

## Land cover heterogeneity in Great Britain as identified in Land Cover Map 2000

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Land cover is an important component of landscape character. The spatial configuration and heterogeneity of land cover can influence species distributions and patterns of biodiversity. Sustainable countryside planning and land management policy in Great Britain require the mapping of land cover heterogeneity at a national scale. Here, we map four measures of land cover heterogeneity across Great Britain using Land Cover Map 2000. We calculate land cover richness, diversity, evenness and similarity within and between  $1 \times 1$  km grid cells of the British National Grid. From this we are able to identify assemblages of land cover types that are associated with high or low landscape heterogeneity, and where they occur geographically.

### 1. Background and heterogeneity measures

Defining landscape character and how this contributes to more intangible measures of countryside quality is now seen as essential to sustainable countryside planning (Haines-Young *et al.* 2004). In Britain, the Countryside Character Network defines landscape character as 'a distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another' (see <http://www.ccnetwork.org.uk>). Landscape character is about uniqueness. Its assessment is based on several components and these can be grouped as natural, cultural/social, perceptual and aesthetic (Swanwick 2002). Land cover, and particularly its spatial characteristics (e.g. pattern, diversity, scale, configuration), are key elements that influence landscape character. In addition, there are well known relationships between landscape-scale patterns and ecological processes which influence biodiversity at the beta-scale (Tracy and Brusard 1994).

Land Cover Map 2000 (LCM2000) mapped the land cover of Great Britain and Northern Ireland using, as far as possible, composites of summer and winter Landsat Thematic Mapper imagery (Fuller *et al.* 2002). The imagery was classified using an object-based approach that identified features in the landscape such as fields, woods and lakes. The minimum mappable unit of LCM2000 is 0.5 ha, which is approximately equivalent to eight Thematic Mapper pixels. To support reporting under the UK Biodiversity Action Plan (UK Biodiversity Steering Group 1995), LCM2000 identified widespread Broad Habitats (Jackson 2000). The 20 Broad Habitats mapped by LCM2000 are shown in figure 1.

From the full spatial resolution LCM2000 data, the percentage cover of each Broad Habitat was calculated per  $1 \text{ km} \times 1 \text{ km}$  square of the British National Grid

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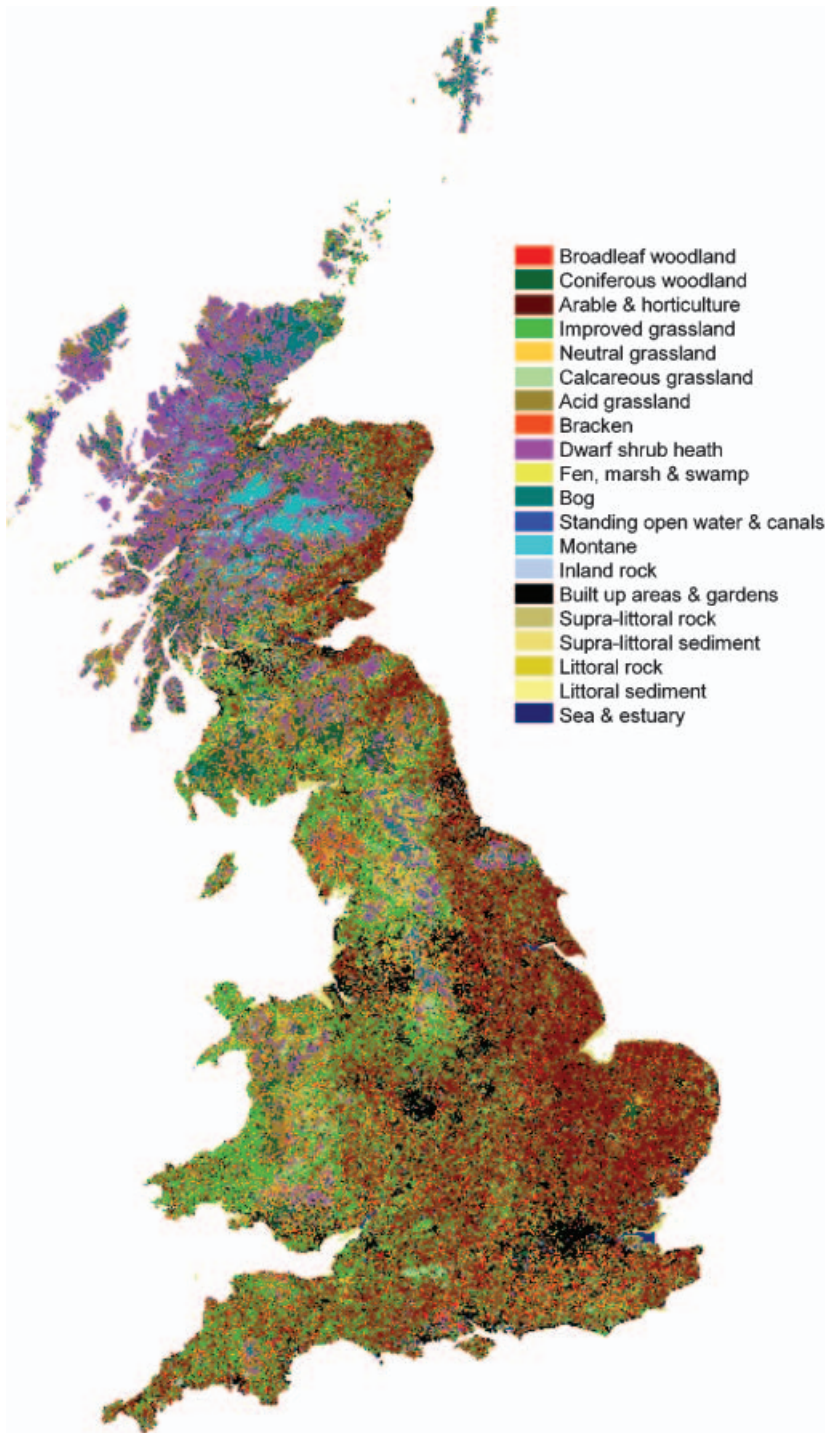


