporting on criteria and weights applied and effective use of output maps. Technical revisions were also proposed, including additional functions allowing users to download the sensitivity output, a "select all" option for the data layers in the viewer and linking/aligning data layers between both the widget and the viewer. All of these recommendations have been considered and are addressed in section 11.3 and Appendix 5.

11.3 Response to Stakeholder Feedback

The purpose of the online questionnaire was to seek user feedback on the applicability of the ESM webtool and to incorporate any final revisions to enhance its performance. Refer to Appendix 5 for a summary of all responses received during the stakeholder engagement phase and the project team responses.

In terms of enhancing the SEA process, one suggestion related to the inclusion of real-world examples in the user manual. The project team were of the opinion that the provision of real-world examples may potentially influence and/or result in a biased view of how users weight different scenarios. The role of the weighting tool is to allow for context-specific consideration of potential sensitivities. In response to this suggestion, the project team has revised the user manual (see Appendix 2) to include a reference to a hypothetical example involving the protection of ecological sites and assigning a weight to the theme of "biodiversity, flora and fauna".

With regard to the future application of the ESM webtool, stakeholders acknowledged the importance of keeping data up-to-date and relevant. It has been suggested on a number of occasions that the webtool should link directly to live datasets. The project team have been updating the webtool as new and relevant data become available as further described below. At the time of writing, the viewer contains 107 spatial datasets (the first version contained 70 datasets). As the widget uses merged and aggregated data, it is not possible to link the webtool to live datasets. The recommendations in terms of the future direction of this project include maintenance arrangements and securing a permanent host to accommodate and regularly update the webtool and datasets.

In relation to the scientific scores applied in the widget, it was recommended that further guidance should be provided in the user manual; however, a detailed explanation of the scientific scores is already provided in the annex of the user manual. The project team have since included on the website terms of reference to refer to this user manual before using the widget. The terms of reference have also been revised to incorporate a link to a narrated online tutorial video, which will be available once the project goes live to the public, and a statement indicating that the widget will take 2–3 minutes to render results. As part of any future iterations, the ESM webtool should incorporate a timer indicator as part of its functionalities to show how long the rendering process is expected to take. This was examined as part of the cost extension; however, the project team does not have the technical capacity or skillset to script a new widget and instead clarification is provided in the user manual and in the terms of reference on the website.

In terms of navigation and ease of use, one stakeholder noted that it was unclear why certain layers were not switching on in the viewer. The project team has since revised the user manual to include the following statement: "Note that the parent SEA theme must be ticked for the selected sublayers to display". This should ensure that users are more aware of the need to switch on the parent theme layer from the outset. It is noted that this is a standard

feature in other online data viewers.[1] With regard to technical redesign and reconfiguration suggestions, it has not been possible to fulfil all of these requests. For example, some stakeholders requested that the sensitivity output be downloaded in another format (i.e. as a GeoTIFF). The ESM project team explored the viability of this request; however, the current set-up of ArcGIS Online (AGOL) is restricted and cannot incorporate this functionality. This would require a team with coding expertise, which was unavailable as part of this cost extension. More details on stakeholder requests and responses are provided in Appendix 5.

A number of additional datasets were recommended by stakeholders for inclusion in the webtool, which have since been considered and included by the project team. For example, flood extent mapping for the current scenario, provided by the OPW, has been included in the webtool as well as data on infrastructure provision, such as road and rail networks and broadband access. Additional socio-economic data have also been included, such as population change, health, labour force, housing stock and journey to work times. Data on historical landfills were requested from the EPA; however, the EPA is not able to distribute these data for external use and recommended contacting each local authority for this information. It is noted that the gathering of data at local authority level is beyond the scope of this project and therefore the dataset has not been included at this stage of the project. The Royal and Grand Canal waterways have been included, as well as the Dublin Bay Biosphere.

The EPA/GSI/Forest Service 2006 soil mapping has since been included in the webtool in addition to the County Geological Sites from GSI. Ecosystem services mapping (from the NPWS ecosystem services mapping project) has also been incorporated in the webtool. The locations of water treatment plants were requested, but Irish Water were unable to provide these data as “it would pose a risk to the security of Irish Water’s water treatment plants with potential risk to public health from drinking water supplies” (Irish Water, July 2018, personal communication). Marine spatial planning data, i.e. offshore mapping, were outside the scope of this project; however, these data are available in Ireland’s Marine Atlas and will be recommended for future inclusion.

With regard to additional functionality, although it was suggested that additional scaling levels would be useful, the project team has already incorporated a number of different scales into the webtool (in response to an initial request from the RPS Group at the beginning of the RSES’s case study). At its current service capacity, it is not possible to render results at any further scales.

1 Department of Agriculture, Environment and Rural Affairs. NIEA Natural Environment Map Viewer. Available at: https://appsd.daera-ni.gov.uk/nedmapviewer/ (accessed 11 January 2019).

12 Conclusions and Recommendations from the Life Testing

Stakeholder responses were limited but focused and feedback highlights the positive contribution that the ESM webtool has made to both (1) the development of the NPF and associated SEA and (2) the early and formative stages in the development of the RSESs and associated SEA. In fact, all of the survey respondents unanimously agreed that the ESM webtool improved the SEA process and confirmed that they would use the webtool again in supporting SEA. In particular, the ability to use the ESM webtool to analyse environmental sensitivity was highlighted as important in informing decision-making and the consideration of cumulative/in-combination effects as well as alternatives during the plan-making process. Piloting the ESM has also contributed to ensuring that the most-up-to-date and SEA-relevant environmental and socio-economic data are provided in a user-friendly interface.

As described in section 11.3, detailed instructions have been incorporated in the terms of reference for the ESM. These include links to the revised user manual and online video tutorial. Also included is clarification that rendering can take 2–3 minutes before mapping outputs are processed. These changes provide more guidance and certainty to future webtool users. Additional explanatory notes have also been included in the user manual to help users navigate the interface, select and display data, and explain the use of scientific scores in the widget.

With regard to the future application of the ESM webtool, stakeholders reiterated the importance of ensuring that data are kept up-to-date and relevant. The project team have maintained and updated the webtool and, at the time of writing, the viewer contains 107 spatial datasets. The webtool has the flexibility to respond to evolving data and functionality demands over time.

Notwithstanding, the ESM project team recognises the importance of maintaining the webtool and therefore recommends that maintenance arrangements and the securing of a permanent host to accommodate and regularly update the webtool and datasets must be considered as part of the future direction of this project.

As requested on a number of occasions, the logical progression for this ESM webtool would involve the incorporation of marine data to assist with the marine spatial planning process and offshore renewable energy development. This ongoing demand for the application of the ESM webtool is indicative of its usability, relevance and ease of use, and is both a positive and an encouraging outcome of this research. Any future direction should, consequently, have regard to this positive stakeholder feedback and ensure the further flexibility and long-term sustainability of the ESM webtool by securing organisational and financial support for its ongoing maintenance and real-life implementation.

12.1 Potential Future Hosting and Maintenance Arrangements

The ESM webtool and ESM widget have been developed using a suite of ArcGIS Desktop and Online services. The widget was developed using ModelBuilder in ArcGIS 10.3 and then published as a geoprocessing task to ArcGIS for Server. Using ArcGIS Web AppBuilder (Developer Edition), this task was configured and integrated into a customised widget for use in the ESM webtool. The ESM webtool was developed using the ArcGIS API for JavaScript, which combines modern web mapping technology and powerful geospatial capabilities (see Appendix 6 for further details).

Because of the system architecture, the anticipated usage of the webtool, and data and functionality maintenance measures, there are a number of specific requirements for the future hosting platform. These relate to:

- ArcGIS software and technology;
- server capacity; and
- access by the AIRO team for data manipulation and updates (or training future maintenance personnel).

Three potential hosting options have been identified as part of this cost extension: (1) keep it in the AIRO server at Maynooth University; (2) transfer it to the

EPA/Eden platform; and (3) transfer it to the OSi/GeoHive platform. The feasibility of long-term hosting options is analysed in Table 12.1.

Transferring the webtool and widget to OSi/GeoHive presents the most feasible and beneficial option, because:

- The OSi platform is built using ArcGIS technology and is fully compatible with the ESM webtool/widget, facilitating a seamless transfer.
- The OSi has an Amazon cloud server, which will ensure multiple user access and application, as well as facilitate rapid processing of data and rendering of results in the widget.
- The cloud service will secure the provision and continuity of the service (i.e. the risk of the server getting infected or failing is minimised).
- The OSi has agreed to host the webtool/widget free of charge, meaning that any software licence, centralised data server and cloud service costs will be covered by the OSi.

It is crucial that a mechanism is put in place to ensure that data, both in the webtool and in the widget, are updated, in order for them to avoid becoming obsolete and the ESM invalid. The webtool and widget have the potential to support and facilitate SEA processes, as long as relevant and up-to-date data are provided.

12.2 Future Directions

The ESM webtool viewer is publicly available (http://airomaps.nuim.ie/id/ESM), but its full functionality (including the widget) has been provisionally provided in a separate link to restrict access until its public launch. All the SEA-relevant datasets included can be visualised and queried and associated maps generated and printed. A reflection on the findings of the live testing of the SEA webtool forms the basis for the recommendations presented next.

The applicability of the widget was validated at sectoral workshops (see Chapter 7 and section 8.3) and during the life testing (Chapter 9). More importantly, stakeholder feedback was very positive and there was strong interest and support for making the ESM webtool accessible to the public. Therefore, a key (and perhaps most important) recommendation for the wider and effective application of the webtool, and for it to support and facilitate SEA processes across planning hierarchies and sectors in Ireland, is the transfer to a long-term host and the commitment

Table 12.1. Long-term hosting options for the ESM webtool

Hosting option	Software compatibility	Server capacity	Access	Comments
AIRO/Maynooth University	✓	×	✓	Server capacity limitations can result in slow data geoprocessing, delaying the rendering of widget sensitivity analysis results (i.e. making the webtool users wait longer for results), which will be augmented when multiple users apply the widget at once. In addition, if the server fails, the AIRO team has to liaise with Maynooth University IT services to restore it, meaning that the webtool will not be available for a period of time during such events
EPA/Eden	×	✓	?	The EPA have moved its geoportal and online mapping systems to open-source software. Transferring the ESM webtool and ESM widget to this platform will require an entire redevelopment of the system (to develop ArcGIS functionality in the open-source platform) and incorporating the specific geoprocessing capability of the widget may not be possible. In addition, transferring it to the EPA may constrain access to the AIRO team, which will mean that the EPA will be in charge of maintaining the webtool (this would require specific training for data pre-processing, homogenisation, etc.)
OSi/GeoHive	✓	✓	✓	OSi uses ArcGIS technology and has a cloud-based high-capacity server and the strategic agreement between the OSi and AIRO would enable the AIRO team to maintain the webtool and widget (data updates, functionality adjustments, etc.)

IT, information technology.

to maintain the system, the model and the data behind it.

