MESA: Mapping Environmentally Sensitive Assets

A spatial tool to support environmental management.

UN environment programme WCMC

NORWEGIAN ENVIRONMENT AGENCY

Norad

Suggested citation

NEA and UNEP-WCMC (2020) MESA: Mapping Environmentally Sensitive Assets - A spatial tool to support environmental management.

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Acknowledgements

This work has been completed with funding and contributions from the Norwegian Environment Agency under the Oil for Development Programme.

OIL FOR DEVELOPMENT

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This document forms part of Version 2.2 of the MESA tool in conjunction with FME-QGIS process files. It was designed for use with FME Workbench 2019 and QGIS Desktop 3.10. Further versions of the tool are anticipated and care should be taken to ensure the version of all constituent parts are aligned.

1. Introduction

1.1 Definition of terms

Environmental Sensitivity Atlas: a collection of maps and supporting narrative text presenting spatial data on the sensitivity of ecological and/or socio-economic assets to a specific pressure.*

Environmental Sensitivity: a combination of susceptibility and importance of affected asset that signifies the potential impact of a given pressure.*

Environmental Asset: a collective term for ecological and socio-economic assets.*

Ecological Asset: naturally occurring entities that provide ecological "functions" or services….including those which have no economic values, but bring indirect uses benefits, options and bequest benefits or simply existence benefits which cannot be translated into a present day monetary value[1].

Socio-Economic Asset: natural or anthropogenic entities that provide social, cultural, economic or political value which may or may not have a quantifiable monetary value.*

Importance: An asset's value either at a global, national, or local scale in relation to its rarity, significance, functional and intrinsic value.*

Susceptibility: The degree to which an asset will be affected by a pressure, based on the predicted severity of the impact and the asset's ability to recover once the pressure has ceased.*

Sensitivity: Overall rating of the consequences of allowing an impact to occur. This combines both the importance and susceptibility of an asset to a given pressure. *

Functional Value: the contribution a species' traits (unique behavioural or physical characteristics of a species) make to the maintenance of an ecosystems health and resilience)[2].

Intact Forest Landscape: a seamless mosaic of forest and naturally treeless ecosystems within the zone of current forest extent, which exhibit no remotely detected signs of human activity or habitat fragmentation and is large enough to maintain all native biological diversity, including viable populations of wide-ranging species[3].

Ecologically Viable Forest: area of forest in which canopy cover is maintained above 60%[4].

** Due to the multiple overlapping definitions for this term within the literature a clear definition of what is meant by this term within the context of this document has been provided.*

[1] OECD (2005) Environmental Assets. *Glossary of Statistical Terms*
[2] Adapted from Cernansky R (2017) The Biodiversity Revolution *Nature* **546** (7656)
[3] Intact Forest Landscapes (2017) Technical Definition of IFL
[4] Adapted from World Bank (2019) Forest-Smart Mining: Identifying Factors Associated with the Impacts of Large-Scale Mining on Forests

1.2 Aim

MESA (Mapping Environmentally Sensitive Assets) is a tool intended for a broad audience of individuals working on the development and use of environmental sensitivity maps in various contexts. It provides a step-by-step protocol for developing an environmental sensitivity atlas based on a standardised methodology that was developed following a review of multiple existing methods. This protocol is combined with an FME-based tool for the processing of environmental data and QGIS for visualising the final atlas. It can be applied for a variety of intended uses (e.g. strategic planning, project management and emergency response) and includes context-specific considerations to be made during the mapping process. Its key purpose is to support environmental management of the oil & gas sector, which is referred to throughout, but it is equally applicable to other sectors.

The document was originally developed to support a regional environmental sensitivity mapping workshop in Arusha (Tanzania), in September 2019, under the Oil for Development programme.

1.3 Environmental sensitivity atlases

Environmental sensitivity atlases are tools that display relative sensitivity of areas to any given pressure. There have been a range of approaches developed for different geographies and sectors, capturing aspects of the importance of a predicted impact upon environmental assets. Atlases are used to screen areas for development, support the Environmental Impact Assessment (EIA) process or respond to incidents. The goal is to help decision-makers understand where vulnerable assets are located and where to plan industrial operations in order to minimise the environmental and social risk.

In general, the development of an environmental sensitivity atlas should follow the procedure outlined in Figure 1, however each step can be adapted to the local context based on the intended use of the atlas, stakeholders' values, drivers of change, data availability and the technical capacity of the users. This document provides step-by-step guidance for the process outlined in Figure 1.

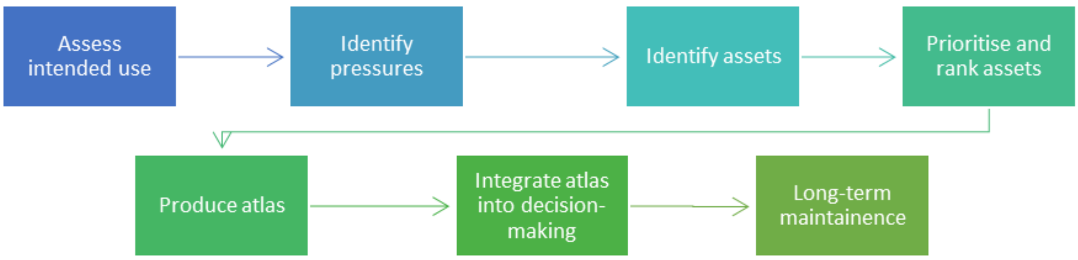


Figure 1: Process for developing environmental sensitivity atlas.

Note: This document addresses the environmental sensitivity mapping process in relation to ecological assets. A separate process should be conducted for socio-economic assets with the appropriate stakeholders and experts. Due to a lack of comparability, the sensitivities of ecological and socio-economic assets are not to be aggregated. Instead, the atlas should present both asset types side-by-side so that both are considered in the decision-making process.

2. Assess intended use

2.1 Understand intended use

Understanding the intended application of the environmental sensitivity atlas is an important first step in guiding its development. Knowing whether the atlas is intended to be used at a strategic (national planning), operational (project management) or tactical (emergency response) level helps identify the appropriate resolution and assets to include, as well as providing a filter for identifying relevant pressures. The intended use will also influence the stakeholders that need to be engaged within the process and the audience to which the final product will be disseminated.

Once the intended use has been identified, consideration should be given to the ways in which it may influence development. These considerations include but are not limited to:

- Is assessment of more than one pressure necessary?
- What level of resolution is needed in order to fulfil the intended use?
- Are temporal changes in sensitivity during the year important for decision making?
- At what level will decision-making occur and will this influence how importance of assets is perceived?
- What is the key audience in order to ensure the intended use can be fulfilled?

For example, an atlas designed to support the planning of oil & gas developments at a national level would likely differ noticeably in its development when compared with one designed to inform emergency response to oil spill (see Figure 2).

2.2 Understand capacity and needs

2.2.1 Technical capacity of developers

Technical capacity of those developing the atlas is a key consideration when planning its creation. This will include an assessment of the level of expertise, processing power and resources available to produce the atlas.

The capacity to assess sensitivity of assets is likely to be dispersed across a number of institutions and external stakeholders. An assessment of key stakeholders should be conducted to ensure there is no gap in the knowledge required to develop the atlas.

The FME-based tool presented in Section 6 requires only limited GIS capacity in order to produce an atlas given the correct input data. While processing power can be intensive depending on size and resolution of the atlas, this can usually be resolved by providing additional storage as described in Section 6.2. As such, in most cases sufficient GIS capacity should be available to generate an atlas. However, a level of technical capacity will be required to maintain and update both the atlas and its underlying data, in particular if it is shared via an online portal.

2.2.1 Technical capacity and needs of users

The technical capacity and needs of the user should also be considered, in particular in relation to the format in which the atlas is disseminated. The approach outlined in this guidance requires developers to have a basic understanding of GIS, but does not have any such requirements for end-users. If user technical capacity is low, then formats that rely on GIS skills to interpret should be avoided, but if capacity is high, GIS formats could be provided either via download or online portal as user needs dictate.

Consideration for how the user will apply the information within the atlas should be clearly defined. If the user is conducting a spatial analysis over large areas and would benefit from being able to interrogate underlying datasets then GIS formats should be prioritised. If the user will need to review the atlas while on-site, or in emergency situations, simplified PDF maps that can be printed and laminated may be more suitable. In many scenarios there may be a need to provide the atlas in multiple formats. This should be established at the onset of the atlas development.

