

Mapping suitability for low enthalpy heating/cooling technologies in Scottish superficial aquifers

1) Context

- Heating, particularly spatial heating, is the single largest source of carbon emissions in the UK.
- Vast majority of spatial heating in the UK is met using gas boilers.
- Strategy to meet 2019 commitments to net zero economy by 2050 address the need for decarbonised heating, partially by commitment to 600,000 GSHP installations per year by 2028¹.
- Is there a suitable resource in Scotland to support this?

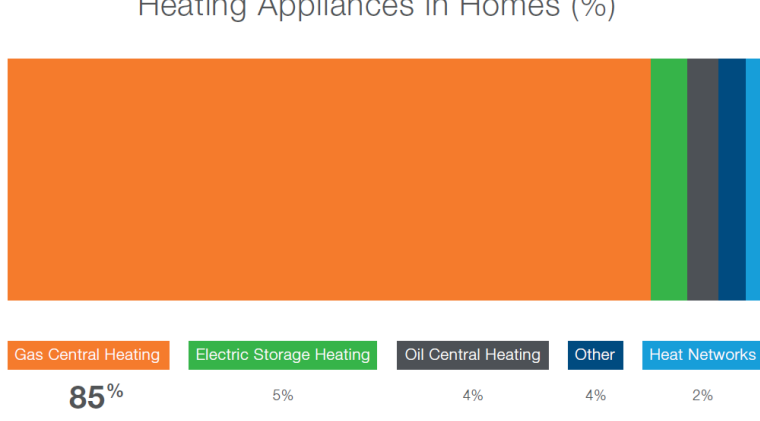
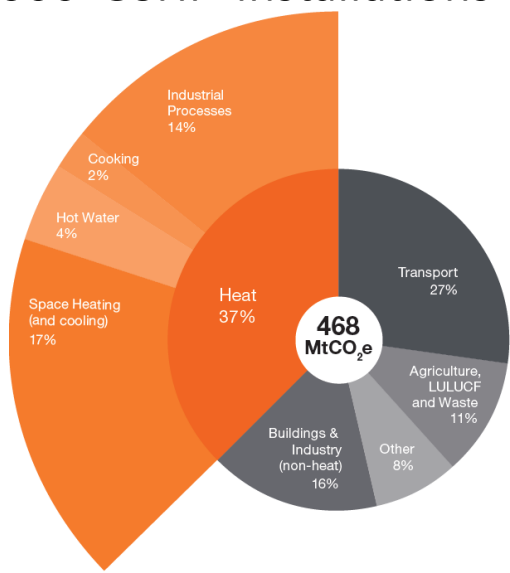


Fig1.1 Left: Space heating appliances in homes in 2016¹.
Fig1.2 Right: UK emissions in 2016 across different sectors¹.



2) Aims

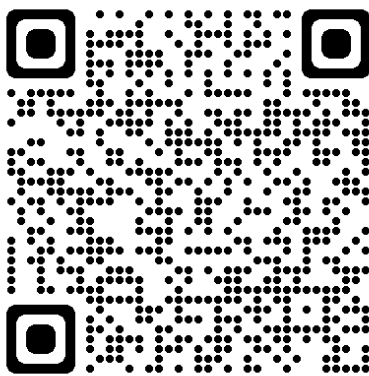
- Do superficial groundwaters have the potential to contribute to heating/cooling decarbonisation in Scotland?
- Identify and combine key criteria.
- Produce a metric by which criteria may quantitatively compared.
- Produce a metric that can observe data confidence.
- Provide a national scale GSHP screening tool for Scotland that can be used to gain a generalised knowledge of subsurface suitability.
- Provide a tool for site selection to advance PhD project.

