

Table 8. Summary correspondence matrix (results expressed per 1000) made by from comparing LCM2000 with the CS2000 field survey squares in Great Britain: results are weighted estimates, using strata based on 40 Land Classes, bootstrapped' to calculate confidence intervals (see text).

LCM	CS2000	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
		Broadleaved, mixed and yew woodland	Coniferous woodland	Boundary and linear features	Arable and horticulture	Improved grassland	Neutral grassland	Calcareous grassland	Acid grassland	Bracken	Dwarf shrub heath	Fen, marsh and swamp	Bog	Standing open water and canals	Rivers and streams	Montane habitats	Inland rock	Built up areas and gardens	Supralittoral rock	Supralittoral sediment	Littoral rock	Littoral sediment	Oceanic seas	
Broadleaved, mixed and yew woodland	1	33	4		3	4	2	1	1	1	0	0	0	0		0	0	3	0	0				53
Coniferous woodland	2	9	50		0	1	1	0	1	1	2	1	1	0		0	0	0	0	0		0	0	66
Boundary and linear features	3																							
Arable and horticulture	4	5	1		212	27	4	0	1	0	0	1	0	0		0	0	7	0	0		0		259
Improved grassland	5	7	0		11	181	13	1	5	1	0	5	1	0		0	0	6	0	0		0		232
Neutral grassland	6	3	0		3	10	2	0	13	3	3	4	5	0		0	0	1	0	0		0		48
Calcareous grassland	7	2	1		2	17	2	1	2	0	0	3	0	0		0	0	2	0	0		0		34
Acid grassland	8	2	1		0	5	1		17	5	9	3	17	0		0	0	1	0	0				62
Bracken	9	0	0		0	0	0		2	4	0	1	2	0		0	0	0	0	0				9
Dwarf shrub heath	10	4	3		0	0	0	0	5	3	35	4	53	0		0	0	0	0	0		0	0	108
Fen, marsh and swamp	11	0				0			0		0	0	0	0		0	3	0	0					1
Bog	12	1	0		1	0	1	0	2	0	6	2	16	0		0	0	0	0	0			0	31
Standing open water and canals	13	0	0			0	0		0	0	0	0	0	7		0	0	0	0				0	7
Rivers and streams	14																							
Montane habitats	15								2		5	0	3			2	0	0	0					12
Inland rock	16	0	0		2	0	0		0	0	0	0	0	0		0	0	0	0			0	0	3
Built up areas and gardens	17	1	0		4	2	1		0	0	0	0	0	0		0	0	38	0	0		0		48
Supralittoral rock	18	0														0		0	0	0		0	0	0
Supralittoral sediment	19	0				0	0											0	0	0				0
Littoral rock	20	0				0	0		0	0	0	0	0	0		0	0	0	1	0		0	0	1
Littoral sediment	21	0				0	0					0	0	0		0	0	1	1	0		4	1	7
Oceanic seas	22	0				0	0		0	0	0	0	0	0		0	0	1	1	1		0	2	12
Total		68	61		238	249	28	3	52	18	61	23	98	9		2	2	61	4	2	0	6	14	1000

BH level (excluding linear features)	61.7
Generalising urban	63.6
Target class level	66.4
Aggregate level	74.1

Summary correspondences (%) are given for Broad Habitats (yellow cells), and allowing for field survey generalisation of urban areas (+blue cells), at LCM2000 Target Class (+pink cells) and Aggregate class levels (+green cells)

Table 9. Summary correspondence matrix (results expressed per 1000) made by from comparing LCM2000 with the CS2000 field survey squares in England and Wales: results are weighted estimates, using strata based on 40 Land Classes, bootstrapped' to calculate confidence intervals (see text).

LCM	CS2000																							Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Broadleaved, mixed and yew woodland	1	48	2		4	6	3	1	1	1	0	0	0	1		0	0	4	0	0				71
Coniferous woodland	2	8	20		0	0	0	0	0	0	0	0	1	0		0	0	0	0	0		0		30
Boundary and linear features	3																							
Arable and horticulture	4	7	1		289	34	5	0	1	0	0	1	0	0		0	0	9	0	0		0		347
Improved grassland	5	8	0		14	226	14	1	3	1	0	4	0	0		0	0	9	0	0				282
Neutral grassland	6	2	0		3	11	3	0	13	2	3	2	1	0		0	0	1	0	0				40
Calcareous grassland	7	3	1		3	25	3	0	2	0	0	1	0	0		0	0	3	0	0				41
Acid grassland	8	3	1		0	5	1		11	5	5	2	5	0		0	0	1						38
Bracken	9	0	0		0	0	0		2	5	0	0	0	0		0	0	0						7
Dwarf shrub heath	10	2	1		0	0	0		2	2	16	1	2	0		0	0	0	0	0				26
Fen, marsh and swamp	11	0			1	0	0		0	0	0	0	0	0		0	0	1						2
Bog	12	1			2	0	2	0	1	0	6	1	3	0		0	0	0						17
Standing open water and canals	13	0	0		0	0	0		0	0	0	0	0	6		0	0	0						6
Rivers and streams	14																							
Montane habitats	15																							
Inland rock	16	0	0		2	0	0		0	0	0	0	0	0		0	0	0	0	0		0		3
Built up areas and gardens	17	2	0		6	2	1		0	0	0	0	0	0		0	54	0	0			0		67
Supralittoral rock	18																							
Supralittoral sediment	19					0	0			0								0	0	0				0
Littoral rock	20	0				0	0											0	0	0			0	0
Littoral sediment	21	0				0	0			0		0		0			0	1	0	1		6	2	11
Oceanic seas	22	0				0	0										0	0	1			3	7	11
Total		83	27		322	312	31	3	36	17	30	13	12	8	0	1	83	1	2		10	9	1000	

BH level (excluding linear features)	69.3
Generalising urban	71.8
Target class level	74.5
Aggregate level	75.5

Summary correspondences (%) are given for Broad Habitats (yellow cells),and allowing for field survey generalisation of urban areas (+blue cells), at LCM2000 Target Class (+pink cells) and Aggregate class levels (+green cells)

Table 10. Summary correspondence matrix (results expressed per 1000) made by from comparing LCM2000 with the CS2000 field survey squares in Scotland: results are weighted estimates, using strata based on 40 Land Classes, bootstrapped' to calculate confidence intervals (see text).

LCM	CS2000																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
		Broadleaved, mixed and yew woodland	Coniferous woodland	Boundary and linear features	Arable and horticulture	Improved grassland	Neutral grassland	Calcareous grassland	Acid grassland	Bracken	Dwarf shrub heath	Fen, marsh and swamp	Bog	Standing open water and canals	Rivers and streams	Montane habitats	Inland rock	Built up areas and gardens	Supralittoral rock	Supralittoral sediment	Littoral rock	Littoral sediment	Oceanic seas	
Broadleaved, mixed and yew woodland	1	7	8	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	21
Coniferous woodland	2	12	104	1	1	2	0	2	1	5	2	2	0	0	0	0	0	1	0	0	0	0	0	132
Boundary and linear features	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arable and horticulture	4	2	2	70	15	4	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	97
Improved grassland	5	4	1	0	6	98	10	0	8	1	0	7	1	0	0	0	1	2	0	0	0	0	0	140
Neutral grassland	6	3	1	0	3	9	2	1	14	5	3	6	13	0	0	0	0	1	0	0	0	0	0	61
Calcareous grassland	7	1	2	0	1	2	1	2	4	0	0	6	1	0	0	0	0	1	0	0	0	0	0	21
Acid grassland	8	2	1	0	7	1	0	29	4	16	6	40	0	0	0	0	0	0	0	0	0	0	0	106
Bracken	9	1	0	0	0	0	0	1	3	0	1	5	0	0	0	0	0	0	0	0	0	0	0	12
Dwarf shrub heath	10	7	7	0	1	1	0	12	4	72	10	146	1	0	0	0	0	0	1	0	0	0	0	261
Fen, marsh and swamp	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bog	12	0	1	0	0	0	0	4	0	7	2	41	1	0	0	0	0	0	0	0	0	0	0	58
Standing open water and canals	13	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	10
Rivers and streams	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montane habitats	15	0	0	0	0	0	0	6	0	14	0	8	0	0	5	0	0	0	0	0	0	0	0	35
Inland rock	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
Built up areas and gardens	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	0	0	0	0	0	12
Supralittoral rock	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supralittoral sediment	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Littoral rock	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Littoral sediment	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Oceanic seas	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	23	26
		39	126	82	134	21	4	83	19	119	42	258	11	6	4	20	8	3	0	0	23	1000		

BH level (excluding linear features)	47.6
Generalising urban	48.4
Target class level	51.5
Aggregate level	71.3

Summary correspondences (%) are given for Broad Habitats (yellow cells),and allowing for field survey generalisation of urban areas (+blue cells), at LCM2000 Target Class (+pink cells) and Aggregate class levels (+green cells)

11. LCM2000 ASSESSMENTS AT COVER CLASS LEVEL

Correspondence matrices were combined via the stratification to give summary matrices for GB, England / Wales (combined) and for Scotland: a matrix was calculated for each stratum or Land Class based upon the sample squares in that Land Class; then the Land Class matrices were combined, each with a weighting according to its extent in GB, England / Wales, or Scotland. Tables 8, 9 and 10 give the summary matrices, based on per-parcel comparisons. The matrices are also summarised at the Aggregate class level, where LCM and FS match closely (Tables 11, 12 & 13). The following discussion examines similarities and some of the underlying cause of difference (NB no section numbers are given as, with sections based on classes, such numbers would conflict with Subclass numbers and thereby cause confusion).

Broadleaved and mixed woodland and **Coniferous woodland**: LCM2000 **Broadleaved and mixed woodland** and the FS *Broadleaved, mixed and yew woodland* show similar extents: UK coverage is 6.3% from LCM2000 and 6.2% from FS. However, direct agreement in the 569 squares is rather lower (44% of LCM2000 **Broadleaved /mixed woodland** is mapped similarly by FS). This is due partly to the fact that many woodlands are small, at or below the minimum mappable unit of LCM2000, and so they are excluded. Hence, a lot of FS *Broadleaved woodland* shows on the map as grassland or arable farmland, the typical situation for small copses and shelter belts. The converse also applies: that openings in a woodland, mapped by FS, are mostly too small to record on LCM2000, so woodlands may appear continuous where they are really open. Differences in the exact outlines of woodlands also contribute. *Coniferous woodland*, generally planted and in larger blocks, records similar coverages (UK 5.5% on LCM2000 and 5.8% through FS) and a far greater direct correspondence (70%).

Arable and horticultural land covers just over 23.4% of the UK according to LCM2000 and 21.5% by FS estimates. LCM2000's higher estimate relates in part to small features such as woodlands, prevalent in arable landscapes but generalised out by LCM2000. About 70% of LCM2000 **Arable and horticultural land** is coincident with FS *Arable*. There are apparent confusions between *Arable and horticultural land* and *Improved grassland* in LCM2000 mapping; these probably relate largely to rotation farming in squares where the survey-year differed in field and satellite surveys. However, there are also misclassifications of grass as arable and *vice versa*. Though this problem is relatively small, because grass and arable farming together make up so much of the UK, the misclassified elements contribute a significant proportion of the total map error. Confusion between arable and built up land is a small but nonetheless significant problem: it relates mostly to erroneous classification of satellite images, where part-grown or ripening crops have spectral signatures readily confused with those of partly vegetated suburban areas.

Improved grassland, 25.7% according to LCM2000 and 25.8% by FS, is the largest single Target cover / BH type in GB. Generally, it is readily recognisable and well-classified on LCM2000. However, the distinction of 'improved' grassland from semi-natural types can be both difficult and controversial. The 'improvement' of a grassland is a continuous process which may start with minor attempts at surface drainage and end with ploughing and reseeding. Other treatments include control of grazing, fertiliser application, liming and herbicide treatments. There is potential for reversion; and abandonment or extensification can give the impression (and the spectral character) of semi-natural swards. Field surveyors use species records and a range of contextual observations not open to the image analyst, though field surveyors also face difficulties in dividing the continuum. There is, inevitably, scope for differences in interpretation by FS and LCM2000; a significant proportion (near 20%) of FS 'improved grassland' is recorded by LCM2000 as semi-natural.

