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# WILDERNESS BRITAIN? USING GIS AND MULTI-CRITERIA EVALUATION TECHNIQUES TO MAP THE WILDERNESS CONTINUUM

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## Abstract

This working paper discusses the difficulties of defining wilderness and describes how the wilderness continuum concept can be used to help map the wilder areas of Britain. Geographical Information Systems and multi-criteria evaluation techniques are used to map the wilderness continuum for Britain and evaluate existing protected areas.

## 1. Introduction

Despite there being no real wilderness areas in Britain; at least not in comparison to those found in such places as Greenland, Antarctica, Alaska and Siberia, it is argued that it is possible, using Geographical Information Systems (GIS), to identify a continuum from the most altered and accessible to the most natural and remote. Wilderness is just one extreme on this continuum or environmental modification spectrum from the "paved to the primeval" (Nash, 1982, p.1; Hendee et al., 1990). With this in mind, this paper applies GIS and multi-criteria evaluation (MCE) techniques to map the wilderness continuum for Britain. From this mapping of the continuum it is possible not only to identify the wildest parts of the country but compare the geographical location of these 'wild lands' and the boundaries of existing protected areas with a view towards identifying areas requiring new or additional protection.

## 2. Wilderness, Britain and the continuum concept

Wilderness as an entity is notoriously difficult to define with various attempts having been made in the literature. Leopold (1921), Nash (1982), Hendee et al (1990) and Oelschlaeger (1991) have all attempted academic definitions, while formal definitions such as that given by US Wilderness Act (1964) have been written for legislative purposes and are in active use. Most definitions stress the natural state of the environment, the absence of human habitation and the lack of other human related influences and impacts. Leopold (1921) defines wilderness as "a continuous stretch of country preserved in its natural state, open to lawful hunting and fishing, devoid of roads, artificial trails, cottages and other works of man" (p.719). Quoting from Section 2c of the US Wilderness Act (1964) "a wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognised as an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain". The act also required that a wilderness retain "its primeval character and influence" and that it be protected and managed in such a way that it "appears to have been affected primarily by the forces of nature".

Clearly few such areas as defined by Leopold and the Wilderness Act exist in Britain today, and where they do they take the form of small and isolated pockets where a natural ecosystem has remained largely unaltered by human activity. Go back of few hundred thousand years, however, and the whole of Britain was a wilderness with no human settlement. It was only with the arrival of early humans across the then land bridge between Britain and the continent that this wilderness began to be eroded by human incursion, settlement and forest clearance. Go back two thousand years and many parts of the country were still home to various species of wild animals commonly associated with North American wilderness; wolf, beaver, bear and lynx (Watson, 1983). Perversely, go back just a few hundred years

and the areas of Scottish Highlands we may be tempted to call wilderness today were the basis of a thriving rural economy. It was only the 'clearances' of the early nineteenth century that erased these traditional crofting communities and re-instated a kind of secondary wilderness (Ridley, 1992). It must be recognised that the wild areas of Britain are part of a constantly changing environmental mosaic and that we cannot hope to maintain and preserve "vignettes" of wilderness as proposed by Leopold for North America's wild lands (Leopold, 1949).

Applying the definition of wilderness used in the Wilderness Act to the British countryside would merely result in a blank map, especially if size criteria like those outlined by Marshall (1930) and McCloskey and Spalding (1989) are applied. True wilderness simply does not exist any more in Britain. Yet, for any given area of the world it should be possible, in theory at least, to identify the most wild tract of land within its boundary regardless of the presence or absence of true wilderness areas. In this context, the above definitions of wilderness are both too qualitative and too restrictive to be useful. More flexible definitions of the wilderness continuum based on quantifiable indices and personal values are required in order to effectively map those environmental characteristics pertaining to wilderness quality.