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| Criterion | Dataset | 1 | 2 | 3 | 4 | 5 |
|----------------------------------|--|--|--|---|---|--|
| | | Unfavourable | Questionable | Neutral or No Data | Encouraging | Favourable |
| Geological Parameters | | | | | | |
| Superficial Coverage | BGS Geology 625k (Superficial) | No known deposits | N/A | Deposits present, No information | N/A | Known deposits exist continuously |
| Deposit Thickness | BGS National Superficial Deposit Thickness Model (Basic) | >1-5m | >5-10m | 0-1m (See STDM guide. Deposits of unproven thickness given value of 1m) | >10-15m | >15m |
| | BGS Buried Valleys (Onshore) | Not Present | N/A | N/A | 10-20m | 20-30m, 30-40m, greater than 40m |
| Superficial Aquifer Productivity | BGS Hydrogeological Maps of Scotland | No aquifer/NSA (Not a significant aquifer) | ILM (Intergranular flow, low-moderate productivity: 0.1-10 l/s) | Unknown geology | Aquifer present, ILMH (Intergranular flow, moderate to high productivity: 1-10 l/s) | Aquifer present, IH (Intergranular flow, high productivity: >10 l/s) |
| | BGS Susceptibility to groundwater flooding | Not considered prone to flooding | Limited Potential for groundwater flooding | N/A | Potential for groundwater flooding in sub-level structures | Potential for groundwater flooding at surface |
| Groundwater Parameters | | | | | | |
| Temperature | Met Office: HADUK-Grid | 1-3C | >3-4.5C | >4.5-6C / no information | >6-7.5C | >7.5C |
| Chemistry | BGS Civils: Sulfate/Sulfide potential | 7 (mapped water-N/A); 1 (Primary calcium sulfate present) | 2,3 | 6 | 4,5 | 0 (Primary sulfate not present) |
| | BGS Civils: Corrosivity (ferrous) | >11 | N/A | 9 to 11 | N/A | <9 |
| Non-geological Parameters | | | | | | |
| Heat demand | Scottish Government: Scotland Heat Map (Kwh/yr) | 372-5,000; & no data | 5,000-20,000 | 20,000-2 x 10 ⁷ | 2 x 10 ⁷ -1.8 x 10 ⁸ | 1.8 x 10 ⁸ -1.355 x 10 ⁹ |
| Protected areas | Scottish Government: SpatialData.gov.scot | Very sensitive ecological, environmental or cultural features, posing significant barriers gaining GSHP permissions. | Land may have several protections/restrictions or sensitive features that will negatively impact potential GSHP installation | Land may be within protected regions with mild impacts on GSHP installation | Land may be within protected regions but has no impact on GSHP installation | No restrictions /environmental protection on land use beyond private permissions |

3) Methods

a: Producing a Favourability Index (FI:0-5)

- Identify key criteria essential to effective GSHP operation.
- Identify existing datasets that quantify these criteria.
- Recategorise these data on a common scale of GSHP favourability to allow comparison.

b: Stacking inputs

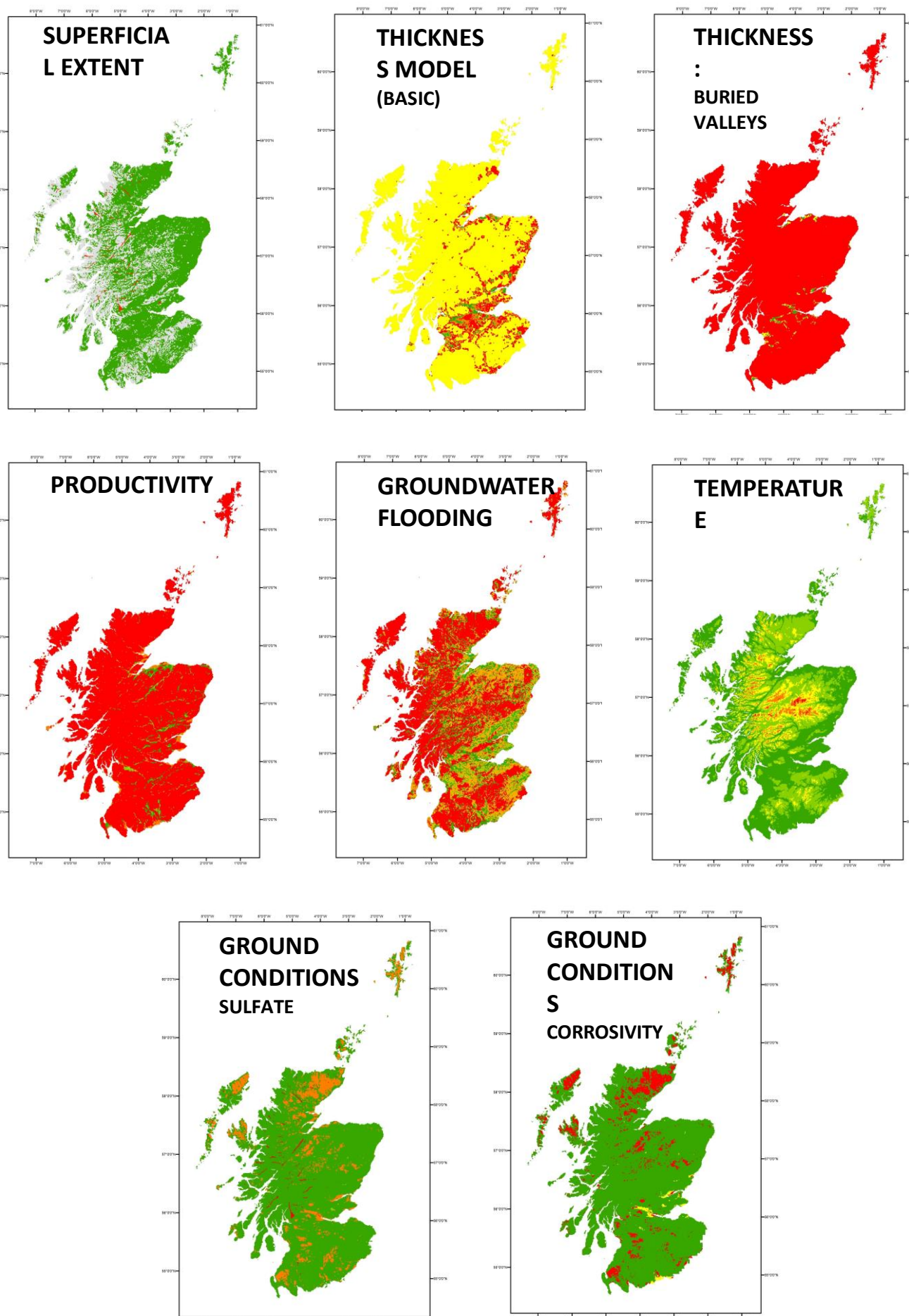
- 10 input datasets used, converted to the same raster format: 1km grid. British National Grid, D_OSGB_1936, cell assignment by maximum area, no priority.
- Cumulative FI scores from multiple inputs over the same unit area can be averaged to produce a 'favourability index' specific to that unit area.

