No High Ground: visualising Scotland's renewable energy landscapes using rapid viewshed assessment tools

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Summary: Rapid viewshed modelling techniques are used to address the conflicts between landscape protection and renewable energy goals in Scotland. The area of the country currently without a view of a wind turbine is calculated and used to identify areas that could be developed as wind farms without further impacting on the non-visible areas. The analysis is repeated for protected landscapes and core wild land areas and lowest impact zones identified. The method used relies on the use of voxel-based real-time viewshed modelling techniques to make these analyses practical.

KEYWORDS: wind turbines, rapid viewshed modelling

1. Introduction:

Tthe Scottish National Party (SNP) has declared new ambitious targets to meet equivalent to 100% of Scotland's energy requirements through renewable sources by 2020. Meanwhile, Scottish Natural Heritage (SNH) have produced figures that show the area of Scotland not impacted by visual intrusion from development is just 28% which has fallen from 31% in 2008 and 40% in 2002 with the greater proportion of the change attributable to onshore wind energy (SNH, 2010). Much of the remaining 28% lies within wild land areas identified by SNH mapping. These are a highly valued part of Scotland's cultural and natural heritage with 91% of Scottish residents saying that wild land is important and needs to be preserved. They are also important for Scotland's economy, with annual revenue from tourism worth an estimated £5-10 billion and policy targets aiming to increase this 50% by 2015.

Clearly there is a conflict between Scotland's renewable energy targets and its landscape/tourism policies. This paper addresses the question of where Scotland can further develop its renewable potential without impacting on or reducing the remaining non-impacted. This is not a trivial task in

terms of spatial analysis and helps shed light on the problem of visual intrusion in valued landscapes. The aims of the paper are to identify lowest impact zones for wind turbines that either do not further reduce the remaining 28% or minimise the cumulative effects on core wild land and other areas designed on landscape quality grounds and so avoid excessive conflict between core policies for Scotland in regard to the environment, renewable energy, economy, livelihood and landscape.

2. Materials and methods

While several authors have already addressed the problem of visual impact assessment and siting of wind turbines using GIS (e.g. Kidner et al., 1996; Baban and Parry, 2001; Bishop, 2002), exhaustive assessment of all possible locations using both a looking in and looking out approach to model cumulative and distance-weighted impacts with high resolution terrain data across whole landscapes has hitherto been hampered by the limits of speed and efficiency of processing. The following analyses are undertaken.

1. Generate viewsheds for all built, approved, planning and scoping-phase turbines (n=4200) to identify all the areas currently without a view of a wind turbine. While this can be achieved using standard, off-the-shelf visibility analysis tools available in proprietary GIS packages with reasonable run times, a new voxel-based viewshed explorer tool (Carver and Washtell, 2012) is used to speed up processing times and calculate the relative proportion of the viewshed occupied by wind turbines for every grid cell in the terrain model based on vertical area visible and taking distance decay into account. A maximum search radius of 30km is applied based on data from Bishop (2002).
2. Using data from step 1, those areas of the country that do **not** have a view of a turbine are identified and these areas used to identify possible new areas for turbine development on the basis that they are **not** visible from within the currently non-impacted areas. This assumes a viewer height of 2m and a turbine height to blade tip of 125m and is run for the entire land area of Scotland plus a coastal 30km buffer at a resolution of 100x100m (*n*cells~22 million). This is repeated for core wild land areas and existing protected areas. Here core wild areas are defined as the top 10 percentile of SNH wildness maps, and the designated areas used are the national parks, National Scenic Areas (NSAs), National Nature Reserves (NNRs), Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). This is done using the voxel viewshed explorer tool which achieves a massive improvement (~1500 fold) on run times over standard tools available in proprietary GIS packages (Carver and Washtell, 2012).

3. Results

Currently, 71% of Scottish countryside is without a view of an installed turbine. However, if all the wind turbines that are currently approved or in the planning or scoping phase are built, then this figure will fall to 49% (Figure 1). Added to the existing visual impact from other human, then it is unlikely that many areas of the Scottish landscape will be free from visual influence by the 2020 target date specified by the SNP. However, logic dictates that there must be some places where a wind farm could be located so that those areas currently without a view of a turbine or other human artefact are either not adversely affected or reduced further still. Results from the analysis carried out here indicate that that there are in fact very few areas that can be further developed without reducing the remaining uninfluenced landscape. This begs a further question: where are the areas which if developed would minimize the extent of intrusion on the remaining uninfluenced landscape? Inherently, the question is rooted in humanistic perception of acceptable levels of cumulative impacts. However, for discussion's sake, the top 10% lowest impact zones are shown (Figure 2). These are located mainly around existing wind farms, as well as various offshore areas.

