A model for large-scale analysis of line of sight, accounting for building heights

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Abstract

This paper presents a computational method for identifying line-of-sight between large numbers of individual properties and landscape features that accounts for buildings potentially blocking the view. It was designed initially to analyse the impact of Scottish wind turbines on house prices. This paper uses this Scottish example to illustrate the method, explain the issues in creating it and explore some possible research applications. We then ask what other questions may be opened up by creating bulk line of sight data. The ability to be able to separate out variables for proximity, line of sight for terrain only and for building heights adds a new dimension to investigating environmental and spatial impacts.

Keywords: spatial economics, GIS

1. Extended Abstract

This paper presents a computational method for identifying line-of-sight between large number of individual properties and landscape features that accounts for buildings potentially blocking the view. It was designed initially to analyse the impact of Scottish wind turbines on house prices (Heblich et al., 2016) –the Scottish example is used to illustrate the method and explain the issues in creating it.

Two aspects dictated the design of the method: the requirement to account for building heights and the need to produce data in bulk for the whole of Scotland, with the former in particular leading to the need for a bespoke program able to deal with issues a standard viewshed approach could not. This is discussed below.

We will discuss the Scottish example before asking what other questions may be opened up by creating bulk line of sight data. The ability to be able to separate out variables for proximity, line of sight for terrain only and for building heights adds a new dimension to investigating environmental impacts on properties.

Scotland has seen rapid growth in the number of windfarms over the last twenty years, with more than 2500 individual turbines now operational (Figure 1). To investigate their possible impact on Scottish property prices, a bespoke line of sight program was developed to produce data then used to re-create Steve Gibbons' analysis of English wind farm impacts (Gibbons, 2015).

We use a 3D 'Digital Elevation Model' (DEM) of the Scottish terrain, specifically Ordnance Survey's "OS Terrain 5" DEM, which provides height above sea level for every 5-by-5 metre grid point. The OS Terrain 5 data can be used to identify which houses have their lines of sight blocked by the physical landscape, but this does not account for the effect of other buildings. To correct for this, we also use building height data for the majority of properties in Scotland, combining Ordnance Survey's Mastermap with LIDAR data from the Centre for Environmental Data Analysis (CEDA). The OS Terrain 5 DEM data's 5 metre resolution is fine enough to allow addition of building footprints and heights derived from the Mastermap and CEDA data. These two sources cover 84% percent of Scottish properties.

To estimate landscape feature visibility, we used 'line of sight' analysis (also known as "intervisibility" analysis)[1]. Figure 3 and Figure 4 illustrate the essentials of this process using the example of a particular property in Glasgow that has its line of sight blocked by another building. These figures illustrate properties in potential sight of the Cathkin Braes wind turbine, installed in 2013[2].

The dotted line on the map of Glasgow in Figure 3 marks an 8.7km line of sight between this example property and the Cathkin Braes turbine. Figure 4 gives the landscape cross-section for this same line (with horizontal distance at 1/8th scale, relative to height), showing how the DEM landscape data - both with and without building heights - is used. The line starts two metres above ground level on the site of the house and 'looks' towards the turbine blade tip height. If the highest point of the tip is visible above landscape and buildings, the line of sight is clear. In this example, for landscape alone, the house (left-hand side of graph) has a clear line of sight. If building heights are used, however (green in Figure 4), line of sight is blocked.

The need for a bespoke approach is caused by a seemingly simple problem: if a line of sight starts at window height in a house (say, at two metres), how to include all other buildings but not let this single property block the view? There are at least two approaches. The first would be to create a whole new viewshed for each property, making sure to lower that property to two metres above the DEM. For the number of properties involved, this is computationally onerous. The approach taken here was to find individual lines of sight using a Bresenham line. This allows the program to discount the building data for the house being viewed from by comparing two different rasters – one with and one without buildings added – and effectively 'walking' to the edge of the building alone the line.