c: Observing data confidence

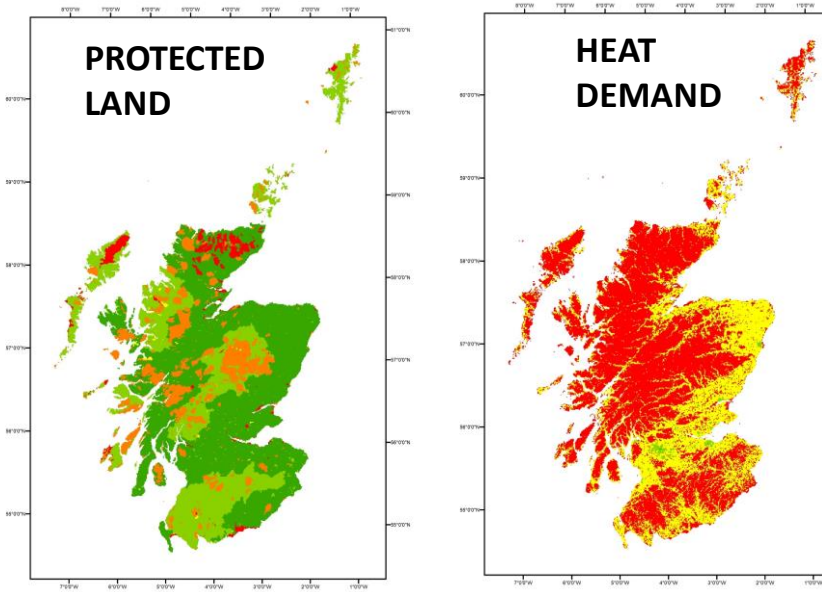
- Data confidence and reliability scored (0-5) for a variety of epistemic and aleatory uncertainties, and biases.
- Each unit area receives a data confidence value that is the average of its uncertainty and bias scores across datasets.

Fig 2.1 Left: Favourability Index 'scoring' table, showing input data conversion to FI values. **Fig 2.2 Right:** Input dataset map tiles, recategorised by FI.