ATLAS 1

Intended use: Informing the national planning of oil & gas operations.

Pressures: A wide range of pressures associated to oil & gas development should be considered including habitat loss, oil spill and disturbance.

Resolution: Assets should be mapped to moderate resolution in order to present information at a scale at which national strategic planning can be conducted.

Time: Temporal aspects not required as at least some pressures will be present year round. A precautionary approach using the assets' maximum sensitivity should be used.

Prioritisation of assets: Global and national priorities should be considered when ranking importance.

Key audience: Atlas should be shared with government institutions involved in national level planning. This may extend outside of institutions involved with oil & gas development.

Format: Atlas should be provided in a GIS format which allows users to interrogate underlying data and establish the causes of sensitivity. Detailed information about assets within each grid cell will give a broader background for further analysis.

ATLAS 2

Intended use: Emergency response to oil spill.

Pressures: Oil spill should be the only pressure considered.

Resolution: Assets should be mapped to high resolution in order identify where localised oil spills would likely have the most significant impacts.

Time: Temporal aspects of sensitivity should be considered (e.g. breeding times) as areas may range from high to low sensitivity depending on when the oil spill occurs.

Prioritisation of assets: Local importance as well as global and national importance should be considered to reflect the level at which decisions will be made.

Key audience: Atlas should be shared with emergency responders, which may include environmental management authorities, coastguards, military or police departments, and companies.

Format: Both GIS and PDF formats should be provided. This would provide emergency response coordinates full access to sensitivity information, while providing on-the-ground response teams quick and easy access to key information. Detailed information about assets within each grid cell will give a broader background for situation specific responses.

Figure 2: Considerations associated with different intended uses of a sensitivity atlas.

3. Identification of pressures

The pressures considered will determine which assets will be most sensitive. Sources of impact are to be clearly identified by users prior to carrying out mapping exercises, as this will determine the selection of experts, stakeholders and datasets relevant to the mapping exercise.

When considering development, it is necessary to consider a number of pressures. For example, oil infrastructure and extraction can lead to pressures such as habitat loss and fragmentation, disturbance and oil spill. In such cases, the full suite of pressures needs to be identified and understood prior to undertaking the exercise (see Table 1).

This process is to be completed in collaboration with appropriate national and industry experts. They may include academics, government institutions, NGOs, civil society, consultants, as well as the industry.

Table 1: Potential pressures from oil & gas operations.

Terrestrial	Coastal	Marine
Oil Spill	Oil Spill	Oil Spill
Habitat Loss	Habitat Loss	Habitat Loss
Habitat Fragmentation	Habitat Fragmentation	Habitat Fragmentation
Disturbance	Disturbance	Disturbance
Atmospheric emissions	Atmospheric emissions	Atmospheric emissions
Aquatic pollution (excl. oil)	Aquatic pollution (excl. oil)	Aquatic pollution (excl. oil)
Soil erosion and degradation	Soil erosion	Increased biological resource use
Airborne particulates (e.g. dust)	Airborne particulates (e.g. dust)	
Increased biological resource use	Increased biological resource use	

4. Identification of assets

While identifying all features that meet the broad definition of ecological assets is ideal, there is a need to find a pragmatic starting point that captures key biodiversity values and limits processing time at the outset. Some recommended ecological assets include:

- Areas with protected status;
- Areas with biodiversity designations (e.g. Key Biodiversity Areas, KBA, or Alliance for Zero Extinction sites, AZE);
- Critical Habitats according to International Finance Corporation's (IFC) Performance Standard 6;

- Areas known to support protected or Threatened Species[5];
- Habitats known to support high biodiversity and ecosystem services (including mangroves, forests, coral reefs); and
- Other assets which are deemed ecologically important.

The identification of assets is to be conducted as part of a multi-stakeholder engagement process involving government institutions, local communities, NGOs and academia.

Asset data need to be spatially referenced, with discrete boundaries, to be included in the environmental sensitivity atlas. These data should follow the data standards outlined in Annex I.

As each asset dataset is dealt with separately during the mapping process, there is no difficulty with multiple assets overlapping, which is likely to occur between different habitats, species and designations (e.g. asset datasets for mangrove habitat and Ramsar Sites could overlap significantly).

5. Prioritisation and ranking of assets

In this guidance, sensitivity is defined as the combination of an asset's importance in a national and/or global context and its susceptibility to the given pressure. Assets need to be assessed according to both their importance and susceptibility in order to produce sensitivity rankings for each asset type.

Asset's importance is likely to be highly contextual and requires the consideration of an asset's value both globally, nationally and locally. When assessing the importance of assets, there is a need to convene a range of stakeholders from government agencies, NGOs, academia and the wider community to get a comprehensive understanding of their relative ecological value. Ecological assets that have socio-economic value as a result of the ecosystem services they provide (e.g. provision of food or water) should be distinguished from non-ecological socio-economic assets such as infrastructure, hotels, etc. The latter are not considered here and should be assessed, mapped and visualised independently.

Susceptibility of assets is based on an understanding of the potential impact from the given pressure on those assets. It is therefore an objective measure that can focus on published literature and expert input. Studies specific to the location are preferable for determining susceptibility, but in the absence of such work, assessments in other regions can also inform this process.

Importance and susceptibility are assessed separately (see below) before being combined to provide an overarching ranking of sensitivity.

[5] Both globally Threatened Species within the IUCN Red List of Threatened Species and nationally Threatened Species contained within national red lists should be considered.

5.1 Importance

An importance assessment identifies the relative conservation importance of identified ecological assets. It is likely to incorporate aspects of legal protection, threat status and irreplaceability.

Assets need to be assigned a score between 1 (lowest) and 5 (highest) based on their importance. This process should account for international, national and local importance and be guided by the intended use of the atlas. For example, an atlas for oil spill response should focus on importance compared to other local assets as the atlas is likely to be used in order to locally prioritise which assets receive an immediate allocation of resources to protect them from the impacts of the oil spill.

Criteria for assessing importance include, but are not necessarily limited to the following:

- Irreplaceability of the assets (internationally and nationally);
- Threat status (for species or ecosystems);
- Functional value;
- Provision of ecosystem services; and
- Legal status.

The identification, importance ranking and mapping of ecological assets have wide-ranging uses, which extend outside of the application of environmental sensitivity mapping for oil & gas development (See Section 7.2). The process effectively creates a national ecological asset atlas, which can then be applied in a range of contexts such as:

- Sensitivity mapping for other pressures;
- Strategic-level planning for development and/or conservation;
- Informing Strategic Environmental Assessments;
- Informing EIA review and monitoring; and
- Encouraging consistency in data use and decision-making processes across government authorities and the private sector.

5.2 Susceptibility

Susceptibility of assets relates to the potential impacts associated with a given pressure. These differ across terrestrial, coastal and marine realms (see Table 1). It is possible to generate separate atlases for each pressure. In certain circumstances, and depending on the intended use of the atlas, it may be possible to produce a cumulative assessment of multiple pressures associated with a specific operation. Careful consideration should be given to the validity and data availability for assessing susceptibility in this manner before producing an atlas.

Susceptibility is assessed based on the potential severity of the impact in terms of decline in the status of the asset (this may be measured as population abundance, habitat extent, quality, or other suitable metric), as well as the potential for the asset to recover from the impact (see Figure 3).