The wilderness continuum concept states that true, pristine wilderness is just one extreme on the environmental modification spectrum (Hendee et al., 1990). At the opposite end of this spectrum is the indoor and totally urbanised environment of the city centre shopping mall or office block where the person is entirely isolated from the natural world. At all stages in between it is possible to identify various environments with varying levels of human modification and naturalness; a city park, suburbia, the urban/rural fringe, farmland, moor and mountain. Identifying the point on the spectrum at which wilderness begins in absolute terms is the hard part when trying to define wilderness using the continuum concept. This is because the idea of wilderness is largely one of personal experience and perception and not one of measurable standards.

Nash (1982) is tempted to let the term wilderness define itself; "to accept as wilderness those places people call wilderness" with emphasis on "not so much on what wilderness is but what men think it is" (p.5). Nash's ideas on the definition of wilderness are more in tune with the idea of wilderness developed in this paper. Here wilderness is considered to be a relative concept; one that is impossible to define in absolute terms since it depends very much on local conditions and individual perceptions. Experiential values are very important when considering the idea of wilderness. Hence the popular quote "one man's wilderness may be another's roadside picnic ground" (Nash, 1982, p.1).

## 3. Developing a GIS approach to mapping the wilderness continuum

Several authors have shown GIS to be a valuable tool for wilderness management (Hendee et al, 1990; Lesslie, 1993; Carroll & Hinrichsen, 1993; Ouren et al, 1994), particularly for mapping, monitoring and analysis. A good example of using GIS to identify and map wilderness areas is given by the Australian Heritage Commission's National Wilderness Inventory (NWI). Here the Australian's have used GIS to successfully identify wilderness areas on the basis of four factors: remoteness from settlement, remoteness from access, apparent naturalness and biophysical naturalness (Lesslie, 1993; Miller, 1995). These are mapped and combined by GIS overlay procedures to define a wilderness quality index. Minimum indicator thresholds are then applied in the NWI to exclude areas which do not meet minimum levels of remoteness and naturalness thus making an absolute distinction between wilderness and non-wilderness land use. Values for remoteness from settlement and remoteness from access are based on distance from the nearest settlement and access feature, respectively. Distance weightings are applied such that a site's remoteness value reflects the influence of town size or road status. A similar approach is adopted for apparent naturalness, with simple weighted distance values calculated for man-made structures. Biophysical naturalness is based on the assumption that the degree of change sustained by the environment is proportional to the intensity and duration of land use activity. The NWI applies five categories of land use intensity based on livestock grazing and forestry. Most of Australia has now been mapped in this way, with large areas of northern Queensland, the New Territories and the central deserts of Western Australia being designated as wilderness.

If the more open ended approach to wilderness definition advocated by Nash (1982) is adopted, then a GIS and MCE approach to mapping the wilderness continuum is much more appropriate than other more prescriptive methods commonly used in GIS-based analyses. This is because, like the continuum concept itself, MCE methods are not restricted by the necessity to specify rigid thresholds or criteria in defining where an entity like wilderness begins and ends.

To meet a particular objective (in this case the mapping of wilderness quality) it is often necessary to consider and evaluate several criteria. This is multi-criteria evaluation or MCE. The basic aim of MCE techniques is to investigate a large number of choice possibilities (geographical locations) in the light of multiple and conflicting objectives (wilderness values). In doing so it is possible to generate rankings of the alternatives according to their attractiveness or suitability (in this case their overall wilderness quality). MCE techniques, originally developed in the planning and operations research fields for evaluating discrete decision choices between a limited number of choice alternatives, have recently been adapted for use with GIS and continuous datasets for site search and suitability mapping applications (Janssen and Rietveld, 1990; Carver, 1991; Eastman et al., 1993).