The total land area protected for its biodiversity is actually quite large and consequently the analysis reports that there are very few areas (Figure 3) that do not have a view of these protected areas. However, fewer areas of Scotland are covered by landscape designations and these are in the main large contiguous areas as opposed to the more fragmented nature of biodiversity and nature protection areas, and therefore the viewshed analysis reveals much larger regions (Figure 4), mainly in Aberdeenshire, which do not have a view of a protected landscape. Results for the core wild land areas (Figure 5) lie somewhere between these two maps, these being more fragmented than the landscape designations, but with a similar distribution.

4. Discussion and conclusions

Results from this work throw up some interesting spatial issues of relativity in regard to cumulative effects and how these reflect people’s actual opinion in regard to visual amenity and value in natural landscapes. However, it is probably the issues of scale, distance decay, thresholds and sensitivity that are of most interest here. One of these reflects Hotelling’s Model (1929) of the economics of location, traditionally applied to the example of ice cream vendors on a beach, but here applied to wind turbine location in respect to landscape impacts. Assuming a landscape devoid of wind turbines, then the first turbine must have an impact, and subsequent turbines will also have additional impact but proportionally less if they are located in close proximity to the first. As a landscape fills up with turbines, then the remaining area free from visual impact shrinks until a second threshold is reached at which point there are no further sites which can be developed without further significant reduction of the remaining area or adding further turbines will have little effect as the majority of the landscape is

impacted already. Again, there are issues about relative and cumulative effects here, but it is clear from the results shown that the second threshold has already been reached. A third, and final, threshold is then reached when there a no areas remaining without a view of a turbine. We may ultimately have to pass this threshold if SNP's plans for 100% renewable energy base for Scotland is ever to be achieved.

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Acknowledgements

The authors wish to acknowledge the support of Ryerson University International Works Placement Fellowship scheme for funding this work, and SNH for access to essential datasets.

Biographies

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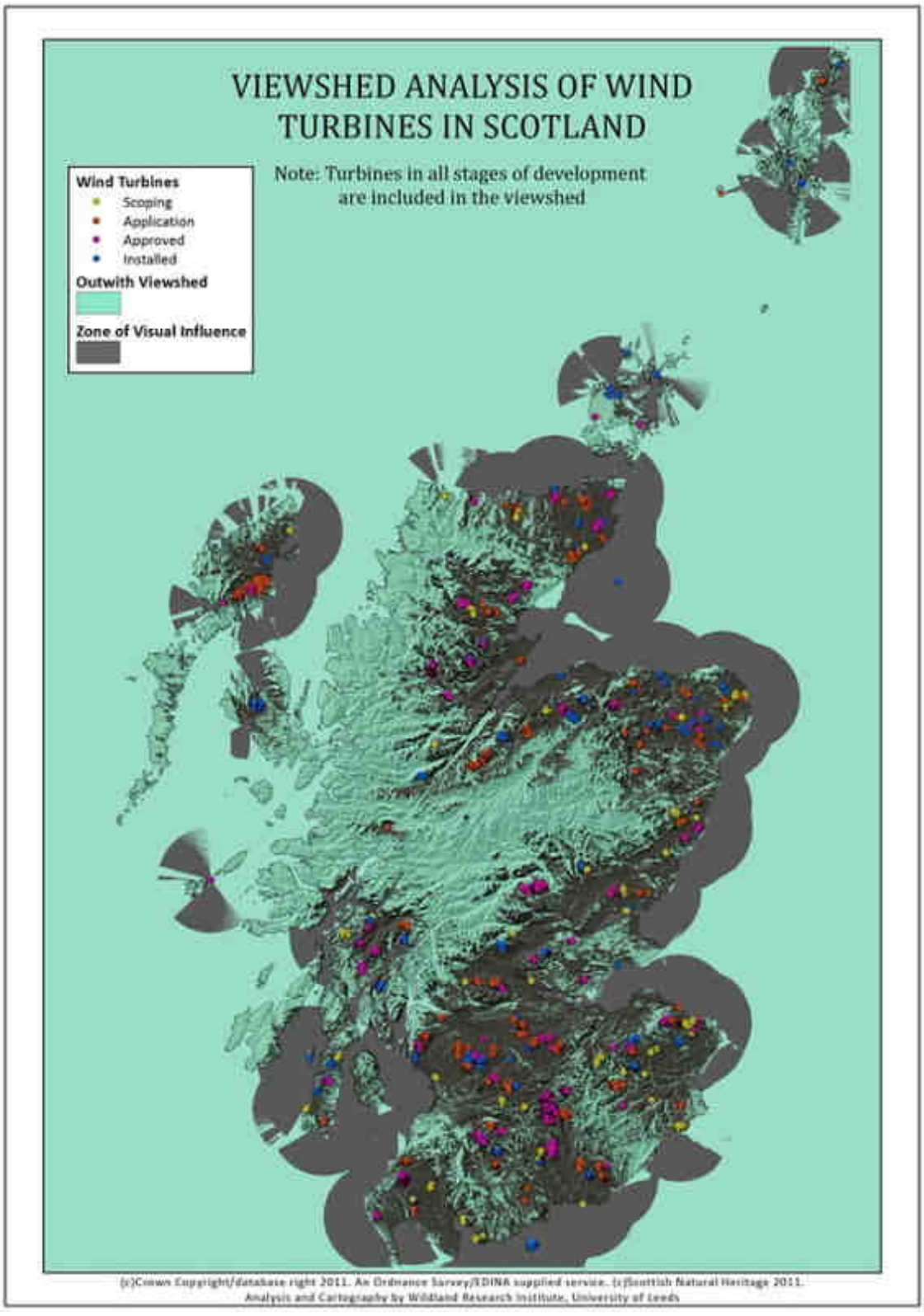