Tables 11-13. Summary correspondence matrices (results expressed per 1000) at Aggregate class level. The matrices were made by comparing LCM2000 with the CS2000 field survey squares. Results were calculated as weighted estimates, using strata based on 40 Land Classes, 'bootstrapped' to generate confidence intervals (see text).

Table 11. Great Britain

	Field Survey	Broadleaved / mixed wood	Coniferous woodland	Arable and horticulture	Improved grassland	Seminatural grass	Mountain, heath, bog	Standing open water	Built up areas and gardens	Coastal	Oceanic seas	Total
LCM2000												
Broadleaved / mixed wood		33	4	3	4	5	1	0	3	0		53
Coniferous woodland		9	50	0	1	3	3	0	0	0	0	66
Arable and horticulture		5	1	212	27	6	0	0	7	0		259
Improved grassland		7	0	11	181	25	1	0	6	0		232
Seminatural grass		8	3	5	33	64	37	0	4	1		154
Mountain, heath, bog		5	3	3	1	20	121	1	1	1	0	155
Standing open water		0	0		0	0	0	7	0	0	0	7
Built up areas and gardens		1	0	4	2	1	0	0	38	0		48
Coastal		0			0	0	0	0	1	6	1	9
Oceanic seas		0				0	0			4	12	17
Total		68	61	238	249	124	164	9	61	12	14	1000
												74.1

Table 12. England and Wales

LCM2000												
Broadleaved / mixed wood		48	2	4	6	6	0	1	4	0		71
Coniferous woodland		8	20	0	0	1	1	0	0	0		30
Arable and horticulture		7	1	289	34	7	0	0	9	0		347
Improved grassland		8	0	14	226	25	0	0	9	0		282
Seminatural grass		8	2	5	42	52	14	0	5	0		129
Mountain, heath, bog		3	1	5	1	9	27	0	1	0		46
Standing open water		0	0		0	0	0	6	0			6
Built up areas and gardens		2	0	6	2	2	0	0	54	0		67
Coastal		0			0	0	0	0	1	8	2	11
Oceanic seas		0				0	0			4	7	11
Total		83	27	322	312	100	43	8	83	13	9	1000

Table 13. Scotland

LCM2000												
Broadleaved / mixed wood		7	8	0	1	2	1	0	1			21
Coniferous woodland		12	104	1	1	7	7	0	1	0	0	132
Arable and horticulture		2	2	70	15	5	1	0	3	0		97
Improved grassland		4	1	6	98	26	3	0	2	0		140
Seminatural grass		7	4	4	17	87	79	0	2	1		201
Mountain, heath, bog		7	8	0	1	40	295	2	1	2	0	356
Standing open water		0	0		0	0	1	9		0	0	10
Built up areas and gardens		0	0	0	0	1	1		9	0		12
Coastal		0			0	0	0		0	4	0	5
Oceanic seas		0				0	0			3	23	26
Total		39	126	82	134	169	387	11	20	11	23	1000
												71.3

Summary correspondences (%) are given for Broad Habitats allowing for field survey generalisation of urban areas (i.e. total for shaded cells).

Semi-natural grasslands, bracken, fens and marshes present some problems in their distinction. Specific *Neutral*, *Calcareous* and *Acid grassland* BHs are not well separated by LCM2000. Differences relate first to problems with ‘rough grasslands’, some of which are semi-natural, others derelict and abandoned swards of unknown origin. The derelict swards may have been agricultural in origin, such as abandoned / neglected grazing or long-term setaside; they may be associated with tree-felling or new planting; or they may have arisen from development, for example, motorway verges, urban rough ground, derelict industrial sites, railway yards, vegetated dumps and quarries. Those associated with urban open-space go largely unmapped by FS. Most rough grasslands fit into the *Neutral grassland* BH, though some are ‘improved’. If the dividing line is hard to draw in the field, satellite imaging has even greater difficulties subdividing these habitats. The rough grasslands of LCM2000 were all treated, for BH mapping purposes, as *Neutral grassland*. In contrast, rough grasslands with species compositions indicating improvement were mapped by FS as *Improved grassland*. LCM2000 distinguished swards trained as ‘rough grassland’ at class Variant level; this distinction may give scope to refine the classification later, through integrated analysis of LCM2000 and FS data.

There is a general problem in separating *Neutral*, *Calcareous* or *Acid grassland* BHs. Quite simply, there is no consistent spectral characteristic which allows accurate distinction by image analysis. In order to comply as far as possible with the needs to map BHs, all LCM2000 semi-natural swards, whatever their origin, were subject to acid-sensitivity masking (Hornung *et al.* 1995) in order to allocate them to an acidity class. There were inevitable weaknesses in a mask based on a 1 km grid, which generalised soil heterogeneities at an even coarser scale and took no account of management practices such as liming. Moreover, the acid-sensitivity map defined acidity classes as ‘highly sensitive’ with a pH <4.5, ‘moderately sensitive’ with a pH between 4.5 and 5.5. and low sensitivity or pH >5.5. While the ‘acid’ label represents truly acid conditions, the moderately sensitive ‘neutral’ category is actually slightly acid and the low sensitivity ‘calcareous’ category includes neutral and calcareous elements. There was no affordable alternative available to the project. Not surprisingly, the results gave a poor match with FS data.

The *Bracken* BH was not a Target class of LCM2000. The Subclasses identified **Bracken** for BH-mapping purposes, but included only that which was growing in open conditions. Because so much of the imagery used to make LCM2000 was recorded in May, when the amount of bracken on the ground would be at the absolute minimum, there was often the tendency for stands to be recorded as the background *Acid grassland*.

The *Fen, marsh, and swamp* BH is defined as being ‘... characterised by a variety of vegetation types that are found on minerotrophic (groundwater-fed), permanently, seasonally or periodically waterlogged peat, peaty soils, or mineral soils. They include fens, flushes, marsh ... and swamps. This BH does not include neutral and improved grasslands on floodplains and grazing marshes, nor bogs, nor areas of carr woodland.’ The FS identifies much more *Fen, marsh, and swamp* (2.4%) than does LCM2000 (0.1%), largely because the surveys treat rush-pastures very differently, with LCM2000 including these in the **Acid grassland** class while FS records them as *Fen, marsh, and swamp*. This distinction led to the FS recording a much greater extent of *Fen, marsh, and swamp* in 1998 than it had in 1990 and has raised questions over the classification. If these rush pastures are to be included in the *Fen, marsh, and swamp* BH, they are identified at LCM2000 Variant level: it will be helpful to check such examples against FS data during follow-up work on integration of the two datasets to see where patterns match.

Heath, bog and montane habitats presented problems in distinctions to BH definitions. LCM2000 targeted dwarf shrub and bog communities knowing that LCMGB of 1990 had already shown the problems in defining bogs to floristically-based standards. Dwarf shrubs grow on many bogs; but not all dwarf shrub coverage signifies bog; and not all bogs have dwarf shrub coverage. Underlying

soil and moisture parameters, particularly peat-formation, dictate the classification. *Dwarf shrub heath* and *Bogs* BHs are mapped very differently by LCM2000 and FS. LCM2000 shows 11.1% cover of heath and 2.3% cover of bog. FS estimates 6.1% heath and 9.6% cover of bog. It is necessary to understand the BH definition in order to explain these differences.

JNCC (Jackson, 2000) state that the *Bogs* BH ‘... covers wetlands that support vegetation that is usually peat-forming ...’ They note that the ‘... habitat type also includes modified bog vegetation that essentially resembles wet or dry dwarf shrub heath but occurs on deep acid peat which would have once supported peat-forming vegetation. Modified bog also includes impoverished vegetation dominated by purple moor-grass or hare’s-tail cotton-grass ... Although there is no agreed minimum depth of peat that can support ombrotrophic vegetation, unmodified bog can be identified floristically by the presence of characteristic species such as cotton-grass ... and peat-forming sphagna ...’ This use of indicator species is the main way that CS2000 field surveyors identified *Bogs*. The JNCC report goes on to say that ‘Peat depth, although somewhat arbitrary, is used as the primary criterion to separate types of modified bog vegetation from the ‘*Dwarf shrub heath*’ broad habitat type ... Therefore vegetation dominated by dwarf-shrubs, cotton-grass ... or purple moor-grass ... on peat greater than 0.5 m deep is classified as bog for the purposes of the Broad Habitat Classification.’ Field meetings with conservation agency staff involved with Phase 1 survey gave support for such a definition.

With this in mind, peat depth was set as the main criterion for distinction of **Bogs** in LCM2000; a British Geological Survey map showing peat drift >0.5 m deep was used to determine the context of ‘heath’ and ‘moor’. Any ‘heath’ or ‘moor’ on deep peat was recoded to bog and any ‘bog’ which did not coincide with peatland was recoded to heath or grass moor (depending on the key cover-component). In the event, the peat mask gave a very conservative picture of the true extent of peatlands: it generated a bog-coverage amounting to a quarter that of the FS estimate and much less than that suggested by Reid and Quarmby (1997). The issue is clearly controversial and needs careful examination. Bog surveys are currently being made by Countryside Council for Wales and Scottish Natural Heritage. Peatland is being mapped by Macaulay Land Use Research Institute and Soil Survey and Land Research Centre. It is proposed to re-examine LCM2000 bogs and heaths in a follow-up programme which will integrate LCM2000 with FS and external data. For the time being, the LCM2000 bog class is described as ‘**Bog (deep peat)**’.

Field reconnaissance for LCM2000 seldom visited *Montane habitats*, as they are not easily accessible. While the *Montane habitats* BH definition relies heavily on floristic composition (Jackson 2000), LCM2000 **Montane** cover was defined by altitude criteria, with all vegetated ground >600 m (see Ratcliffe & Thompson 1988) being treated as *Montane habitats*. LCM2000 records 1.6% coverage against the FS estimate of 0.2%. Clearly there is a difference and there must be questions over whether the altitude-based distinction is well made in this circumstance.

The *Inland rock* BH, while treated as part of the **Heath, bog and montane** Aggregate class, actually covers both natural and artificial exposed rock surfaces. Potentially, they include exposed mountain tops, screes and limestone pavements, as well as various forms of excavations such as quarries and waste tips and quarry waste. LCM2000 distinguished these components as **Inland bare ground**. However, it may erroneously have included temporary bare ground, particularly bare arable land, in this category, where contextual corrections have failed to identify the arable context. Unlike the FS, LCM2000 also mapped **Inland bare ground** in an urban context: this included gravel car parks, railway sidings and derelict industrial land. The consequence is that LCM2000 records four times as much **Inland bare ground** as the FS does *Inland rock*. The overall quantity is however small at 0.9% of LCM2000 or 0.2% of FS cover for the UK. Where, locally, coverage is extensive, it relates generally to the uplands and inclusion with the aggregate **Heath, bog and montane** habitats is appropriate.

It can be seen from the above that the **Dwarf shrub heath, Bogs, Montane and Inland bare** categories of LCM2000 do not directly match the BH definitions. It is for this reason that the classes are put into the **Heath, bog and montane** Aggregate class for some map-presentations and data tabulations.

Water (inland) on LCM2000 is an aggregation of the *Standing open water and canals* and *Rivers and streams* BHs. **Water (inland)** is mapped where >0.5 ha in extent and where its width substantially exceeds the 25 m input pixel size (only being recognised consistently where width is 2 pixels (50 m) and the area >0.5 ha). Smaller water bodies and narrower waterways are not included. There is no attempt to distinguish standing from flowing water. Despite these differences, the LCM2000 cover of **Water (inland)** is near identical to FS estimates for *Standing open water and canals* in GB. UK statistics are not available from FS as the NICS does not report on the class.