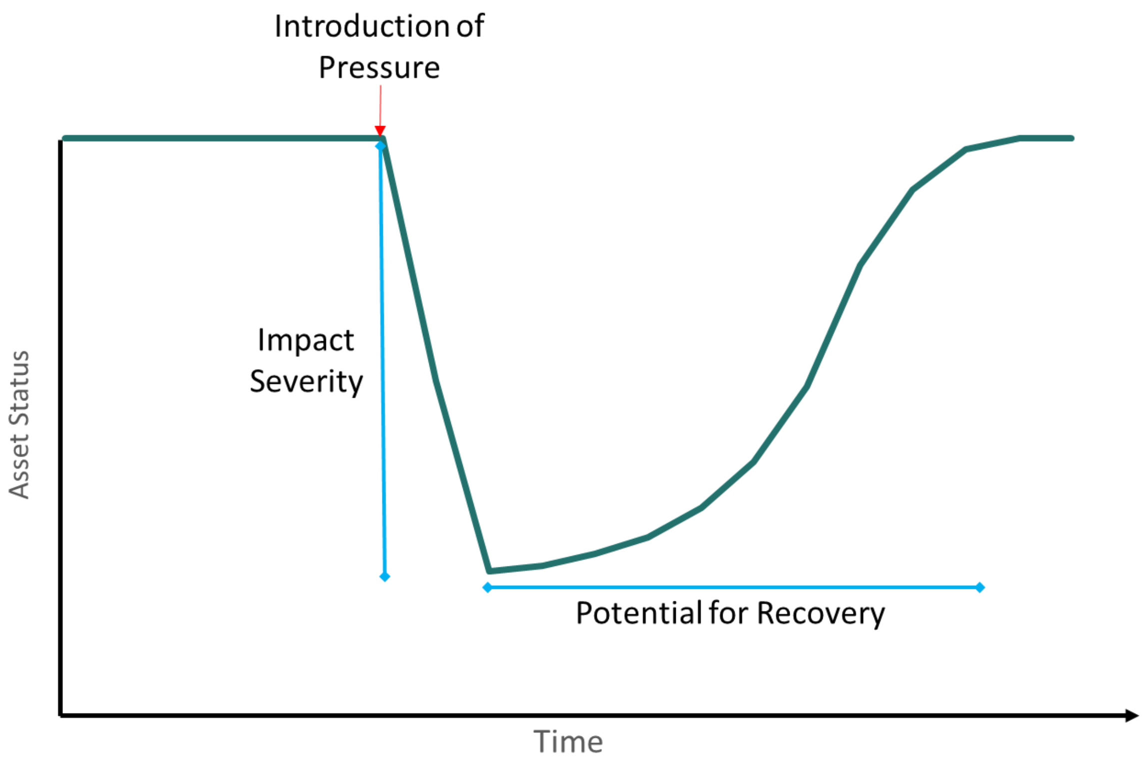


Figure 3: Conceptual approach for the assessment of an asset's susceptibility to a given pressure.

5.2.1 Impact severity

The impact severity score is based on the percentage loss of species population or habitat extent/degradation in a given area assuming the impact is uniformly distributed across that area. The percentage of habitat lost or degraded or the resulting decline in species population can be estimated and assigned to categories based on published literature and expert consultation.

5.2.2 Potential for recovery

The approach outlined for the assessment of potential for recovery has been designed to assess ecological assets. The approach could be adopted for socio-economic assets but may need a degree of modification based on the type of assets assessed. Appropriate expert consultation should be conducted to determine the validity of applying this approach and agree any proposed alterations.

For ecological assets, the potential for recovery score is based on the time it will take for the asset to return to a pre-impact state once the pressure has ceased. The categories of recovery times are shown in Figure 4. Careful judgement is needed in determining when a pressure has ceased and whether restoration is a mandatory requirement of applicable environmental legislation. For example, although habitat loss is likely to occur in a short time frame, its impacts could be long lasting or permanent if the land is not left to regenerate following the activity, while recovery time would be greatly reduced if active restoration is conducted. Recovery that takes greater than 40 years to occur has been classified as irreplaceable as a precautionary measure due to the unpredictable nature of future political, commercial and climatic factors that may influence recovery beyond this timeframe.

Scores for impact severity and the potential for recovery are then combined in a matrix to identify the overall susceptibility of the asset to an impact (see Figure 4).

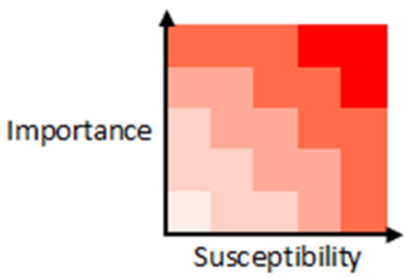
Potential for Recovery	<1 year	1	2	2	3	3
	1-5 years	2	2	3	3	4
	>5-20 years	2	3	3	4	4
	>20-40 years	3	3	4	4	5
	Irreplaceable (>40 years)	3	4	4	5	5
		<1%	1-10%	>10-30%	>30-50%	>50%
		Impact Severity				

Figure 4: Susceptibility matrix combining impact severity and potential to recover. Susceptibility ranges from Low (green) to Very High (red), with assets that experience very severe impacts with limited or no potential to recover being the most susceptible.

5.3 Combining

Once the importance and susceptibility rankings have been established, they are combined to produce sensitivity rankings for each asset type. This is done multiplicatively and translated into one of five sensitivity rankings using the ranking matrix (see Figure 5). It is this sensitivity ranking that is displayed in the environmental sensitivity atlas.

Environmental Sensitivity = Asset Importance x Asset Susceptibility



<2	=	Very Low
≥2 – 5	=	Low
≥5 – 10	=	Moderate
≥10 – 20	=	High
≥20	=	Very High

Figure 5: Sensitivity ranking matrix combining the importance and susceptibility rankings for each asset.

While this can be conducted manually if desired, in practice the combination is automated as part of the atlas production using the FME-based tool (see Section 6.5).

6. Atlas production

6.1 Procedure overview

The input data for a sensitivity atlas can be processed manually using standard GIS tools such as ArcGIS Pro or QGIS. This approach will require multiple operations and continuous management of datasets. The protocol developed for MESA relies instead on an FME-based tool[6] (FME Workbench 2019) for the processing of input data and QGIS[7] for visualising the final atlas. FME, from Safe Software, is a spatial Extract, Transform and Load (ETL) tool that minimises the risk of errors due to manual processing of data. This is done by extracting datasets from a source, transforming them into a destination format and structure using repeatable workflows and lastly loading datasets into a target database or file format.

The processing component of MESA is split in six stages (Figure 6), which are detailed in the sections thereafter with specific instructions on how to run the FME-based tool.

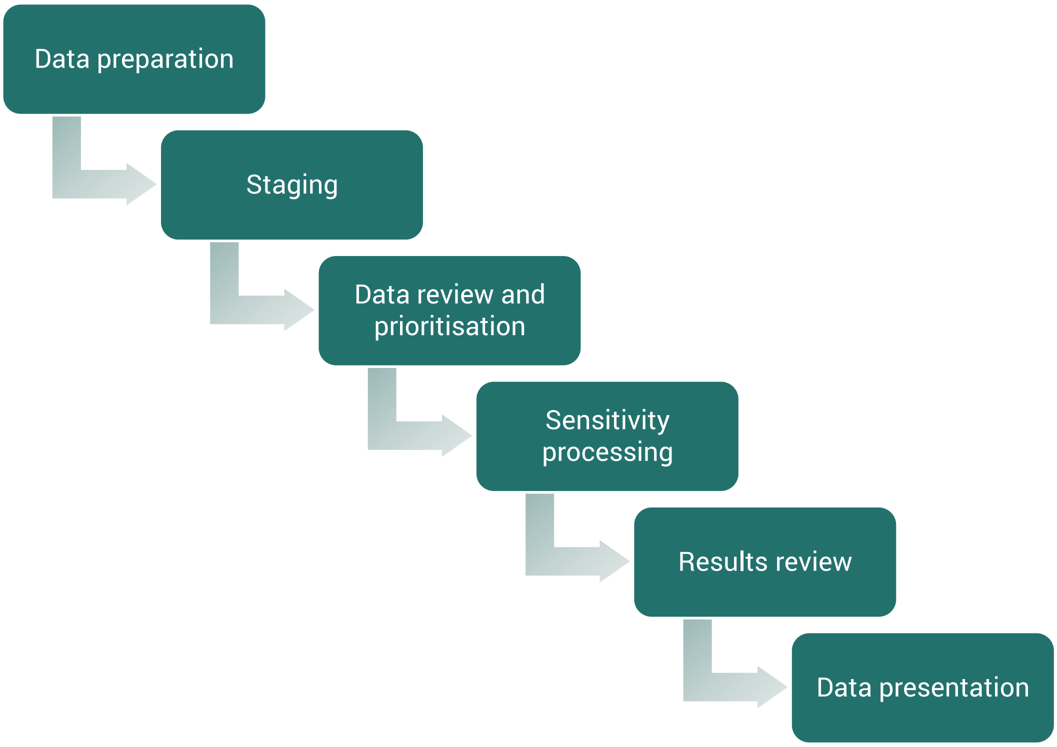


Figure 6: Overview of the processing of data for the environmental sensitivity atlas.

6.2 Processing capacity

Processing of a sensitivity atlas is limited by three factors: processing capacity, storage capacity and internal working memory (RAM).

