MAPPING CLIMATE RISK
METHODS, OPTIONS, AND APPROACHES FOR IRELAND

C-RISK STUDY SERIES #3
<table>
<thead>
<tr>
<th><strong>Risk:</strong></th>
<th>Potential for consequences where something of value is at stake and where the outcome is uncertain. Risk results from the interaction of hazards, exposure, and vulnerability</th>
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</thead>
<tbody>
<tr>
<td><strong>Metadata:</strong></td>
<td>Information about a data set. It may include the source of the data; creation date and format; projection, scale, resolution, and accuracy; and reliability with regard to some standard</td>
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<tr>
<td><strong>Weights:</strong></td>
<td>A number that tells how important a variable is for a particular calculation. The larger the weight assigned, the more that variable will influence the outcome of an analysis</td>
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<tr>
<td><strong>Attribute:</strong></td>
<td>A characteristic of a geographic feature, typically stored in tabular format and linked to the feature in a relational database. The attributes of a well-represented point might include an identification number, address, and type</td>
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<tr>
<td><strong>Raster:</strong></td>
<td>A spatial data model made of rows and columns of cells. Each cell contains an attribute value and location coordinates. Groups of cells that share the value represent geographical features</td>
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<tr>
<td><strong>Vector:</strong></td>
<td>A data structure used to represent linear geographical features. Features are made of ordered lists of x, y coordinates and represented by points, lines or polygons.</td>
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<tr>
<td><strong>Layer:</strong></td>
<td>A logical set of thematic data. These act as digital transparencies that can be laid on top of each other for viewing or analysis purposes</td>
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<td><strong>Spatial scale:</strong></td>
<td>Geographic scale most relevant to the application of an indicator – e.g. national, sub-national, regional, local</td>
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<tr>
<td><strong>Scale:</strong></td>
<td>The ratio or relationship between a distance or area on a map and the corresponding distance or area on the ground</td>
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<tr>
<td><strong>Resolution:</strong></td>
<td>The area represented by each pixel in an image</td>
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Climate change risk assessments (CCRAs) provide a sound basis for: i) making decisions on whether risks, and what level of those risks, are acceptable, to the society or community, and ii) obtaining, collating, and analysing information on how risks deemed unacceptable can be reduced to below threshold levels of acceptability and potential opportunities realised.

Risk is not only defined by exposure to a hazard, but also includes vulnerability deriving from losses and damages associated with impacts. This means that several different types of data are used to measure risk. Deciding how to communicate risk to different people is critical.

Climate change creates both short and long-term changes to social and economic conditions in society. Therefore a CCRA must go beyond just measuring changes to the nature, magnitude, or frequency of physical events. The individual and social impacts of a changing climate are more significant over the long-term than the actual physical changes to the climate. The impact of these changes, and not the changes themselves, are what affects individuals and society.
The quality of outputs produced by any CCRA is highly dependent on the quality of the data inputs. This is especially true with a mapping exercise that can help support the analysis and communication of the assessment. While individual datasets can display important messages about both status and trends of conditions, a CCRA must combine data in order to examine cumulative impacts. Identifying reliable sources of verified data is a vital first step.

- **Climate data:** the Irish Meteorological Service holds an archive of meteorological data with some records extending for 100+ years. Several datasets are still being collected nationally. Paleoclimate analysis and other archives also provide information on climate conditions over periods outside the historical records. These data provide information on climate variability and the stability of key factors that determine Ireland’s climate. Many of these datasets are housed on the open-source information platform: Climate Ireland. In addition, a series of key documents describing the status of Ireland’s climate and knowledge associated with observed and projected climate impacts have been published by the EPA Climate Change Research Programme (e.g. DESMOND, M., et al 2017, DWYER, N. 2012, NOLAN, P. 2015).

- **Socio-economic data:** the Central Statistics Office conducts a national census every five years. Data collected include, but are not limited to, demographics and family size, education, migration, employment, housing and health aspects. In addition, the Irish Social Science Data Archive holds a record of research projects focused on numerous themes including poverty, socio-economic status, and inequality.
Complex spatial decisions, such as allocating land to development or evaluating aspects of risk in particular geographical areas, require information and tools to aid in understanding the inherent tradeoffs. They also require mechanisms for incorporating and documenting the value judgements of interest groups and decision makers. GIS data can set the stage by displaying individual maps of decision criteria. These individual maps can then be overlayed once the scales are calibrated.