The result for all properties produces a dramatic difference: without building heights, 80% of Scottish properties within 15km of a turbine are identified as having a line of sight to at least one. This drops to 32% when building heights are used. Figure 5 illustrates this difference for Dunfermline, showing properties that can "see" at least one turbine in yellow. The number drops dramatically once building heights are accounted for, and the result is more 'grainy' than would be produced by a simple viewshed (e.g. for a point in Glasgow, Figure 2).

[1] Code and guidance for this is available at the Sheffield Methods Insitute github page: github.com/SheffieldMethodsInstitute/windfarmsHousePrices

[2] See e.g. "£5m city turbine will be visible around world (From Evening Times)." 2013. www.eveningtimes.co.uk/news/13256714.__5m_city_turbine_will_be_visible_around_world

The procedure is memory intensive and so the modelling method builds itself around a batch process, with batches of landscape rasters, properties and landscape features collated in Python/QGIS. These can process larger groups of turbines together (e.g. the Whitelee wind farm to south of Glasgow in Figure 3Figure 3 is processed in one batch).

Shows how much difference building heights can make. It compares a rural area of Scotland (left) with Glasgow (right), showing the percentage of properties with a wind turbine in 1km bands, up to 15km. Green bars indicate those properties with a turbine within Euclidean distance range; blue bars are the percentage that can "see" a turbine accounting only for landscape (this could be considered also as "can see a turbine from within my neighbourhood, just not necessarily from my window"); red account for building heights. The figure illustrates the difference of being in an urban area.

This ability to separate out line of sight accounting for building heights opens up new research questions. For example, as well as asking about the impact of new landscape features like wind turbines on property prices, one can ask: has their siting and visibility affected communities equally? Historically, energy development impacts have fallen disproportionately on poorer communities - has wind power followed the same pattern or bucked it?

Figure 7 shows the underlying pattern of Scottish house prices over time. Properties are separated into those sited in places where a wind turbine was built in a visible spot *at some point in that sale period* and those that were not. The former group have always been in poorer areas (using house price as a proxy for wealth).

However, this only accounts for terrain - the answer changes if building heights are included. Figure 8 and Figure 9 break the Scottish Index of Multiple Deprivation into fourteen bins, with the most deprived on the left. What proportion of those SIMD zones have 80% or more properties that can see a turbine?

Figure 8 accounts for terrain only and supports the previous figure: it appears that less deprived areas are less exposed. However, adding building heights for Figure 9 produces a much more mixed picture and, for the largest 10-15km distance band, the result appears to be reversed, with less deprived areas being more exposed.

The line of sight model is now being used to create datasets of visibility for green spaces to investigate the possible health effects of being able to *see* them, not just be near them. It is also being used to find out visibility to trees in Ontario, Canada.