The Australian approach may be adapted, using similar factors, to fit within a GIS and multi-criteria evaluation framework to identify the wilderness continuum in Britain. The *raison d'être* behind this is that whereas Australia still retains large tracts of wild and primitive landscapes around which lines can reasonably be drawn for management and preservation, Britain cannot possibly afford such a luxury. By far the greater majority of the British landscape have been altered in some way, such that few real wild and primitive areas remain. In addition, the vast majority of the landscape has some economic value and even in those areas that may be considered wild this goes far beyond tourism and 'wilderness' dependent activities such as mountaineering and ski touring. For example, the wilder areas of the Scottish Highlands are much valued as a land resource for deer stalking and fishing. This makes the definition of policy boundaries on purely conservational and environmental grounds difficult and even undesirable. There are areas of the country that do, however, retain certain wilderness qualities; lack of obvious human structures, near natural self-seeded vegetation patterns, remoteness and inaccessibility. These can be identified using the continuum concept and highlighted for appropriate management. It is suggested here that a GIS/MCE approach is best suited for this purpose since it is flexible and allows individual perceptions to be taken into account.

GIS-based MCE routines are adapted and used here for describing and evaluating datasets and opinions relevant to the problem. This work focuses on defining the wilderness continuum for Britain rather than trying to identify discrete boundaries for Britain's wildest areas. By adopting an GIS/MCE approach to mapping, the minimum threshold constraints used in the Australian NWI can be safely dropped allowing the full variation in the data and statements of individual preference, made via factor weights, to be used to best effect. The key issue is reflected in Nash's statement that "one man's wilderness may be another's roadside picnic ground" (1982, p.1) in that different people have different perceptions as to what wilderness is. This not only refers to that point along the continuum at which a person considers that wilderness begins, but also to the relative importance a person may place on particular factors affecting the wildness of the landscape. Only through the incorporation of MCE type techniques can GIS effectively cope with such variability in the data and how it is applied.

## 4. Data and analysis

Several existing digital datasets are used to create four factor maps describing remoteness from population, remoteness from access, apparent naturalness and biophysical naturalness. A 1 km resolution raster is used for the storage and subsequent analysis of all datasets.

Remoteness from population is based here on the 1991 UK Census of Population. Rather than base this factor simply on the distance from nearest settlement weighted by settlement size (Lesslie, 1993), remoteness from population is based here on a linear distance weighted decay model for all populated

cells within a 25 km radius of the target cell. This radius is chosen since it represents the distance an individual can reasonably walk in a day over rough terrain. The factor map shown in figure 1 is therefore more representative of true population accessibility as it is not influenced by the size of the nearest settlement but more by the total population of settlements within 25 km of a given site and the distance of those settlements from that site.

Remoteness from access is based on distance from commonest form of mechanised access; namely road transport. A similar weighted linear distance decay model to the above is used to calculate the inaccessibility factor map shown in figure 2. Remoteness from access is defined here as weighted linear distance from road networks, such that unclassified roads are weighted lower than motorways. The weighting schemes for roads are shown in table 1.

Apparent naturalness is defined here as the unweighted linear distance from highly visible non-natural features such as dams, power lines, radio masts, railway lines, roads, etc. This dataset is, at present, incomplete. Roads and railway lines are currently available at a national level, but more detailed digital datasets are required to show the locations of other human features. In the analysis presented here, simple unweighted linear distance from roads and railway lines is used as an approximation of overall apparent naturalness. This is not entirely unreasonable since most human features large enough to have a significant negative impact on wilderness quality will be on or near a road or railway line for ease of access. The apparent naturalness map is shown in figure 3.

Biophysical naturalness is defined as the naturalness of the land use and associated vegetation cover. This is derived here from land cover data available on the Department of the Environment's Countryside Information System (CIS). The Landsat TM derived land cover data provided by the CIS gives the total hectares per square kilometre of particular land cover types found within each 1 km grid square in Britain. These figures have been used to derive a map indicating the likelihood of finding natural or near natural ecosystems based on the weighted sum of areas of different land cover types in each grid cell. To do this land cover types were grouped into one of four 'naturalness' classes and weighted as shown in table 2. The resulting factor map is shown in figure 4.

All the above datasets were created and analysed using the GRID module in the Arc/Info GIS. Factor maps describing remoteness from population, remoteness from access, apparent naturalness and biophysical naturalness for the whole of Britain were all standardised onto a 0 to 255 scale and combined using user-specified factor weights and a simple MCE model. The output from the model represents the spatial construct of the users own wilderness continuum.

