A National Coastal Erosion Risk Assessment for Scotland

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Introduction

Coastal areas have historically been utilised for human settlement on account of an abundance of the natural resources required for survival and development. In the UK, living close to the coast remains desirable today as a consequence of the range of ecosystem services and benefits that coasts provide.

The geography of Scotland, with a highly undulating hinterland, long and indented coastline, together with a large number of islands, means that **much of the economic, social, and cultural assets are largely located at the coast**. Approximately 70% of the Scottish population (ca. 3.5 million people) live within 10 km of the coast (Scottish Executive, 2005). Approximately, 20% of the Scottish coast is thought to be 'soft', along which 35% of all buildings and infrastructure are located. The Climate Change Risk Assessment for Scotland states that **"maps of past erosion, current state and future erosion conditions are required"**.

The Climate Change (Scotland) Act 2009 requires Scottish Ministers to develop a Scottish Climate Change Adaptation Programme. **Coastal erosion has implications for agriculture, tourism industry, transport sector, infrastructure, buildings, urban environment along with cultural and natural heritage interests.** Only 9% of Scotland's shoreline (six local authorities (LAs)) have, or are developing, a Shoreline Management Plan. Government, Agencies and LAs have obligations to incorporate coastal erosion within their work. Therefore, **a pressing need exists to improve the understanding of coastal erosion within Scotland at a national scale,** so that the potential direct and indirect impacts on coastal populations and assets can be fully assessed to inform sustainable coastal management decision making.
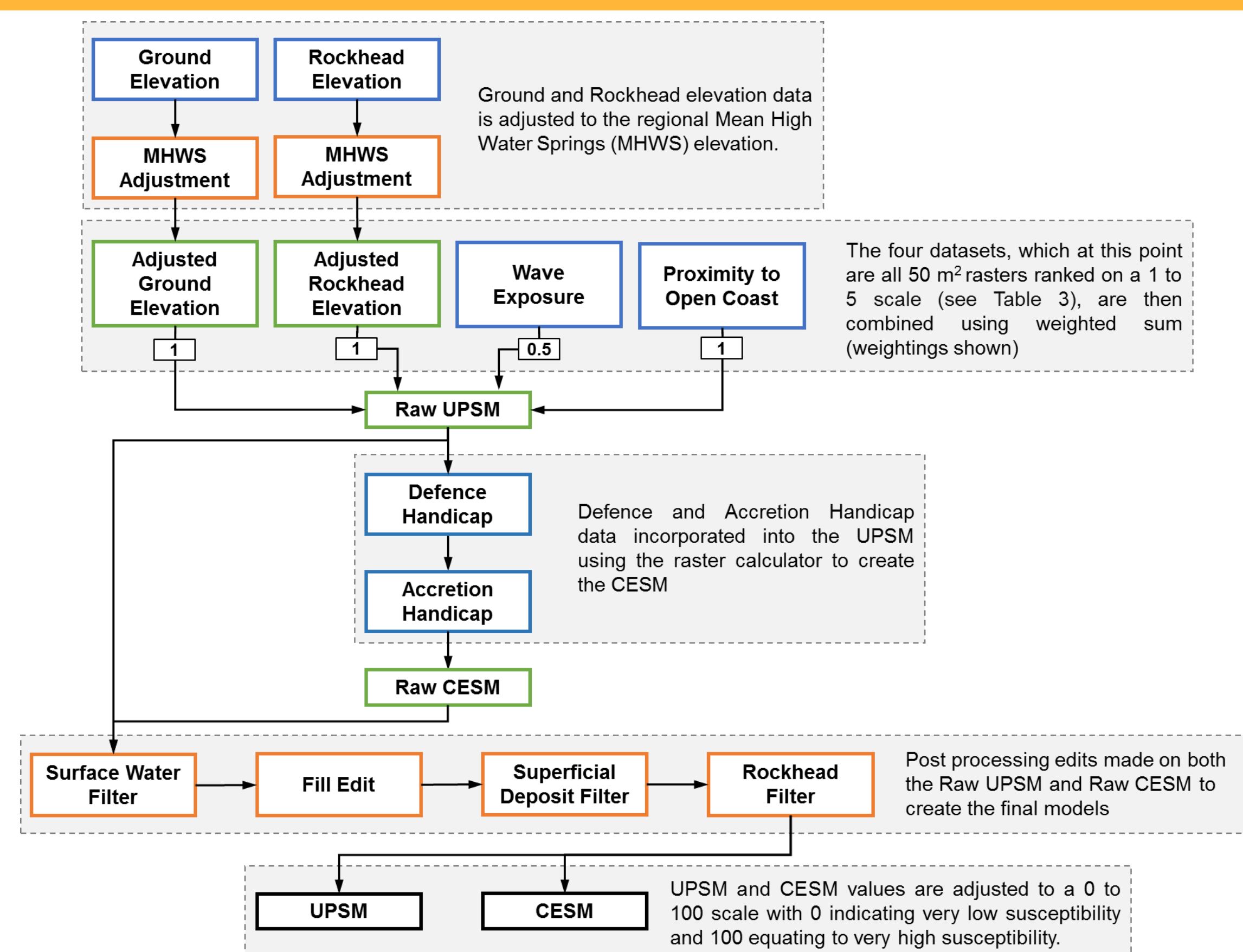
Methodology