There are data limitations remaining that continue to affect the mapped outputs and further efforts are needed to address such current data limitations (see section 6.3). In addition, there is potential to further enhance the functionality of the webtool by incorporating additional geoprocessing tools and datasets. There are six key areas that could be explored to expand the capability of the webtool and widget:

- **Addressing data gaps and expanding the geographical coverage**. The webtool and widget could be enhanced by including additional datasets as these become available (such as landscape character areas and new census datasets). Datasets for Northern Ireland could also be incorporated to allow potential transboundary and transnational sensitivities to be considered. In addition, offshore datasets to support SEAs of plans and programmes related to the marine environment (e.g. seabed survey, protected habitats) could also be included.
- **Including additional geoprocessing tools to support SEA**. The webtool focuses on the baseline environment. It enables exploration of the reasons why environmental criteria are susceptible by interrogating the attributes associated with each dataset. In addition, contextualising the selection of environmental criteria to the scope of the plan/programme allows susceptible aspects to be strategically addressed. Further development of the webtool is necessary to address how these areas can be impacted, as well as to more effectively consider the potential for cumulative effects. Additional geoprocessing tools can be incorporated to address this. For example, a systematic approach has been developed to examine spatially accumulated anthropogenic actions and effects (Lally, 2016), which could be incorporated and thus contribute towards adopting a system approach when measuring sensitivity.
- **Including an additional geoprocessing tool to support AAs**. The webtool has been developed to support SEA processes; however, there is potential to develop and include an additional geoprocessing tool to support AAs. An AA widget would focus on the assessment of European sites [SACs/Special Protection Areas (SPAs)], including habitats and species at water catchment level. The inclusion of additional datasets (e.g. river flow, ecological corridors, green areas and stepping stones) and the adoption of suitable methods (e.g. least-cost path) would enable the examination of potential land use conflicts specific to the AA process.
- **Developing sector-specific ESM widgets**. Sectoral widgets, similar to those developed in the project for testing the applicability of the ESM webtool in the renewable energy and land use sectors (see section 8.3), could facilitate specific assessments by incorporating sector-relevant datasets, buffer distances, scientific scores, etc., and thus provide a more comprehensive set of sector-specific considerations.
- **Increasing assessment resolution**. Providing mapping outputs at a higher resolution (e.g. 20 m × 20 m) could facilitate local-level assessments and perhaps expand the applicability of the ESM widget to EIA.
- **Maintaining past/outdated datasets as data are updated.** This is to enable the webtool to capture changes over time and, in this way, support the monitoring stage of SEA and plan/programme iterations.

12.3 High-level Recommendations

A number of critical issues have been identified during the development and testing of the webtool and widget. The following recommendations are put forward to address these:

1. The ESM webtool is applicable and valid only if a comprehensive and up-to-date set of SEA-relevant datasets is available. Addressing current data gaps resulting from availability and accessibility constraints, and tackling scale and quality limitations in the datasets included in the webtool, are warranted for a fully comprehensive and detailed sensitivity assessment. **Recommendation**: maintain the datasets included in the webtool to ensure its applicability and validity.
2. A number of key spatial datasets are currently lacking at the national level and some datasets

remain restricted for public viewing/use (see Appendix 5 for some examples).
Recommendation: prioritise national data standardisation, completion and public release to address current availability and quality limitations in certain SEA themes, including biodiversity, landscape, cultural heritage, geology and soils, and material assets. More specifically, the creation and/or completion of the following national datasets should be prioritised: landscape character areas, scenic routes and protected views, record of monuments and places, habitat mapping, greenways and ecological corridors, blueways,[2] soil productivity and water treatment plants.

3. The widget currently focuses on the receiving environment and thus fails to examine existing human activities and, in this way, adopt a system approach to inform SEA processes.
Recommendation: incorporate development-related datasets (e.g. location of existing windfarms, quarries and industrial activities) and develop an additional widget to further explore the potential for cumulative effects and enable a system-based analysis. This recommendation is heavily reliant on funding, availability of development-related datasets (e.g. individual proposals/projects) and stakeholder engagement.

2 An example is provided by Blueways Ireland: http://www.bluewaysireland.org/ (accessed 11 January 2019).

References

Adger, W.N., 2006. Vulnerability. *Global Environmental Change* 16: 268–281.

Antunes, P., Santos, R. and Jordão, L., 2001. The application of Geographical Information Systems to determine environmental impact significance. *Environmental Impact Assessment Review* 21: 511–535.

Atkinson, S. and Canter, L., 2011. Assessing the cumulative effects of projects using geographic information systems. *Environmental Impact Assessment Review* 31: 457–464.

Brooks, N., Adger, W.N. and Kelly, P.M., 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change* 15: 151–162.

Carpenter, S.R., Walker, B.H., Anderies, J.M. and Abel, N., 2001. From metaphor to measurement: resilience of what to what? *Ecosystems* 4: 765–781.

CCC (Clare County Council), 2015. *Clare County Development Plan 2017–2023 – Strategic Environmental Assessment – Environmental Report*. Clare County Council, Ireland. Available online: https://www.clarecoco.ie/services/planning/clare-county-development-plan-2017-2023/ (accessed 16 January 2019).

Chen, Y., Yu, J. and Khan, S., 2010. Spatial sensitivity analysis of multi-criteria weights in GIS-based land suitability evaluation. *Environmental Modelling and Software* 25(12): 1582–1591.

Cox, R., 2013. *Environmental Communication and the Public Sphere*. Sage Publishing, Thousand Oaks, CA.

DHPCLG (Department of Housing, Planning, Community and Local Government), 2018. Project Ireland 2040: The National Planning Framework for Ireland. DHPCLG, Dublin. Available online: http://npf.ie/ (accessed 16 January 2019).

EC (European Commission), 2001. Directive 2001/42/EC of the European Parliament and of the Council of 27th June on the assessment of the effects of certain plans and programmes on the environment. OJ L 197, 21.7.2001, p. 30–37.

EC (European Commission), 2003. Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC. OJ L 156, 25.06.2003, p. 17–25.

EC (European Commission), 2014. Directive 2014/52/EU of the European parliament and of the Council, of 16 April 2014, amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment. European Commission. OJ L 124, 25.4.2014, p. 1–18.

EMRA (Eastern and Midland Regional Assembly), 2017. Invitation to Tender for Professional Services for Strategic Environmental Assessment (incorporating a Regional Level Flood Risk Appraisal) and an Appropriate Assessment of (a) the Eastern and Midland Regional Spatial Economic Strategy (Eastern and Midland RSES), (b) the Southern Regional Spatial Economic Strategy, and (c) the Northern and Western Regional Spatial Economic Strategy (Northern and Western RSES). August 2017.

EPA (Environmental Protection Agency), 2015. *GISEA Manual: Improving the Evidence Base in SEA*. EPA, Johnstown Castle, Ireland. Available online: http://www.epa.ie/pubs/advice/ea/giseamanual.html (accessed 16 January 2019).

Geneletti, D., Bagli, S., Napolitano, P. and Pistocchi, A., 2007. Spatial decision support for strategic environmental assessment of land-use plans. A case study in southern Italy. *Environmental Impact Assessment Review* 27: 408–423.

González, A., 2012. GIS in environmental assessment: a review of current issues and future needs. *Journal of Environmental Assessment Policy and Management* 14: 1250007.

González, A., Gilmer, A., Foley, R., Sweeney, J. and Fry, J., 2011a. Applying geographic information systems to support strategic environmental assessment: Opportunities and limitations in the context of Irish land-use plans. *Environmental Impact Assessment Review* 31(3): 368–381.

González, A., Donelly, A., Jones, M., Klostermann, J., Groot, A. and Breil, M., 2011b. Community of practice approach to developing urban sustainability indicators. *Journal of Environmental Assessment Policy and Management* 13(4): 591–617.

Hegmann, G. and Yarranton, G.A., 2011. Alchemy to reason: Effective use of cumulative effects assessment in resource management. *Environmental Impact Assessment Review* 31: 484–490.

Jones, C., Baker, M., Carter, J., Jay, S., Short, M. and Wood, C., 2005. Evaluating the SEA of land-use plans. In Jones, C., Baker, M., Carter, J., Jay, S., Short, M. and Wood, C. (eds.), *Strategic Environmental Assessment and Land-use Planning – An International Evaluation*. Earthscan, London, pp. 28–43.

Kværner, J., Swensen, G. and Erikstad, L., 2006. Assessing environmental vulnerability in EIA – the content and context of the vulnerability concept in an alternative approach to standard EIA procedure. *Environmental Impact Assessment Review* 26: 511–527.

Lally, A., 2016. Developing GIS approaches to cumulative effects assessment. Unpublished MSc Dissertation. Trinity College Dublin, Ireland.

Lawrence, D.P., 2007. Impact significance determination – pushing the boundaries. *Environmental Impact Assessment Review* 27: 770–788.

Malczewski, J., 2000. On the use of weighted linear combination method in GIS: common and best practice approaches. *Transactions in GIS* 4(1): 5–22.

Marull, J., Pino, J., Mallarach, J.M. and Cordobilla, M.J., 2007. A land suitability index for Strategic Environmental Assessment in metropolitan areas. *Landscape and Urban Planning* 81: 200–212.

Office of the Attorney General, 2004a. European Communities (Environmental Assessment of Certain Plans and Programmes) Regulations 2004 (S.I. No. 435/2004). Available online: http://www.irishstatutebook.ie/eli/2004/si/435/made/en/print (accessed 16 January 2019).

Office of the Attorney General, 2004b. Planning and Development (Strategic Environmental Assessment) Regulations 2004 (S.I. No. 436/2004), as amended. Available online: http://www.irishstatutebook.ie/eli/2004/si/436/made/en/print (accessed 16 January 2019).

Office of the Attorney General, 2011. European Communities (Environmental Assessment of Certain Plans and Programmes) Regulations 2011 (S.I. No. 200/2011). Available online: http://www.irishstatutebook.ie/eli/2011/si/200/made/en/print (accessed 16 January 2019).

Pavlickova, K. and Vyskupova, M., 2015. A method proposal for cumulative environmental impact assessment based on the landscape vulnerability evaluation. *Environmental Impact Assessment Review* 50: 74–84.

RPS Group, 2017. National Planning Framework Strategic Environmental Assessment. Prepared by RPS Group. for the Department of Housing, Planning and Local Government. September 2017. Available online: http://npf.ie/wp-content/uploads/2017/09/Environmental-Report-%E2%80%93-Ireland-2040.pdf (accessed 16 January 2019).

Skondras, N.S., Karavitis, C.A., Gkotsis, I.I., Scott, P.G.B., Kalyd, U.L. and Alexandris, S.G., 2011. Application and assessment of the environmental vulnerability index in Greece. *Ecological Indicators* 11: 1699–1706.

Therivel, R., 2004. *Strategic Environmental Assessment in Action*. Earthscan, London.

Toro, J., Duarte, O., Requena, I. and Zamorano, M., 2012. Determining vulnerability importance in Environmental Impact Assessment – the case of Colombia. *Environmental Impact Assessment Review* 32: 107–117.