The MCE method used here is a very simple one called weighted linear summation. This is shown below in mathematical form, but in plain English it simply multiplies the standardised factor maps by

their user-specified weights and adds these up to create the final continuum map. Standardisation of the factor maps onto a common scale is necessary in order to allow the direct comparison of factor maps measured on different scales.

$$W_{sum} = \sum_{j=n}^{J} w_j(e_{ij}) \qquad (1)$$

where:

| | | |
|---|---|---|
| $W_{sum}$ | = | position on wilderness continuum |
| $w_j$ | = | jth user-specified factor weight |
| $e_{ij}$ | = | standardised score |
| $n$ | = | number of factors |

Other MCE routines have been adapted for use within Arc/Info, including ideal point analysis, hierarchical optimisation and concordance/discordance models (Carver, 1991). These perform more complex analyses of conflicting criteria and objectives and in doing so each produce slightly different results. Choice of the most appropriate MCE model can therefore introduce certain problems (Carver, 1991), but a weighted linear summation model is used here for the sake of simplicity and to illustrate the principles involved.

Example results from the analysis described are shown in figures 5 and 6. By applying different factor weights, different continuum maps can be produced reflecting different people's experiential values concerning their ideas of wilderness using the MCE model. Figure 5 shows a continuum map based on user weights that stress remoteness from population and access, while figure 6 shows a continuum map based on user weights that stress apparent and biophysical naturalness. The weights used are shown in table 3.

The differences between the two maps are obvious and serve to illustrate just how different people's perceptions affect the mapped outcome. Yet, the overall geographical pattern is similar showing how the wilder ends of the continuum focus on particular regions of the country, notably the north west and central Highlands and Border regions of Scotland, the Lake District and North Pennines in England and the mountains of mid-Wales. The key point to note is that both maps are essentially correct, at least in the eyes of their originators, and both could equally be used as a basis for further work on wilderness and associated landscape conservation policy in Britain.

## 5. Evaluation of existing protected areas

Despite the focus of this work being on developing techniques for mapping the wilderness continuum and despite the problem associated with defining where along this continuum wilderness begins and ends, it is still tempting to use the above maps as a basis for identifying the wildest areas of country. This is necessary if the continuum is to be used as the basis for evaluating the coverage of existing protected areas.

The 'wild' areas shown in figures 7 and 8 are derived from the continuum shown in figure 5 by selecting the wildest 1% and the wildest 10% of the country, respectively. For the purpose of discussion these are overlaid with the boundaries of existing protected areas within Britain. These include National Parks, Areas of Outstanding Natural Beauty (AONBs), Heritage Coasts, National Scenic Areas, Environmentally Sensitive Areas and Regional Parks. Looking at these maps it can be seen that while existing protected areas may contain landscapes of high wilderness value, a significant proportion of the wildest areas of the country are not formerly protected by conservation area status. However, small parts of these areas may classified as SSSI's (Sites of Special Scientific Interest), NNR's (National Nature Reserves), Biosphere Reserves or RAMSAR sites not covered by the conservation area boundaries shown here. Together with the fact that the greater majority of Britain's wildest areas are within private and not public ownership, the results shown in figures 7 and 8 have certain implications for the preservation of what is left of Britain's wild landscapes. Notably, the majority of Britain's wildlands occur in the north west Scottish Highlands. Many of these landscapes may be regarded as secondary wilderness, created during the 'clearances' and maintained subsequently by land management practices focused on deer stalking, grouse shooting, sport fishing and sheep. As long as land management practises are responsible and sympathetic to the environment, then these wild areas will be protected without need for formai policy. However, as suggested earlier in the paper, the landscape mosaic of Britain is constantly changing, so some form of vigilance is required concerning land use pressures affecting the wilder parts of the country. Policies and action plans specific to the preservation and re-creation of wild landscapes within Britain are currently being formulated by relevant organisations and conservation groups. Much interest has been generated for example in plans by the Royal Society for the Protection of Birds (RSPB) and the World Wildlife Fund (WWF) Scotland for re-creating parts of the old Caledonian Pine Forest in Sutherland, while more wide ranging studies regarding the scope for wilderness in England have been made by the Countryside Commission (Countryside Commission, 1994).