BELOW GROUND FACTORS



ABOVE GROUND FACTORS



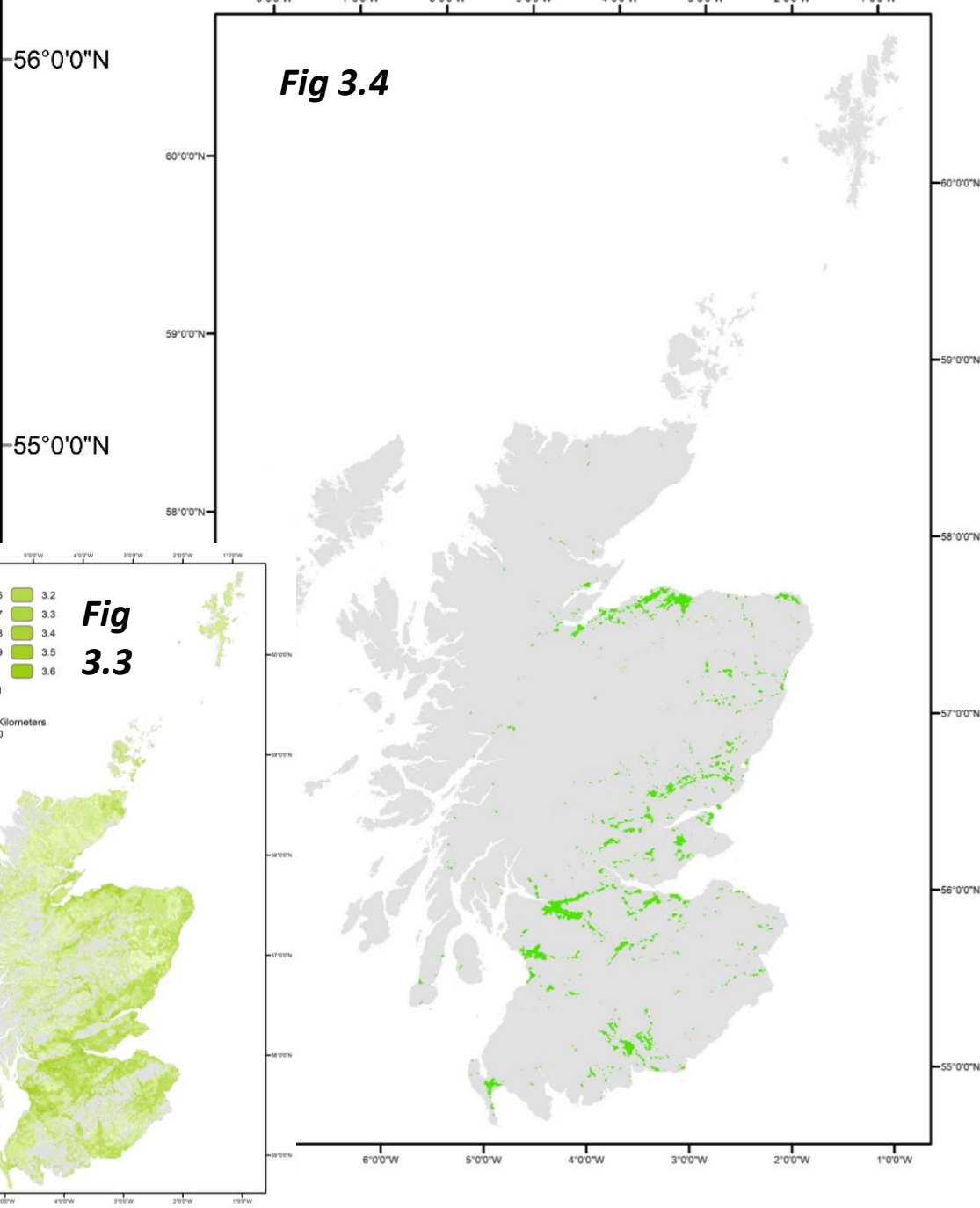
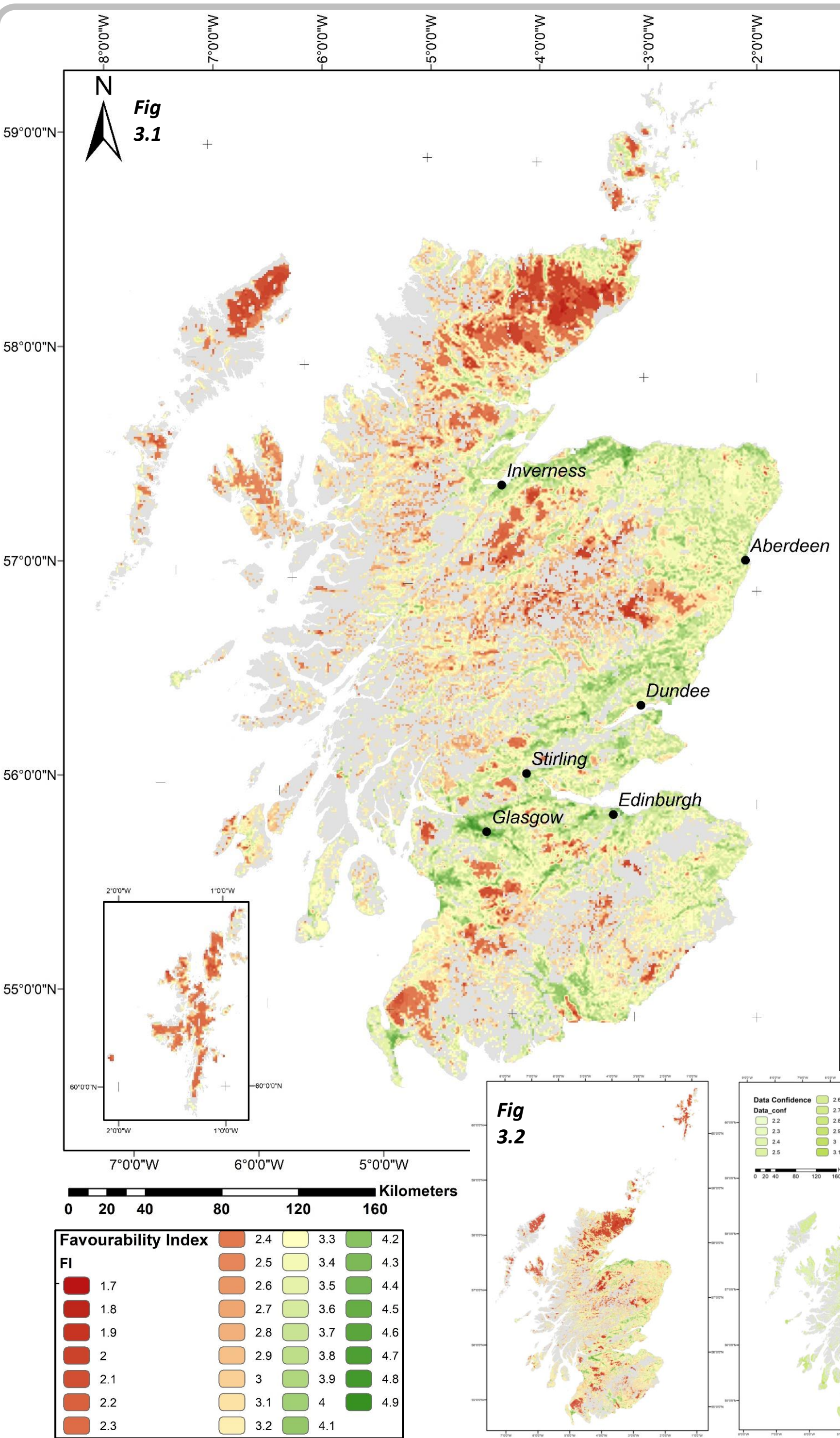
4) Results