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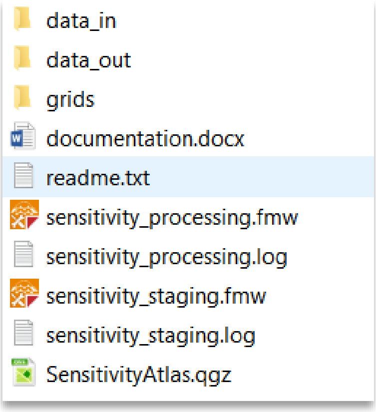
[6] The latest FME Desktop version is available at: https://www.safe.com/support/downloads/.
[7] QGIS standalone version 3.10 or higher is available at: https://qgis.org/en/site/forusers/download.html.

Processing capacity is the most important factor, with a clock speed of at least 3 GHz being recommended. Due to the script of the FME-based tool, multiple cores will not contribute towards processing speed.

Low storage capacity will also limit processing speed due to reduced swap space and increased shifting of information. It is however possible for the FME-based tool to read data from an external storage system (disk or memory stick) and hence preserve the computer's internal working memory (RAM). Fast transfer 8 GB memory sticks are recommended to contribute towards processing speed.

6.3 Data preparation

For the FME-based tool to stage the data adequately, naming conventions are applied to the data and folder structure, as shown here.



6.3.1 Input data

1) Add input asset data (as shapefiles or geopackage files) into the folder **data_in**. Sub-folders or zip files can be used if necessary.

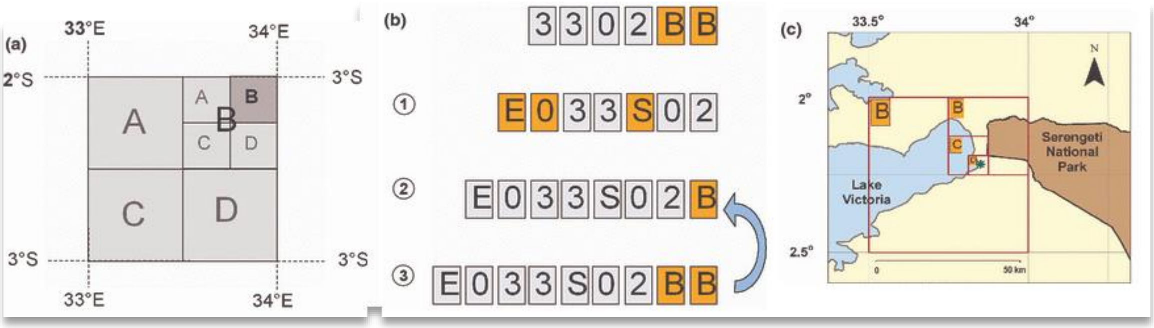
Please note that all asset data within one dataset are treated uniformly. Consequently, a dataset (one file) will be processed according to the susceptibility and importance rankings assigned to the associated file as a whole. In order to enable an asset type to be assigned multiple sensitivity rankings based on a sub-dividing criteria, the data should be spilt into separate files during this data preparation stage. For example, protected areas may require multiple sensitivity rankings based on the legal importance associated with the designation (e.g. National Park vs Forest Reserve) and so the dataset should be split into multiple files.

6.3.2 Spatial grids

2) Add spatial grids (as shapefiles or geopackage files) into the **grids** folder.

Although sensitivity mapping does not require a specific type of grids, MESA is currently based on the Quarter Degree Grid Cell standard[8]. This standard has global coverage and enables the use of differently sized grid cells. By styling grid cells differently, sensitivity as well as susceptibility and importance of an asset can be displayed. Spatial grids for use at national level have been developed[9] with grid cells ranging from 55 x 55 km (Level 1) to 850 x 850 m (Level 7). Smaller grid cells can be used to produce a sensitivity atlas of a smaller area of focus.

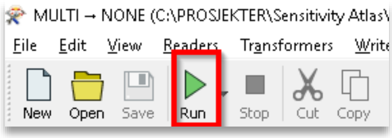
[8] More information is available at: https://en.wikipedia.org/wiki/QDGC.
[9] National QDGC spatial grids are available for download at https://github.com/miljodir/mesa.



6.4 Staging

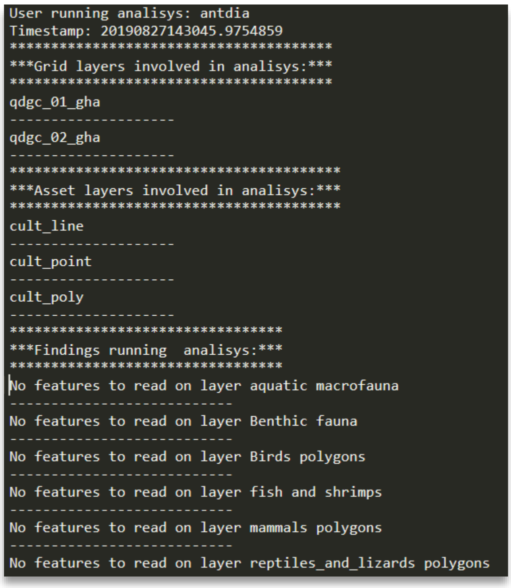
3) Double-click on the file **sensitivity_staging.fmw** to open the FME-based tool.

4) Click **Run**



An excel file is produced and added into the **data_out** folder under the name **output_to_edit_<datestamp>.xlsx**. A report file titled **report_<datestamp>.txt** is produced, containing the following:

- Windows Username from the user running the process;
- Grid layers involved;
- Asset layers involved; and
- Findings in layers (no features, not properly defined coordinate system, no defined coordinate system, duplicated layer, errors in the layers).



```
User running analisys: antdia
Timestamp: 20190827143045.9754859
**************************************
***Grid layers involved in analisys:***
**************************************
qdgc_01_gha
-------------------
qdgc_02_gha
-------------------
***************************************
***Asset layers involved in analisys:***
***************************************
cult_line
-------------------
cult_point
-------------------
cult_poly
-------------------
********************************
***Findings running  analisys:***
********************************
No features to read on layer aquatic macrofauna
---------------------------
No features to read on layer Benthic fauna
---------------------------
No features to read on layer Birds polygons
---------------------------
No features to read on layer fish and shrimps
---------------------------
No features to read on layer mammals polygons
---------------------------
No features to read on layer reptiles_and_lizards polygons
```

6.5 Data review and prioritisation

5) Open the **output_to_edit_<datestamp>.xlsx** file in the **data_out** folder and add the susceptibility, global and/or local importance ranking values for each dataset.

1	Datasett	susceptibility	local_importance	global_importance	combined_importance	Latest_update_date	asset_type	asset_name	asset_referencenumbe	asset_date
2	dataset_1	5	1	5	5	20190724		GHA_forest_60_reclass_poly		20190724
3	dataset_2	4	2	4	4	20190319		GHA_marine_PA_WHS_Ramsar_IUCN_1a_1b_2		20190319
4	dataset_5	3	3	3	3	20190724		GHA_terr_primary_forest_reclass_poly		20190724
5	dataset_7	4	3	4	4	20190319		GHA_terr_PA_WHS_Ramsar_IUCN_1a_1b_2		20190319
6	dataset_9	2	1	2	2	20171208		GHA_terr_seagrass		20171208
7	dataset_10	4	2	3	3	20171128		GHA_marine_mangroves		20171128
8	dataset_11	3	1	5	5	20190725		GHA_terr_KBA_IBA		20190725
9	dataset_13	1	2	4	4	20190624		GHA_marine_seamounts		20190624
10	dataset_14	1	3	3	3	20171208		GHA_marine_saltmarsh		20171208
11	dataset_15	2	3	4	4	20190319		GHA_marine_PA_everything_else		20190319
12	dataset_17	3	1	5	5	20171208		GHA_marine_seagrass		20171208
13	dataset_18	3	5	3	5	20190724		GHA_marine_mhwhale_reclass_poly		20190724
14	dataset_19	3	2	2	2	20190724		GHA_marine_sperm_whale_reclass_poly		20190724
15	dataset_22	4	3	1	3	20171128		GHA_terr_mangroves		20171128
16	dataset_23	5	4	5	5	20190319		GHA_terr_PA_everything_else		20190319
17	dataset_24	2	3	3	3	20190725		GHA_marine_KBA_IBA		20190725
18	dataset_8							tbl_qdgc_01		
19	dataset_20							tbl_qdgc_02		
20	dataset_21							tbl_qdgc_03		

Each green row relates to an asset layer, whereas orange rows relate to grid levels. Deleting any of the layers or grid levels restricts the calculations for the sensitivity atlas. For example, if only grid levels 1 to 3 are required, deleting the rows named **qdgc_04_country** to **qdgc_07_country** reduces and speeds up the calculations. If possible, the attributes **latest_update**, **asset_type**, **asset_referencenumber** and **asset_date** should also be filled in. This could be useful for filtering and prioritisation of the resulting database at a later stage.