Built up and gardens are mapped in greater detail by LCM2000 than the FS *Built up areas and gardens*. LCM2000 distinguished open spaces >0.5 ha in the built landscape. FS treated urban land as continuous without recording open spaces in the urban zone. Consequently, the FS recorded more 'built up' land and less grassland, woodland and waterway. And as a result, FS *Built up* includes LCM2000 woodlands, grasslands and water. LCM2000 recognised urban areas comprising a mixture of built and vegetated surfaces as **Suburban and rural development** and those with little if any vegetation as **Continuous urban**.

Coastal habitats of *Supralittoral rock, Supralittoral sediment, Littoral rock and Littoral sediment* are, with the exception of some notable dune systems, shingle beaches and estuaries, relatively small habitats, often near to or below the resolution of LCM2000. They are treated as an **Coastal habitats** Aggregate class for reporting purposes; however, they are recognised at BH level in LCM2000 Subclasses and shown on maps as two classes: **Supralittoral rock and sediment** and **Littoral rock and sediment**. The distinction of these BHs (and aggregations thereof) relies upon definition of a high water mark, and use of OS 1:50 000 maps and local knowledge to indicate whether a surface is solid rock or sedimentary in recent origin. Neither type of information could be provided or applied with the precision and consistency to allow accurate separation at the resolution of LCM2000. As a result, the relative quantities recognised by LCM2000 and FS differed; they contribute a negligible amount to overall cover and overall non-correspondence. The greatest difference however relates to the tidal state at the time of imaging. As a result, some inter-tidal areas were under-represented; conversely, other offshore inter-tidal sediments, outside the FS population of terrestrial 1 km squares, were recorded by LCM2000 but not by FS. It must be recognised that neither survey provides nationally consistent and accurate estimates of coastal BHs.

The *Boundary and linear features* BH was not targeted by LCM2000. LCM2000 only includes linear habitats which have an area >0.5 ha: to have been resolved by the images they will also have been =2 pixels wide. Linear features were, however, mapped by the FS. As a consequence, the 2.5 m grid samples used in correspondence testing also recorded these items; they constituted about 3% of the landscape area. Because they were intentionally excluded in LCM2000, *Boundary and linear features* (and *Rivers and streams*) were excluded as distinct BHs in calibration.

12. LCM2000 ACCURACY?

The correspondence between LCM2000 and the FS is **not a measure of LCM2000's accuracy**. The FS does not provide 'ground truth': differences in resolution, the data-model and timing of surveys contribute to differences in correspondence. Nonetheless, it is possible to identify differences attributable to inherent characteristics of the surveys and others which relate to error

(Fuller *et al.* 1998). We might thus deduce a broad accuracy-value for LCM2000. Because LCM2000 did not directly map BHs, accuracy is best assessed at Target class level.

LCM2000 segments, compared with FS parcels, show a basic correspondence of 63.4% in per-parcel comparisons at Target class level (allowing for the FS generalisation of *Built up areas* and the LCM2000 omission of *Boundary and linear features* and *Rivers and streams*). As correspondence cannot realistically exceed the 88% repeatability of the FS, LCM2000 seems to be scoring at least 72% of its maximum potential. About 5% of the mis-match is explained by the 25 m grid underlying the image parcels, compared with the continuously variable structure of the field survey (if the field data are resampled onto the 25 m grid, the result shows 95% correspondence with the original input data). The MMU of LCM2000, which only records segments >0.5 ha, contrasts with the 0.04 ha MMU of the FS and explains many of the differences, especially for habitats which occur in less extensive stands (more than 4% of the area recorded by FS comprised parcels, not linear features, which were below the LCM2000 MMU). Time-differences explain other mis-matches: the FS was predominantly made in 1998; LCM2000 used images mainly from 1998-2001; (squares surveyed by field and satellite surveys in the same year are some 6% closer in correspondence than the national average). Evidently up to 15% of differences can be explained by the underlying structure of LCM2000 and, additionally, by its coarser MMU, and by date-differences. This suggest that LCM2000 may record Target classes with 87% success; to quote a figure of *c.* 85% accuracy at Target class level seems realistic.

13. CALIBRATION OF LCM2000 TO FIELD SURVEY

13.1 Operation

The calibration matrices, derived from inter-comparison of FS and LCM2000 data (see Section 11) were the basis of a calibration of LCM2000 cover-estimates to FS-equivalence. While a common classification was not a pre-requisite for inter-calibration, the BH classes were generated from both FS and LCM2000 data and were used for such calibration.

FS values for each land class in a given stratum or Land Class are estimated from LCM2000 values by multiplying the LCM2000 areas in each class by the calibration matrix, i.e.

$$FS = M \times LCM \quad \text{Equation 1}$$

where *FS* and *LCM* are vectors of the proportions in each BH. *M* is an average calibration matrix, derived from a set of matrices M_1, M_2, \dots, M_S , i.e. one for each of the *S* field squares belonging to the given stratum. Each element, M_{ij} , of the matrix *M* denotes the value for row *i* column *j* of the calibration matrix, i.e. the proportion of LCM type *i* classified as FS type *j*.

Consider the hypothetical calibration matrix below:

Calibration matrix LCM2000	Field survey		
	broadleaved	conifer	urban
<i>broadleaved</i>	0.75	0.10	0.15
<i>conifer</i>	0.10	0.85	0.05
<i>urban</i>	0.05	0.05	0.90

Results have been normalised so values sum to ‘1’ across the rows. LCM2000 summary cover statistics (in italics below) are fed into the matrix:

LCM2000 Input cover values	Field survey		
	broadleaved	conifer	urban
<i>broadleaved</i> 1000	750	100	150
<i>conifer</i> 500	50	425	25
<i>urban</i> 200	10	10	180
Calibrated output statistics	810	535	355

They are multiplied by the correspondence values to give output statistics which, if summed (bold), show how the same landscape might have been recorded by a comprehensive FS.

To calculate confidence limits for the calibrated estimates, bootstrap samples (Efron & Tibshirani 1998) of FS estimates are obtained by random simulated re-sampling of matrices M_1, M_2, \dots, M_S with replacement, calculating the calibration matrix and applying the above calibration formula. The approach can be extended to allow for stratification, where a set of confusion matrices for each stratum is available. The FS squares were selected according to a stratified random sampling scheme, with the 40 Land Classes defining the strata. The national estimates of FS values are calculated by areally weighting the estimates derived separately for each stratum i.e.

$$FS = \frac{A_1 F_1 + A_2 F_2 + \dots + A_n F_n}{A_1 + A_2 + \dots + A_n} \quad \text{Equation 2}$$

where A_i is the stratum area, and F_i is the vector of the proportions in each land cover type, of the i^{th} Land Class stratum. Each F_i is re-calculated for each bootstrap sample by randomly sampling from the set of confusion matrices from the given stratum (Equation 1). It was found that 1000 bootstrap samples were sufficient to calculate the 95% confidence intervals. Bias-corrected percentile limits were calculated to remove any bias that arises because the true parameter value is not the median of the distribution of estimates (Efron & Tibshirani 1998).

GB statistics on BHs were generated from LCM2000 calibrated cover, with confidence limits on each calibrated value. Weighted estimates with confidence limits were also calculated for England, Wales, England / Wales combined, and for Scotland (drawing upon Land Classes according to their presence and extent in each Country). A calibrated estimate of BH coverage was also made for Northern Ireland, assuming that the GB-calibration would apply; while there were weaknesses in this assumption, there is reason to believe that the same broad levels of over- and under-estimation applied when mapping BHs from satellite images. The calibration procedure generated calibrated statistics to match FS per-pixel cover, per-segment cover and per-parcel cover.

Table 14. Estimates of Broad Habitat cover for Great Britain from calibrated LCM2000 data: results give the mean of a bootstrapped estimate, with the bias-corrected 95-percentile range. Results are compared with estimates based on the sample-based field survey approach of Countryside Survey 2000: the 2 standard errors is used to estimate the 95-percentile range for the field survey.

Broad Habitats	LCM	LCM bias corrected confidence interval		FS	
	mean	lower	upper	Total	2 x SE
Broadleaved, mixed and yew woodland	16125	14679	17019	14710	1960
Coniferous woodland	12995	11677	14079	13740	3068
Arable and horticulture	54743	52433	57300	52490	4546
Improved grassland	59200	56811	61871	54820	4284
Neutral grassland	6674	5850	7525	6130	1084
Calcareous grassland	533	215	899	650	578
Acid grassland	12337	10699	14398	12950	2356
Bracken	3840	3140	4372	4390	1132
Dwarf shrub heath	14048	11909	16026	14870	2718
Fen, marsh and swamp	5273	4196	5846	5470	1332
Bog	22578	21037	26048	22180	3484
Standing open water and canals	1709	1433	1845	1900	1110
Montane habitats	606	117	1399	490	618
Inland rock	639	347	877	560	236
Built up areas and gardens	17652	16597	19812	13310	2282
Supralittoral rock	782	582	858	770	268
Supralittoral sediment	341	244	425	530	350
Littoral rock	0	0	1	0	0
Littoral sediment	977.2	568.8	1140.3	1380	940

Figure 14. A plot of the Broad Habitat cover estimates for Great Britain from calibrated LCM2000 and sample-based field survey as given in Table 12. The error bars show the 95-percentile range for each. The regression equation and R^2 values are given on the chart.

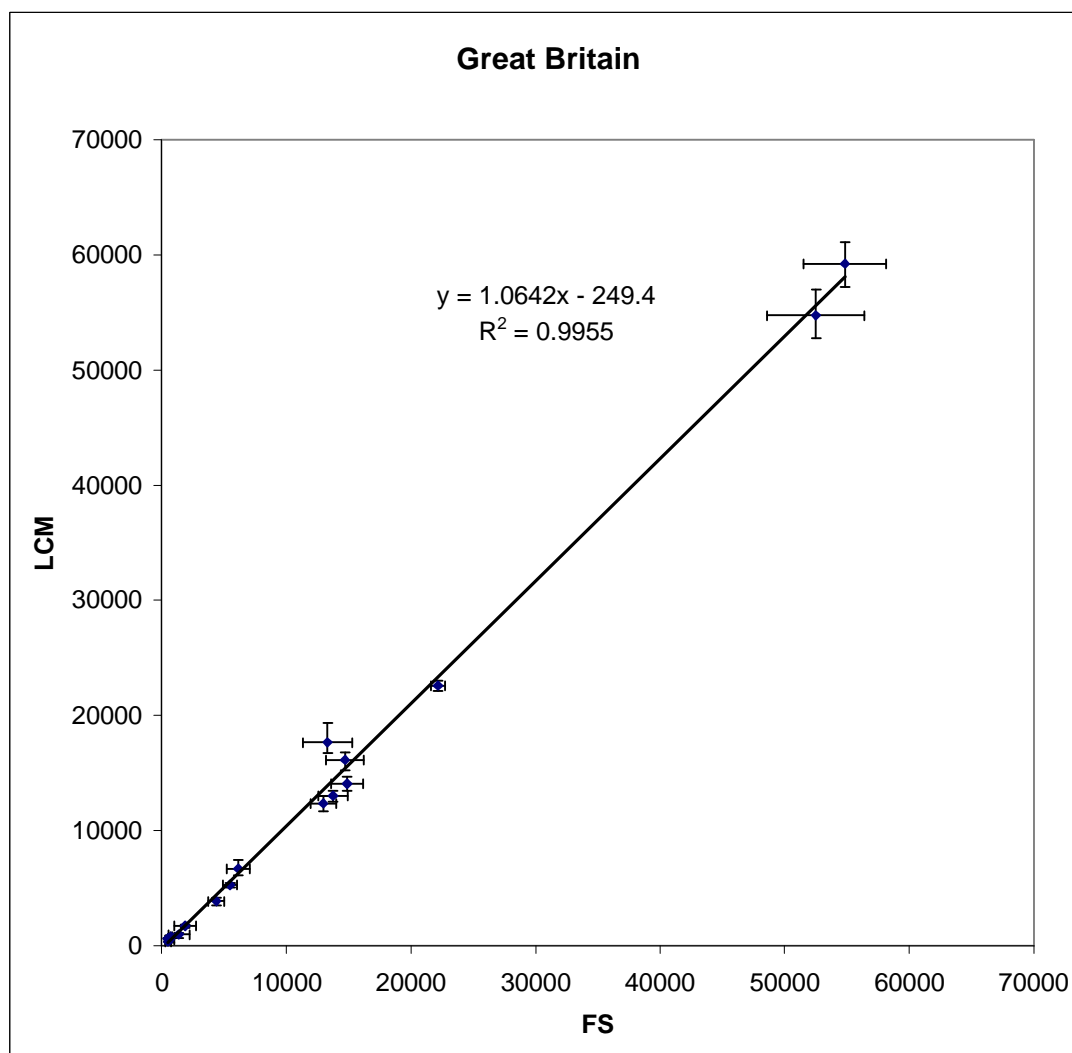


Table 15. Estimates of Broad Habitat cover for England from calibrated LCM2000 data: results give the mean of a bootstrapped estimate, with the bias-corrected 95-percentile range. Results are compared with estimates based on the sample-based field survey approach of Countryside Survey 2000: the 2 standard errors is used to estimate the 95-percentile range for the field survey.