Figure 1. Viewshed analysis of wind turbines in Scotland

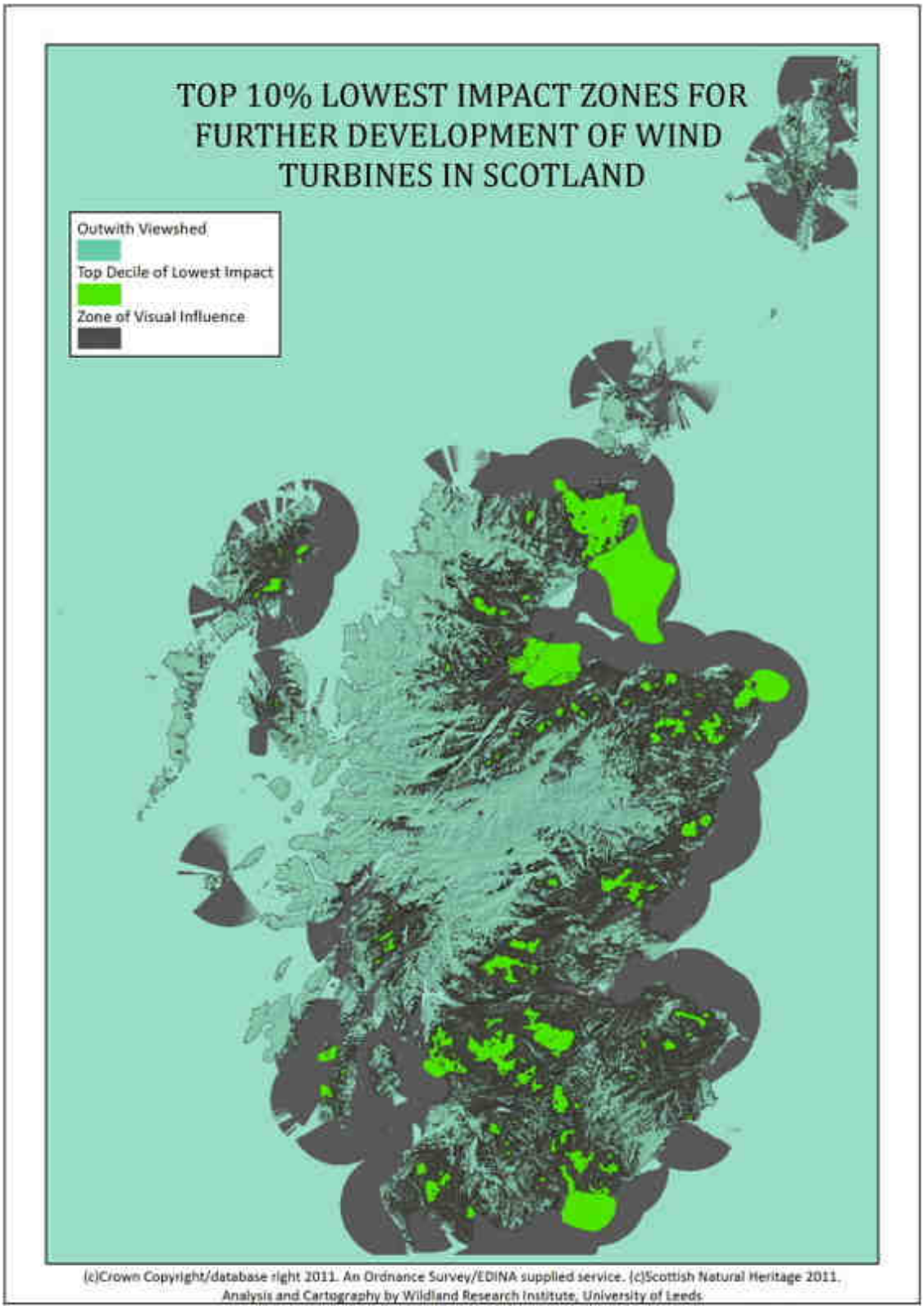

Figure 2. Top 10% lowest impact zones for further development of wind turbines in Scotland