Figure 1: A simplified methodology workflow to create the Underlying Physical Susceptibility Model (UPSM) and the Coastal Erosion Susceptibility Model (CESM). Blue boxes correspond with input data, orange boxes are GIS processing steps, green boxes are intermediate data, and black boxes are the final outputs. See Fitton et al. (2016) for further information.

The workflow consists of four stages: establishing physical susceptibility to coastal erosion, assessing the vulnerability of coastal communities, determination of the assets exposed to coastal erosion, and establishing coastal erosion risk.

Physical Susceptibility: The research methodology (Figure 1) uses a number of raster datasets, which are ranked on a 1 to 5 scale, and combined to produce **two national scale coastal erosion susceptibility models** with outputs as a **50 m raster**: the **Underlying Physical Susceptibility Model (UPSM)** which represents the natural inherent erosion susceptibility of the coastline and; the **Coastal Erosion Susceptibility Model (CESM)** which is the UPSM output moderated by the addition of artificial coastal defences and sediment accretion.

Vulnerability: The vulnerability of the population to coastal erosion is assessed using **the Coastal Erosion Vulnerability Index (CEVI), which uses a geodemographic classification tailored to the socioeconomic characteristics of Scotland at postcode level** (Experian's Mosaic Scotland). Cutter et al. (2003) identified indicators relevant to unspecific US environmental hazards, e.g. socioeconomic status, gender, race, and ethnicity, age, and many others. Using these vulnerability indicators as a basis, **vulnerability indicators were selected from Experian's Mosaic Scotland classification data that are most applicable to coastal erosion vulnerability**. When combining the indicators it is useful to include weightings, as demonstrated by Willis et al. (2010) to highlight the most discriminatory indicators

Exposure and Risk: The locations of assets, such as **residential properties, roads, and rail are compared with the CESM** to establish exposure of coastal erosion. The CEVI is then used to establish the **residential populations that are both exposed and highly vulnerable**, i.e. coastal erosion risk.