Broad Habitats	LCM	LCM bias corrected confidence interval		FS	
	mean	lower	upper	Total	2 x SE
Broadleaved, mixed and yew woodland	10894	9974	11513	9970	1510
Coniferous woodland	2821	2317	3258	2980	1178
Arable and horticulture	47070	45062	49331	43890	3912
Improved grassland	40165	38151	42046	36630	3316
Neutral grassland	4260	3654	5029	3910	918
Calcareous grassland	377	102	726	350	330
Acid grassland	3969	3258	4637	3820	1026
Bracken	1501	1142	1795	1660	644
Dwarf shrub heath	2938	2300	3563	3620	1316
Fen, marsh and swamp	1331	1080	1483	1480	566
Bog	1060	603	1484	980	554
Standing open water and canals	512	357	601	890	876
Montane habitats	18	8	29	0	16
Inland rock	123	78	139	120	74
Built up areas and gardens	14435	13487	16080	10420	1986
Supralittoral rock	121	57	150	140	78
Supralittoral sediment	162	103	204	240	220
Littoral rock	0			0	0
Littoral sediment	812	462	955	1180	836

Figure 15. A plot of the Broad Habitat cover estimates for England from calibrated LCM2000 and sample-based field survey as given in Table 12. The error bars show the 95-percentile range for each. The regression equation and R2 values are given on the chart.

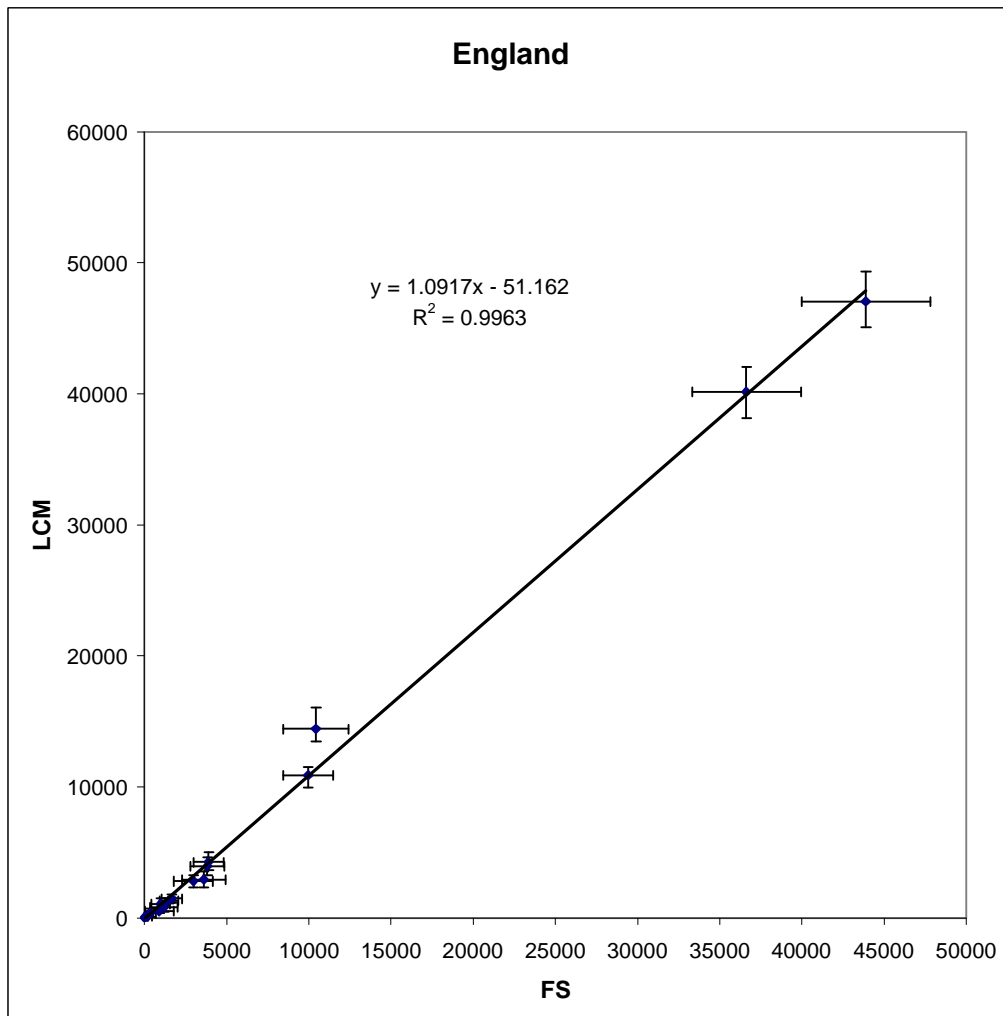


Table 16. Estimates of Broad Habitat cover for Wales from calibrated LCM2000 data: results give the mean of a bootstrapped estimate, with the bias-corrected 95-percentile range. Results are compared with estimates based on the sample-based field survey approach of Countryside Survey 2000: the 2 standard errors is used to estimate the 95-percentile range for the field survey.

Broad Habitats	LCM	LCM bias corrected confidence interval		FS	
	mean	lower	upper	Total	2 x SE
Broad Habitats	mean	lower	upper	Total	SE
Broadleaved, mixed and yew woodland	2016	1609	2376	1738	517
Coniferous woodland	820	502	1072	818	643
Arable and horticulture	1340	1151	1635	2207	501
Improved grassland	8145	7465	8633	7676	1284
Neutral grassland	590	487	653	533	151
Calcareous grassland	23	8	43	24	27
Acid grassland	1766	1258	2355	1651	769
Bracken	889	558	1237	1073	561
Dwarf shrub heath	963	649	1246	1225	673
Fen, marsh and swamp	578	397	761	618	311
Bog	785	462	1313	814	661
Standing open water and canals	122	101	143	163	121
Montane habitats	7	4	11	0	0
Inland rock	44	14	73	49	36
Built up areas and gardens	1228	1084	1513	1380	409
Supralittoral rock	46	22	63	55	33
Supralittoral sediment	43	21	65	70	61
Littoral rock	0.0				0

Figure 16. A plot of the Broad Habitat cover estimates for Wales from calibrated LCM2000 and sample-based field survey as given in Table 12. The error bars show the 95-percentile range for each. The regression equation and R^2 values are given on the chart.

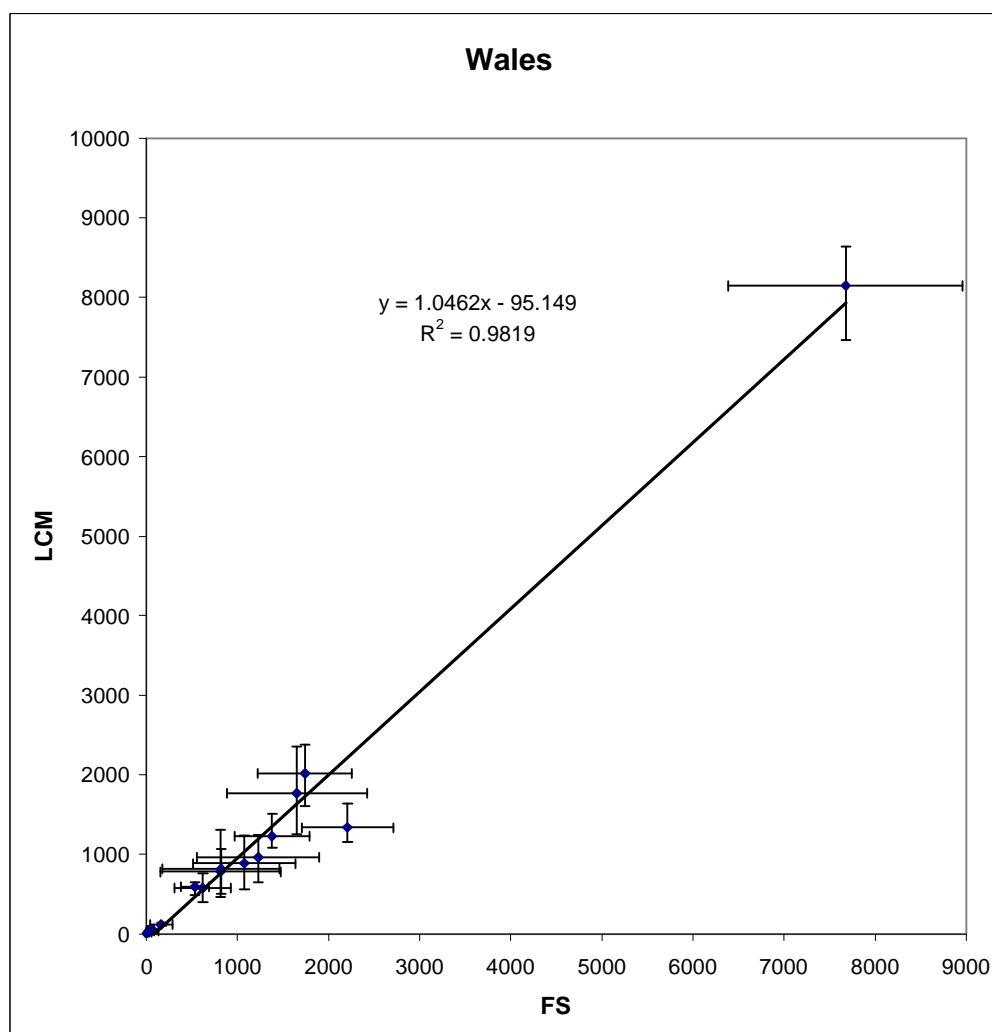
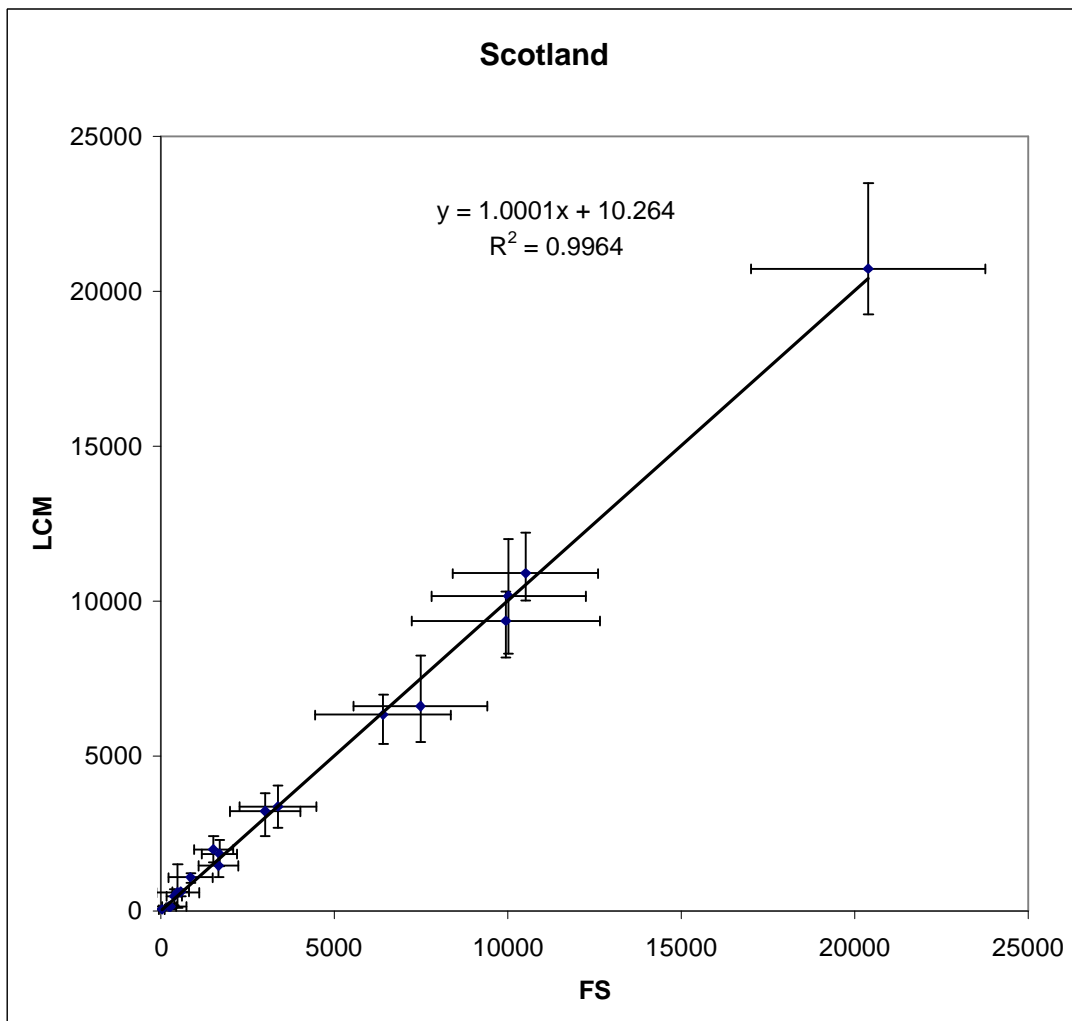