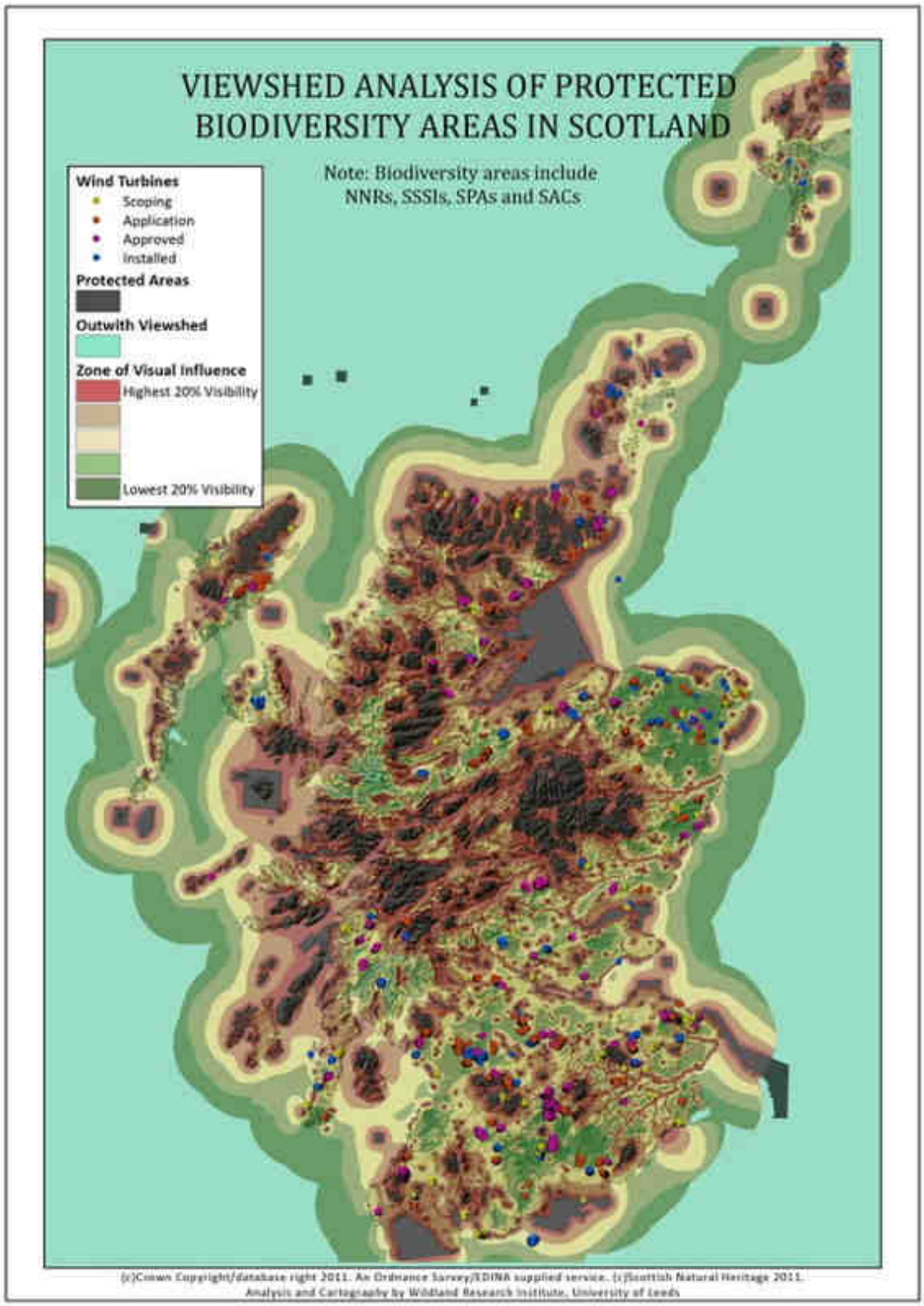

Figure 3. Viewshed analysis of protected biodiversity areas in Scotland