Tran, L.T., O'Neill, R.V. and Smith, E.R., 2010. Spatial pattern of environmental vulnerability in the Mid-Atlantic region, USA. *Applied Geography* 30(2): 191–202.

Wang, X.D., Zhong, X.H., Liu, S.Z., Liu, J.G., Wan, Z.Y. and Li, M.H., 2008. Regional assessment of environmental vulnerability in the Tibetan Plateau: development and application of a new method. *Journal of Arid Environments* 72: 1929–1939.

Yoo, G., Kim, R. A. and Hadi, S., 2014. A methodology to assess environmental vulnerability in a coastal city: application to Jakarta, Indonesia. *Ocean & Coastal Management* 102(A): 169–177.

Abbreviations

AA	Appropriate assessment
AGOL	ArcGIS Online
AIRO	All-Island Research Observatory
API	Application programming interface
CDP	County Development Plan
CFRAM	Catchment Flood Risk Assessment and Management
CORINE	Coordination of Information on the Environment
DCCAE	Department of Communications, Climate Action and Environment
DCHG	Department of Culture, Heritage and the Gaeltacht
DHPLG	Department of Housing, Planning and Local Government
EIA	Environmental Impact Assessment
EMRA	Eastern and Midland Regional Assembly
EPA	Environmental Protection Agency
ER	Environmental report
ESM	Environmental Sensitivity Mapping
Esri	Environmental Systems Research Institute
GIS	Geographic information system
GSI	Geological Survey Ireland
GUI	Graphical user interface
HTML	Hypertext Markup Language
IPPC	Integrated Pollution Prevention and Control
MXD	Map Exchange Document
NHA	Natural Heritage Area
NIAH	National Inventory of Architectural Heritage
NPF	National Planning Framework
NPWS	National Parks and Wildlife Service
NWRA	Northern and Western Regional Assembly
OPW	Office of Public Works
OSi	Ordnance Survey Ireland
pNHA	Proposed Natural Heritage Area
REST	Representational State Transfer
RMP	Record of Monuments and Places
RPA	Record of Protected Areas
RSES	Regional Spatial and Economic Strategy
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
S.I.	Statutory instrument
SPA	Special Protection Area
SRA	Southern Regional Assembly
UCD	University College Dublin
WFD	Water Framework Directive

Glossary

Environmental Impact Assessment	Assessment of the effects of certain projects on the environment. It entails the preparation of an environmental impact statement to inform decision-making
Environmental sensitivity	In the context of the ESM project, susceptibility of the receiving environment or of the environmental factors (e.g. protected habitats, water bodies) to anthropogenic stressors or changes associated with the implementation of a plan, programme or project
ESM webtool	Environmental Sensitivity Mapping online decision support system that allows centralised visualisation and querying of SEA-relevant spatial datasets and examination of environmental sensitivity. It comprises of a viewer, where all available SEA-relevant datasets can be visualised and queried, and a widget, which enables creation of plan-specific environmental sensitivity maps
Esri ArcGIS	Mapping and analytics software. More information is available at https://www.esri.com/en-us/home
Esri ArcToolbox	An integrated application developed by Esri. It provides a reference to the toolboxes to facilitate user interface in ArcGIS for accessing and organising a collection of geoprocessing tools, models and scripts
Geodatabase	A way to store GIS information in one large file, which can contain multiple point, polygon and/or polyline layers
Geographic information systems	Array of technological tools for the management, analysis and display of spatial data that can provide evidence-based information to support impact assessment and decision-making
Geoprocessing	A framework/model and set of tools for processing geographical and related data
HTML	Hypertext Markup Language (HTML) is the standard markup language for creating web pages and web applications
Mitigation	Measures that may involve preventing impacts altogether or reducing their magnitude as much as possible and/or probability of occurrence, or putting in place measures to remedy effects after they have occurred or to compensate for them by providing environmental benefits elsewhere
ModelBuilder (in ArcGIS)	A visual programming language for building geoprocessing workflows
Multi-criteria assessment	In the context of GIS, the combined evaluation of multiple datasets with the associated multiple attribute values in a spatially specific manner
MXD	Map Exchange Document (MXD) is a file format used to store the maps created from ArcGIS software
Output map	In the context of the ESM project, the map that captures the relative environmental sensitivity of the plan/programme area
Plan	In the context of spatial planning, the framework for land use or sectoral actions in a particular area (e.g. regional, county, city, town or local area)

Programme	In the context of spatial planning, the overall strategy that establishes the requirements to be incorporated into plans
Raster	In the context of GIS, dataset where space is divided into rectangular building blocks (grid cells or pixels), each of which is filled with measured attribute values with topological relationships automatically fixed
REST services	Representational State Transfer (REST) is an architectural style that defines a set of constraints and properties based on Hypertext Transfer Protocol (HTTP). Web services that conform to the REST architectural style, or RESTful web services, provide inter-operability between computer systems on the internet
Scientific scores	In the context of the ESM project, scores on a scale from 1 to 3 (meaning low to high, respectively) applied to harmonise the relative degree of sensitivity of environmental factors based on statutory measures, thresholds and targets (e.g. ecological designations, air quality thresholds)
Script	A scripting or script language is a programming language that supports scripts; programs written for a special run-time environment that automate the execution of tasks that could alternatively be executed one-by-one manually
Server (deployment)	Hosts the final ESM WebApp and provides the necessary web-accessible environment from where the live ESM webtool is deployed and activated via the existing ESM webtool web address
Server (GIS)	Hosts the underlying datasets for both the viewer and the widget and relevant GIS software required for data generation and publication – ArcGIS 10.5 and ArcGIS for Server.
Strategic Environmental Assessment	Assessment of the effects of certain plans and programmes (and, in some jurisdictions, policies) on the environment. It presents a structured and participative process containing a set of tools to assist in the integration of environmental considerations and promote informed decision-making at plan/programme level
Strategic Environmental Assessment themes and criteria	Strategic Environmental Assessment themes include population and human health; biodiversity, flora and fauna; water; soils and geology; air and climatic factors; cultural heritage; landscape; material assets; and the inter-relationship between the above factors. In the context of the ESM project, SEA criteria refer to any relevant spatial datasets associated with the above themes
Vector	In the context of GIS, a dataset where the representation of spatial features is made through points, lines and polygons (or areas). Vector objects have associated attributes and topological relationships can be built among both features and attributes
WebApp	A web application or web app is a client–server computer program that the client (including the user interface and client-side logic) runs in a web browser
Weights	In the context of the ESM project, value judgments of subjective nature that enable factoring in stakeholder/public perceptions on significance of issues or concerns
Widget	In the context of the ESM project, the web application developed and included in the ESM webtool with the specific functionality of combining SEA-related environmental criteria, their associated scientific scores, and weights to generate plan/programme-specific environmental sensitivity maps

Appendix 1 SEA-relevant Themes and Criteria Included in the ESM Webtool

Administrative boundaries
CSO census settlements (2016)
Local authorities
Metropolitan area spatial plans
Regional assemblies
Strategic planning areas
WFD management units
Air and climatic factors
Air zones
Coal restricted areas
Flood extents – current scenarios (coastal and fluvial)
Historical flood extents
Soil carbon
Vegetation carbon
Water retention
Wind speeds
Biodiversity, flora and fauna
Ancient woodlands
Annex I habitats
Birdwatch sensitivity
Coastal habitats (saltmarshes)
Contribution to potential ecological networks
Dublin Bay Biosphere
Forest inventory and planning system
Legally protected and policy-relevant species
Margaritifera sensitive areas
NHAs

PNHAs
Salmonid rivers (S.I. No. 293 only)
SACs
SPAs
Terrestrial biodiversity
Woodland habitats
Cultural heritage
Irish Landmark Trust
Museums, collections and archives
National Inventory of Architectural Heritage (NIAH)
Sites and Monuments Record
Walled towns of Ireland
World Heritage Sites
Landscape
Landscape character areas
Material assets
Active quarries
Airfields and airports
Broadband access
Current wind farms
Discharge licences (Pollutant Release and Transfer Register)
Extractive Industries Register
Grand and Royal Canals
Historical mine district sites
IPPC Licences
Journey time to work/education, 30 minutes to 1 hour
Journey time to work/education, > 1 hour
Landfill sites
Licensed waste facilities
Ports
Railway network

Road network
Settlements
Waste water treatment plants and status
Population and human health
Disability – total population, 2016 %
General health bad – total population, 2016 (SAs) %
General health very bad – total population, 2016 (SAs) %
Housing stock: holiday home, 2016 (SAs) %
Housing stock: vacant, 2016 (SAs) %
Labour force unemployed, 2016 (SAs) %
Pobal HP Deprivation Index 2016 (EDs)
Population change, 2006–2016 (EDs) %
Population change, 2011–2016 (EDs) %
Population change, 2011–2016 EDs
Population density per square kilometre
WFD RPA groundwater drinking water
WFD RPA surface water drinking water (lakes)
WFD RPA surface water drinking water (rivers)
Soils and geology
Bedrock 500k
CORINE land cover type
County Geological Sites
Geoparks
Landslide events
Landslide events perimeter
Landslide susceptibility
Mineral locations
Outcrops
Peat bogs
Soil permeability
Soils (Irish Soil Information System)
Soils (National Soil Survey)

Water
Aquifer vulnerability
Bedrock aquifer
Biological Q values
Groundwater source protection areas
Hydrometric areas
Water abstraction points 10–50 m
Water abstraction points 50 m–1 km
Wetlands
WFD coastal and transitional water bodies risk
WFD coastal and transitional water bodies status
WFD groundwater risk
WFD groundwater status
WFD lake water bodies risk
WFD lake status
WFD river water bodies risk
WFD river status
WFD RPA nutrient sensitive areas (lakes, coastal and transitional water bodies)
WFD RPA nutrient sensitive areas (rivers)
WFD RPA recreational waters (coastal and transitional)
WFD RPA recreational waters (lakes)
WFD RPA shellfish areas
WFD RPA water-dependent habitats SACs
WFD RPA water-dependent habitats SACs (rivers/cliffs/bog drainage patterns)
WFD RPA water-dependent habitats SPAs
Water management units

CSO, Central Statistics Office; ED, electoral division; SA, small area; SI, Statutory Instrument.

Appendix 2 User Manual


Environmental Sensitivity Mapping (ESM)
supporting environmental assessment processes in Ireland

USER MANUAL

1. INTRODUCTION

The ESM webtool is designed to facilitate multiple data interactions. Its purpose is to enable geographical exploration of environmental considerations onshore and to combine relevant environmental datasets to produce **environmental sensitivity** maps in **support of Strategic Environmental Assessment** (SEA).

This user manual is intended to facilitate its application and provide guidance on the preparation of sensitivity maps while highlighting some critical considerations.

2. FUNCTIONALITY

Specific **locations** can be searched in the **search engine** at the top of the web viewer. The Environmental Sensitivity Mapping (ESM) webtool will automatically zoom in to the searched location.