Table 17. Estimates of Broad Habitat cover for Scotland from calibrated LCM2000 data: results give the mean of a bootstrapped estimate, with the bias-corrected 95-percentile range. Results are compared with estimates based on the sample-based field survey approach of Countryside Survey 2000: the 2 standard errors is used to estimate the 95-percentile range for the field survey.

Broad Habitats	LCM	LCM bias corrected confidence interval		FS	
	mean	lower	upper	Total	2 x SE
Broadleaved, mixed and yew woodland	3215	2422	3804	3000	1020
Coniferous woodland	9354	8176	10296	9940	2708
Arable and horticulture	6329	5384	6984	6400	1958
Improved grassland	10892	10018	12191	10510	2088
Neutral grassland	1825	1438	2276	1680	502
Calcareous grassland	133	43	232	270	468
Acid grassland	6603	5448	8228	7480	1938
Bracken	1450	1081	1844	1660	568
Dwarf shrub heath	10147	8295	11996	10020	2226
Fen, marsh and swamp	3365	2672	4038	3370	1104
Bog	20733	19248	23495	20390	3368
Standing open water and canals	1075	906	1206	850	632
Montane habitats	581	90	1499	480	618
Inland rock	472	184	699	380	220
Built up areas and gardens	1989	1561	2401	1510	562
Supralittoral rock	615	456	679	570	244
Supralittoral sediment	135	83	189	230	210
Littoral rock	0	0	1		44
Littoral sediment	44	34	61	20	86

Figure 17. A plot of the Broad Habitat cover estimates for Scotland from calibrated LCM2000 and sample-based field survey as given in Table 12. The error bars show the 95-percentile range for each. The regression equation and R^2 values are given on the chart.



The calibrated estimates (Tables 14-17) are very close to direct FS estimates: when LCM2000 BH estimates are plotted (Figures 14-17) against FS estimates for GB and the 3 countries, slopes are near to unity and the intercepts close to the origin (see Table 18), illustrating that there is little bias in the estimation. R^2 values very close to '1' imply a close linear relationship.

Table 18. Slopes, intercepts and R^2 results obtained when calibrated LCM2000 Broad Habitat cover statistics are plotted against field survey estimates of the same cover statistics. Results are derived per-pixel, per-parcel and per-segment for Britain and constituent countries.

		Slope	Intercept	R^2
Great Britain	Per-pixel	0.936	289	0.996
	Per-parcel	0.965	-99	0.990
	Per-segment	0.884	947	0.994
England	Per-pixel	0.913	72	0.996
	Per-parcel	0.937	-112	0.991
	Per-segment	0.878	322	0.996
Wales	Per-pixel	0.939	107	0.982
	Per-parcel	0.978	65	0.967
	Per-segment	0.867	186	0.978
Scotland	Per-pixel	0.996	6	0.996
	Per-parcel	1.019	-98	0.990
	Per-segment	0.921	355	0.987

Because per-pixel estimates give direct equivalence to FS cover, the results which follow are based on per-pixel calibrations. Per-parcel estimates gave similar values, albeit with minor variations due to the bootstrap sampling. Segment-based bootstrapped estimates generate FS coverage but on the LCM2000 spatial framework (i.e. estimating what LCM2000 segments given FS labels would record as coverage). The values are so close that they support almost entirely the original field estimates; however, the LCM2000-based estimates produce tighter confidence limits. The near-universal correspondence is remarkable. While the derived datasets come together in the process of calibration, the measures of coverage are essentially independent. The extrapolation of sampled FS cover statistics via the Land Classes is an entirely different approach to the generation of the same statistics by use of a calibrated comprehensive survey from satellite imagery.

Calibration in Northern Ireland produced mixed results. For 11 BHs estimated by FS and LCM2000 alike, 9 values were closer to FS estimates after calibration, and 2 were apparently worse (Table 19). When these values were plotted (Figure 18) the original slope and intercept of 1.06 and -17 were adjusted to 0.84 and +214 respectively, further from the expected values of 1.00 and 0 respectively; and the R^2 value of 0.79 was marginally worse than the original 0.81. This impact on the regression lines is due substantially to the dominating effect of the points for the very extensive 'improved grasslands'. It is clear, however, that other factors are operating in Northern Ireland and that GB-based calibrations do not apply very effectively. For example, we know that, in GB, LCM2000 over-estimates semi-natural grasslands: calibration against FS serves to moderate the over-estimate and to generate more realistic statistics. In Northern Ireland, semi-natural grasslands are much more commonplace. The uncalibrated LCM2000 estimate for *Acid*, *Calcareous* and *Neutral grasslands* is 2783 km² in total; calibrated, the figure is 1459 km²; the FS gives an estimate of 2830 km², much closer to the LCM2000 original. Clearly, calibrations made in GB do not apply in this example in Northern Ireland. It is highly likely that other calibration estimates can also be distorted rather than being improved.

LCM2000 can be used to generate calibrated data for any region, whether administrative or physiographic, within GB. Regional data are given (Table 20) for BH coverage in the six Environmental Zones (EZs) of GB, as used to report CS2000 FS results (Haines-Young *et al.* 2000). There must be serious questions as to whether the small size of the FS sample is adequate to allow estimation of cover statistics below this broad regional level.

13.2 Conclusions regarding calibration

The calibrated statistics, whether at national levels or broad regional scales, probably give CS2000's 'best' current estimates for the BHs at these levels. They certainly record mean values which compare favourably with FS estimates, but with confidence limits which are much tighter (about half the FS range). They take full account of the heterogeneity of the UK landscape and base the cover-estimates on comprehensive survey. While such a survey might itself show inaccuracies through satellite mapping, the calibration to the FS ensures that significant under- and over-estimates are taken into account. The close agreement of the statistics has much further ramifications: the weakness of the FS has been its inability to make reliable estimates of cover at local to regional levels. LCM2000 offers potential to do better, as it is providing site-specific survey. At Aggregate class level, LCM2000 is, even without calibration, likely to give results which would match a field survey recorded at this level of detail, albeit one with the lesser spatial resolution of LCM2000. At Target class level, LCM2000 is likely, in general, to be 85% correct, but with the potential, locally, for gross errors. LCM2000 calibrated against field data may give scope for local and regional census to BH standards. However, the calibration is only based on the 40 Land Class regions and it is likely that regionally-based calibrations cannot apply below, or perhaps even at, the regional level: similar problems to those seen with the Northern Ireland calibration are likely. Nonetheless, the local values are surveyed rather than estimated and hence are much more reliable than would be the equivalent field-based estimates. Thus local results are likely to be very sound for Aggregate classes and reasonably so for Target classes. Whether there is scope to produce BH cover estimates at local level needs to be tested independently. It was not possible within the scope of LCM2000 production and reporting to validate this approach. However, such work is envisaged in follow-up research on integration.

Table 19. Coverage of Broad Habitats in Northern Ireland from raw (uncalibrated) LCM2000; calibrated using the calibration matrix derived for the UK; compared with Northern Ireland Countryside Survey cover estimates. The calibrated LCM2000 statistic is judged 'better' or 'worse' if it is closer to or further from the field survey estimate than the uncalibrated original.

Broad Habitats	LCM raw total	LCM calibrated mean	NICS FS Total	Calibrated statistic
Broadleaved, mixed and yew woodland	253	691	510	better
Coniferous woodland	520	569	610	better
Arable and horticulture	908	1654	590	worse
Improved grassland	7005	5772	5680	better
Neutral grassland	1073	526	2540	worse
Calcareous grassland	464	51	10	better
Acid grassland	1246	882	280	better
Bracken	17	253	40	better
Dwarf shrub heath	1042	713	130	better
Fen, marsh and swamp	0	416	530	better
Bog	440	1272	1480	better

Figure 18. A plot of the Broad Habitat cover estimates for Northern Ireland from calibrated LCM2000 and sample-based field survey as given in Table 17. The regression equation and R2 values are given on the chart.