Figure 1. The 20 Broad Habitats mapped in Land Cover Map 2000.

(BNG). The BNG provided a regular spatial framework in which the land cover information of over 6.6 million parcels of LCM2000 could be summarized for calculating heterogeneity measures. By adopting a regular grid it remains possible, albeit at a 1 km spatial resolution, to extract land cover information and heterogeneity measures for any area of interest, such as administrative areas, river catchments or environmental zones. Land cover heterogeneity was examined both within and between neighbouring 1 km BNG squares, based on the percentage cover of Broad Habitats. Four measures of heterogeneity were generated.

1. Land cover richness ( $R$ ): the total number of Broad Habitats per BNG square.
2. Land cover diversity ( $D$ ): calculated per BNG square using Simpson's Index (Simpson 1949):

$$D = 1 / \sum p_i^2 \quad (1)$$

where  $D$  is Simpson's index,  $p_i$  is the percentage cover of Broad Habitat  $i$ .

3. Land cover evenness ( $E$ ): calculated per BNG square as:

$$E = D/R \quad (2)$$

where  $E$  is evenness,  $D$  is Simpson's index and  $R$  is land cover richness.

4. Land cover similarity ( $S$ ): calculated between neighbouring BNG squares using the Bray–Curtis similarity index (Bray and Curtis 1957):

$$S = 1 - \sum |x_i - y_i| / \sum (x_i + y_i) \quad (3)$$

where  $S$  is the Bray–Curtis measure of similarity,  $x_i$  is the percentage cover of Broad Habitat  $i$  in one square, and  $y_i$  is the percentage cover of the same Broad Habitat in an adjoining square. The similarity score for each 1 km BNG square was calculated as the average when comparing with the surrounding eight squares.

Based on 20 Broad Habitats the possible range of scores for each BNG square is 1 to 20 for both land cover richness ( $R$ ) and diversity ( $D$ ). Land cover evenness ( $E$ ) has a possible range of  $1/R$  to 1 and land cover similarity ( $S$ ) of 0 to 1. Compared with land cover richness ( $R$ ), which indicates the total number of Broad Habitats per BNG square, land cover diversity ( $D$ ) gives more weight to common land cover types. Thus,  $D=R$  only if all land cover types are equally represented. Similarly, land cover evenness ( $E$ ) will have a score of 1 when all land cover types are equally represented. For land cover similarity ( $S$ ), the Bray–Curtis index will equal 0 when no land cover types are shared and 1 when all land cover types are shared between neighbouring BNG squares.

## 2. Results and discussion

The maps of land cover richness, diversity, evenness and similarity at a 1 km scale for Great Britain are shown in figures 2(a)–(d).