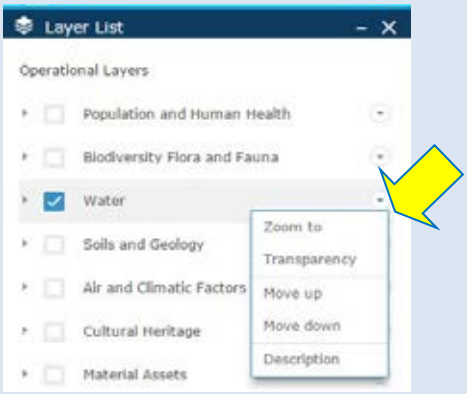
A number of **basic tools** can be found at the bottom of the web viewer, as illustrated and explained below.

Icons (left to right): Layer List, Legend, Widget Chart, Google Street View, Swipe and Add Shapefile

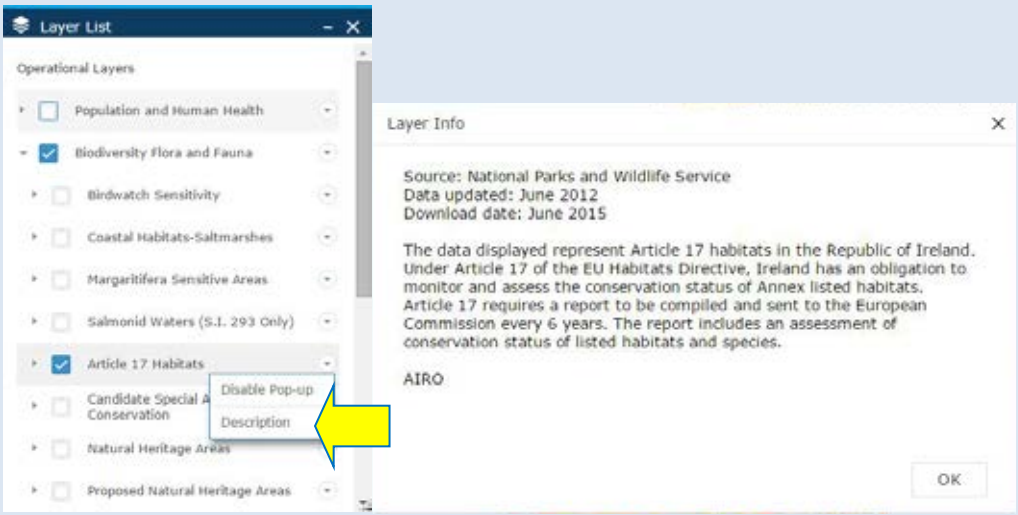
Select the **Layer List** icon to obtain a list of the **available spatial datasets**. To visualise any of these, tick on the relevant environmental theme and then tick on the relevant spatial dataset(s). The dataset(s) will be displayed on the viewer. Note that **the parent SEA theme must be ticked for the selected sublayers to display**.

Multiple datasets can be visualised simultaneously. However, note that wide coverage datasets, such as bedrock geology, may obscure the display of other datasets. In such cases, turn on/off relevant datasets one by one (or use the Swipe tool – see below for details).

You can use the dropdown menu to the right to zoom in to a given environmental theme (i.e. to the datasets contained within it), adjust its transparency or move it up or down the list to display on top/below other themes.



To obtain metadata, including a description of the spatial dataset, use the dropdown menu to the right of the dataset name and click on “Description”.



The **Legend** icon will launch a window providing the **legend of the selected spatial datasets** (i.e. categorisation and symbology of those currently displayed on the map).

This icon opens the **ESM Widget** window where you can define the geographical extent and the variables to be combined **to generate an environmental sensitivity map**. See further detail in section 3 below.

Google Street View allows **three-dimensional and 360º visualisation of streets and their surrounding landscape/environment**. Click on the icon and drag the little man onto the map to see the street view for that location. You can pan around and also visualise the location in aerial and bird’s-eye view forms.

The **Swipe tool** enables the **swiping of a selected dataset to visualise the underlying dataset(s)**. It opens a menu with the themes turned on in the Layer List, from which the dataset to swipe can be defined. Scroll the associated bar to swipe.

Use the **Add Shapefile** option to **upload an external shapefile**. The shapefile will be displayed in the viewer. The shapefile must be zipped for uploading and contain no more than 1000 features.

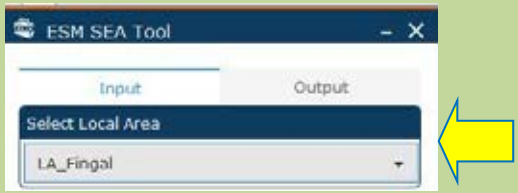
3. APPLYING THE WIDGET

The sensitivity maps are based on the principle that the more environmentally susceptible factors that co-occur at a given location, the more sensitive that area may be to change(s). For example, the overlap of multiple ecological designations [such as candidate Special Areas of Conservation (SACs) and proposed Natural Heritage Areas (NHAs)] with extreme vulnerability aquifers and high soil permeability would highlight significantly sensitive environmental areas in terms of both biodiversity and water, thereby providing early warning of potential land use conflicts. The identification of such co-occurrence of environmental sensitivities can also contribute to cumulative effects assessments. The datasets are aggregated on the basis of scientific scores that reflect their quality, risk or protection status, agreed a priori through stakeholder consultation (see the Annex).

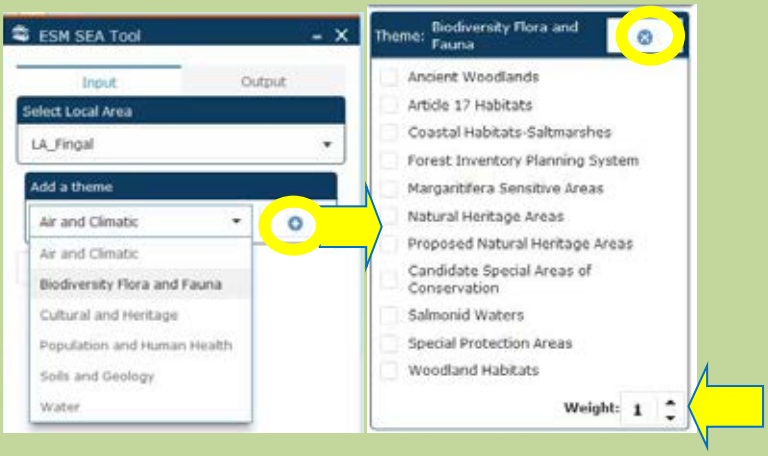
Plan/programme-specific environmental sensitivity maps can be created as follows:

The **ESM Widget** will launch a new window where environmental datasets can be selected and brought into the sensitivity mapping.

Step 1. **Select the study area**. This may be a region, county or water catchment depending on the geographical extent of the plan/programme being assessed. Pull down the menu option to obtain a list of administrative areas and catchments and select the relevant one. The sensitivity mapping will be undertaken for this selected area with only a 10-km buffer zone (or cushion) around it. This is to examine the potential for any transboundary sensitivities that may also be affected by the plan/programme.



Step 2. Next **select the SEA theme** by clicking on the + icon. This will display the datasets available for that theme – tick on those that are relevant to the assessment of the plan/programme. These criteria should be selected in a rational manner, linking them to issues and considerations identified during scoping. You can add additional environmental themes and associated relevant datasets as appropriate. You can remove a theme by clicking on the x icon. Note that the model will not run if a theme is selected without any linked datasets within it.



Step 3. **Define weights** for each environmental theme added to the sensitivity mapping. These user-defined weights are to emphasise the relative importance of a given environmental theme (and the associated datasets selected for the assessment): 1 denotes neutral weight, whereas a weight of 2 indicates that the selected theme is relatively more important because of its overall significance or the likelihood of it being significantly affected by the plan/programme under assessment (e.g. if a key objective of the plan is to protect ecological sites, a weight of 2 could be assigned to the theme "biodiversity, flora and fauna"). Ideally, the assignment of weights and, therefore, the magnification of the sensitivity of a given environmental theme is to be defined and agreed through stakeholder consultation during SEA scoping.

WARNING: Environmental themes and factors represented by the ESM webtool datasets must be selected and combined in a sensible way, incorporating only considerations that are relevant to the plan/programme under assessment and applying rational relative weights.

When selecting environmental datasets and applying weights, bear in mind that:

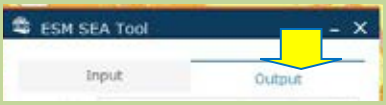
A. *The more spatial datasets selected, the higher the likelihood of sensitivity in the study area. It is the user's responsibility to coherently select relevant spatial datasets and weights for the creation of meaningful sensitivity maps that are relevant to and appropriate for the assessment of the plan/programme.*

B. *Particular care should be given to avoid double counting issues by selecting datasets that are directly related. For example, selecting ancient woodlands, Annex I habitats and woodland habitats would overemphasise the sensitivity of certain woodlands. Similarly, selecting aquifer vulnerability, WFD (Water Framework Directive) groundwater status and groundwater source protection areas would overstate the sensitivity of this natural resource. If this is the intention of the assessment, it should be clearly stated so or taken into consideration when interpreting the output map(s).*

C. *Weights are to be used only to emphasise the relative significance of an environmental aspect. Applying a weight of 2 to more than two SEA themes would magnify and possibly overstate the overall sensitivity of the study area. When all considered themes are equally important in the assessment, a weight of 1 should be applied to all.*

When relevant SEA themes, associated datasets and weights are defined, press Go at the bottom of the widget window. The Help option will direct you to this user manual and to a video demonstration.

The system will automatically generate a sensitivity map and bring you to the Output tab of the window. You can **return to the Input tab if you want to perform a new assessment** with different datasets and weights.



This Output tab includes a legend with the **categorisation of sensitivity**. These categories are based on the number of environmental sensitivities overlapping at one location, where 0 is no occurrence, 1–3 is occurrence of one high environmental sensitivity (or three low-sensitivity datasets), 4–6 indicates two high or one high and two moderate overlapping sensitivities, and so on.

Step 4. **Prepare for printing** by turning on the relevant administrative boundaries and adjusting the transparency of the sensitivity dataset (now included in the legend as "ESM Result"). For guidance on visualising datasets and adjusting transparency refer to page 1 of this user manual.

For printing purposes, change the map title (e.g. to reflect the name of the plan/programme or indicate "SEA supporting environmental sensitivity mapping"), select the format (e.g. PDF or JPG) and define the author(s) of the map. Authorship should be defined in order to defend the rationale for using the selected variables/weights and the resulting mapped output.

Press **print** to obtain a layout map. This includes the mapped output of the sensitivity analysis, the sensitivity categorisation legend and a clear indication of the selected datasets and applied weights for clarity and transparency. The output map appears at the bottom of the window – select it to open it in a web page and save it to your computer.

If you generate multiple sensitivity maps (by going back to the Input tab and changing the selected datasets and weights), the print option will generate multiple outputs accordingly, and these will be listed in the window. These will be removed/deleted automatically once the session ends (save them to your computer for future access/use).