- ☑ The column **combined_importance** is filled in automatically through a formula picking the highest value from the columns **local_importance** and **global_importance**
- ☑ Do not add any values to the orange grid-related rows
- ☑ Keep only one excel file in the **data_out** folder

6) Save and close the **output_to_edit_<datestamp>.xlsx.**

6.7 Sensitivity processing

7) Double-click on the file **sensitivity_processing_fmw** to open the FME-based tool.
8) Click **Run**

The processing time depends on the number of asset layers as well as the size and number of grids and the area size of the country or region to be processed (see Section 6.2). It is recommended to start with the coarser grid levels (1-3) and some test asset layers before moving on to a higher resolution with more asset layers.

The key output is a geopackage[10], with all asset layers and grids transformed from their original coordinate systems into EPSG:4326 (WGS84 Lat Long) for consistency. The geopackage contains seven produced tables and an additional number of tables related to the number of input asset layers (see Table 2). The tables can be queried using QGIS or ArcGIS Pro. Both ArcGIS Pro and QGIS will allow you to choose a different presentation projection.

For more information on the tables and their attributes please refer to Annex II.

[10] As defined by the Open Geospatial Consortium. More information is available at: https://www.geopackage.org/.

Table 2: List of output tables from the sensitivity processing.

Table name	Description
tbl_asset_[assetname]	Copy of the input asset data (shapefile or other).
tbl_asset_allobjects	Copy of all asset objects in the assets.
tbl_full	All features resulting from the interaction of each input asset with any grid cell.
tbl_dissolved	Table resulting from merging/dissolving grid cells by the attributes *combo_sensitivity_max* and *grid_type.*
tbl_grid_overview	Table listing grid cells holding information from the calculations and spatial relationships, each unique.
tbl_grid	All grids imported as part of the analysis.
tbl_metadata	Table listing all metadata pertaining to the asset tables.
tbl_issues_in_original_layers	Table containing findings in original layers to be fixed by the user. All the elements in this table have been taken away from the calculations.

6.9 Data review

9) Inspect all layers in QGIS by opening the geopackage contained in the **data_out** folder.
10) Check the sensitivity values are consistent with the susceptibility and importance rankings used.

6.10 Data presentation

11) Open the QGIS project showing the tables from the geopackage with an OpenStreetMap[11] background map (WMS layer) in grey levels.

The QGIS project is based on a standardised visualisation of the sensitivity atlas to enable the following:

- Select grid size for viewing data;
- Browse through the maps within QGIS;
- Create map plates based on regions or specific areas;
- Analyse data; and
- Export data.

[11] More information is available at: https://www.openstreetmap.org/copyright/en.

Although ESRI describes some limitations[12] with the use of geopackages in ArcGIS Pro, it is possible to present sensitivity atlas data produced with MESA using ArcGIS Pro. The geopackage can also be used for presenting the data as web maps online using Geoserver[13] or other similar tools.

6.10.1 QGIS project overview

The initial map pane of the QGIS project displays a map overview and a list of layers on its left-hand side, including most layers listed in Table 2 (see Section 6.7). The original asset layers are not included in the QGIS project but can be added as explained below. New background maps and other layers of relevance may also be added to the QGIS project.

To add the original asset layers to the QGIS project:

1) Drag and drop the geopackage file
2) Choose all the **tbl_asset_[assetname]** or **tbl_asset_allobjects**
3) Click **Ok**
4) Check **Add layers to a group**

6.10.2 Styling

The styles recommended for visualising sensitivity are implemented in the QGIS project. The styling rules are presented in Table 3.

Table 3: Recommended styles for sensitivity levels.

C			Code	Hex-code	Colour sample
X<2	=	Very Low	E	#FFFFB2	
5>X≥2	=	Low	D	#FECC5C	
10>X≥5	=	Moderate	C	#FD8D3C	
20>X≥10	=	High	B	#F03B20	
X≥20	=	Very High	A	#BD0026	

6.10.3 Filtering layers according to grid cell size

Not all output tables listed in Table 2 (see Section 6.7) are published as layers as some retain several dimensions. The following layers are structured in groups, based on the **grid_type**

[12]As stated on: https://community.esri.com/community/open-platform-standards-and-interoperability/blog/2019/08/14/how-can-i-use-ogc-geopackages-in-arcgis-pro.
[13] Geoserver and Geopackage: https://docs.geoserver.org/latest/en/user/community/geopkg/.

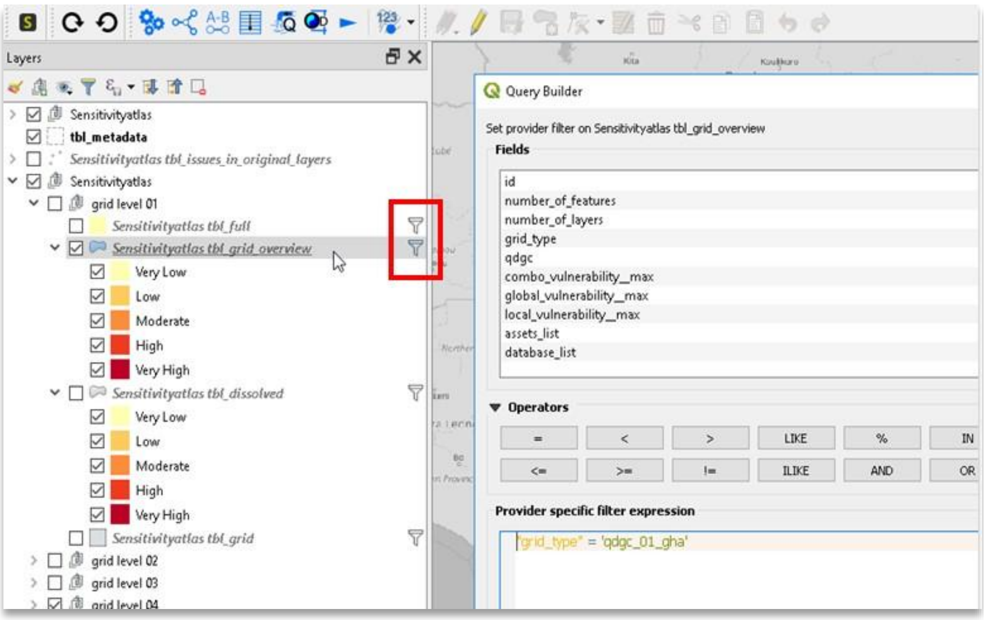
attribute values: **tbl_full, tbl_grid_overview**, **tbl_dissolved** and **tbl_grid.** A filter can be applied to differentiate grid cell sizes as explained below. The following layers are not grouped according to grid cell size: **tbl_metadata** and **tbl_issues_in_original_layers.**

To build a grid_type filter:

1) Right-click on a layer and select "**Filter**"
2) Select **grid_type** as the field
3) Enter a specific filter expression

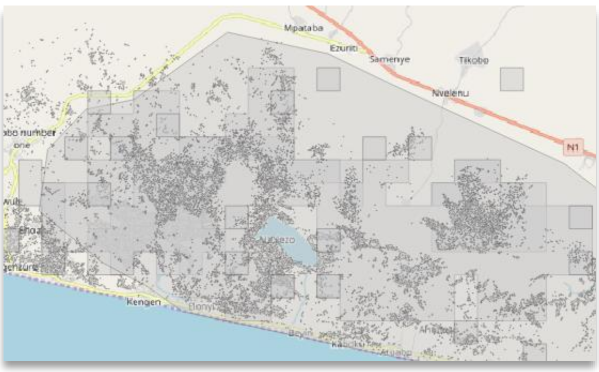
For example, the group **grid level 01** results from the filter **"grid type" = 'qdgc_01_country'**.