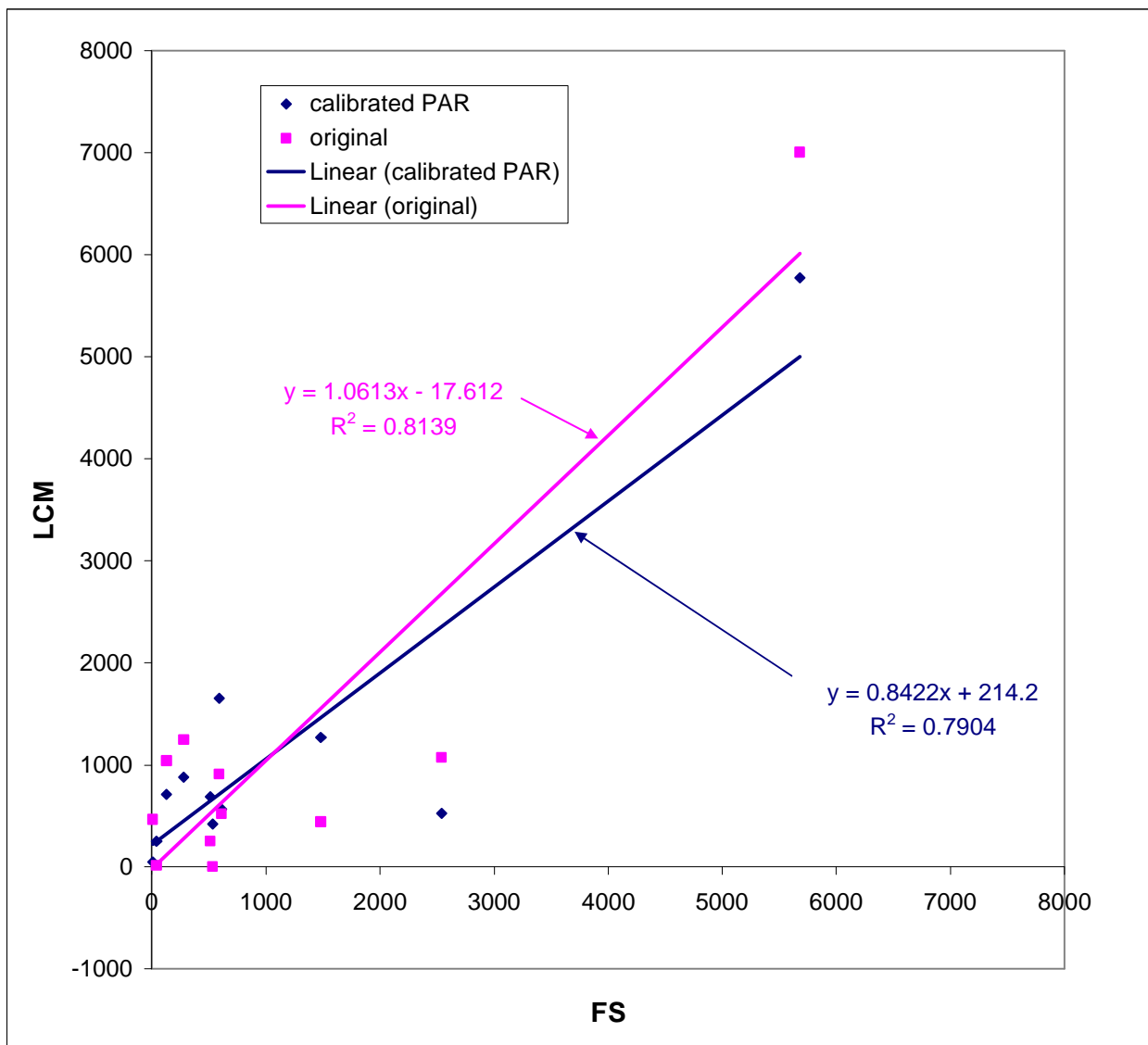


Table 20. Broad Habitat cover statistics (km²) for the 6 Environmental Zones of CS2000, derived by calibration of LCM2000 cover to CS2000 field survey; also statistics estimated directly from the field survey with the ranges based upon the FS means plus or minus 2 standard errors

	EZ1					EZ2				
	LCM sample mean	LCM bias corrected 95% confidence		FS		LCM sample mean	LCM bias corrected 95% confidence		FS	
		lower	upper	lower	upper		lower	upper	lower	upper
Broadleaved, mixed and yew woodland	6185	5599	6911	4315	6937	4737	4216	5166	3642	5374
Coniferous woodland	828	550	995	341	1024	1209	866	1452	609	2639
Arable and horticulture	33253	31630	35034	29381	36186	14505	13124	16215	10507	15040
Improved grassland	15252	13611	16581	10815	15624	25275	23932	26888	21442	26142
Neutral grassland	1955	1540	2530	1147	2557	1971	1534	2350	1242	2316
Calcareous grassland	296	28	666	-51	584	124	57	253	1	221
Acid grassland	317	82	728	-56	538	494	300	668	219	972
Bracken	146	99	174	46	262	613	388	716	162	1593
Dwarf shrub heath	72	29	93	-42	286	387	152	660	42	1070
Fen, marsh and swamp	256	147	367	63	354	740	548	841	205	1447
Bog	62	28	100	-12	102	54	40	70	-78	496
Standing open water and canals	259	166	343	-213	1516	191	124	260	55	294
Montane habitats	0			0	0	6	2	10	0	0
Inland rock	76	58	81	7	142	16	6	31	4	28
Built up areas and gardens	7093	6203	8387	3518	6726	8230	7422	9424	4879	7915
Supralittoral rock	0			0	0	217	113	285	83	304
Supralittoral sediment	1	1	1	-1	3	247	156	329	24	583
Littoral rock	0			0	0	0			0	0
Littoral sediment	94	85	120	-296	862	943	517	1124	337	1817

	EZ3					EZ4				
	LCM sample mean	LCM bias corrected 95% confidence		FS		LCM sample mean	LCM bias corrected 95% confidence		FS	
		lower	upper	lower	upper		lower	upper	lower	upper
Broadleaved, mixed and yew woodland	1949	1454	2366	996	2147	1394	1166	1574	874	1486
Coniferous woodland	1582	1173	2128	527	2466	2000	1504	2460	768	2649
Arable and horticulture	622	364	957	185	889	5447	4669	6106	3649	7065
Improved grassland	7575	6539	8087	5655	8938	6793	6157	7632	5237	7957
Neutral grassland	933	639	1304	435	1185	1263	971	1626	818	1570
Calcareous grassland	1	0	2	0	2	0			0	0
Acid grassland	4930	4198	5908	3384	5890	841	515	1112	421	1257
Bracken	1641	1197	2204	1040	2358	433	235	640	188	691
Dwarf shrub heath	3444	2620	4097	2707	5633	563	286	796	104	1706
Fen, marsh and swamp	939	757	1196	683	1451	723	477	885	378	1048
Bog	1730	1172	2523	704	2385	963	623	1435	304	2040
Standing open water and canals	183	159	202	-41	500	81	35	117	-14	137
Montane habitats	20	10	32	-6	25	6	3	10	0	0
Inland rock	78	34	124	29	134	279	11	450	-10	372
Built up areas and gardens	380	272	464	157	407	1566	1130	1936	607	1659
Supralittoral rock	2	0	5	-2	5	51	38	66	2	107
Supralittoral sediment	0	0	1	0	1	78	21	128	-65	328
Littoral rock	0			0	0	0			0	0
Littoral sediment	0			0	0	5	2	9	-1	9

	EZ5					EZ6				
	LCM sample mean	LCM bias corrected 95% confidence		FS		LCM sample mean	LCM bias corrected 95% confidence		FS	
		lower	upper	lower	upper		lower	upper	lower	upper
Broadleaved, mixed and yew woodland	814	528	990	323	1094	1055	435	1684	221	2007
Coniferous woodland	2947	2288	3542	1892	5127	4136	3490	4867	2759	6674
Arable and horticulture	722	508	920	41	1951	49	9	104	-3	87
Improved grassland	2908	2364	3540	1613	4368	1135	606	1656	137	1705
Neutral grassland	431	236	612	61	700	130	57	197	22	198
Calcareous grassland	155	41	270	-201	737	1	0	2	-1	3
Acid grassland	1191	859	1475	921	2250	4564	3415	6225	3286	6829
Bracken	594	405	843	283	1062	450	253	635	219	877
Dwarf shrub heath	2325	1815	3067	1439	2969	7388	5421	8975	4983	8842
Fen, marsh and swamp	1767	1242	2391	786	2745	828	533	1098	510	1275
Bog	8911	8181	10074	6610	11068	10794	9407	12984	8003	12744
Standing open water and canals	433	307	556	125	591	545	447	596	-154	1010
Montane habitats	34	14	229	-6	12	544	62	1386	-139	1096
Inland rock	25	12	61	25	130	166	98	295	31	219
Built up areas and gardens	310	198	427	118	479	101	37	195	-7	158
Supralittoral rock	599	396	708	246	702	102	82	155	-25	117
Supralittoral sediment	83	54	111	20	164	10	10	10	-2	6
Littoral rock	1	0	2	0	0	0			0	0
Littoral sediment	13	0	36	-27	61	0			0	0

14. UK LAND COVER

Summary statistics for UK land cover are given in Figure 19a-e. It can be seen from these that more than 54% of the UK is used for intensive agriculture (**Arable and horticultural land** or **Improved grassland**) or is developed (**Built up land**). The remaining 46% is largely semi-natural. Woodlands occupy 25% of this semi-natural land with **Broadleaved woodland** and **Coniferous woodland** about equal in extent. **Mountain, heaths and bog** cover 34% of the low intensity land; semi-natural grass swards (including rougher examples of improved swards) form 36% of all semi-natural. **Coastal habitats** and **Open water**, while important, are small in extent.

The four countries of the UK differ markedly from each other. Intensive use for agriculture or development affects nearly three-quarters of England, about two-thirds of Northern Ireland and about half of Wales. In Scotland, less than a quarter is intensively farmed or developed.

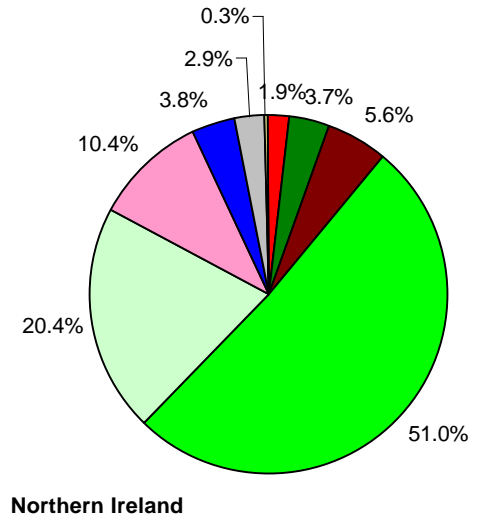
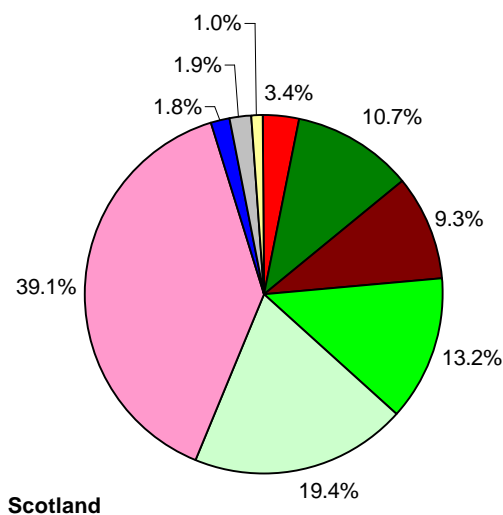
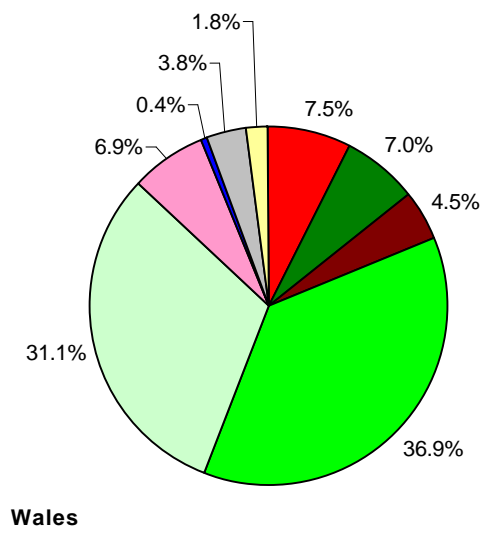
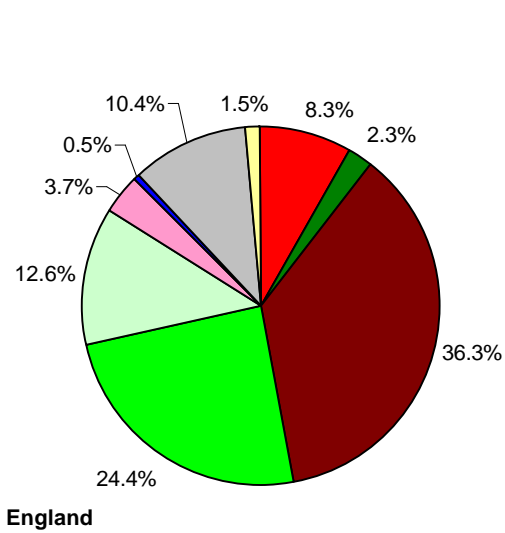
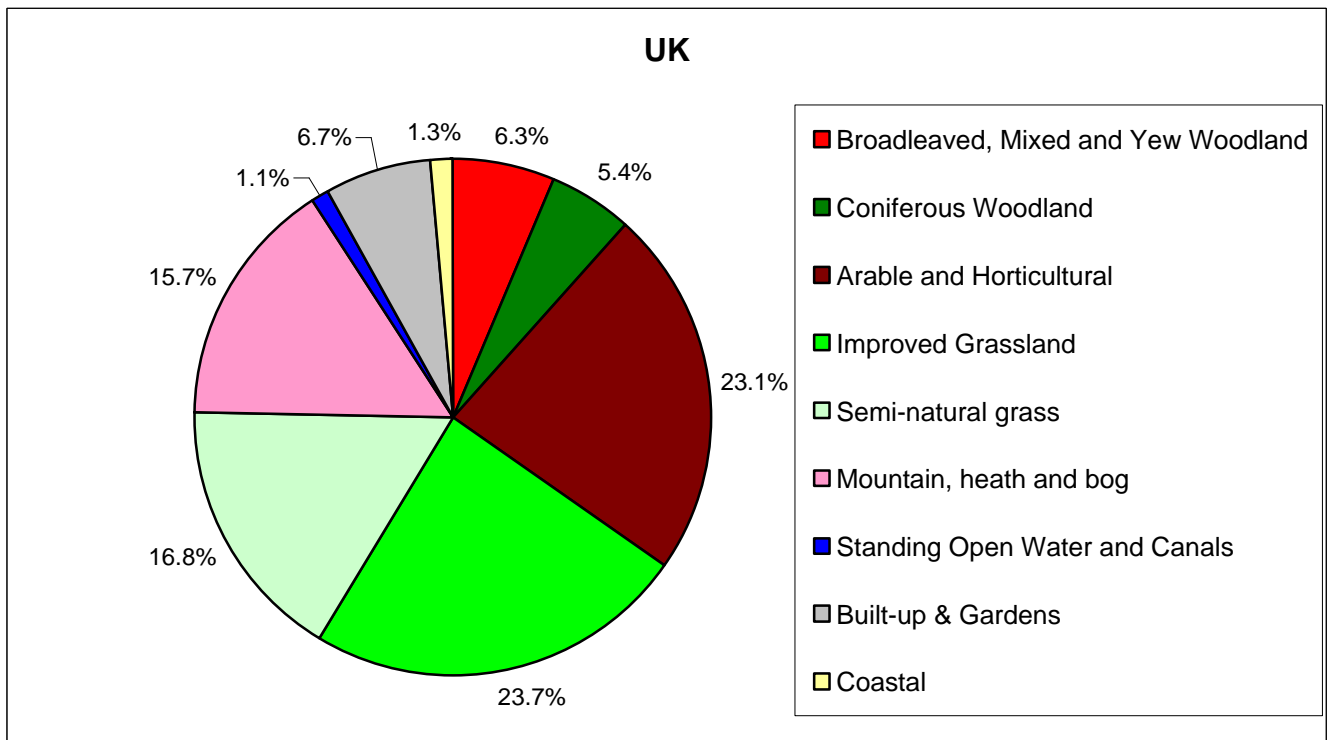
The semi-natural land of England is evenly split between woodlands and grasslands. In Wales, the balance is similar but with a far greater overall extent. Scotland is dominated by **Mountain, heath and bog** which makes up more than half of all its semi-natural land. Northern Ireland also has reasonably extensive **Mountain, heath and bog** and **Semi-natural grass** but, at the resolution of LCM2000 which excludes linear examples, is notably short of woodland cover.