Results

Physical Susceptibility: Once the four ranked data layers (Figure 2) are summed together an aggregate score is achieved (the UPSM). **Areas which are highly susceptible to erosion have a high aggregate score** (the maximum score is 17.5). Figure 3 shows a local scale example of the UPSM at St. Andrews (west coast of central Scotland). To integrate the influence of defences and sediment accretion into the UPSM, a 'handicap' value was assigned to these two datasets. For areas that benefit from the presence of coastal defences a handicap value of -5 for 'hard' defences and -3 for 'soft' defences was deemed appropriate. Figure 4 shows the CESM at St. Andrews. See *jmfitton.xyz/cesm_scotland* for a webmap of the UPSM and CESM.
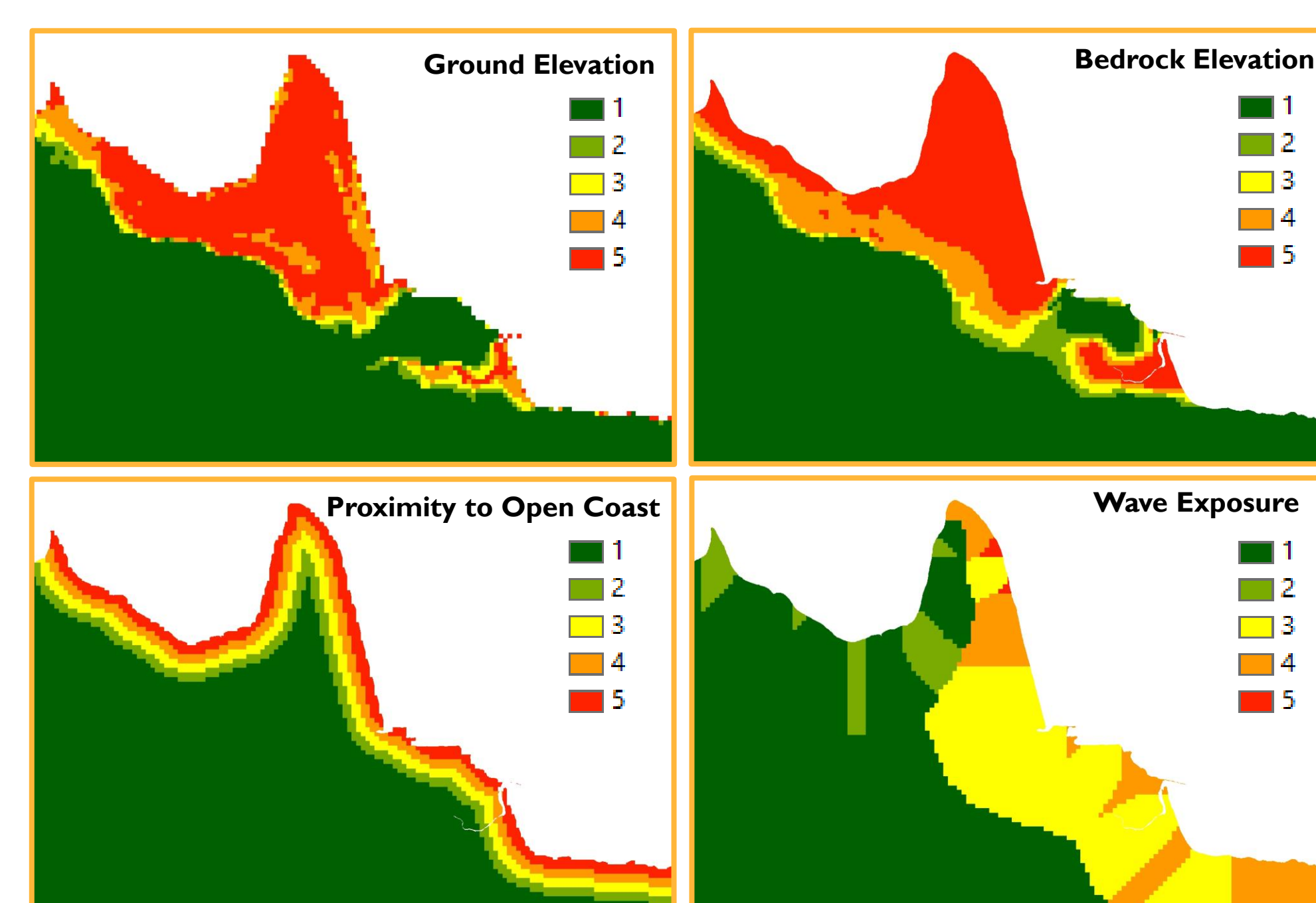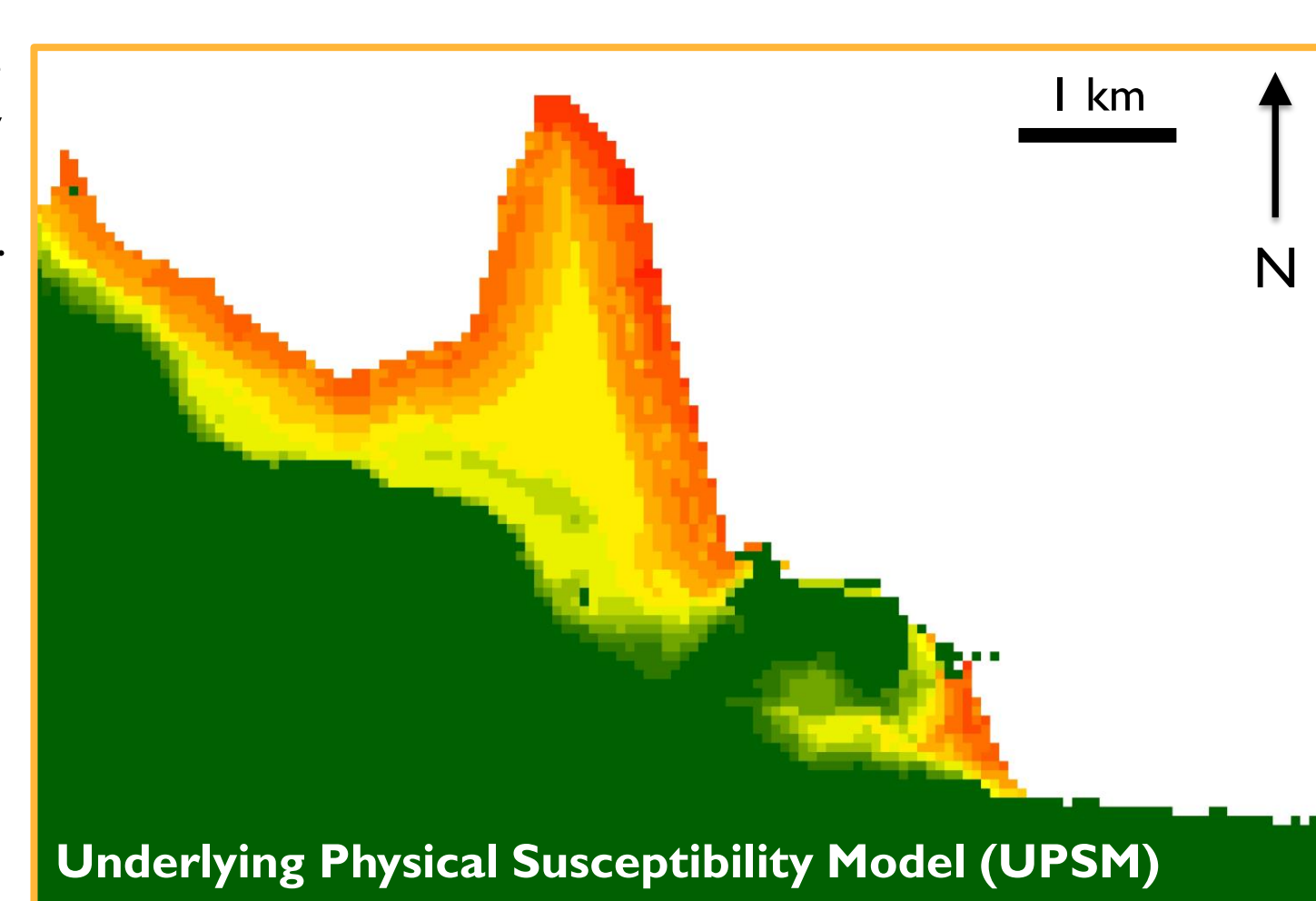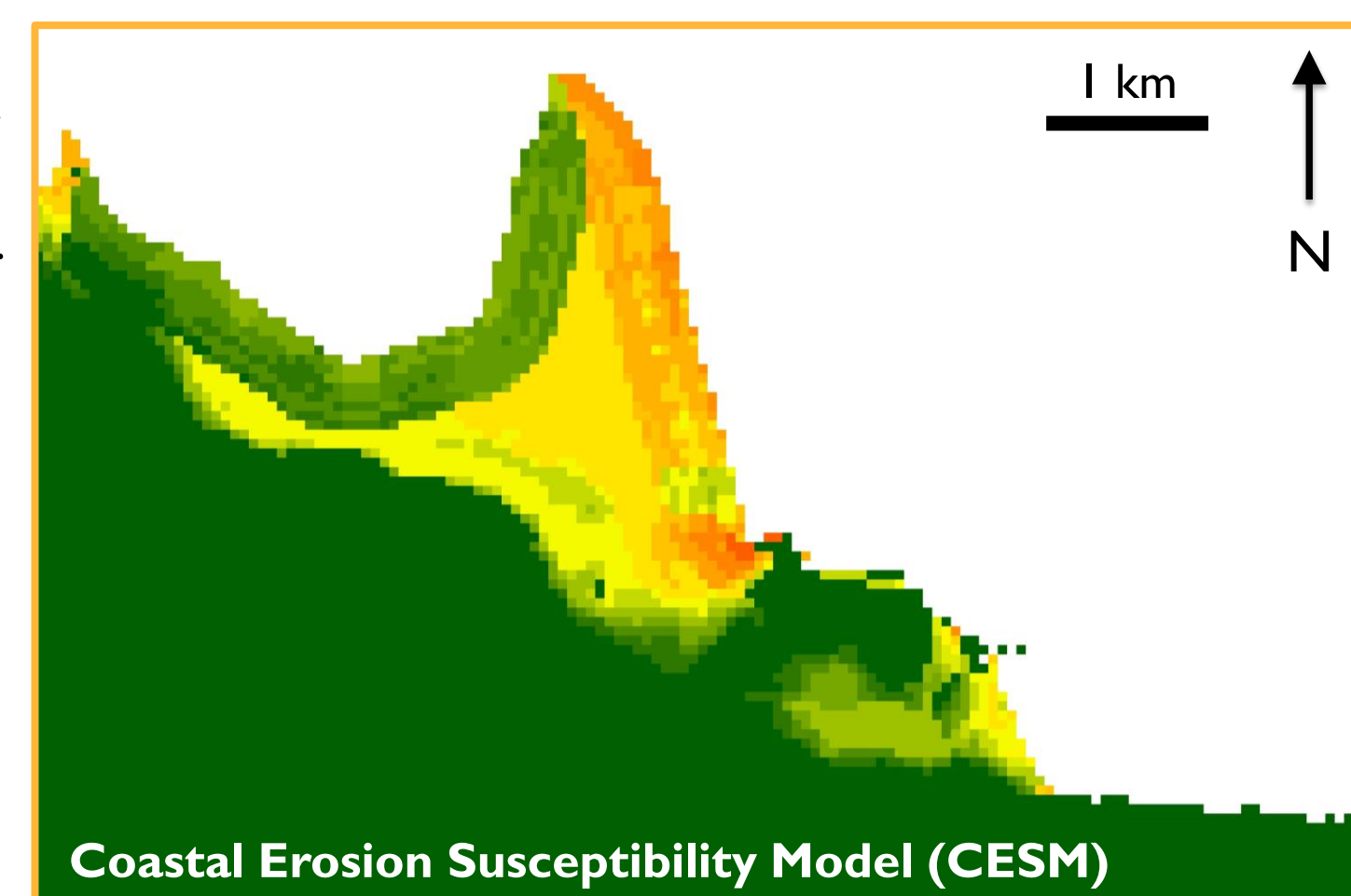