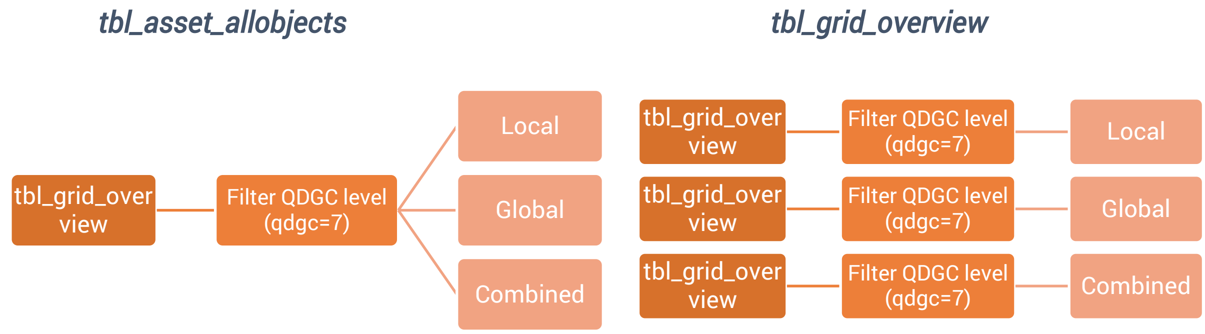
The icon displayed beside the layer indicates a filter.



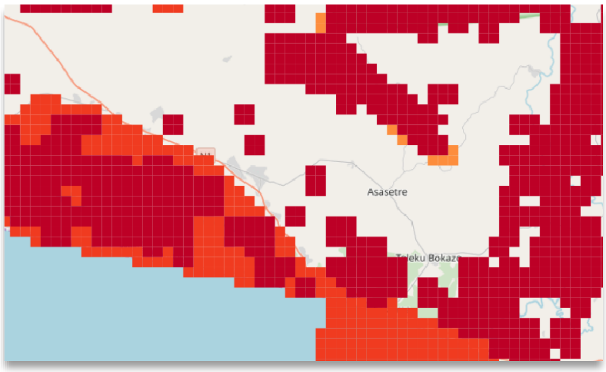
6.10.4 Visualising output tables

As mentioned in Table 2 (see Section 6.7), **tbl_asset_allobjects** holds all asset objects from all asset layers used in the calculation of the sensitivity values. As the asset objects vary in their nature and may overlap, it is recommended to visualise them as grey transparent boxes with a thin black outline, as shown here.

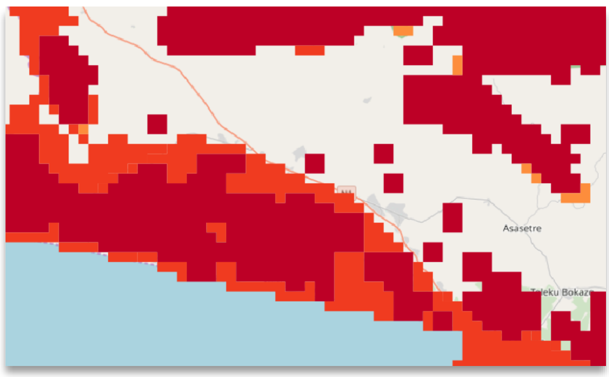




tbl_grid_overview holds all maximum sensitivity calculations per grid cell. Once a filter to differentiate grid cell size has been applied, the three sensitivity values can be visualised - local, global and combined, as shown here.



tbl_dissolved holds all maximum sensitivity calculations dissolved into separate sensitivity classes. The dissolution is done on grid cell size (QDGC level) and sensitivity value levels (local, global or combined). There will no longer be lines displayed between grid cells as each polygon will correspond to the dissolution of several grid cells, as shown here.



7. Integrate sensitivity atlas into decision making

7.1 Environmental Management

Note: The process detailed in this guidance was designed for application within the oil & gas sector, however it can be aligned with the environmental management of other sectors. While each sector is unique, in many cases the pressures are likely to be similar. For example, habitat loss would be a common pressure across multiple sectors.

The main objective of developing a sensitivity atlas is to support effective environmental management of the sector(s) for which it has been developed. As outlined in Section 2 the intended use and capacity of users should be considered at the outset of atlas development. The atlas can be used as a screening tool to determine where project alternatives should be considered, and where more rigorous Environmental Impact Assessments (EIA) are required. To maximise the atlas' utility, appropriate training for the relevant decision-making personnel is advised to ensure they are able to interpret the atlas correctly.

The environmental sensitivity atlas should ideally be adopted and understood by all regulating institutions involved in the management of the sector(s) to ensure consistency in decision-making and the requirements placed upon the companies operating in the sector.

Making the atlas accessible to the private sector allows them to also use it as a screening tool, encouraging greater avoidance of highly sensitive areas as defined by government and non-government stakeholders. This can potentially reduce the number of high risk applications for development. .

The atlas can also be used by government institutions as part of the review process for EIAs. By identifying the assets and pressures linked to the sensitivity of an area the atlas helps determine whether an EIA has covered all potentially impacted assets and considered all of the potential pressures that may be caused or exacerbated by the development. It can also support the monitoring plan that should be implemented once environmental permits are issued by identifying those assets where ongoing monitoring would be required to ensure the mitigation measures are effective.

7.2 Supporting documentation

While the focal output for an environmental sensitivity atlas will be the maps generated, it is important these are supported by a range of contextual information in order to help support their interpretation.

Key information that should be integrated within supporting documentation should include:

- Introduction: including the intended use of the atlas and acknowledgement of the institutions that have contributed to its development;
- Map plates: displayed at a scale appropriate to facilitate the intended use;
- Summary statistics: high level summary of the number of assets included and the distribution of sensitivity across the area covered by the atlas;
- Environmental assets: overview of the assets included within the atlas, including photographs, description and source of the dataset incorporated for each asset; and
- Sensitivity assessment: outcome of sensitivity ranking, including their corresponding importance and susceptibility rankings, as well as the stakeholders included in the assessment of each asset type. For certain pressures (e.g. oil spill) it may also be useful to provide details on recommended responses if the asset is exposed to the pressure.

Additional supporting documentation may be required to meet the specific needs of certain users. For example, emergency responders may require an additional version of the atlas to be provided with key elements of each map plate highlighted in order to facilitate quick decision-making. Consultation with users should inform the development of any additional documentation.

7.3 Atlas of environmental assets

A key benefit of developing an environmental sensitivity atlas is that by identifying environmental assets and ranking their importance in a global, national, or local context, a secondary atlas can be produced to serve as an inventory of important environmental assets at the appropriate scale. This atlas will have applications for wider use including conservation planning at different scales, the National Biodiversity Strategy and Action Plan, and reporting against government commitments. As such, this atlas should be shared with appropriate government institutions and NGOs, and potentially made accessible to the public where appropriate (see Section 7.4).

7.4 Restrictions for external dissemination

If the intended audience includes external stakeholders (e.g. private sector or NGOs) then consideration needs to be given to what data can be made available, and to whom. Environmental sensitivity atlases contain numerous underlying datasets that may vary in terms of their ownership and license agreements and may have restrictions regarding dissemination to third parties. There may also be datasets for which it would be undesirable to enter the public domain (e.g. access to turtle nesting site data facilitates increased poaching).

Organisations contributing data to the atlas may request access to the end product. This should be considered carefully up front when negotiating data sharing agreements to ensure the atlas is not shared more widely than desired.

Data restrictions should be made clear in the metadata in order to ensure datasets are managed appropriately. If maintaining data in a GIS platform, then varying levels of access can be created to ensure that the correct organisations have permission to access the appropriate datasets.

Alternatively, the atlas can be disseminated as printed or PDF maps without the ability to visualise or interrogate underlying datasets. Organisations can then be required to submit access requests for underlying data, which can be screened on a case-by-case basis.

8. Long-term maintenance

8.1 Data updates

For an atlas to remain effective in the long term, datasets need to be updated and maintained. Data management should be budgeted at the start of the process with the understanding that it requires ongoing financial and institutional effort. Budgets should consider the time needed to maintain and update existing datasets, including accessing databases and other sources that collate new information.

Annex I: Data Standards should be completed for each dataset to provide an overview of the timeframe in which datasets require updating. Maintenance frequency can occur daily, monthly, yearly or even intermittently and what is appropriate will depend on the rate of change of assets and the practicality of capturing this with updated data. For example, a change in a species' population status will take years rather than months and therefore updates to the dataset can be conducted annually and still capture these changes. While the timeframe for updating data will vary depending on the asset and the level of development and environmental change in country, as a minimum, datasets are to be updated in line with the following guidance:

- The IUCN Red List classifies data older than 10 years as out of date ; and
- The Key Biodiversity Areas Partnership aims to update their data every 8 – 12 years.