Multiple-criteria decision analysis (MCDA), as this approach is known, is a family of techniques that aid decision makers in formally structuring multi-faceted decisions and evaluating the alternatives. This allows the examination of multiple and conflicting criteria and objectives (Carver, 2007, Greene et al, 2011).

One of MCDA’s strengths is its ability to simultaneously consider both quantitative and qualitative data, as long as they can be represented using an ordinal or continuous scale. It also allows importance, in the form of weights, to be added to map variable before an aggregated output is developed. This means that different weights can be applied to represent priorities, hazards, or vulnerabilities in each layer of a cumulative product.
Several data-driven decisions need to be made during a risk mapping process. These include:

- **The types of data that could be used in the analysis**
  - Will the data shown represent only one aspect of risk (e.g. only vulnerability or exposure) or several aspects?
  - Will trends over time be shown?
  - Are the datasets compatible in terms of scale, calibration, and geo-reference?
  - What assumptions were made when the data were generated and collated?
  - Are the data from a reputable and legitimate source?

- **The representation of data**
  - Will the data shown be comparable to global data or national data?
  - Will the data be distributed around the mean and the standard deviation or the median?
  - How will uncertainty be accounted for?

- **The resolution of data**
  - What is the best scale to display the data at?

The following depictions show how this decision tree can be applied but do not provide a definitive answer to climate risk in Ireland as it currently stands.
Overview: The measurement of social vulnerability identifies population characteristics that influence the social burden of risks and how those factors affect the distribution of potential losses. Social vulnerability is most often described using individual characteristics of people (age, race, health, income, type of dwelling unit) but it also includes place inequalities - those characteristics of communities and the built environment, such as the level of urbanization, growth rates, and economic vitality, that contribute to the social vulnerability of places.

Data selected: Whilst numerous composite indices of social vulnerability have been used around the world (e.g. PoBal Index, SoVI) most have common elements such as population structure and education levels that are collected during census exercises. For this map, six variables were used to create an Ireland-focused index based upon the methodology used to develop the spatial multi-criteria social/environmental vulnerability index (SEVI model). The variables used were:

1. Dependency Ratio \((\frac{\text{population } <15 + \text{population } >65}{\text{total population}})\)
2. Education Ratio \((\frac{\#\text{people } >15 \text{ with upper 2\text{o} education or higher}}{\text{total population } >15})\)
3. New to Region Ratio \((\frac{\#\text{people with a low ability to speak English}}{\text{total population}})\)
4. Isolation Ratio \((\frac{\#\text{households with 1 person}}{\text{total #households}})\)
5. Occupancy Ratio \((\frac{\#\text{households}}{\text{total population}})\)
6. Unemployment ratio \((\frac{\#\text{people out of work}}{\text{total #people working and out of work}})\)

Assumptions/Limitations: As with all composite indices, ensuring that there is no double counting of aspects of vulnerability is difficult. Whilst this index avoids scale issues due to the inclusion of census data only, distinguishing between absolute and relative vulnerability remains a challenge.
An overview of how social vulnerability could be calculated through a Modified SEVI Layer that shows hotspot areas around the country.

**Representation:** Relative scoring around the mean and standard deviation

**Data source:** [Central Statistics Office](#)

**Resolution:** 1 km pixel (SAPS)
Overview: The built environment includes existing structures, infrastructure systems, critical facilities, and cultural resources. Critical public assets are those that are essential for supporting the social and business needs of both the local and national economy. These assets will have a high consequence of failure, but not necessarily a high likelihood of failure. Assessment of assets often involves the integration of threat, vulnerability, and consequence information. This can guide management decisions around protective measures and urgency of action. Understanding the density of critical assets is the first step to determining associated site-specific risk.

Data selected: The location and aggregation of critical assets per km² was identified from existing government data sources (https://data.gov.ie). For this map, specific assets included are:

- Airports
- Main harbours
- Fishing ports
- Ferry ports
- Power plants
- Hydro-electric stations
- Waste water facilities
- Rail + road networks
- Schools
- Hospitals
- Nursing homes

Assumptions/Limitations: The decision was made to incorporate large water storage facilities as well as agricultural assets into the land use cover map to reduce the possibility of double counting and layer overlap. In addition, this approach allows for more nuanced weighting if needed. This map does not show any state or structural vulnerability for any asset.
A depiction of how critical asset density, showing as-expected concentrations in urban areas in the country, could be calculated. This corresponds to increased population density and service demand.