Figures on following pages

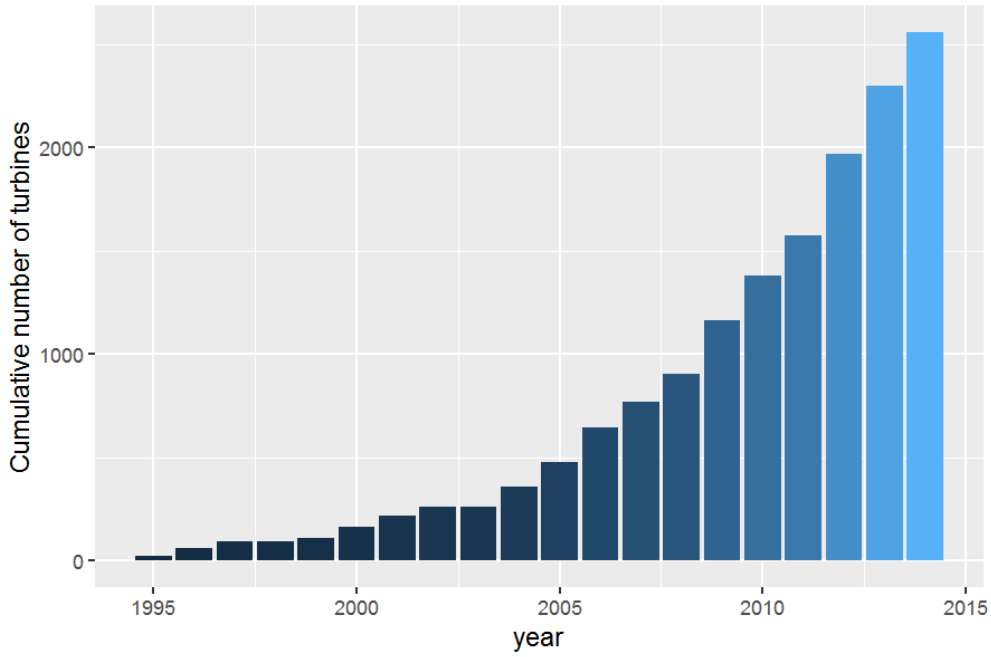

Figure 1: cumulative count of turbines built in Scotland up to 2014

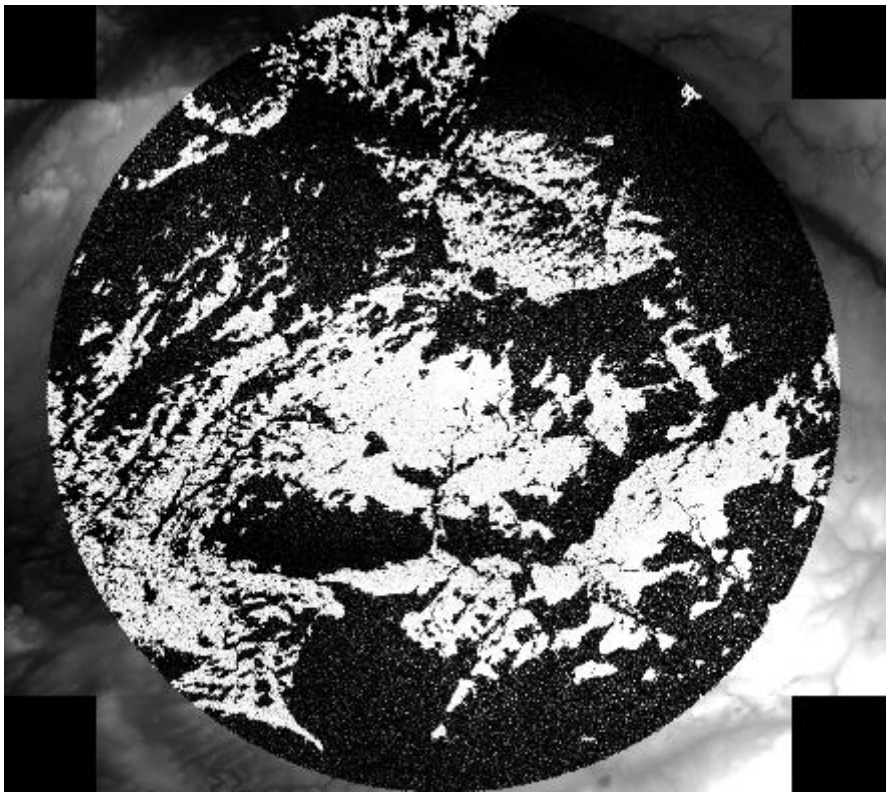

Figure 2: typical viewshed for terrain only

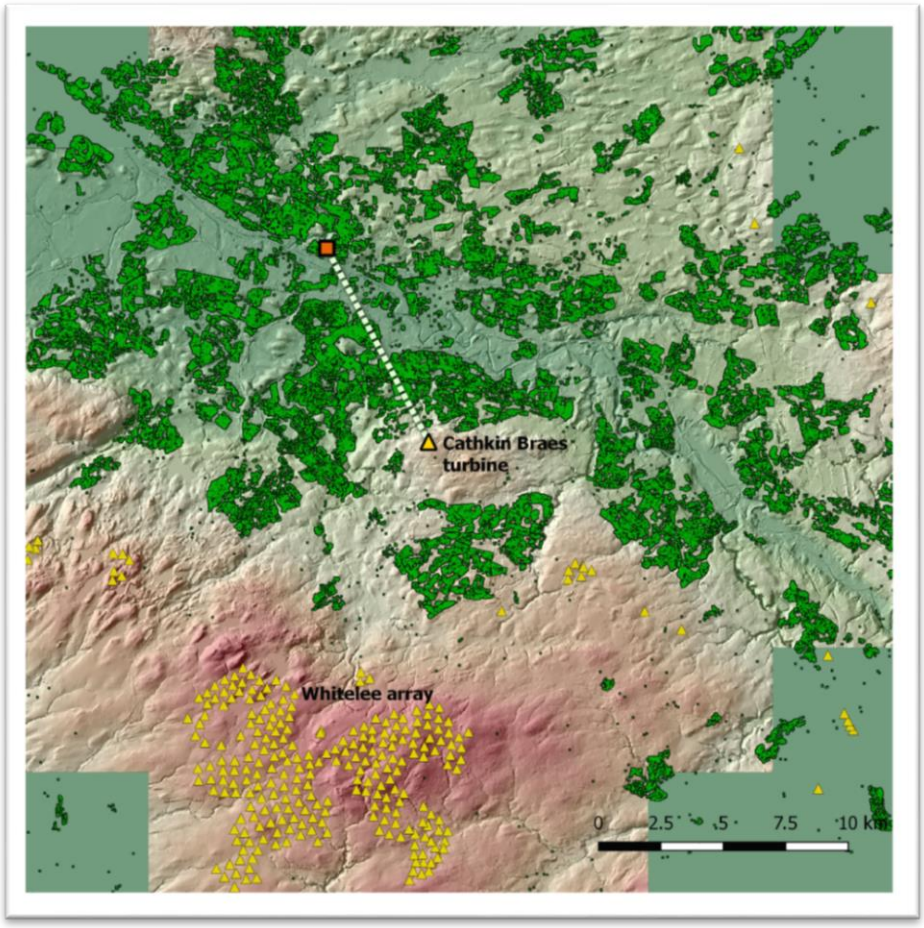

Figure 3: Digital Elevation Model for Glasgow area. Repeat-sales properties in green. Wind turbines are yellow triangles. Dotted line is an