Any new assessment of the assets carried out earlier should be integrated within the atlas as soon as possible. In order to achieve this, resources are needed to periodically update, process and manage data, maintain the atlas' functionality and store the atlas on a platform where it can be accessed by its intended users. This requires long-term financial and institutional support.

8.2 Data storage

Data can be stored locally or on a cloud-based system. Local storage does not require on-going financial support, other than for maintenance of the infrastructure. Data are stored on site and can be accessed through local servers, which ensures faster and potentially more secure access to the data. However, with a local server, any damage to the site, such as that caused by unstable power supplies, could put the data at risk of being lost or in other ways compromised.

Alternatively, data can be uploaded to a cloud-based system which is fit for purpose. Various platforms exist (such as Arc, Mapbox and Google) to store data. An advantage is that data management is outsourced to a 3rd party, while maintaining the ability to restrict access to the data. This ensures that data are backed-up and removes the need to maintain in-house data storage facilities. Cloud storage of data comes with an on-going cost associated, which varies depending on whether an off-the-shelf product can be used or whether a tailored solution is required (based on the data type and access restrictions required). If this is the desired solution, then costs should be budgeted at the beginning of the mapping process.

When deciding on local or cloud storage options, country-specific considerations should be taken into account to ensure national institution mandates and government policies are abided by regarding the storage of data.

Annex I: Data standards

Standards for asset datasets.

File format

Data are to be provided in a shapefile format and contain either:

- Points;
- Polylines; or
- Polygons.

Attribute data

While limited attribute data are required to generate an overall environmental sensitivity atlas, the inclusion of attribute data provides additional drill-down functionality, which can improve the value of the environmental sensitivity atlas. Users can interrogate attribute data to better understand the underlying assets related to an area's sensitivity.

For each of the asset types a standard has been developed drawing on best practice. While it may not be possible to complete all fields for every asset, data providers should endeavour to include as many as possible.

Protected Areas

Data standards for protected areas have been drawn from the minimum required attribute data for inclusion in the World Database of Protected Areas (WDPA). The requirements are outlined in Table A2.1 below, with more detailed descriptions available in Appendix 1 of the WDPA User Manual.

Table A2.1: Description and allowed values for attributes of protected area data.

Field Name	Type	Length	Allowed Values
PA_DEF	Text (String)	20	**Allowed values**: 1 (meets IUCN and/or CBD PA definition); 0 (does not meet IUCN and/or CBD PA definition.
NAME	Text (String)	254	Name of the protected area (PA) as provided
ORIG_NAME	Text (String)	254	Name of the protected area in original language
DESIG	Text (String)	254	Name of designation

DESIG_TYPE	Text (String)	20	**Allowed values**: National, Regional, International, Not applicable
MARINE	Text (String)	20	**Allowed values**: 0 (100% Terrestrial PA), 1 (Coastal: marine and terrestrial PA), 2 (100% Marine PA)
REP_M_AREA	Number (Double)	N/A	Marine area in square kilometres
REP_AREA	Number (Double)	N/A	Area in square kilometres
STATUS	Text (String)	100	**Allowed values**: Proposed, Inscribed, Adopted, Designated, Established.
STATUS_YR	Number (Long Integer)	12	Year of enactment of status
PARENT_ISO3	Text (String)	20	**Allowed values**: SIO 3166-3 character code of country where the PA is located.
ISO3	Text (String)	20	**Allowed values**: ISO3166-3 character code of country or territory where the PA is located.
GOV_TYPE	Text (String)	254	**Allowed values**: Federal or national ministry or agency, Sub-national ministry or agency, Government-delegated management, Transboundary governance, Collaborative governance, Joint governance, Individual landowners, Non-profit organisations, For-profit organisations, Indigenous peoples, Local communities, Not Reported.
MANG_AUTH	Text (String)	254	Individual or group that manages the protected area
IUCN_CAT	Text (String)	20	**Allowed values**: Ia, Ib, II, III, IV, V, VI, Not Applicable, Not Assigned, Not Reported

Other Biodiversity Designations

Data standards for Other Biodiversity Designations are based around the proposed Key Biodiversity Area data standards (Table A2.2). However, environmental sensitivity mapping does not require the same level of details, and some fields are therefore omitted.

Table A2.2: Description and allowed values for attributes of Other Biodiversity Designations data.

Field Name	Type	Length	Allowed Values
NAME	Text (String)	254	Name of the area as provided
ORIG_NAME	Text (String)	254	Name of the area in original language

DESIG	Text (String)	20	**Allowed values**: KBA, AZE
CRIT_MET	Text (String)	20	**Allowed values**: AZE, A1, A2, B1, B2, B3, B4, C, D1, D2, D3, E
TRIGGER	Text (String)	254	Name of the species, ecosystem type, or biological process triggering designation.
MARINE	Text (String)	20	**Allowed values**: 0 (100% Terrestrial), 1 (Coastal: marine and terrestrial), 2 (100% Marine)
REP_M_AREA	Number (Double)	N/A	Marine area in square kilometres
REP_AREA	Number (Double)	N/A	Area in square kilometres
YEAR	Number (Long Integer)	12	Year of designation
PARENT_ISO3	Text (String)	20	**Allowed values**: SIO 3166-3 character code of country where the PA is located.
ISO3	Text (String)	20	**Allowed values**: ISO3166-3 character code of country or territory where the PA is located.

Habitats

Habitat datasets are likely to be more variable in nature than Protected Areas and Other Biodiversity Designations, reflecting a level of national and local specificity. As a result, the data standards (Table A2.3) are less prescriptive.

Table A2.3: Description and allowed values for attributes of habitat data.

Field Name	Type	Length	Allowed Values
TYPE	Text (String)	20	Name of habitat type
MARINE	Text (String)	20	**Allowed values**: 0 (100% Terrestrial), 1 (Coastal: marine and terrestrial), 2 (100% Marine)
REP_M_AREA	Number (Double)	N/A	Marine area in square kilometres
REP_AREA	Number (Double)	N/A	Area in square kilometres
PARENT_ISO3	Text (String)	20	**Allowed values**: ISO 3166-3 character code of country where the PA is located.
ISO3	Text (String)	20	**Allowed values**: ISO3166-3 character code of country or territory where the PA is located.

OTHER	Text (String)	254	Additional relevant information specific to the habitat

Species

Species datasets vary depending on the level of study that has been conducted. It is assumed that for species with spatial datasets available, sufficient study has been carried out to complete each of the attributes in Table A2.4 below, however it is possible that some may be not applicable or unknown.

Table A2.4: Description and allowed values for attributes of species data.

Field Name	Type	Length	Allowed Values
SPECIES	Text (String)	100	Name of species
IUCN_STATUS	Text (String)	20	**Allowed values**: CR, EN, VU, NT, LC, DD, NE
NAT_STATUS	Text (String)	100	Status under national assessment or legislation
TYPE	Text (String)	20	**Allowed values**: F (Feeding Ground), B (Breeding Ground), M (Migratory Route), O (Multiple use or Other)
HABITAT	Text (String)	254	Species habitat preference if known.
MARINE	Text (String)	20	**Allowed values**: 0 (100% Terrestrial), 1 (Coastal: marine and terrestrial), 2 (100% Marine)
REP_M_AREA	Number (Double)	N/A	Marine area in square kilometres
REP_AREA	Number (Double)	N/A	Area in square kilometres
PARENT_ISO3	Text (String)	20	**Allowed values**: SIO 3166-3 character code of country where the PA is located.
ISO3	Text (String)	20	**Allowed values**: ISO3166-3 character code of country or territory where the PA is located.
OTHER	Text (String)	254	Additional relevant information specific to the species

Metadata standards

In addition to data relating to individual assets, it is important for asset datasets to have metadata associated with them that enables clear understanding of the content, source and age of the dataset. Maintaining metadata in a standard format, such as in Table A2.5 below, helps users and data managers to manage datasets efficiently and easily identify datasets that require updating.

Table A2.5: Description and allowed values for attributes of species.