Representation: Relative scoring around the mean and standard deviation

Data source: [https://data.gov.ie](https://data.gov.ie)

Resolution: 1 km pixel (SAPS)
Overview: The density of privately held assets, in the form or residential properties, provides a key measure of population distribution across Ireland that aren’t highlighted by land use cover data. These correlate, in part, to critical asset density but also link to environmental phenomena such as the urban heat island effect (Valsson and Bharat, 2009). In addition, understanding density can help to predict the economic impact of hazards such as large storms or flooding.

Data selected: This map shows data from the Central Statistics Office associated with Census 2016 Small Area of Population Statistics (SAPS) theme 5 - private households. These data are processed at a 1km raster grid to allow for compatibility with the other layers used in this assessment.

Assumptions/Limitations: The logical next step associated with housing density is a property values layer that would allow a more detailed economic assessment of housing stock to be completed. In addition, knowledge of material types and construction methods associated with each property would provide the basis for economic estimation of direct flood damage to buildings is using the method of depth-damage functions (USACE, 1996) in line with European Union Floods Directive (2007/60/EC).
A depiction of how residential property density across the country correlates to major urban centres could be calculated. These data also help to represent the concentration of private assets on a national scale.

- No residential property
- Low residential property density
- Moderate residential property density
- High residential property density
- Extremely high residential property density

**Representation:** Relative scoring around the mean and standard deviation

**Data source:** [Central Statistics Office](https://www.cso.ie)

**Resolution:** 1 km pixel (SAPS)
Overview: Landcover data enable the study and understanding of changes in the environmental system over time as well as the identification of possible conflicts between socio-economic landuse and ecological systems, biodiversity and natural landscapes. On a more local scale, the landcover data can show how man-made surfaces, agricultural lands and ecological communities are changing and interacting. This approach enables efficient mapping over large areas and inaccessible lands without the need for in-field surveys.

Data selected: The Corine Land Cover (CLC) dataset maps landcover based on two main properties - its natural bio-geographical properties (e.g. peatlands and natural grasslands) and its anthropogenic uses (e.g. pastures, arable land, etc.). For this map, the updated CLC2012 dataset was used. These data are used widely by public bodies, researchers, scientists and private companies for a range of applications including water management, air quality, land planning, waste management, telecommunications and agriculture/forestry. In addition, National Heritage Areas, Special Areas of Conservation, and Special Protection Areas were added to this layer.

Assumptions/Limitations: Corine was designed as a pan-European dataset. Its classification structure and spatial resolution were designed to fit the wide range of environmental regions of Europe and not any one country. In addition, it has a minimum mapping unit of 25 hectares, which is not sufficient for local applications such as urban planning or forest management, that require more detailed scales. The most simplified classification schema for Corine was used for this mapping exercise to avoid overlap in description and content of the classes.
Simplified Corine land cover (CLC) could be used to provide national scale maps of landcover and land-cover change. National protected areas could also be added to this layer.

**Representation:** Relative scoring around the mean and standard deviation

**Data source:** [Corine land cover data (EPA)](http://corine-land-cover.eea.europa.eu)

**Resolution:** 1:100,000 scale
Overview: Hazards are physical phenomena that have the potential to cause damages and losses to human and natural systems impacting human health, livelihoods, and/or natural resources. Data on the frequency and magnitude of hazards are often collected at national and local scales as well as aspects of economic, social, and biophysical damage. Climate related hazards are many and varied. Some are slow in their onset (e.g. changes in temperature and precipitation, or agricultural losses), while others happen more suddenly (e.g. storms and floods). Hazards also interact with each other creating a series of cascading events that magnify risks to people and infrastructure.

Data selected: This map shows only one hazard - shoreline change. This dataset has been created by the EUROSION project at a scale 1:100,000 and in vector format for the European coast. Of the 7,800 km of coast in Ireland, up to 3,500 km may be susceptible to erosion, because it is made up of soft sediments (Devoy, 2003).

Assumptions/Limitations: Limiting this layer to one hazard obviously limits its utility. However, identifying data layers of sufficient quality in a form that can be incorporated into this multiple-criteria decision analysis can often prove difficult due to the lack of available data at a national scale. Over time it is expected that this layer would change as relevant data become available from multiple sources.
Coastal shoreline change showing morpho-sedimentological patterns, geological patterns, erosion trends along the Irish coast could be used to depict one type of hazard.

**Representation:** Relative scoring around the mean and standard deviation

**Data source:** [EUROSION project](http://www.eurosion.org)

**Resolution:** 1:100,000 scale
**COMPOSITE DATA**

**Data selected:** This map is a composite of the layers previously presented. The categories displayed are related to the aggregation of the scores from the other layers. This allows risk to be visualised for a static snapshot in time based on best available data. This map only provides a baseline of risk and not a projection of change under different climate scenarios.