example line of sight (matches figure below) for a sample Glasgow property to Cathkin Braes turbine tip.

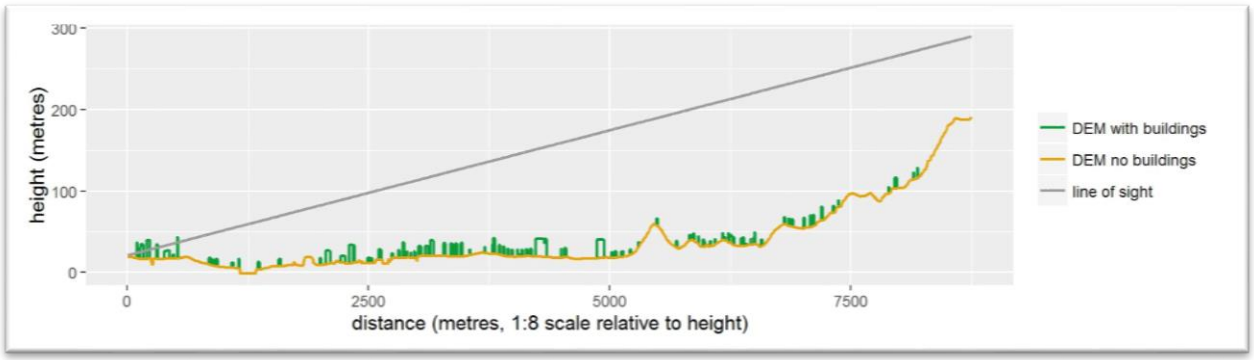

Figure 4: example line of sight blocked by buildings that would not be blocked by landscape alone. Matches dotted line in above figure. Property on left, Cathkin Braes turbine tip on right. Note horizontal distance is 1/8 of actual scale, relative to height.