Finally, certain ethical problems arise at this juncture. It may transpire that if these results are widely published, the remaining wild areas of the country would be brought to the attention of the country's burgeoning number of outdoor recreationalists, who in turn may actively seek out these wild areas thereby destroying the very experience they sought in the first place. The counter argument to this is

that if these areas are not formerly identified and protected then we run the risk of loosing them to the pressures of development, such as from forestry and non-wilderness dependent forms of tourism. This is often quoted as the crux of wilderness management; manage it and the essential values of wilderness are lost, do not manage it and it is lost through development. It is maintained here that the arguments in favour of bringing these areas to the close attention of conservationists and policy makers far outweigh the risks in terms of over use.

## 6. Further work

Plans for further work in this area include the adaptation of the method and datasets described here to larger scale studies of specific policy areas such as national parks and environmentally sensitive areas. A recent feasibility has been carried out in the Peak National Park using higher resolution datasets and more complex modelling techniques (Carver, 1996). Algorithms describing off-road accessibility are of particular interest since depending on such factors as terrain, vegetation cover and footpath provision, travel times, and hence remoteness, are not equal in all directions. Initial results suggest that with appropriate datasets, GIS/MCE and other modelling techniques could be extremely useful tools in the mapping and subsequent decision-support activities of national park authorities in regard to landscape planning and management.

One further avenue of research arising out of this work that may be worth investigating focuses on the opposite end of the wilderness continuum as defined here. It is clear from figures 5 and 6 that the same techniques that are used here to identify wild, low impact areas can be used to identify urban, high impact areas. Such an approach may be useful in studies of urban form and process as well as providing useful comparisons in geodemographic research. Clearly, larger scale studies would require substantially different datasets to those used in the mapping of wilderness continuum for the Peak National Park. The emphasis of these data would be on urban infrastructure rather than the natural environment. However, similar methodological approaches may be adopted particularly in studies relating to the provision of open space in and near to urban areas.

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**Table 1.** Weights applied to road type

| *Road type:* | *Weight:* |
|---|---|
| Motorway | 7 |
| Primary route, dual carriage way | 6 |
| A road, dual carriage way | 5 |
| Primary route, single carriage way | 4 |
| A road, single carriage way | 3 |
| B road | 2 |
| Unclassified | 1 |

**Table 2.** Land cover types indicating biophysical naturalness

| *Land cover type:* | *Naturalness class:* | *Weight:* |
|---|---|---|
| Bog, Bracken, Dense shrub heath, Open shrub heath, Heath grass, Inland water, Salt marsh, Sea/estuary | 1 | 4 |
| Coniferous woodland, Deciduous woodland, Managed grassland, Rough grass | 2 | 3 |
| Tilled land | 3 | 2 |
| Suburban, Urban | 4 | 1 |

**Table 3.** Factors weights

| *Factor map:* | *Weight (Figure 6):* | *Weight (Figure 7):* |
|---|---|---|
| Remoteness from population | 0.4 | 0.1 |
| Remoteness from access | 0.3 | 0.2 |
| Apparent naturalness | 0.2 | 0.3 |
| Biophysical naturalness | 0.1 | 0.4 |