Perhaps unsurprisingly no BNG square contains all 20 Broad Habitats (figure 2(a)); the maximum present in one square is 14. Figure 3(a) shows the histogram of land cover richness. Over 90% of BNG squares have between 3 and 9 Broad Habitats, 72% have between 4 and 7. The average number of Broad Habitats per 1 km BNG square is 5.4.

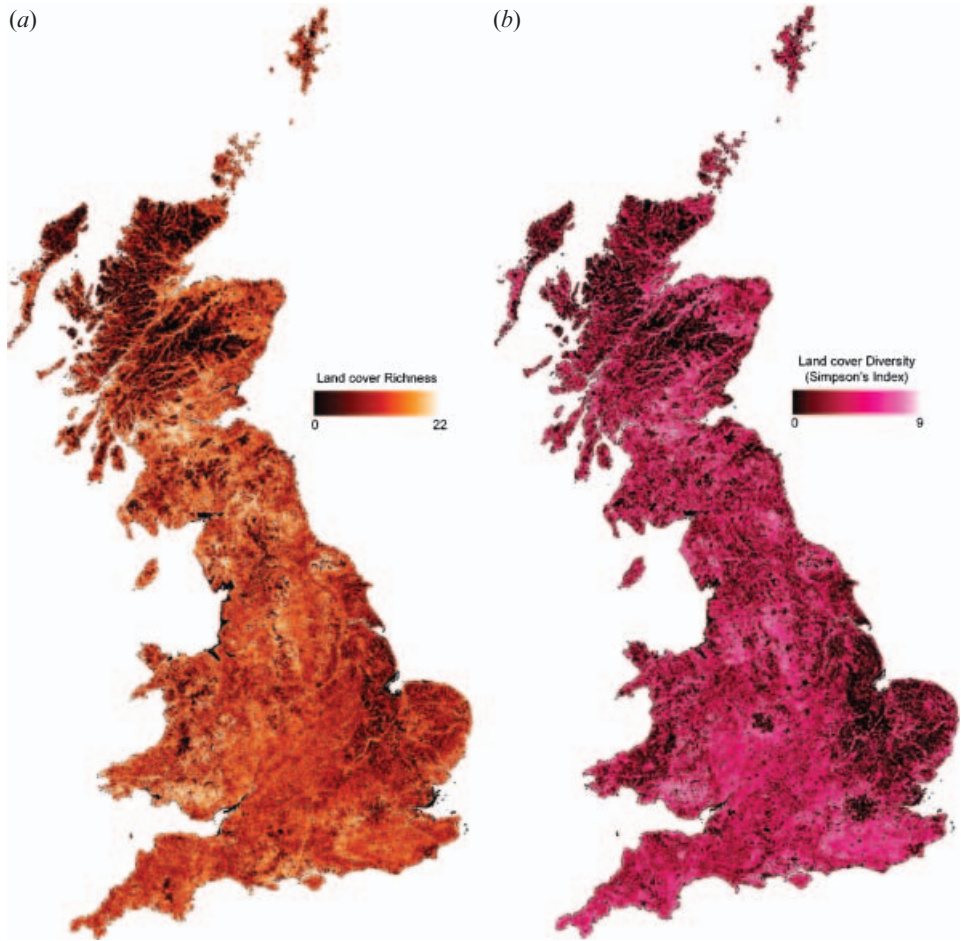


Figure 2. Land cover heterogeneity measures calculated per 1 km BNG square from LCM2000: (a) richness; (b) diversity; (c) evenness; and (d) similarity. (*Continued opposite.*)

The range of land cover diversity scores is 1 to 8.89 (figure 2(b) and cover). The average diversity score is 2.41; over 90% of BNG squares have a diversity score between 1 and 4 (figure 3(b)). Compared with the land cover richness scores, this demonstrates that in most BNG squares one or more Broad Habitats has a limited coverage. This can be quantified by examining land cover evenness (figure 2(c)). The range of scores is 0.11 to 1 (figure 3(c)). An evenness score of 1 means that all Broad Habitats present within a BNG square have the same percentage cover. Less than 1.5% of BNG squares have an evenness score of 1.0 and all of these have only one Broad Habitat present. Only 4% of BNG squares have an evenness score  $>0.8$ ; these have between 1 and 10 Broad Habitats present. Over 80% of BNG squares have an evenness score  $<0.6$ . The average evenness score is 0.47. Land cover similarity (figure 2(d)) has a spatial dimension, being an average score for each BNG square with its eight neighbours. The range in land cover similarity scores is 0 to 1 (figure 3(d)), with a mean of 0.66. Thus, as would be expected, most BNG squares are reasonably similar to their neighbours, with less than 13% having an average similarity score of  $<0.5$ .