4. LIMITATIONS OF THE WEBTOOL

The ESM webtool and ESM widget are to be used to **support and inform SEA processes**. The following aspects need to be considered during their application:

- The **quality of the ESM outputs** (i.e. sensitivity maps) **depends on the quality of the data** entered into the assessment. The ESM webtool is fully reliant on existing and publicly available spatial datasets from third-party sources. As a result, data gaps (e.g. current omission of Record of Protected Structures or scenic landscapes in the ESM webtool because of data availability and access constraints), and any scale and quality/completeness issues associated with the datasets already included, can affect the comprehensiveness and detail of the sensitivity analysis. The All-Island Research Observatory (AIRO) takes no responsibility for any errors/inconsistencies/gaps in the included datasets.
- **Data** included in the ESM **are static**, **representing** data available in **a given point in time** (the last data update took place in July 2018). Therefore, certain datasets (i.e. those that are regularly updated, such as ecological designations) could be outdated when applying the webtool and widget, affecting the validity of the outputs. The metadata associated with each dataset indicate when the last update took place and this should be taken into consideration when interpreting the results. Future iterations of the ESM project may be able to incorporate dynamic/live standardised map services in order to automatically update datasets as these become available.
- The **availability of more data for certain SEA themes** (e.g. a large number of water-related spatial datasets because of Water Framework Directive requirements) could result in an unintended imbalance of environmental sensitivity towards a given theme if all datasets were to be selected. As this has implications for the assessment outputs, a sensible number of criteria should be selected to avoid unintended bias (unless a particular environmental consideration is specifically intended to be emphasised).
- The **inter-relation of certain environmental factors** (e.g. water-dependant habitats and species), as well as the **inter-connection between natural features** (river networks or wildlife corridors), requires consideration of **catchment-based analysis,** as opposed to the application of administrative boundaries. Due consideration should therefore be given to examining sensitivity at the catchment level, as appropriate, with a particular focus on contributing upstream elements (e.g. streams feeding into a designated water body).
- **Scientific scores** determine the intrinsic vulnerability of each environmental dataset and are the basis by which datasets are aggregated for the sensitivity analysis. Scientific scores range from 1 (low – e.g. coniferous forests, unrestricted coal areas) to 3 (high – e.g. SACs, groundwater source protection areas) and have been defined for each dataset in consultation with stakeholders. See the Annex for detailed information on scientific scores. These should be taken into consideration when interpreting the ESM outputs.

- **Weights applied** to the SEA themes **affect the ESM outputs**. Significance weights can be determined by the end-user or by a stakeholder group. In all cases, significance weights are subjective but not arbitrary (i.e. they should be based on evidence). For an effective assessment, a range of relevant experts should be consulted to determine appropriate weights for specific themes, and the effect that weights have in the relative sensitivity outputs examined.
- The **sensitivity maps have a resolution of 100 m × 100 m**. This resolution has been adopted as it provides sufficient detail for regional and county-level assessments. All vector datasets have been converted to 100 m × 100 m resolution rasters and, in doing so, detail is lost at the local level. Therefore, mapped outputs are not to be examined/scrutinised by zooming in tight to local areas, as the 100 m × 100 m resolution does not enable fully representative considerations/issues at that level.

Given the above considerations**, the ESM outputs should be treated as indicative rather than definite**. The sensitivity maps are a direct product of selected criteria and applied weights. The maps aim to highlight the relative environmental sensitivity of different areas and are to be used to provide early warning, advise on the potential for land use conflicts and, in this way, promote evidence-based planning. They should not be used to identify no-go areas or provide a green light for development. In fact, they can also be understood as assets to a region given the range of ecosystem services they provide.

Processing time: it can take up to 3 minutes for the widget to run and produce the sensitivity map, depending on the size of the study area and the number of variables selected. Please be patient.

ANNEX: SCIENTIFIC SCORES ASSIGNED TO THE ESM WIDGET DATASETS

The scientific scores associated with the environmental datasets included in the ESM widget were identified and agreed at two stakeholder workshops involving national SEA experts, consultants, local authority planners and heritage officers, and government representatives.

The scientific scores are embedded into the widget raster files and cannot be modified. They are classified as follows: 1 = low; 2 = moderate; and 3 = high.

The scores are assigned on the basis of (1) their quality status and representativeness as indicators of environmental quality (e.g. extreme vulnerability aquifers obtain a scientific score of 3 whereas low vulnerability aquifers are classified as 1); (2) their legislative protection or conservation priority (e.g. SACs are given a score of 3 whereas proposed NHAs are scored as 2); and (3) their risk (e.g. flood risk areas are considered to have a score of 3 whereas the rest of lands are be given a score of 1).

The following table presents the scientific scores assigned to each dataset included in the ESM widget.

Dataset	**Sensitivity scores: 1 = low 2 = moderate 3 = high**			**Basis**
	1	**2**	**3**	
Population and human health				
WFD RPA groundwater drinking water			**X**	Statutory: protection priority
WFD RPA surface water drinking water (lakes)			**X**	Statutory: protection priority
WFD RPA surface water drinking water (rivers)			**X**	Statutory: protection priority
Biodiversity, flora and fauna				
Ancient woodlands				
Ancient woodland			**X**	Value judgment: protection priority
Possible ancient woodland			**X**	
Long-established woodland (LEW I)		**X**		
Long-established woodland (LEW II)		**X**		
Annex I Habitats			**X**	Statutory: legal protection and indicator of environmental quality
Coastal habitats (saltmarshes)		**X**		Statutory: protection priority and environmental quality
Forest inventory and planning system				
Deciduous		**X**		Value judgment: environmental quality
Coniferous	**X**			
***Margaritifera*-sensitive areas**				

Dataset	Sensitivity scores: 1 = low 2 = moderate 3 = high			Basis
	1	2	3	
Catchments of SAC populations listed in S.I. No. 296 of 2009			X	Statutory: legal protection and indicator of environmental quality
Catchments of other extant populations			X	
Catchments with previous records of *Margaritifera* but current status unknown		X		
NHAs			X	Statutory: legal protection
Proposed NHAs		X		Statutory: protection priority
Salmonid rivers (S.I. No. 293 only)			X	Statutory: legal protection
SACs			X	Statutory: legal protection
SPAs			X	Statutory: legal protection
Woodland habitats		X		Value judgment: environmental quality
Water				
Aquifer vulnerability				
High/extreme/rock near surface			X	Value judgment: environmental quality
Moderate		X		
Low/water	X			
Aquifer categorisation				
Pure limestones that are designated as karst aquifers			X	Value judgment: environmental quality
Pure limestones that are not designated as karstic aquifers, impure limestones and Precambrian marbles		X		
Non-carbonate rocks	X			
Biological Q values				Statutory: protection priority
Groundwater source protection areas			X	Statutory: protection priority
RPA nutrient sensitive areas (lakes)			X	Statutory: protection priority
RPA nutrient sensitive areas (rivers)			X	Statutory: protection priority
RPA recreational waters (lakes)			X	Statutory: protection priority
RPA recreational waters (coastal/rivers)			X	Statutory: protection priority
RPA water-dependant habitats (SAC)			X	Statutory: protection priority
RPA water-dependant habitats (SPA)			X	Statutory: protection priority
Wetlands		X		Statutory: environmental quality
WFD groundwater status				
Good	X			Statutory: environmental quality
Poor		X		
WFD lake status				
High		X		Statutory: environmental quality
Pass/good/moderate	X			
Poor/bad		X		
WFD river status				

Dataset	Sensitivity scores: 1 = low 2 = moderate 3 = high			Basis
	1	2	3	
High		X		Statutory: environmental quality
Pass/good/moderate	X			
Poor/bad		X		
Soils and geology				
Geoparks and geosites			X	Statutory: international importance
Outcrops		X		Value judgment: protection priority
Peat bogs		X		Statutory: protection priority
Well-drained soils		X		Value judgment: environmental quality
Poorly drained soils		X		Value judgment: environmental quality
Air and climatic factors				
Air zones				
Dublin/Cork/cities	X			Value judgment: environmental quality. Omitted as a sensitivity criteria
Rural areas	X			
Coal-restricted areas				
Restricted	X			Value judgment: environmental quality. Omitted as a sensitivity criteria
Unrestricted				
Historical flood extents			X	Statutory: risk status
Cultural heritage				
NIAH		X		Statutory: protection priority
RMP			X	Statutory: legal protection

NIAH, National Inventory of Architectural Heritage; RMP, Record of Monuments and Places; RPA, Record of Protected Areas; SPA, Special Protection Area.

Appendix 3 Consulted Organisations

Organisations
Arup
Birdwatch Ireland
Clare County Council
Coillte
Conservation and Amenity Advisory Services (CAAS) Ltd
Department of Communications, Energy and Natural Resources
Department of Environment, Heritage and Local Government
Eastern and Midland Regional Assembly
EirGrid
EPA
Fáilte Ireland
Fingal County Council
Freelance ecology, landscape and environmental consultants
Irish Water
Kerry County Council
Kildare County Council
Kilkenny County Council
Mayo County Council
Meath County Council
Mott MacDonald Ireland
National Parks and Wildlife Service
National Roads Authority
Northern and Western Regional Assembly
Northern Ireland Environment Agency
Office of Public Works
RPS Group
South Dublin County Council
Sustainable Energy Authority of Ireland

Teagasc

Transport Infrastructure Ireland

Waterford County Council

Wexford County Council

Appendix 4 SEA-relevant Spatial Data Inventory

A SEA-relevant spatial data sources inventory has been maintained throughout the ESM project. The inventory contains references to over 900 datasets and has been updated every 6 months. The latest update is available for download from the EPA website: http://www.epa.ie/pubs/advice/ea/seaspatialinformationsourcesinventory-march2019.html (accessed 16 April 2019). As the inventory is updated regularly, this URL will change in future. To access the inventory, Google search the terms “SEA spatial data sources inventory”.