**Figure 1.** Remoteness from population

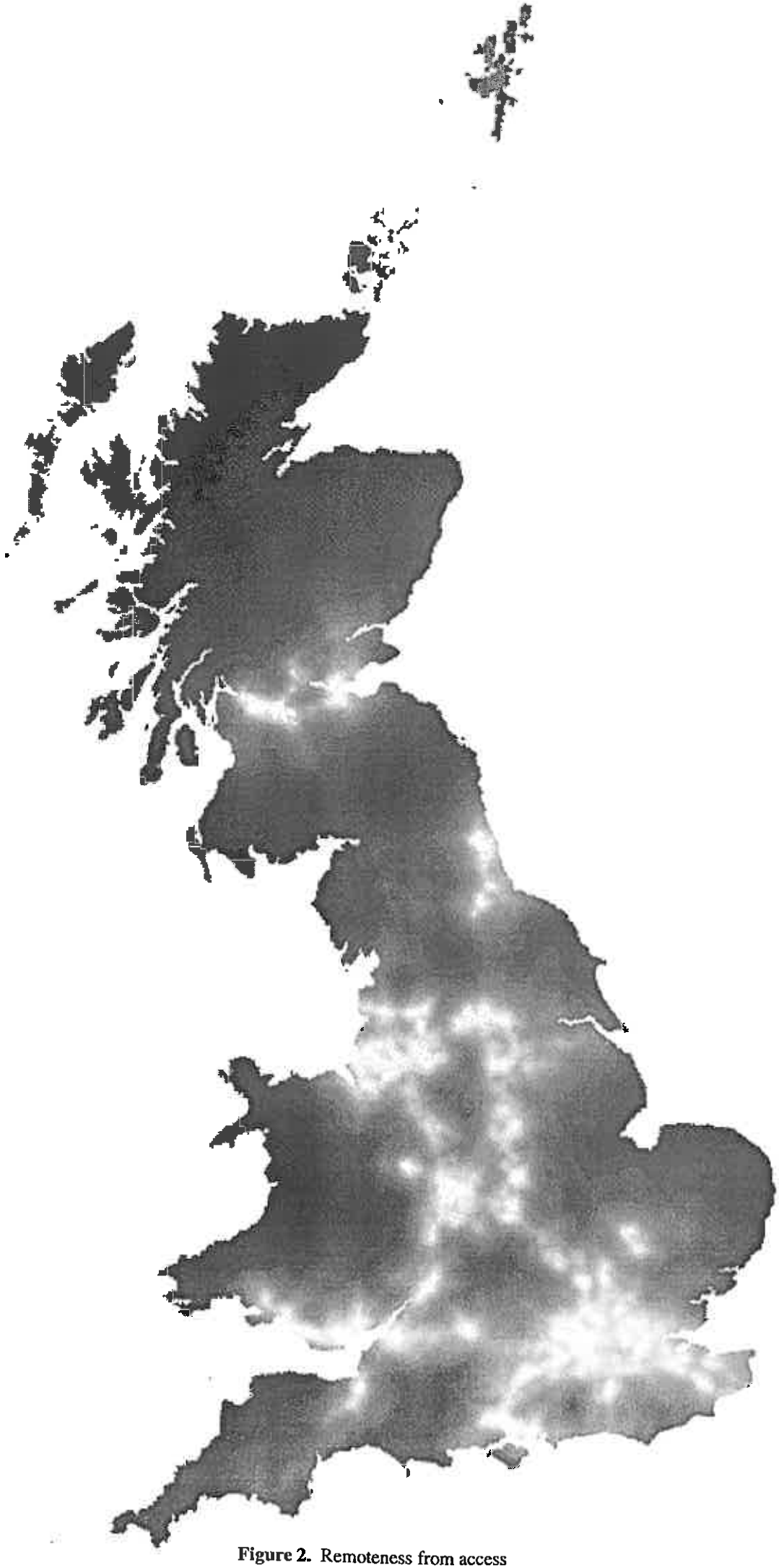

**Figure 2.** Remoteness from access

**Figure 3.** Apparent naturalness

**Figure 4.** Biophysical naturalness

**Figure 5.