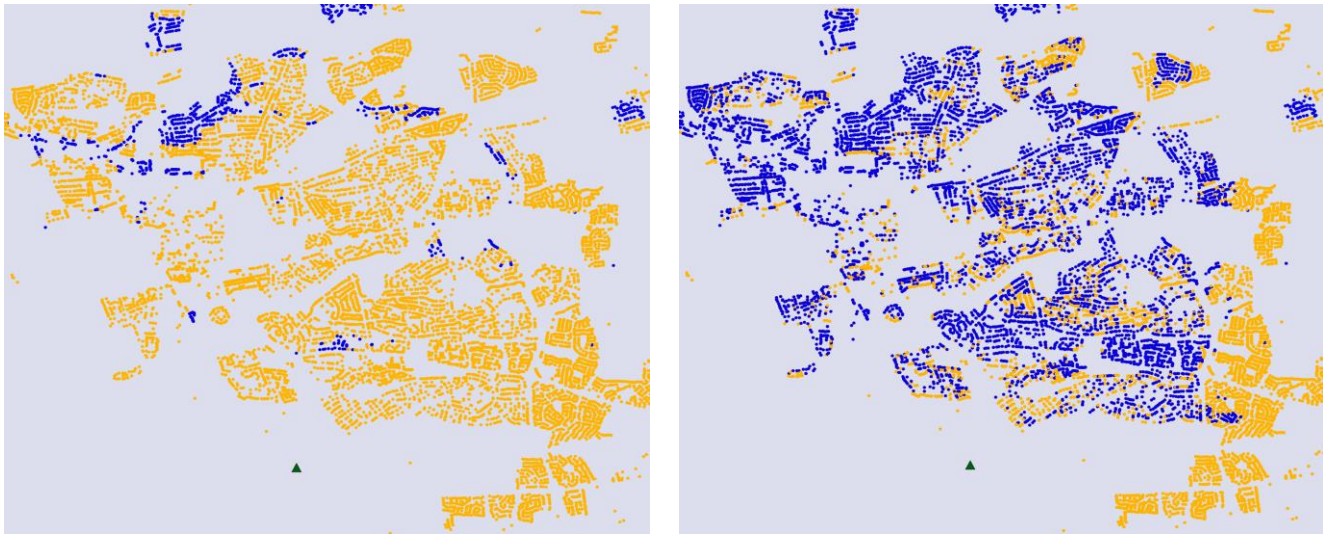

Figure 5: an example of the difference between a 'landscape only' line of sight analysis and including buildings. Dunfermline in Scotland. Properties marked in yellow can "see" at least one turbine. Left: landscape only; right: landscape and buildings.