Appendix 5 Stakeholder Feedback on the Life Testing

Summary of stakeholder feedback (with number of respondents for each question) and project team responses:

Stakeholder feedback	Project team response
Q1. Did you use/apply the ESM webtool?	
Yes: 4 No: 2	
Q2. At what planning level was the ESM webtool applied?	
National plan/programme: 3 Regional plan/programme: 3	
Q3. How do you think the ESM webtool has contributed to the SEA process?	
The webtool improved the SEA process: 6 The webtool did not add value to the SEA process: 0	
Q3a. In which way did the ESM webtool enhance the SEA process?	
• The ESM outputs reduced screening/scoping time: 2 • Centralised access to spatial datasets in a single web interface facilitated rapid and combined exploration of issues: 5 • Exploration of environmental sensitivity outputs facilitated identifying potential land use conflicts: 6 • The option to weight environmental themes enabled factoring in scoping priorities and/or concerns: 2 • The sensitivity maps informed the development and assessment of alternatives: 4 • The webtool enabled examining of the effect that stakeholder values can have on the overall sensitivity of different areas: 2 • The sensitivity maps enabled exploration of potential cumulative effects: 6 • The ESM webtool contributed to assessment transparency: 6 • The ESM webtool contributed to assessment consistency (e.g. comparability across regions): 4 • Other: “One of the most positive aspects of the tool is that it provides an audit trail of the information used to support assessments. While allowing the user to dictate weighting values is key to allowing the user tailor assessments to specific scenarios, the tool could be made more user-friendly by providing real world scenarios that clearly highlight typical weightings that could/should be used for different suites/combinations of environmental themes and activities. These worked real world scenarios could be included in the user manual”	The project team believe that the provision of real-world examples may potentially influence and/or result in a biased view of how users weight different scenarios. The role of the weighting tool is to allow for context-specific consideration of potential sensitivities. Instead, the user manual has referenced a hypothetical example involving the protection of ecological sites and assigning a weight to the theme of “biodiversity, flora and fauna” (see user manual)
Q3b. Please specify why you feel that the ESM outputs did not add value to the SEA process	
None	
Q4. Would you apply the ESM webtool again in the future?	
Yes, it is a useful support tool for SEA: 3 Yes, it is a very useful tool to inform SEA and planning: 3 Other: “While the tool is very useful it should be noted that its usefulness is limited by the quality of available data. To optimise the usefulness, the tool should be (1) updated regularly to take account of newly acquired data and/or (2) linked directly to live datasets”	The project team have been updating the webtool as new and relevant data become available. The viewer now contains 107 datasets. As the widget uses aggregated data, it is not possible to link the webtool to live datasets. The recommendations in terms of future direction of this project include ensuring that maintenance arrangements are put in place and securing a permanent host to accommodate and regularly update the webtool and datasets

Stakeholder feedback	Project team response
Q5. Are you aware of the scientific scores applied in the ESM widget for harmonising the sensitivity of the various environmental factors? If yes, do you agree with the scientific scores assigned to them?	
• Yes, and I concur with the harmonised scores assigned by experts in the field: 5 • Yes, but I found (some of) the assigned scores inadequate and I adjusted them by applying a higher weight to the related theme: 1 • Other: "Further guidance should be provided in the user manual on the scientific scores"	There is a detailed explanation of the scientific scores included in the Annex of the user manual. The project team have included in the ESM viewer's terms of reference a specific link to refer to this user manual before use (the user manual can be accessed both in the terms of reference page and in the widget dialogue box)
Q6. Did you explore different sensitivity maps by selecting different themes?	
• Yes, I explored different sensitivity scenarios by selecting different criteria (using different spatial data layers): 5 • No, I did not explore different sensitivity scenarios: 1 • Other: "Worked examples would help illustrate how the tool can be applied to a broad range of programmes/plans and scenarios"	See responses to 3a above
Q7. Did you explore different sensitivity maps by applying different weights to the chosen SEA themes?	
• Yes, I explored different sensitivity scenarios by adjusting the weights applied to different SEA themes: 3 • Yes, I explored different sensitivity scenarios by adjusting both environmental criteria and weights: 2 • No, I did not explore different sensitivity scenarios: 1	
Q8. Was the ESM webtool easy to navigate and use?	
• Yes, the functionality of the ESM webtool is intuitive: 4 • Yes, but I had to read the user manual to learn how to apply the webtool: 2 • Yes, but I watched the demonstration video to learn how to apply the webtool: 1 • No, the webtool interface is not user-friendly (please specify why in the "Other" field below): 1 • No, the webtool was not intuitive and the user manual was not clear (please specify why in the "Other" field below): 0 • Other: "It's sometimes confusing why certain layers aren't switching on until you realise the parent layer also [sic] needs to be on. If the layer nesting was a bit wider and more obvious, I think this would"	The user manual has been edited to include the following statement: "Note that **the parent SEA theme must be ticked for the selected sublayers to display**")
Q9. Are there any important SEA-relevant spatial datasets missing in the webtool? Do you have any recommendations for additional spatial data to be included?	
• CFRAMS data • The historical landfills register would be useful. • "Soil type layer is the Irish Soil Information System 'Soil Associations' layer at 250k scale, which I find is not the most intuitive/informative. Would suggest also including the EPA/GSI/Forest Service 2006 Soil mapping at 50k scale with the soil types (AMinDw, etc.)" • The County Geological Site/Geological Heritage Areas • Locations of water treatment plants • Ecosystem services mapping, when available • Maritime spatial planning in due course • "Not all the layer list data sets are available for input into the tool"	**Flood extent mapping** for the current scenario has been included in the webtool **Historical landfills** data were requested from the EPA; however, they are not able to distribute them for external use; it is outside of the scope of this project to contact each local authority for access to the historical landfill data, which in fact may not be complete The EPA/GSI/Forest Service **2006 soil mapping** and **County Geological Sites** have been included in the webtool. Irish Water were contacted for data on the location of **water treatment plants**; however, they are unable to provide these data because of potential risks to security and public health Marine spatial planning (i.e. offshore mapping) is outside the scope of this project **Ecosystem services** mapping has been incorporated where available and relevant **Dublin Bay Biosphere** data have been included in the webtool

Stakeholder feedback	Project team response
Q9. continued	
	Broadband access, journey to work/education, health, labour force and housing stock data have also been included in the webtool Not all of the data within the viewer are available for input into the widget as they have been specifically selected and assigned scientific scores in consultation with stakeholders to generate an environmental sensitivity map. Only data within the viewer that represent intrinsic environmental sensitivity are included in the widget
Q10. Would the webtool benefit from any additional functionality? Do you have any recommendations for including additional exploratory tools in the interface?	
• "A colleague applied the web-tool so I cannot answer" • "Nothing at this stage but hopefully it is flexible enough to respond to evolving practices over time" • "Additional scaling levels would be useful, perhaps a dialog which shows the current scale. Sometimes it's not clear how zoomed in or out an output ESM is going to be until it's run. Perhaps an option to zoom to ESM study area". • "Availability of graph widget"	A number of different zoom-in scales have been incorporated into the webtool. Given current service capacity it is not possible to render at any further scale A graph tool was originally in the webtool but only for historical census data, and the webtool presents only current population figures. Moreover, the graph functionality can be applied to a single criterion only and, therefore, could not be of use to capture any of the widget outputs
Q11. Have you encountered any technical difficulties applying the ESM webtool or ESM widget (e.g. data not loading)?	
• "Not applicable to me, a colleague applied the web-tool and I utilised the output for the assessment stage of SEA" • "Can take time to run but this is to be expected" • "Sometimes the large national datasets take time to load, but this is expected". • "None"	The terms of reference, to be read before the user can launch the webtool, have been revised to include a statement indicating that the widget will take 2–3 minutes to render results
Q12. Please provide any other comments you may have	
• "The web tool is a beneficial tool but it is reliant on the baseline datasets available which can be a key limiting factor" • "Very good tool to assist plan makers and has great potential around alternatives" • "Ability to add shapefiles is an excellent feature"	

Additional feedback received/comments (separate from and in addition to the online questionnaire):

Stakeholder comment	Project team response
• "It would be nice if there could be a piece of text, saying something along the lines of '**It may take several minutes for the results to complete**', just so people know that once they select to run the report, it will take a little time. (Just in case some people get frustrated if nothing appears automatically, and/or possibly if they think the tool has hung for some reason). We have something similar for our SEAGIS Reporting tool, saying that it may take 2–3 minutes to generate the pdf. It provides info the user that it is working"	The terms of reference, to be read before the user can launch the webtool, have been revised to include a statement indicating that the widget will take 2–3 minutes to render results. As part of any future iterations, the ESM webtool should be designed to incorporate a new timer indicator as part of the widget's functionalities to show how long the rendering process is expected to take. This was not possible as part of this cost extension as the project team did not have the relevant technical skill set required to redesign the widget
• "I think when the tool loads up first, it is a little daunting for non GIS people -it's very lean which is great to use as it's not cluttered, however I think if could benefit from adding a button which links to a video tutorial which shows the workings of the tool, that newbie's can view a narrated short video of it being used. (Maybe a pdf of it also being used also would help)"	The terms of reference, to be read before the user can launch the webtool, will incorporate a future link to a narrated online tutorial video once the project goes live to the public

• "Thank you for the opportunity to evaluate the ESM web tool. I like the look and feel of the design" • "I have been able to use it at our offices after the training session in UCD once or twice" • "I found the viewer and the tool to be user friendly" • "In my opinion the level of content in the themes and their associated layers is pitched well for the users it is aimed at. Some of the more detailed layers did take a bit of time to load but overall I think the performance is good" • "There are no descriptions on the themes and I think it would be useful to put something there, even it is only a list of what is in each theme, at least the user would know that there is no missing info"	The ESM viewer has since been updated to include a description for each of the SEA theme layers
• Enable downloading of the sensitivity output, i.e. in GeoTIFF format	The ESM project team has explored the potential to download the sensitivity output; however, the current AGOL set-up is restricted and cannot incorporate this functionality. This would require a team with coding expertise, which is unavailable as part of this cost extension
• "Is it possible to include an option for 'select all' under each grouping in the viewer"?	As the webtool has been designed and updated it has not been possible to include this functionality in retrospect. In any future iterations of the webtool, the design specifications should have regard to this request from the outset
• "Is it possible to link/align the widget to the data viewer and when layers are selected in the widget that they are automatically selected in the data list so they are correlated and each included dataset can be subsequently queried"	This has not been possible as part of this cost extension because of current skill set and technical capacity. Furthermore, the ESM project team is not aware of this functionality being available elsewhere
• "Also in the 'terms and conditions' window indicate that the produced sensitivity maps should be "printed" in the widget output window for clear reporting on criteria and weights applied and effective use of output maps"	It has been detailed in the user manual and online tutorial video (references and links provided for both in the terms of reference) that the produced sensitivity maps should be printed in the widget

Appendix 6 Summary of the Overall Technical Development of the ESM Webtool

A6.1 Technical Guidance

This appendix provides a summary of the overall technical development of the ESM webtool and details of the main operational components. A 'Technical Handover Document – Development of the ESM Webtool' has also been prepared as a means of guiding and assisting with the transferability of the final ESM webtool. This provides more details on the aspects outlined below.

A6.2 Operating Platform and Servers

The ESM webtool (both viewer and widget) has been developed using Esri ArcGIS technology, published via ArcGIS Server, with outputs integrated into an ArcGIS JavaScript/HTML-driven web application built using ArcGIS WebAppBuilder (Developer Edition). This is the current online technology that AIRO uses for its entire online national mapping infrastructure and is accessible from all devices (tablet, smartphone, etc.).

The ESM webtool platform provides a user-friendly interface that allows users to select and query all SEA-related environmental datasets from a left-hand menu. The ESM widget is accessed via an icon on a toolbar located at the bottom centre of the map window; when activated it opens a graphical user interface (GUI) that allows users to select specific variables and assign user weights (Figure A6.1).