Figure 2: Examples of the ranked datasets used within the UPSM and CESM at St. Andrews (west coast of central Scotland).

Figure 3: Example of the Underlying Physical Susceptibility Model (UPSM) at St. Andrews (west coast of central Scotland). This is created by aggregating the data shown in Figure 2.
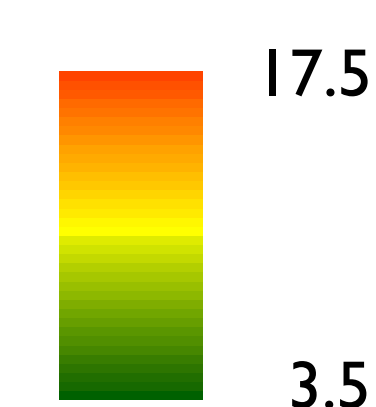

See *jmfitton.xyz/cesm_scotland* for a webmap of the UPSM and CESM.

Aggregate Score

17.5

3.5

Areas with high susceptibility to coastal erosion have a high aggregate score

Figure 4: Example of the Coastal Erosion Susceptibility Model (CESM) at St. Andrews (west coast of central Scotland). The CESM **includes the influence of coastal defences and sediment accretion** on the UPSM.

Vulnerability: A total of **633,977 residential properties** were identified as having 'Very High' coastal erosion vulnerability by the CEVI.

Exposure: Comparing the CESM with asset data identified the following assets were exposed to coastal erosion:
- **3,310 residential properties** (equating to a value of £526m)
- **179 km of road** (estimated direct replacement cost of £1.1bn)
- **13 km of rail track** (estimated direct replacement cost of £2bn)

Risk: **1,273 residential properties** are considered to have both high susceptibility to coastal erosion (derived from CESM), and very high vulnerability (derived from the CEVI).

Conclusion

The research presented here uses **models of the physical environment and vulnerability of the population to assess the assets and communities potentially exposed, and at risk, from coastal erosion in Scotland**. Prior to this research, this holistic and national approach to assessing coastal erosion risk had not been undertaken. **Coastal managers now have available a dataset that will support more sustainable, and socially just, decision making**. However, to further prioritise management, the locations where erosion and accretion are currently on going, is required, and will be delivered as part of the National Coastal Change Assessment (NCCA – see *dynamiccoast.com*). However, **a method to communicate the susceptibility, exposure, vulnerability and risk aspects of the coastal erosion hazard is needed,** that is informative to coastal manager and the public, whilst minimising the potential negative impacts (e.g. property blight) of releasing such information.

Fitton JM, Hansom JD, & Rennie AF. (2016) *A national coastal erosion susceptibility model for Scotland.* Ocean and Coastal Management; 132:80-9.

Willis I, Gibin M, Barros J, & Webber R. (2010) *Applying neighbourhood classification systems to natural hazards: a case study of Mt Vesuvius.* Natural Hazards; 70:1-22.