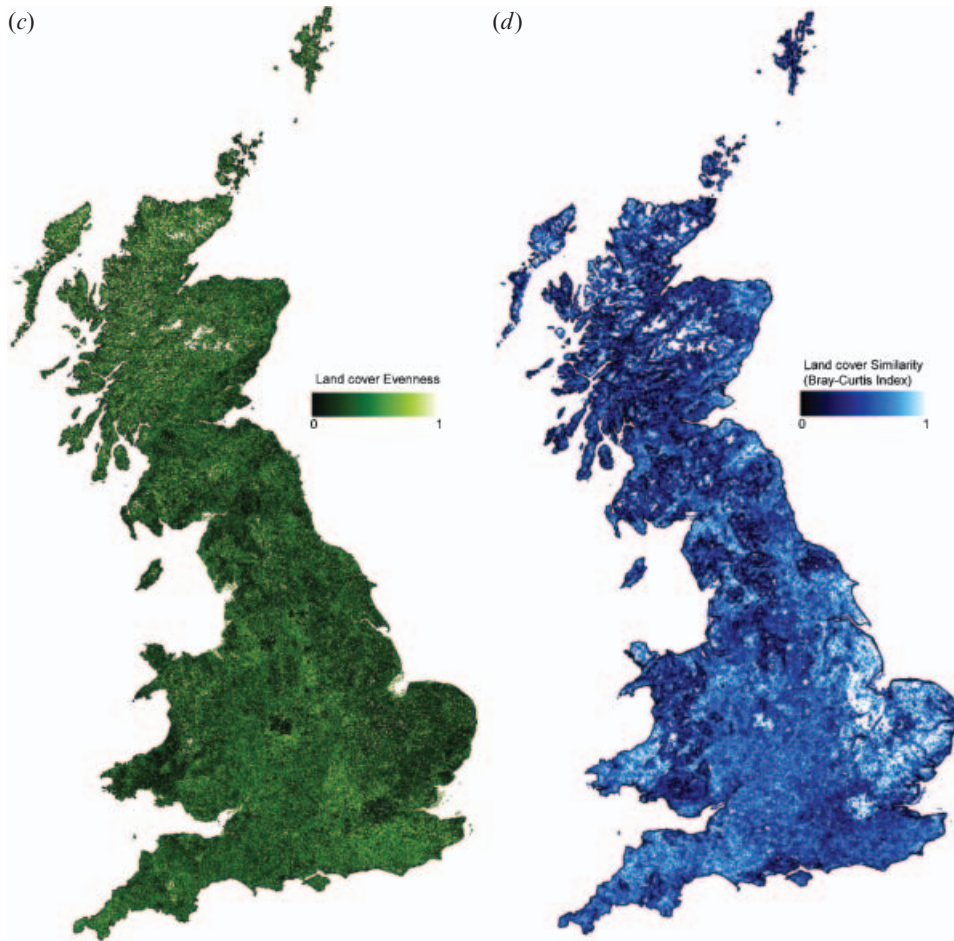


Figure 2. *Continued.*

What does this tell us about the British landscape? Certain assemblages of land cover types occur in landscapes of low heterogeneity. Table 1 gives diversity scores for BNG squares grouped into eight land cover assemblages. Each BNG square is assigned to a land cover assemblage based on whichever has the highest total coverage of the component land cover types. Compared with the national average diversity score of 2.41, low diversity occurs in BNG squares with a dominant land cover of ‘heath, bog, montane’ (1.89), ‘arable and horticulture’ (2.23) or ‘coastal habitats’ (2.29), whilst high diversity occurs where the dominant land cover is ‘woodland’ (2.94) or ‘semi-natural grass, bracken, fen, marsh’ (2.90). The spatial configurations these results represent can be seen in figure 2(b) (and cover). Low diversity occurs in patches along the eastern fringes of Great Britain, most notably East Anglia and Lincolnshire, associated with intensive agricultural land use. Low diversity also occurs in upland areas dominated by heaths and bogs; most notably in the Scottish Highlands and Hebridean Islands and in the Cambrian Mountains of central Wales. The Flow Country of peatland bog in northern Scotland also has low land cover diversity. Finally, the major conurbations, in particular London and Birmingham, also stand out as islands of low land cover diversity compared with the