The ESM webtool and underlying applications, as currently developed and deployed, are accessed via specific Microsoft Windows Servers hosted within the Computer Centre at Maynooth University – Server A (GIS) and Server B (Deployment). Server A (GIS) is the main server and hosts the underlying datasets for both the viewer and the widget, as well as relevant GIS software required for data generation and publication, i.e. ArcGIS 10.5 and ArcGIS Server. Server B (Deployment) is primarily used to host the final ESM WebApp and provides the necessary web-accessible environment from where the live ESM webtool is

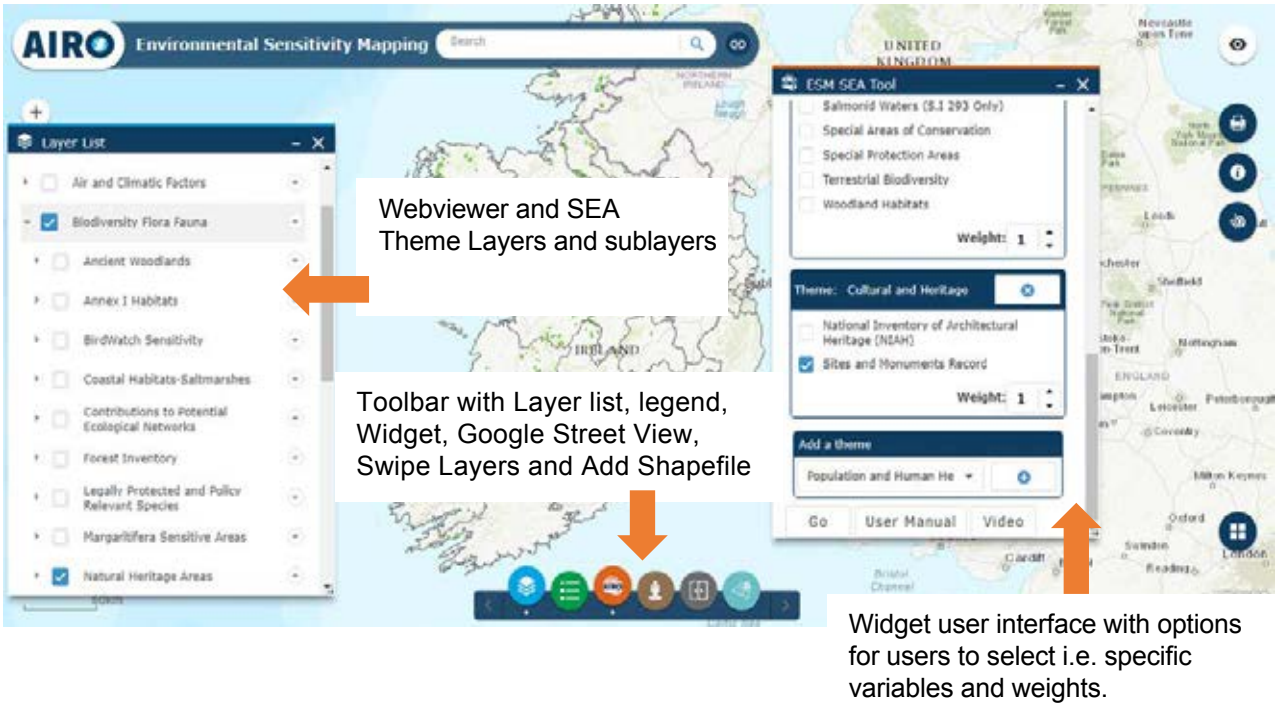


Figure A6.1. Screenshot of the ESM webtool platform and interface.

deployed and activated via the ESM webtool web address (http://airomaps.nuim.ie/id/ESM_GP/) – note that this address may change depending on final hosting of the ESM webtool.

Figure A6.2 details the entire ESM webtool infrastructure and systematic production flow through the following stages: stage 1 (mapping, modelling and publication), stage 2 (web map development), stage 3 (web app design) and stage 4 (final deployment). The following section provides detail on each of these four stages.

A6.3 ESM Mapping Infrastructure and Production Flow

A6.3.1 Stage 1 (mapping, modelling and publication)

Stage 1 of the ESM production flow is carried out on Server A (GIS). As previously noted, this Windows server hosts all of the relevant datasets underpinning both the viewer and the widget and all of the relevant GIS software (ArcGIS 10.5 and ArcGIS Server) necessary to produce and publish the main mapping services that are accessible on the deployed ESM webtool.

Server A (GIS) contains a folder structure from where all AIRO-related mapping and datasets are stored in specific project folders. The ESM project folder (C:\Projects\ESM\) contains two key separate folders where all the final datasets for both the viewer and the widget are stored: ESM_WebViewer (Jan 2018) and ESM_Widget_GP. This folder also contains a folder called ESM_Print which contains a .mxd file for the print layout.

The ESM_WebViewer (Jan 2018) folder contains eight individual SEA theme (e.g. biodiversity, flora and fauna; water; air quality and climate) file geodatabases (.gdb), which store the final set of relevant mapping files for each theme that allow the development of the ESM Viewer. Within each .gdb file there is also a .mxd file for the overall theme. For instance, the Air_Climatic_Factors.mxd integrates all mapping files in the .gdb file into a single map document. Once the

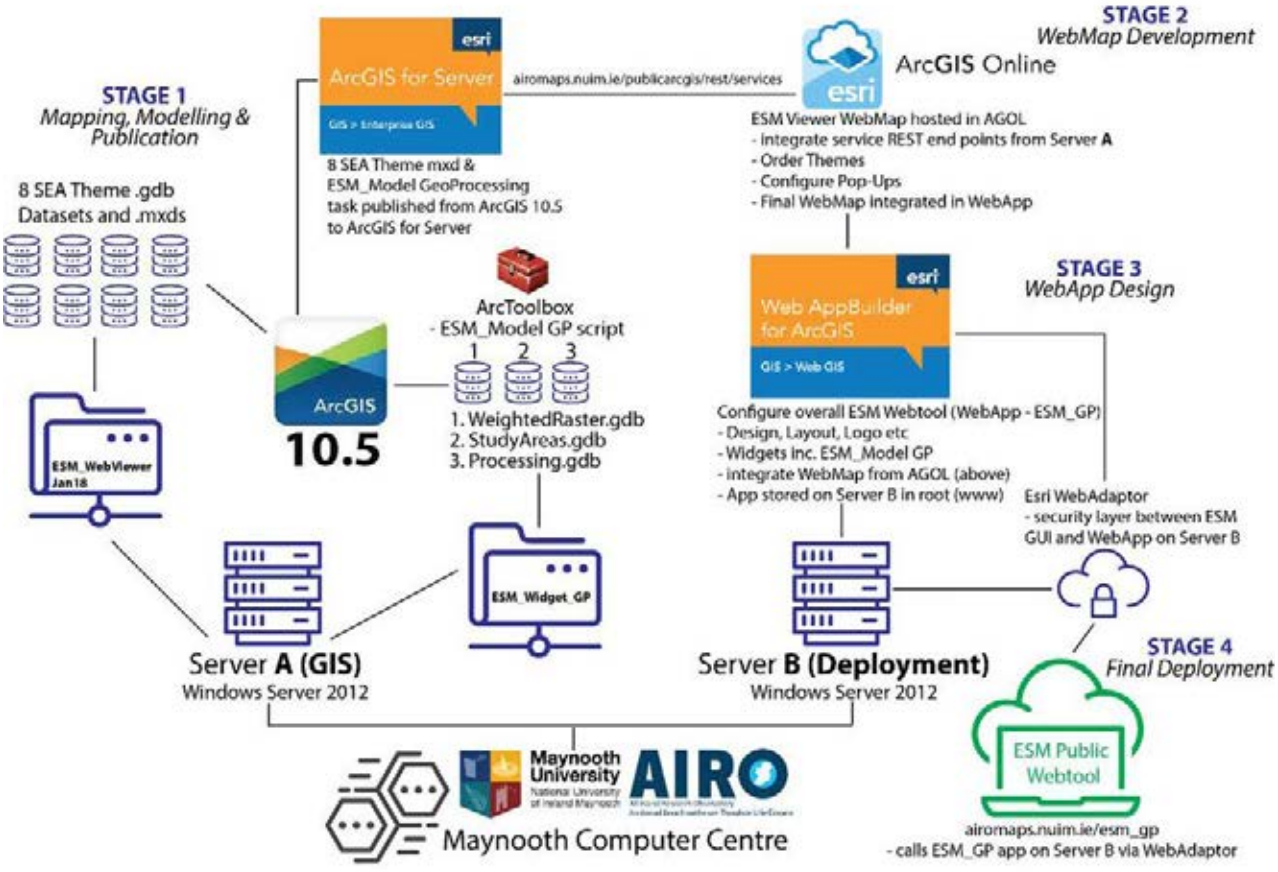


Figure A6.2. Environmental sensitivity map infrastructure and production flow.

final .mxd files have been prepared and saved using ArcGIS 10.5, they are published to the ArcGIS Server as a service (REST endpoint) to the ESM folder on the AIRO Rest Directory (airomaps.nuim.ie/publicarcgis/rest/services).

These services and associated links are then used in the development of the web map in stage 2 (web map development) on AGOL.

The ESM_Widget_GP folder contains all of the relevant geodatabases and ArcToolbox scripts that operate the ESM widget. Within this folder, there are three geodatabases that are accessed through the ESM Model: (1) the WeightedRaster.gdb, which contains all the raster files (including scientific scores) used in the underlying model; (2) the StudyAreas.gdb, which contains a mapping file of all of the study areas (local authorities, regional authorities, etc.) available for selection in the ESM widget GUI; and (3) a Processing.gdb, which is used to store temporary processing files as part of the operating model.

Another key element within this folder is the ESM_Model geoprocessing model, which is located within ArcToolbox – this model is the underlying set of geoprocessing tools and tasks that operate the ESM widget. This novel widget was initially developed using a series of geoprocessing tools within ArcGIS Desktop ModelBuilder (see model description below). Once the model accurately produced the required sensitivity results, it was necessary to publish the geoprocessing task to ArcGIS Server as a geoprocessing service for integration within the web app (stage 3 web app design) and finally on the client-side GUI on the ESM WebTool. The published geoprocessing task (within the web app) provides users with a series of options on the client side, namely the ability to select (1) the study area of interest; (2) the variables they are interested in; (3) the weights they wish to apply; and, finally (4) a "Go" button, which activates the geoprocessing task on the server side.

On activation of the "Go" button two main sets of information are sent to the server-side geoprocessing model on Server A (GIS): (1) the variables and weights to be included in the model and (2) the selected study area. The overall model flow from user interaction with the GUI to final map output is outlined in Figure A6.3.