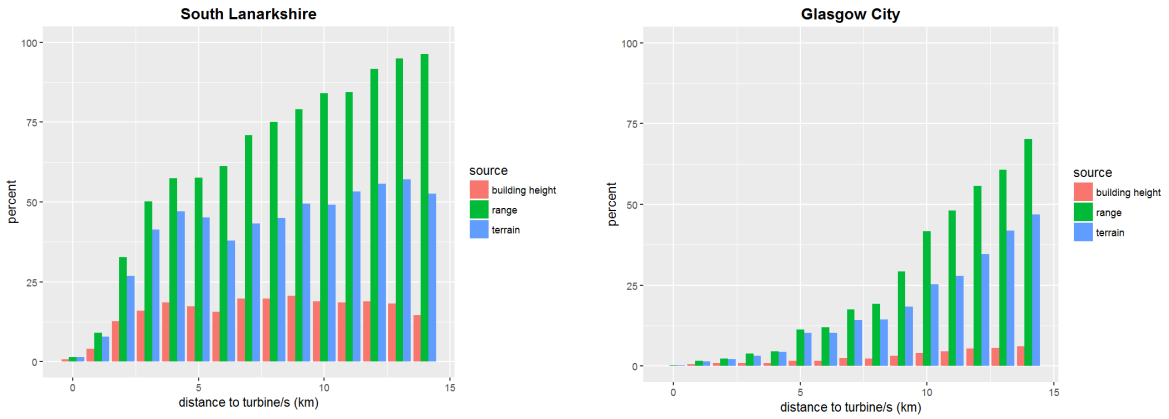

Figure 6: difference in exposure to turbine visibility for a rural vs urban area of Scotland. Y axis shows percent of properties in each 1km distance band. "Range" is just having at least one turbine in that distance band;

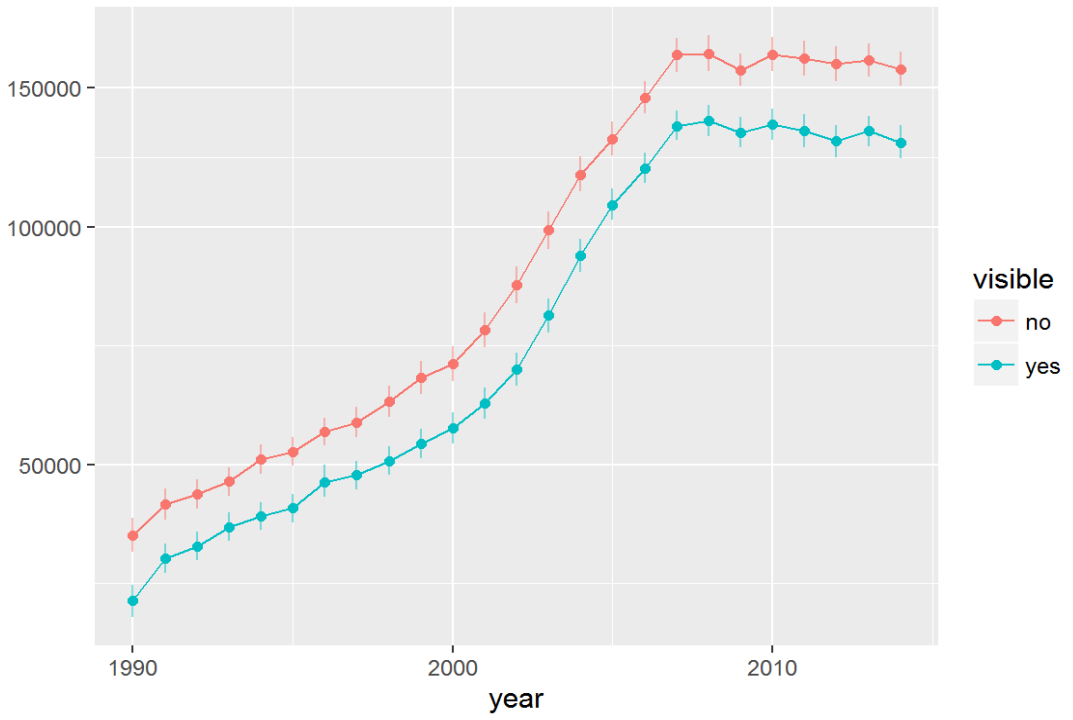

Figure 7: Scottish property prices from 1990 to 2014 via Registers of Scotland. Separated into those that have had a turbine built within "sight" at some point in that time range. These have always been in places where property prices were cheaper.