Field	Allowed Values
Dataset Type	1. Protected Area 2. Other Biodiversity Designation 3. Habitat 4. Species
Data Format	1. Polygon 2. Polyline 3. Point
Resolution	
Last Updated	Year of last update
Maintenance Frequency	1. Continual 2. Daily 3. Weekly 4. Fortnightly 5. Monthly 6. Quarterly 7. Biannually 8. Annually 9. AsNeeded 10. Irregular 11. NotPlanned 12. Unknown
Data Provider	Organisation responsible for maintaining the dataset
Restrictions	Level of restrictions placed on dissemination of the dataset. E.g.: 1. No dissemination 2. Within organisation only 3. Within government institutions only 4. Selected external organisations 5. Public
Person Responsible	Name & email of the point of contact for the data set

Annex II: Tables

tbl_asset_[assetname]

Copy of the input asset data, with one table per input asset layer. These datasets are not added to the QGIS project.

Attribute name	Description
primarykey_id	ID number
original attributes	According to documentation available
asset_pkid	Unique global id assigned for this particular asset object

tbl_asset_allobjects

This table holds all spatial objects from the input asset layers. Data on importance, susceptibility and sensitivity (code and value) have been added. Asset attributes have been removed, but are still available in the respective asset tables.

Attribute name	Description
id	ID number
original_coordsys	Coordinate system for the original asset dataset
asset_pkid	Unique global id assigned for this particular asset object
combo_sensitivity_value	Combined sensitivity value
combo_sensitivity_code	Combined value mapped to code (A/B/C/D/E)
local_sensitivity_value	Local sensitivity value
local_sensitivity_code	Local value mapped to code (A/B/C/D/E)
global_sensitivity_value	Global sensitivity value
global_sensitivity_code	Global value mapped to code (A/B/C/D/E)
susceptibility	Susceptibility value
combined_importance	Combined importance value, drawn from the higher between local_importance and global_importance.
local_importance	Local importance value
global_importance	Global importance value
Dataset	Reference to dataset per number in excel file
Latest_update_date	Date for latest update as found in source file
asset_type	From optional field in excel file

asset_name	From asset filename
asset_referencenumber	From optional field in excel file
asset_date	Date for established dataset date as found in source file
_geometry_name	Geometry name

tbl_grid

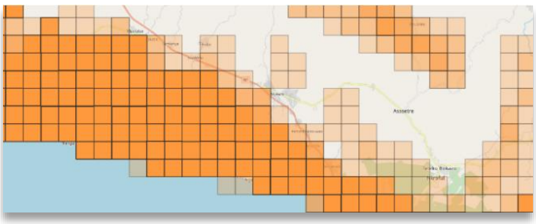
All grids imported as part of the analysis are collected in a single table.

Attribute name	Description
id	ID number
grid_type	Name of grid layer
qdgc	Unique reference id for each grid cell

To filter the grid level, query **grid_type**, which holds the name of the grid layers as a value. For example, the grid layer **qdgc_06_country.shp** has “**grid_type**” = ‘**qdgc_06_country**’.

tbl_full

This table lists all features resulting from the interaction of each input asset with any grid cell. The querying process outlined above is also applicable to this table. The visualisation of this table indicates where more assets are active, as shown here.

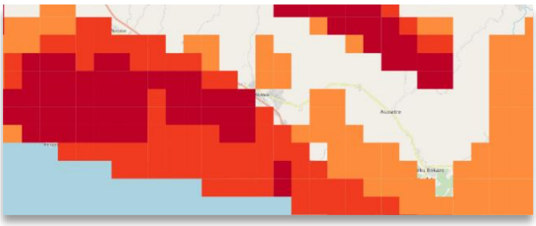


Attribute name	Description
id	ID number
grid_type	Reference to the grid name. This is also a unique key which can be joined with the tbl_grid
qdgc	Unique reference id for each grid cell
asset_pkid	Unique global id assigned for this particular asset object
Asset_name	Asset name
combo_sensitivity_value_max	Maximum combined sensitivity value in this grid location
combo_sensitivity_code_max	Combined value mapped to code (A/B/C/D/E)

local_sensitivity_value_max	Maximum local sensitivity value in this grid location
local_sensitivity_code_max	Local value mapped to code (A/B/C/D/E)
global_sensitivity_value_max	Maximum global sensitivity value in this grid location
global_sensitivity_code_max	Global value mapped to code (A/B/C/D/E)

tbl_grid_overview

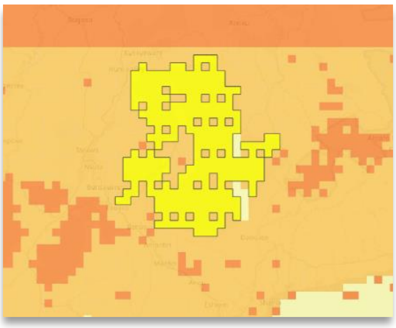
This table lists cell grids holding information from the calculations and spatial relationships, each unique.



Attribute name	Description
id	ID number
number_of_features	Number of features involved in each grid cell
number_of_layers	Number of layers involved in each grid cell
grid_type	Reference to the grid name. This is also a unique key which can be joined with the tbl_grid
qdgc	Unique reference id for each grid cell
combined_sensitivity_value	Maximum combined sensitivity value in this grid location
combined_sensitivity_code	Combined value mapped to code (A/B/C/D/E)
global_sensitivity_value	Maximum global sensitivity value in this grid location
global_sensitivity_code	Global value mapped to code (A/B/C/D/E)
local_sensitivity_value	Maximum local sensitivity value in this grid location
local_sensitivity_code	Combined value mapped to code (A/B/C/D/E)
asset_list	List with the unique identifier (asset_pkid) of all assets involved in each grid cell. This id can be used to find the original objects in the table tbl_asset_allobjects
database_list	List with the unique identifier of all layers involved in each grid cell

tbl_dissolved

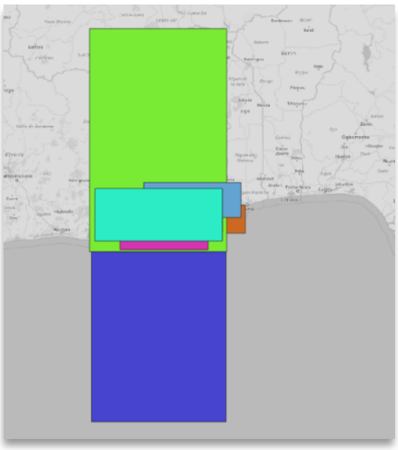
This is the table resulting from merging grid cells by **combo_vulnerability_max** and **grid_type** values. Cells may be dissolved, resulting in less geometries.



Attribute name	Description
id	ID number
grid_type	Reference to the grid name. This is also a unique key which can be joined with the tbl_grid
global_sensitivity_value_max	Maximum value for global sensitivity.
global_sensitivity_code_max	Code calculated based on the global sensitivity value
local_sensitivity_max	Maximum value for local sensitivity
local_sensitivity_code_max	Code calculated based on the local sensitivity value
combined_sensitivity_value_max	Maximum value for combined sensitivity
combined_sensitivity_code_max	Code calculated based on the combined sensitivity value

tbl_metadata

Table listing metadata from each asset and grid level involved in the process. The bounding box for each layer is extracted as its geometry.



Attribute name	Description
primarykey_id	ID number
layer_type	Identifies layer as either ‘asset_layer’ or ‘grid_layer’
_numberoffeatures	Number of features within the layer.
computername	Operating system name for the computer running the FME-based tool
path_filename	Path, name and extension for the asset file

asset_name	Name of the asset is usually asset file name
global_importance_value	Assigned global sensitivity value
global_importance_code	Assigned global sensitivity code
local_importance_value	Assigned local sensitivity value
local_importance_code	Assigned local sensitivity code
combined_importance_value	Assigned combined sensitivity value
combined_importance_code	Assigned combined sensitivity code
original_coordsys	Original coordinate system
latest_update_date	Last update drawn directly from .xml file in shapefile
actual_coordsys	EPSG:4326. All assets are transformed to this coordinate system during processing
ending_timestamp	Ending point in time for the process with date + time
start_timestamp	Starting point in time for the process with date + time
username	Operating system username running the process

tbl_issues_in_original_layers

This table contains findings in original layers to be fixed by the user. All the elements in this table have been taken away from the calculations.

Attribute name	Description
original_layer	Name of the layer
details	Type of problem reported (for example 'Self intersection')
Issue_found	Group of issues (for example 'Fails OGC Simple standard')

UN environment programme

WCMC

NORWEGIAN ENVIRONMENT AGENCY

Norad