** Wilderness continuum stressing remoteness factors

**Figure 6.** Wilderness continuum stressing naturalness factors

**Figure 7.** Wild Britain: top one percent

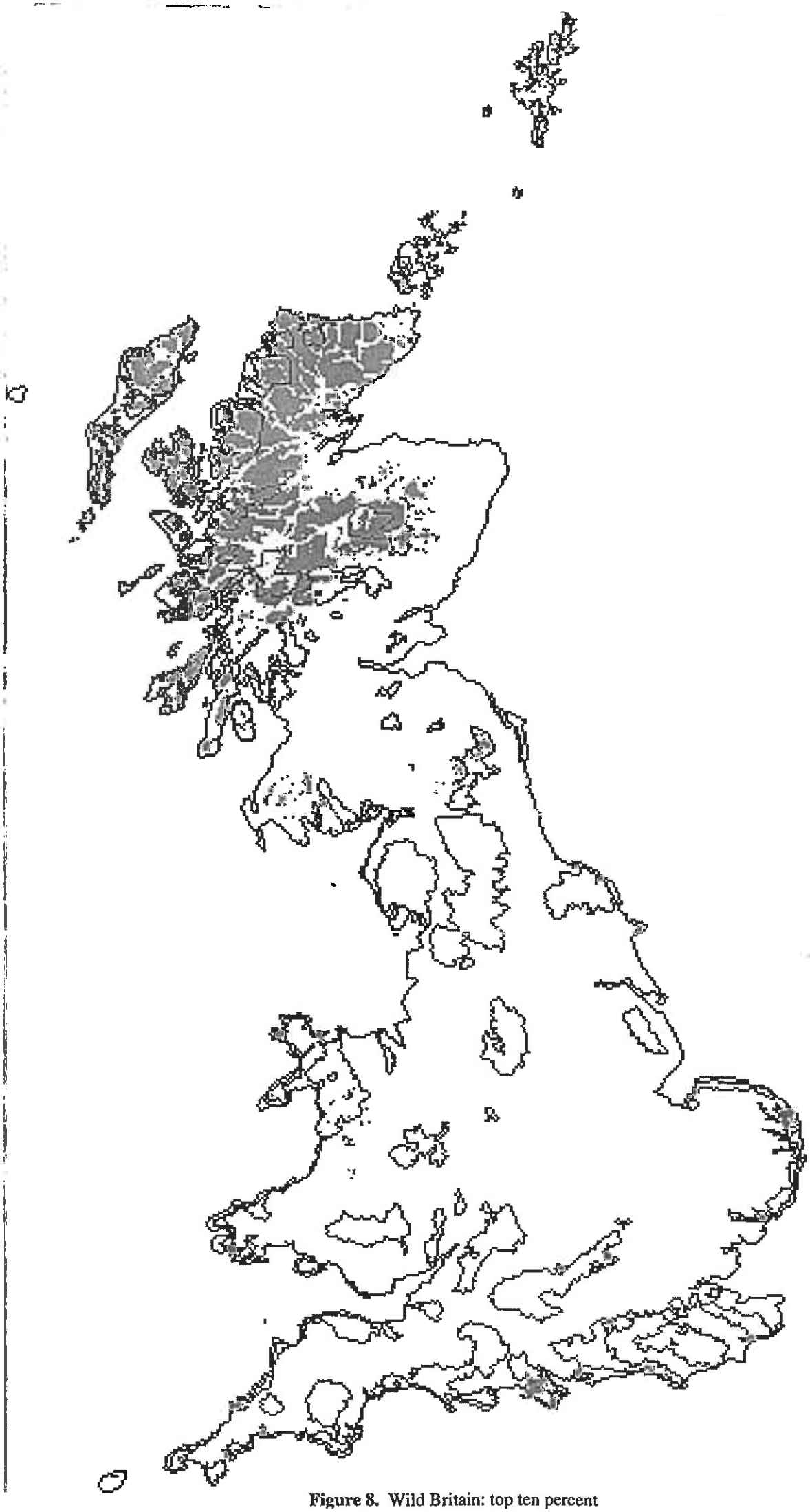

**Figure 8.** Wild Britain: top ten percent