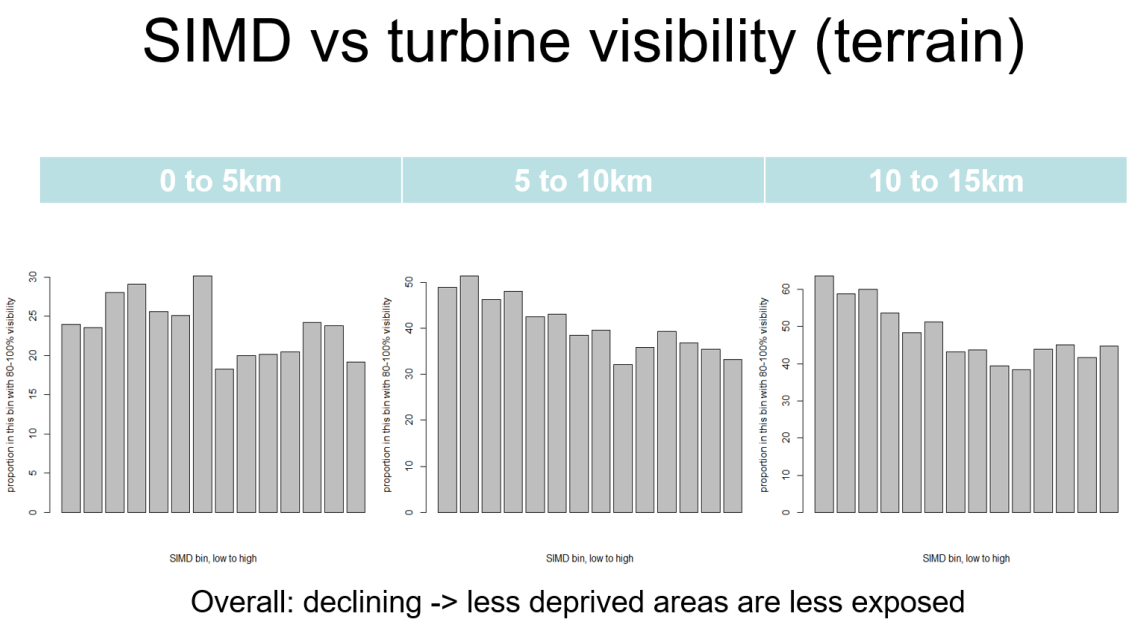

Figure 8: Scottish Index of Multiple Deprivation versus 80-100% of properties can "see" a turbine, account for terrain only.

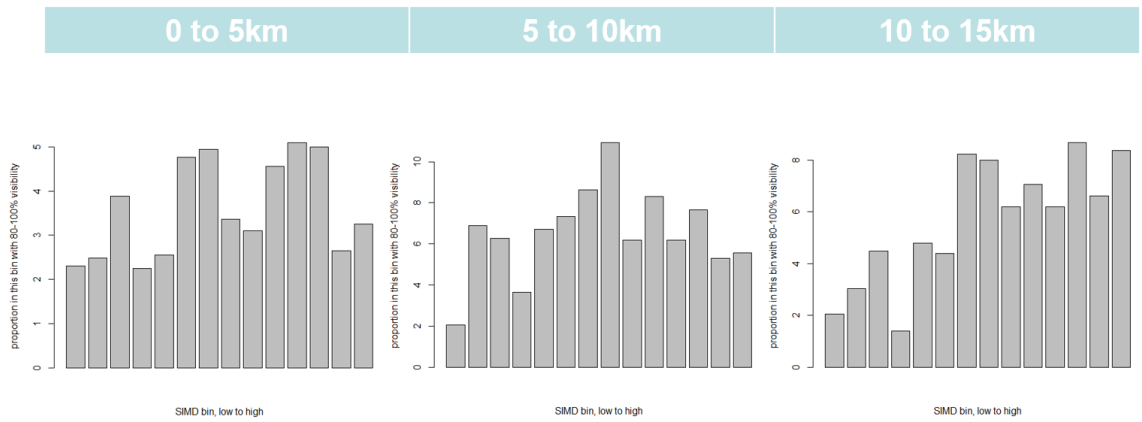

Figure 9: Scottish Index of Multiple Deprivation versus 80-100% of properties can "see" a turbine, account for building heights.

2. Acknowledgements

This work was funded by ClimateXchange Scotland and, in part, by AQMeN via the ESRC.

3. References

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