Fig 3.1: Superficial deposit GSHP favourability map of Scotland, including above and below ground factors. Deposits range FI: 3.2, mean FI: 3.3, max 4.9, with 2,214km² identified as high suitability (FI≥4).

Fig 3.2: Below ground only favourability map. Very similar statistically (range 3.0, max 4.7). Spatially, extreme FI areas remain, however middling values have dropped. Using same key as Fig 3.1.

Fig 3.3: Data confidence map of Scotland, using a similar but separate 0.0-5.0 scoring system. Values derived from input analysis (section 3). Dark areas indicating high confidence overlie those highlighted in fig 3.4

Fig 3.4: Map highlighting regions scoring FI values of 4.0 or greater. Represent areas of future interest to this project



5) Conclusions

- Highest favourability areas coincide with population centres even without considering above ground (human) factors. 2011 census data shows approx. 25% of Scottish population (1.3 million) live in an area with an FI value of 4 or greater, suggesting GSHPs in superficial aquifers do represent a significant resource for future decarbonisation of heating/cooling demand.
- Specific sites may now be targeted within this high FI region for specialised assessment.
- Screening tool shows superficial sourced groundwater is not a universal heating/cooling resource across Scotland, and should not be treated as such in future decarbonising targets.
- Screening tool inherits availability bias from its input datasets, and is subject to individual geoscientist FI categorisation bias.