15. CHANGE DETECTION

Landscape changes interest many users. The measurement of such changes demands high levels of precision to map real differences and to distinguish them from localised errors. Changes between LCMGB 1990 and LCM2000 were probably relatively small - FS suggests 17% at BH level - and detectable changes would generally have been exceeded by combined error rates. In a comprehensive National survey, the necessary precision for change detection cannot be achieved consistently by satellite-based mapping alone. The LCM2000 classification rightly sought to remove known deficiencies in the 1990 classification and to bring field and satellite surveys into closer match, even though the detection of change would be compromised. The segment-based approach of LCM2000 generated different results from the 1990 raster product. The classification based on BHs precluded direct comparison with 1990 classes.

Nevertheless, there will have been real changes in the period 1990-2000; and it may be possible to select intelligently, from those differences mapped, the elements which are attributable to change and those attributable to error and / or differences in the data products. The way to advance this work will be to use more intelligent approaches. The FS of 1990 and 1998 provided a measure of the expected directions and rates of change (Haines-Young *et al.* 2000). An intelligent approach might use these data. Calibration results identify LCM2000 under-estimates and over-estimates in 2000 which should be taken into account in analyses of change. The probabilities of classification recorded in LCM2000 point to possible errors in classification. All such clues could be used to select apparent changes which fit the known patterns of change. This approach will be the subject of research and development, beyond the scope of the production phase.

Figure 19. Pie charts showing the cover of Aggregate classes (uncalibrated statistics) for a. the UK and b-e. its constituent countries from LCM2000.



16. CONCLUSIONS

1. LCM2000 has, for the first time, mapped land cover for the whole of the UK from satellite images.
2. A period with a high incidence of cloudy weather in the target year of 1998 and subsequently doubled the number of images required to complete cloud-free coverage of the UK.
3. The procedures of LCM2000 proved robust and helped to overcome the difficulties of part-clouded data and the use of many different satellite images to build the complete UK mosaic.
4. A range of pre-processing procedures, new to LCM2000, gave improved data for classification. However, the use of haze correction was unable to counteract the worst effects in some images. The use of illumination correction for terrain-induced effects did not (and could not have) compensated for extremely low light levels in mid-winter coverage of north-facing slopes in more northerly latitudes.
5. The segmentation procedure proved robust and effective in segmenting the parcel-based structure of the UK landscape. Perhaps more surprisingly, segmentation was remarkably good at picking out urban, suburban and developed rural areas in the landscape. This ability to detect the major heterogeneity - the presence of the developed land - while aggregating the component pixels of the heterogeneous development parcel into a sensible structure, applied not only to the obvious examples of developed land but also applied when subdividing mosaics of cover in unenclosed semi-natural landscapes.
6. The training procedure based upon segments proved more efficient and more objective than normal manual methods for delineation of training areas. The review procedure based on 'colour charts', showing the spectral characteristics of training areas, allowed the construction of soundly-based spectral subclasses.
7. The spectral classification was used to build 72 thematic classes. These Variants were then aggregated at various levels: there are 26 Subclasses, mapped consistently across the UK. From these it is possible to simulate the 20 Broad Habitats, though with some departures from the standard definitions. The Subclasses also aggregated to 16 Target classes, mapped with consistency and a high level of accuracy. The BH classification and the Target classification give common classes at the Aggregate class level. Map display classes are those Target classes and Subclasses which are mapped reasonably accurately, are sufficiently widespread to show at the national scale and serve to bring out the patterns in intensively used and semi-natural landscapes.
8. Calibration suggests that LCM2000 maps Target classes with an accuracy level of >85%. This is probably less than the intended 90% accuracy, a consequence of the large quantity of imagery 'off-target' in terms of dates. Lesser accuracy is achieved for BHs. Indeed some BHs differ markedly from field survey 'equivalent' classes. The differences reflect the problems in defining BHs based upon physical properties of the substratum (soil type, pH and water content) and those best recognised by indicator species.
9. The process of calibration allows LCM2000 mapping to generate calibrated BH statistics with direct equivalence to field-surveyed BHs. It is believed that the comprehensive coverage of LCM2000 and the calibration based on field survey detail gives the 'best' estimates of BH cover and distribution. It is also believed that the combination of field detail and satellite coverage give scope for the generation of BH statistics down to the local level, something that neither survey could achieve on its own. This needs to be tested more fully.
10. LCM2000 is being made available to users at various levels of detail. The 'Level-2 Dataset' comprises ArcView 'Shape Files' as a topologically structured vector format carrying attributes which identify individual parcels, give a count of total pixels and core pixels, plus a process history descriptor (with a scene-identifier, probability indices and KBC rules applied). The Level-2 classification gives Target classes and Subclasses (26 types) coded to relate to BHs. The Level-3 Dataset gives details down to Variant level (72 types overall), also coded to relate

to BHs. The Level-3 dataset includes extra details on heterogeneity, recording the top five per-pixel classes and their fractional cover within the segment.

11. A 'Raster Dataset' derived from the Subclasses of the Level-2 Dataset gives a 25 m raster map based on per-parcel classification, and generalised accordingly.
12. The Raster Dataset is further generalised as 1 km products summarising: class dominance at the 26 Subclass level in a single layer dataset; also summary % cover per 1 km² for the 26 Subclass types (i.e. a 26-layer dataset) and Aggregate classes (a 10-layer dataset) in CIS format.
13. LCM2000 offers a data structure which can satisfy wide ranging user-needs. The vector-format of the data records the 'real' structure of the landscape, based upon land use and land cover parcels. It offers so much more scope than the conventional per-pixel products of the earlier LCMGB. With retention of all segments >0.5 ha, it offers far better resolution than other satellite-derived vector products such the manually mapped European CORINE Land Cover dataset with its 25 ha MMU.
14. LCM2000 records the structural patterns of the landscape and shows the spatial inter-relations of parcels and habitats. It therefore lends itself much better to applied uses where patterns affect processes, and an understanding the spatial inter-relations is a necessary precursor to understanding such processes and predicting their consequences.

17. GLOSSARY OF TERMS AND ACRONYMS

Acid-sensitivity map: (Hornung *et al.* 1995) used to label semi-natural grasslands as probably 'acid', 'neutral' or 'calcareous'; this map defined acidity sensitivity classes as highly sensitive - pH <4.5 (i.e. truly acid), moderately sensitive - pH >4.5 and <5.5. (treated for KBC purposes as neutral but really slightly acid) and low sensitivity - pH >5.5 (really including neutral and calcareous components).

Aggregate classes: 10 in number, combining Target classes and Subclasses to a simplified 10-class level where the resultant 'classes' compare closely with equivalent Broad Habitat-aggregations; at this level, maps and statistics from LCM2000 and field survey broadly coincide. Thus Aggregate classes are used for reporting purposes.

Attribute: refers here to a data item, held in the geographical information system, recording information about a GIS object; an attribute may be a numerical value (e.g. altitude), an alphabetical code (e.g. Aw = arable (wheat)) or a text string labelling or describing the parcel (e.g. the processing history descriptor).

BAP: UK Biodiversity Action Plan.

Bootstrapping: a statistical technique used to generate mean statistics and confidence intervals from sampled data. The bootstrap approach is based on the principle that, in the absence of any other knowledge about a population, the distribution of values found in a random sample is the best guide to the distribution in the population. The data values are sampled with replacement and the statistics computed through many iterations. These computed values, the bootstrap sample, are used to estimate properties of the statistic such as confidence intervals.

Broad Habitats: a classification by the UK Biodiversity Group to encompass the entire range of UK habitats as an aid to the implementation of, and reporting under, the UK Biodiversity Action Plan.

CIS: see Countryside Information System.

Class Variants: 72 in number, are a thematic aggregation of spectral subclasses and components of Target classes and Subclasses.

Core pixels: those pixels of a segment which extracted after shrinking the segment geometry to avoid edge-pixels; they were used in deriving training statistics and/or in deriving a segment's mean reflectance values for use in classification.

Countryside Information System: a Microsoft Windows-based program developed to give policy advisers, planners and researchers easy access to spatial information about the British countryside, especially Countryside Survey data.

CS1990: Countryside Survey 1990

CS2000: Countryside Survey 2000.

DTM: digital terrain model.

ETM: Enhanced Thematic Mapper, a sensor on the satellite, Landsat 7, recording visible and infrared reflectances.

EZ: Environmental Zone, a simplification of the 40 Land classes of Britain into 6 zones, with Northern Ireland forming a seventh.

FS: field survey (here referring specifically to the field element of Countryside Survey 2000).

GIS: geographical information system.

IRS: Indian Research Satellite

KBC: Knowledge-based correction.

Land classes: a stratification of the landscape of Britain to ensure that the sample field survey of CS2000 is representative of the range of different environments found in England, Wales and Scotland. There were 40 strata in CS2000, based upon the original 32 ITE Land Classes of CS1990; in 2000, the original 32 were subdivided to give classes which were specific to the 3 countries (i.e. individually, they did not cross borders): the resultant 40 classes (Haines-Young *et al.* 2000) are thus sometimes called National Land Classes.

LCM2000: Land Cover Map 2000.