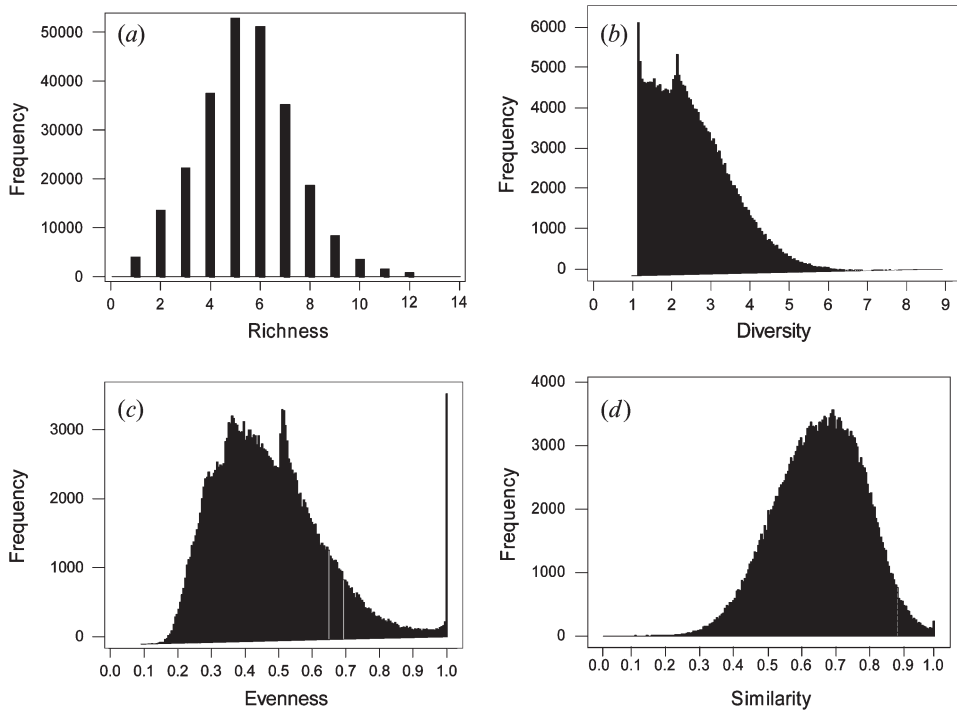


Figure 3. Histograms of land cover heterogeneity measures for Great Britain: (a) richness; (b) diversity; (c) evenness; and (d) similarity.

national average. Areas of high land cover diversity are more diffusely distributed, but can be found: in the North and South Downs and Weald of south-east England; around the fringes of the Brecon Beacons in south Wales and of the Peak District and Pennines in north-central England; in northern County Durham; and the Carron Valley area north of Glasgow in Scotland. These are areas of semi-natural grasslands (either calcareous or acidic) and, in particular, a mixture of or transition between unenclosed semi-natural grasslands and predominantly small-scale enclosed pasture, often with scattered woodlands. These are the locally heterogeneous

Table 1. Diversity scores for eight terrestrial land cover assemblages and for Great Britain as a whole.

Land cover assemblage	Minimum	Maximum	Mean	Standard deviation
Coniferous, broadleaved, mixed woodland	1	8.89	2.94	1.19
Arable and horticulture	1	7.25	2.23	0.86
Improved grassland	1	7.11	2.58	0.68
Semi-natural grass, bracken, fens, marshes	1	8.85	2.90	1.19
Heath, bog, montane habitats	1	7.87	1.89	0.85
Inland water	1	7.40	2.52	1.12
Built up and gardens	1	7.83	2.47	1.03
Coastal habitats	1	7.68	2.29	1.32
GB total	1	8.89	2.41	1.02

cultural landscapes that score positively in the natural, cultural/social, perceptual and aesthetic categories of landscape character assessment.

### 3. Conclusions

The heterogeneity of the British landscape reflects the nature of the environment and how it has been managed. Understanding and representing this using LCM2000 data could be key to explaining species distributions and patterns of biodiversity in Britain (Fuller *et al.* 2005), thereby leading to informed land management policy. The datasets presented in figure 2 are produced consistently and objectively and therefore can be a valuable input to national-scale landscape character assessment and the determination of countryside quality. The approach described in this paper could be applied to other regionalizations, such as the National Land Classes, Environmental Zones or Countryside Character Areas. This work shows that environmental information derived from Earth Observation data at the national level can support complex multi-disciplinary research and government policy.

### Acknowledgement

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