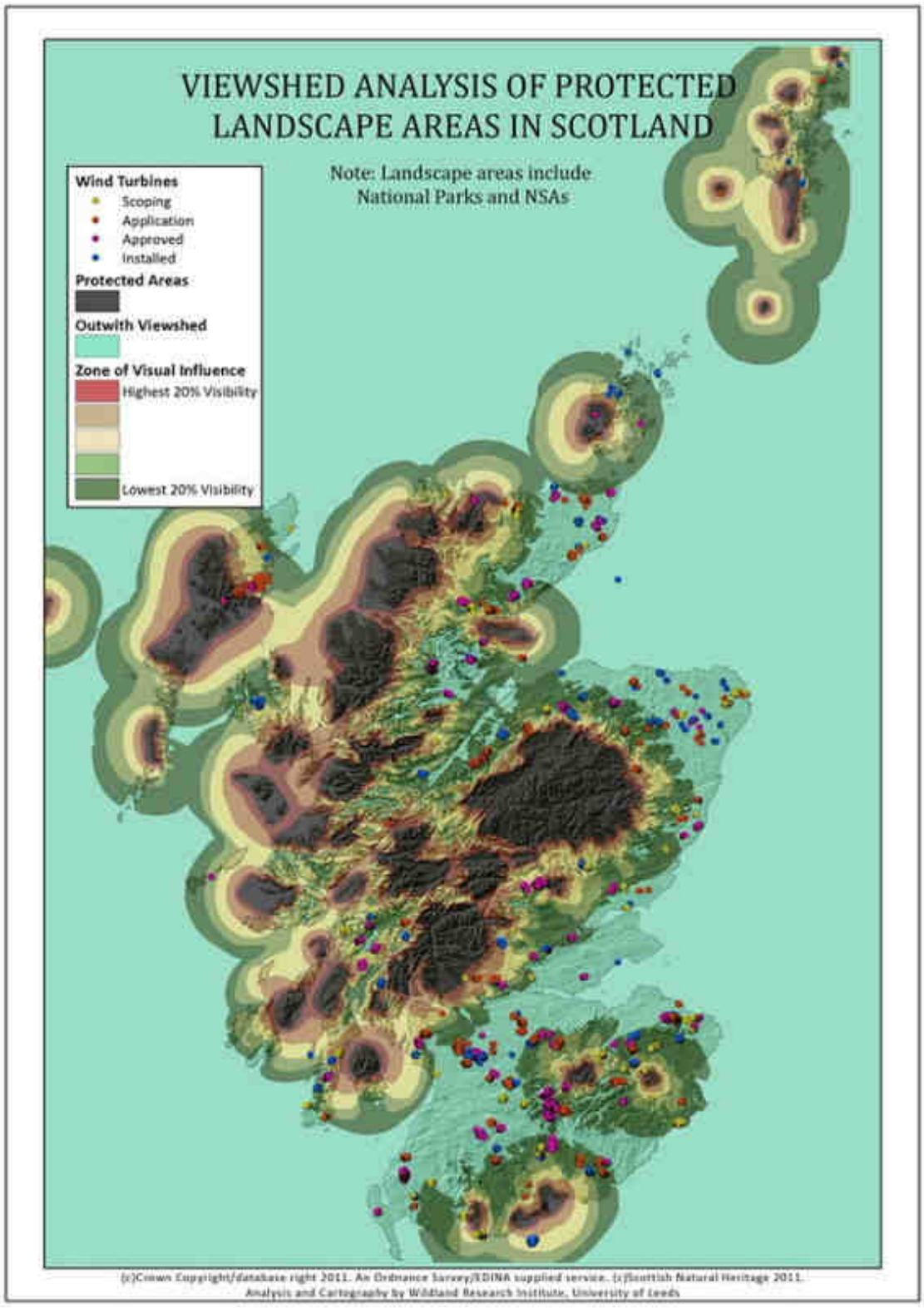

Figure 4. Viewshed analysis of protected landscape areas in Scotland

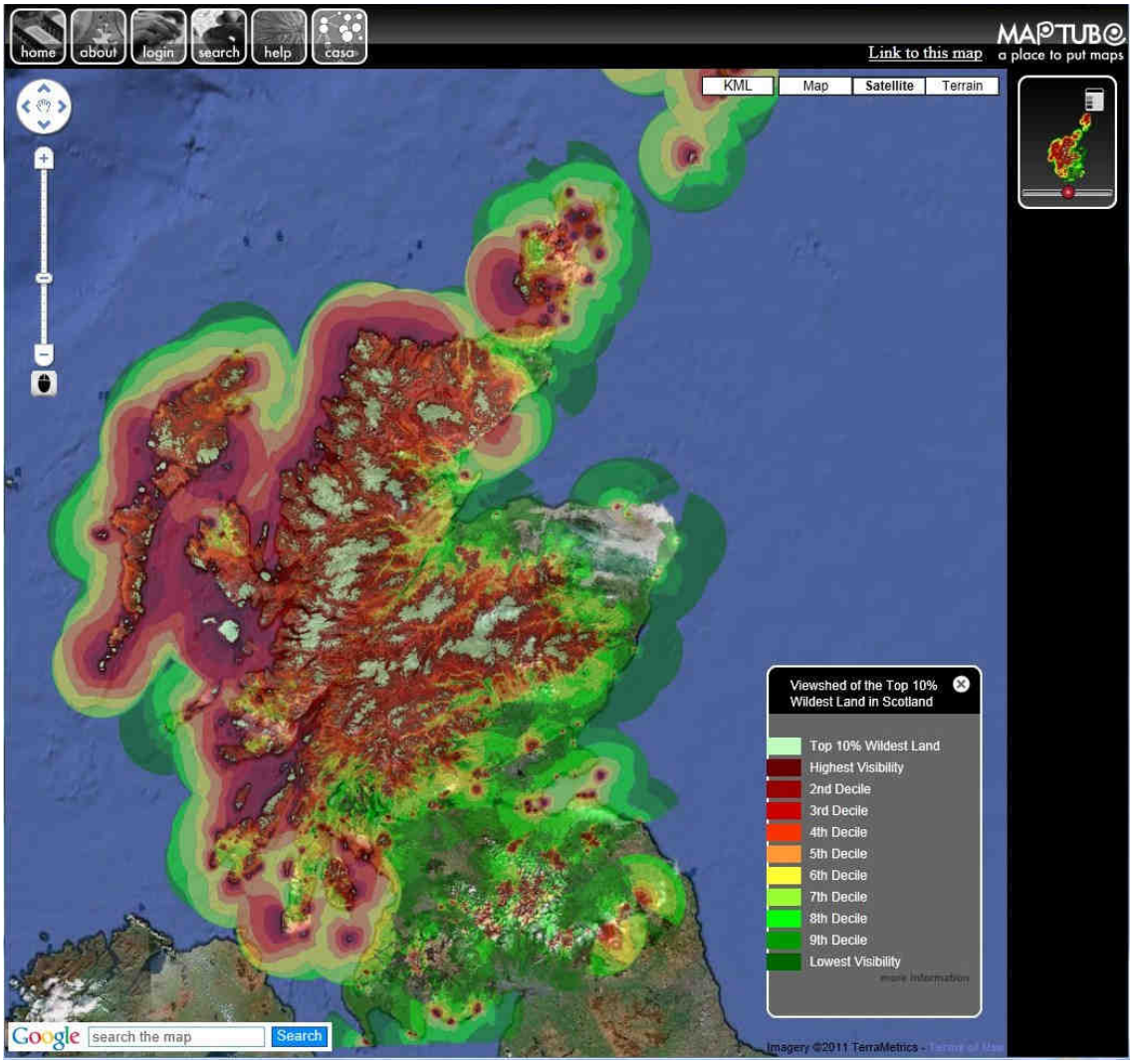

Figure 5. Viewshed analysis of core wild land areas in Scotland

http://maptube.org/map.aspx?s=DGxXppVkHLSnMJmcEJDApcHAp1bAoTjd