**Caveat:** Methodologically one important decision was made while generating this composite. During aggregation, it became clear that values between the layers were conflicting and creating an inaccurate representation of risk through double counting of natural capital. Therefore, a land use layer made up solely of National Heritage Areas, Special Areas of Conservation, and Special Protection Areas was generated and used in the composite in place of the Corine landuse cover layer.

**Assumptions/Limitations:** This map represents risk relative to Ireland and, as so, cannot be used to compare across countries. National comparisons are only possible if the same data representations are used. No weights have been applied to this map. The application of weights can be used to reflect national, regional, or local priorities for management as well as social or economic values. Weights can be added to each layer or to individual data sets used to construct each layer as required.
A depiction of risk at a national scale across Ireland can be generated by aggregating social, economic, environmental, and hazard data.

**Very low risk**

**Low risk**

**Moderate risk**

**High risk**

**Extremely high risk**

**Representation**: Relative scoring around the mean and standard deviation

**Data source**: Combined datasets

**Resolution**: 1 km pixel
The power of risk assessment lies not only in visualising static risk of social and economic variables but also looking at changes over time to hazards and climatic conditions. IPCC AR5 (2014) documented projected changes under specific scenarios which provide the basis for national projections of, temperature, sea level rise, precipitation levels and the frequency of extreme events.

Global mean surface temperature is likely to exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (high confidence) and exceed 2°C for RCP6.0 and RCP8.5 (high confidence) by the end of the 21st century (IPCC 2014). Even if each country meets its Intended Nationally Determined Contributions plans, submitted to the United Nations Framework Convention on Climate Change (UNFCCC-COP21), these projections, and those of changes in precipitation, remain the best available global data from which to extrapolate national changes.
Many effects of climate change have specific, measurable impacts on natural capital, economic activity, and social wellbeing, that when coupled with likelihood projections, allow for the identification and prioritisation of risk. Interdependencies and cascading effects, as well as international trends and geopolitical disruptions can add uncertainty to economic estimates. Determining the likelihood and impact of future climate changes creates an important evidence base for adaptation and mitigation activities at all scales.
LIMITATIONS

**DATA AVAILABILITY?**
Assessing the components of risk (hazards, vulnerability, and exposure) and projecting risk into the future, is hindered by poor data availability, particularly socio-economic data. Data about future populations may be available but these data cannot be used to assess the future levels of education, unemployment, social isolation etc.

**DATA UNCERTAINTY?**
Levels of uncertainty surrounding climate projections of the physical climate of the Earth for the coming decades, including how much and how quickly the Earth will warm, sea level will rise, and the weather will change still exist. How people, ecosystems, and structures will experience these changes is still uncertain which hinders investment and political and social decision-making.

**SOLUTIONS!**
Exploring other options for obtaining data; e.g. downscaling global or macro-regional scenarios, or data collection through surveys, participatory methods, and interviews can supplement existing data. Broad stakeholders engagement may increase the availability of data, benefiting both the accuracy of results, and usability by national and local decision-makers.

**SOLUTIONS!**
Scientists and policy makers are now more aware that solutions to climate change will require scientific practices to change and prioritise decision support. Increased efforts to produce, disseminate, and facilitate the use of data and information in order to improve the quality and efficacy of climate-related decisions can help reduce uncertainty driven inaction.
Changes in Ireland’s climate are in line with global trends. Regional Climate Modelling simulations have been used to assess the impacts of these trends on the mid-21st-century climate of Ireland (NOLAN, 2015). National climate data are more accessible than ever before. The challenge of making sure these data can be used in both regional decisions and local decisions remains key.

Understanding the magnitude of climate risks at a national scale provides a platform for policy cohesion and resource distribution. Understanding the urgency (a measure of the degree to which action is needed in the next five years to reduce a risk or realise an opportunity from climate change) at the regional or local level enhances increased ownership of results and actions.

The evolution of climate policy in Ireland is an iterative process under the Climate Action and Low Carbon Development Act, the National Climate Change Adaptation Framework, and National Mitigation Plan. The effectiveness of Ireland’s response to climate change is contingent on continued information gathering and understanding of impacts on a sectoral or cumulative basis.

Ensuring cohesion between policy frameworks while allowing for flexibility in approaches is a critical step towards the national goal of a Climate Resilient Ireland. While the process of identifying and mapping datasets to assess risk is an important step, providing space for open dialogue and stakeholder engagement remains just as important.