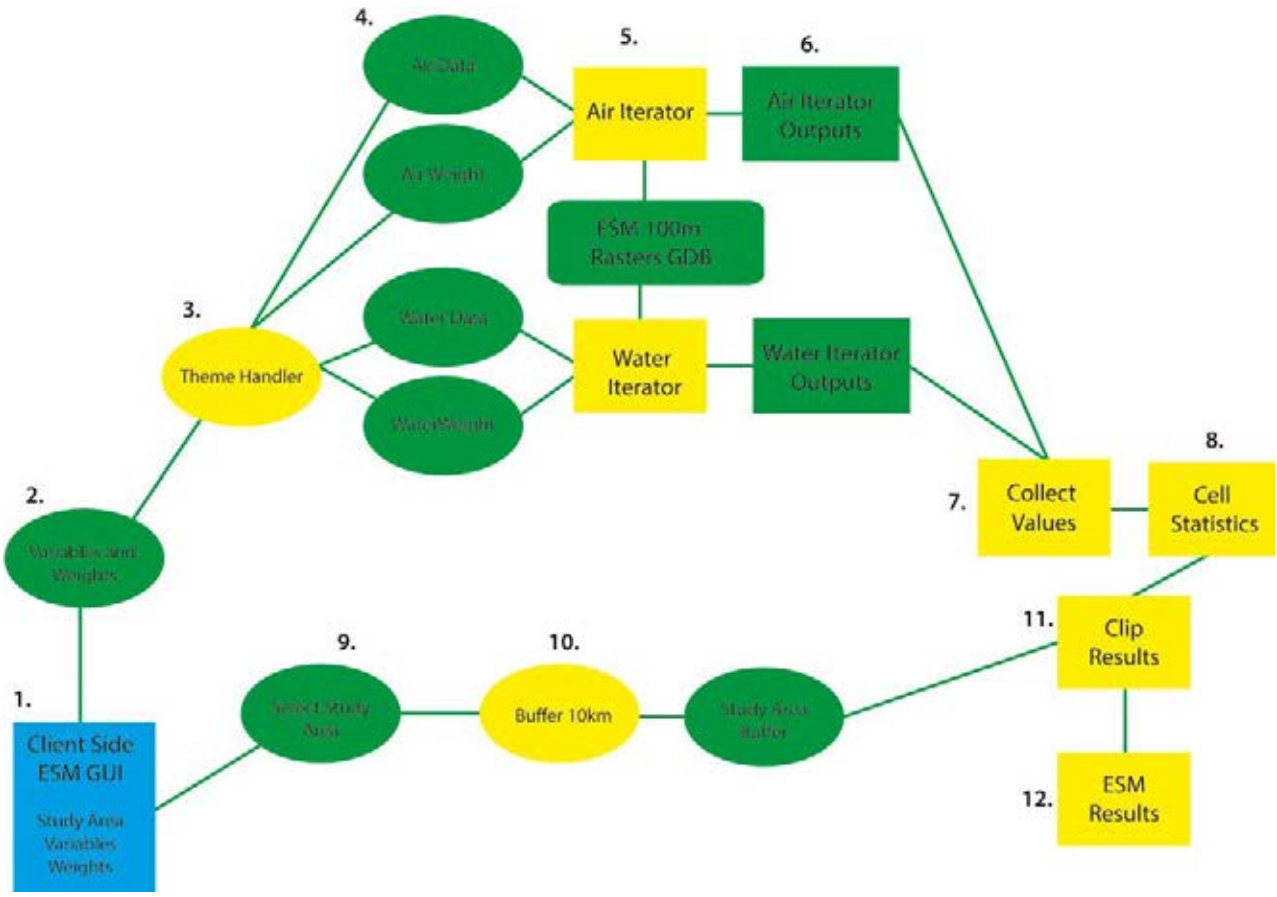


Figure A6.3. Environmental sensitivity map overall model flow diagram.

This process and each of the 12 steps are discussed in detail in the Technical Handover report.

A6.3.2 Stage 2 (web map development)

With all related services for both the viewer and the widget now published to ArcGIS Server, the next stage in the development process is to configure the web map on AGOL.

Using the AIRO AGOL user account, a web map was configured to host the ESM content. The feature services (published .mxd files) hosted on the AIRO server for each theme were added to this new ESM web map. The feature layer for each theme was added to the viewer by selecting the correct AIRO REST service endpoint from the REST Directory on Server A (GIS).

With the content in place, a pop-up for each feature in the map was configured. The purpose of the pop-up is to provide more detailed information about individual map features when they are clicked on by the end user. This is achieved by accessing the underlying attribute dataset, which is published with the map service. Pop-up configuration was carried out for all of the layers in the ESM viewer via the pop-up configuration window within the AGOL. The content for each pop-up was limited to the attribute information that accompanied each feature layer. Therefore, the content was dependent on what was provided by the data provider within the source shapefiles.

With the completed web map, the next stage was to construct the web application that would host the web map for the end user. The ESM web app was developed using ArcGIS Web AppBuilder (Developer Edition).

A6.3.3 Stage 3 (web app design)

This stage of the process involves the overall design of the final web app, which provides the user interface and various functions (ESM widget, print widget, scroll tool, etc.) and integrates the web map as configured in stage 2 (web map development). As with all AIRO web apps, a customised application with specific AIRO branding was configured locally using Web AppBuilder V2.3 (Development Edition). As part of this process, additional functionalities are configured to enable the end user to navigate the map, access Google Street View, print the map, annotate the map, add user data and carry out simple geoprocessing tasks (e.g. measure). Within this configuration, the ESM_Model geoprocessing widget (stage 1) is also added to the application at this point via the geoprocessing Task Service, as published in stage 1.

To enhance functionality and the overall look and feel of certain widgets (i.e. the ESM widget and print widget), as well as the overall user interface, certain additional configuration steps were taken to ensure that functionality aligned with the requirements set out in the project specification. Web AppBuilder (Developer Edition) allows app developers to access the file and code structure of the app and edit them using a combination of JavaScript and HTML. This enables developers to edit and adjust fine details related to the look and function of widgets and the overall design of the app – far beyond the scope of what can be done using the Web AppBuilder program interface. Using a standard text editor (Visual Studio Code, etc.) to adjust the widgets and app, the final configuration steps were undertaken at this point (colour schemes, font of text, size of text, etc.).

Following the completion of the design and build of the web app, a period of testing was undertaken to ensure the correct functionality of each component part of the completed web app.

On completion of testing, the final web app was exported from Web AppBuilder. The final output is a zipped folder containing almost 2000 individual files. The final web app is now ready for deployment and loading on the web-accessible Server B (Deployment) – see stage 4.

A6.3.4 Stage 4 (final deployment)

As described above, the operation platform for this infrastructure is shared across two Microsoft Windows servers. Server A (GIS) contains the GIS data, models and content for the viewer and Server B (Deployment) contains the completed web application, where it can be accessed by end users over the internet. The two servers have very different functions. Server A (GIS) is a GIS server and is not visible or accessible via the internet. As such, it is not possible to access this server or its content remotely over the internet, ensuring that the content stored on this server is secure. To access the content on this server, Esri

have developed a specific security measure called the WebAdaptor. The WebAdaptor is configured on Server B (Deployment) and enables secure access to all of the relevant map and model content for the completed ESM WebTool on Server A (GIS).

A second key role of the web-accessible Server B (Deployment) is to host the completed ESM web application. Server B (Deployment) contains a folder that can be accessed over the internet using a URL (www.ServerB/FolderName; this URL is for internal access only). By placing the competed web application in this web-accessible folder, we can access the completed web application over the internet. Of the 2000 configuration and functional files in the completed web app, there is a single overarching configuration file (.config), which triggers a cascade of functions once opened. This cascade of functions launches the web app and opens the map interface online.

By placing the ESM_GP web app in the web-accessible folder, we have a URL that now looks like the current URL we use to access the ESM web viewer (www.ServerB/id/ESM_GP; this URL is for internal access only). By applying a redirect on the name of our server, we can produce a URL that is more relevant to the public and that can be shared in the public domain. By applying the redirect, we remove the name Server B and replace this with airomaps.nuim.ie. Following this final step, we can now access the completed web application, which is stored in a web-accessible folder that is accessible internally and publishable.

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Developing and Testing an Environmental Sensitivity Mapping Webtool to Support Strategic Environmental Assessment in Ireland

Authors: Ainhoa González Del Campo, Christina Kelly, Justin Gleeson and Eoghan McCarthy

Identifying Pressures

This report and the associated Environmental Sensitivity Mapping (ESM) webtool, developed by the research team, are a response to the need to enhance consistency and transparency in Strategic Environmental Assessment (SEA) practice. For SEA to effectively inform planning processes, a systematic and accessible approach that provides clear information and ensures comparability between assessments is key. Development pressures on the landscape need to be efficiently examined and the potential for cumulative effects on the environment need to be considered. The output of this research enables the creation of environmental sensitivity maps that capture the accumulated concentration of sensitive environmental features on the landscape, which help to address some of these challenges and direct development to suitable locations.

Tight assessment time frames, the need to consider disparate and multiple data sources, and engaging stakeholders and the general public require significant effort by consultants and plan makers. The developed ESM webtool addresses some of these time and resource pressures and provides an opportunity to streamline assessments by centralising information, facilitating public participation, enabling creation of plan-specific maps and providing a robust evidence base to inform spatial planning.

Informing Policy

This research informs policy through the ESM webtool, as it can serve as an empirical and systematic approach and as a more objective critical foundation to promote informed impact assessment and planning. The research outputs promote best practice in the implementation of EU directives and reinforce consideration of their obligations. More specifically, the outputs contribute to improving the effectiveness of SEA, Environmental Impact Assessment and appropriate assessment through the provision of a systematic and evidence-enabling online tool. This results in improved compliance with national sustainability objectives through better, more transparent and evidence-based assessment of plans and programmes that set the basis for projects. In addition, it inculcates a culture of excellence among plan and programme makers and SEA teams, encouraging more than legal compliance (through the incorporation of environmental sensitivity analysis, for example), and contributes to the implementation of the INSPIRE Directive through data exchange and sharing, as well as to the Aarhus Convention and e-governance strategies on access to environmental information.

Developing Solutions

The webtool provides an invaluable resource for SEA by facilitating access to multiple spatial datasets in a single interface (datasets that, prior to the publication of the webtool, were accessible through multiple sources and websites). This saves SEA consultants, local authorities and governmental departments, among others, a lot of time and effort in SEA and planning processes. It also provides a platform for the general public and stakeholders to explore environmental and planning considerations, and it can serve as an educational tool.

The webtool contains novel functionality: it is the first online geoprocessing tool that enables the creation of context-specific maps by anyone, without the need for any technical geographic information system skills. This tool allows the user to combine datasets and incorporate public perceptions in a participatory way, creating plan-specific environmental sensitivity maps. These maps graphically and meaningfully highlight potential sensitivities, pointing to where development would need to be carefully considered and sensitively planned. In this way, the maps can inform sectoral planning discussions and decisions for developing alternatives that avoid or minimise potentially incompatible or unsustainable zonings.

The webtool has been tested by the research team in a number of case studies, including real-life settings, namely as part of live SEAs of the National Planning Framework and the Regional Spatial and Economic Strategies. This piloting has verified the usability of the webtool and the veracity of the output maps. Users have confirmed that it contributes to assessment consistency and transparency.

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