LCMGB: Land Cover Map of Great Britain (the survey of 1988-92 which was part of Countryside Survey 1990).

Level-2 Dataset: ARC/View 'Shape Files' which record a topologically structured vector dataset carrying the following attributes: a unique segment label; a total pixel count; a count of core pixels; a classification giving Target class / Subclass (26 types) coded to relate to the widespread BH; a process history descriptor (with scene-identifier, probability indices and KBC rules applied).

Level-3 Dataset: ARC/View 'Shape Files' which record a topologically structured vector dataset carrying the following attributes: a unique segment label; a total pixel count; a count of core pixels; a classification giving Target class / Subclass / Variant (72 types overall) coded to relate to the widespread BH; a process history descriptor (with scene-identifier, probability indices and KBC rules applied).

LISS: the Linear Imaging Self-scanning Sensor of the Indian Research Satellite.

MIR: middle infrared.

MMU: Minimum mappable unit. LCM2000 retains all segments with 9 or more pixels (on the basis that a 3 x 3 pixel segment can contain a 'pure' core pixel); segments with ≤ 8 pixels (≤ 0.5 ha in area) are 'dissolved' into surrounding segments, with each pixel individually attached to the neighbouring segment which was most similar in spectral character.

NIR: near infrared.

Object: an item, in fact a polygon, in the LCM2000 GIS database.

Parcel: a parcel (sometimes called specifically a 'land parcel') is an area on the ground, often a field but perhaps with no boundary such as a woodland, a patch of relatively uniform vegetation (e.g. heath), a built up area, or a water body.

Peat drift: includes all superficial strata of peat, based on a British Geological Survey drift map (http://www.bgs.ac.uk/products/digitalmaps/digmapgb_drift.html). Peat drift is used to define bogs (i.e. with peat depth > 0.5 m) as distinct from heaths and moors (with peat < 0.5 m).

Per-parcel comparisons: where field survey parcels and their classes were compared with a class-label for the same parcel derived from LCM2000.

Per-pixel comparisons: between field survey maps and LCM2000 maps - a direct overlay, with no regard to the structure of either dataset.

Per-segment comparisons: where labels in LCM2000 segments are compared with the segment's dominant class according to field survey.

Raster: a grid-based data structure used in GIS and image analysis systems.

Raster Dataset: specifically here the derived dataset from the Subclasses of the Level-2 Dataset giving a 25 m grid-based map incorporating the spatial refinements of LCM2000 (i.e. based on per-segment classification, and generalised accordingly).

Segment: the spectrally-defined aggregation of image pixels into a vector polygon, held in the GIS database; the term 'segment' is intended to distinguish the resultant feature from a 'land parcel' which refers to the actual feature on the ground. Often, segments record parcels, but with differences which relate to the underlying 25 m structure of the image.

Spectral classes: cover types with distinct spectral signatures: for example, 'shaded north-facing' and 'sunlit south-facing' are two distinct spectral classes of 'improved grass'; chalk, clay and peat soil background give different spectral classes of 'wheat'. Spectral classes may differ according to species content, crop variety, phenology, management practices, atmospheric haze, cloud shadow or any other factor with an impact on the recorded spectral reflectance.

Subclasses: 26 in number, an aggregation of the thematic class **Variants**; they were defined to give, as far as possible, the full complement of Broad Habitats; they also give details beyond the BH classification.

Summary Products: several products at 1 km: class dominance at the 26 Subclass level, stored as a single layer dataset; summary % cover per 1 km², for the 26 Subclass types (i.e. a 26-layer dataset); class dominance dataset in CIS format; the Subclass dataset in CIS format; an Aggregate class dataset in CIS format.

Summer target period: the main growing season for arable crops, from mid-May to late July in southern Britain, or later in Scotland, excluding May but continuing into August; 1998 was the first choice year, then 1999, 2000, and 2001.

Target classes: 16 in number, giving the nearest match to Broad Habitats which could be achieved consistently and with a high level of accuracy; where there are fundamental differences in the exact definitions of Broad Habitats and Target classes this is reflected by differences in the selected Subclass nomenclature.

Target period: see 'Summer target period' and 'Winter target period'.

Training: the procedure by which a sample of known cover types is defined in the image processing system to deduce the spectral characteristics of classes, to form the basis for automatic extrapolation by the system to classify examples of unknown land cover.

TM: Thematic Mapper, a sensor on the Landsat 5 satellite, recording visible and infrared reflectances.

Variants: see **class Variants**.

Vector: a digital line held as a series of x-, y-coordinates in a geographical information system.

Winter target period: from the time of the first frosts (about October) to late April in southern Britain and well into May in the Scottish Highlands (i.e. until deciduous trees were in full leaf); the target winter was from Autumn 1997 to Spring 1998, but winters of 1998-99, 1999-00 and 2000-01 were also considered.

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APPENDIX I. IMAGES USED IN CONSTRUCTION OF LAND COVER MAP 2000

Summer or winter	Sensor	Date	Full or part-scene	Primary data or infill	Satellite path	Row (standard scenes)	Latitude (special orders)	Longitude (special orders)
W	TM	21/11/1996	Full	Infill	203	-	51°57'N	2°19'W
W	TM	15/01/1997	Full	Infill	204	23		
W	TM	04/03/1997	Full	Primary	204	21		
S	TM	30/05/1997	Full	Infill	205	21		
S	TM	30/05/1997	Full	Primary	205	22		
S	TM	04/06/1997	Full	Primary	208	20		
S	TM	10/07/1997	Full	Primary	204	23		
W	TM	10/09/1997	Full	Infill	206	22		
W	TM	21/09/1997	Full	Infill	203	22		
W	TM	21/09/1997	Full	Infill	203	23		
W	TM	21/10/1997	Quarter	Primary	205	24 Q3		
W	TM	21/10/1997	Quarter	Primary	205	-	53°1'N	4°17'W
W	TM	28/10/1997	Full	Primary	203	-	51°24'N	2°39'W
W	TM	28/10/1997	Full	Primary	206	22		
W	TM	01/11/1997	Quarter	Primary	202	-	54°0'N	0°13'E
W	TM	01/11/1997	Full	Primary	202	-	52°46'N	0°30'E
W	TM	01/11/1997	Full	Primary	202	-	51°13'N	1°12'W
W	TM	01/12/1997	Full	Primary	204	22		
W	TM	12/12/1997	Quarter	Infill	201	-	51°7'N	0°22'E
W	TM	22/12/1997	Full	Primary	207	19		
W	TM	22/12/1997	Full	Primary	207	20		
W	TM	25/01/1998	Full	Primary	205	22		
W	TM	25/01/1998	Quarter	Primary	205	-	50°23'N	5°32'W
W	TM	03/02/1998	Full	Primary	204	23		
W	TM	03/02/1998	Full	Primary	204	24		
W	TM	03/02/1998	Full	Primary	204	25		
W	TM	14/02/1998	Full	Primary	201	-	52°48'N	1°1'E
W	TM	14/02/1998	Full	Primary	201	-	51°13'N	0°18'E
W	TM	28/02/1998	Full	Primary	203	22		
W	TM	28/02/1998	Full	Primary	203	23		
W	TM	28/02/1998	Quarter	Primary	203	-	55°37'N	1°24'W
W	TM	01/05/1998	Full	Primary	205	21		
S	LISS III	01/05/1998	Full	Primary	012	031		
S	LISS III	01/05/1998	Full	Primary	012	-	+ 20% S	
WS	LISS III	13/05/1998	Full	Primary	004	27		
S	TM	14/05/1998	Quarter	Primary	200	23 Q3	-	-
S	LISS III	16/05/1998	Full	Primary	015	030		
S	LISS III	16/05/1998	Full	Primary	015	031		
S	LISS III	16/05/1998	Full	Primary	015	032		
S	TM	19/05/1998	Quarter	Primary	203	-	55°15'N	1°36'W
S	TM	19/05/1998	Full	Primary	203	-	54°1'N	1°28'W
S	TM	19/05/1998	Full	Primary	203	-	52°26'N	2°14'W
S	TM	19/05/1998	Full	Primary	203	-	50°57'N	2°53'W
S	LISS III	20/05/1998	Full	Primary	011	031		
S	LISS III	20/05/1998	Full	Primary	011	-	+ 40% S	
S	TM	30/05/1998	Full	Primary	200	24	-	-
S	TM	30/05/1998	Mini	Primary	200	-	50°56'N	0°54'E

Summer or winter	Sensor	Date	Full or part-scene	Primary data or infill	Satellite path	Row (standard scenes)	Latitude (special orders)	Longitude (special orders)
S	TM	09/08/1998	Full	Primary	201	-	52°17'N	0°46'E
S	TM	09/08/1998	Quarter	Primary	201	-	50°57'N	0°0'E
W	TM	20/09/1998	Full	Primary	207	-	54 40' N	7 21' W
W	TM	16/11/1998	Full	Primary	206	21		
SW	LISS III	13/05/1999	Full	Primary	004	26		
S	TM	18/05/1999	Full	Primary	207	21		
S	TM	18/05/1999	Full	Primary	207	22		
S	TM	20/05/1999	Full	Primary	205	21		
S	L7ETM	29/07/1999	Full	Infill	207	19		
S	L7ETM	29/07/1999	Full	Primary	207	19		
S	L7ETM	29/07/1999	Full	Primary	207	20		
S	TM	30/07/1999	Full	Primary	206	20		
S	TM	30/07/1999	Full	Primary	206	21		
S	TM	30/07/1999	Full	Primary	206	22		
S	L5TM	01/08/1999	Full	Primary	204	020	56°50'N	1°41'W
S	TM	01/08/1999	Full	Primary	204	21		
S	TM	01/08/1999	Full	Primary	204	22		
S	L7ETM	10/09/1999	Full	Primary	204	23		
W	L7ETM	17/09/1999	Full	Primary	205	19		
W	L7ETM	17/04/2000	Full	Primary	202	023		
W	LISS III	04/05/2000	Full	Primary	010	26	+70% S	
W	L7ETM	05/05/2000	Full	Primary	206	20		
SW	LISS III	07/05/2000	Full	Primary	004	028	+80% S	
SW	LISS III	10/05/2000	Full	Primary	003	028	+90% S	
W	L7ETM	12/05/2000	Full	Infill	207	19		
W	L7ETM	12/05/2000	Full	Infill	207	20		
SW	L5TM	13/05/2000	Full	Primary	206	019		
S	L7ETM	29/07/2000	Full	Primary	207	022		
S	LISS III	08/08/2000	Full	Primary	010	024		
W	L5TM	26/09/2000	Full	Primary	206	018		
S	L7ETM	12/05/2001	Full	Infill	202	022		
S	L7ETM	13/05/2001	Full	Infill	202	023		

SW/WS codes indicate borderline decisions with actual use first

TM is Landsat 5 Thematic Mapper

L7ETM is Landsat 7 Enhanced Thematic Mapper

LISS III in the Indian Research Satellite

Special orders are those shifted from standard path-row format

APPENDIX II. A BRIEF REVIEW OF BROAD HABITATS WITH AN ASSESSMENT OF THEIR DISTINGUISHING FEATURES IN RELATION TO LCM2000 MAPPING.

1. Broad-leaved, mixed and yew woodland	Broad-leaved woodlands are characterised by stands >5 m high with tree cover >20%; scrub (<5 m) requires cover >30% for inclusion in this BH. Such fine distinctions cannot be made through remote sensing. It is a particular problem, albeit relatively rare, that open-canopy woodland (stands with trees <<50%) are in the BH; they may not be mapped consistently, due to the dominance of the non-woodland plants. Stands with near-closed canopies can be interpreted straightforwardly in the field and pure examples can normally be found for training the classifier. Broad-leaved evergreen trees (a part of this BH) rarely occur in stands >1ha, suitable for training and thereby appropriate for classification. Mixed woodland (with >20% broadleaved trees) was trained separately though, where individual stands of broad-leaved or evergreen trees exceeded the minimum mappable unit, they were treated as separate blocks within the woodland: in many parts of the UK, truly 'mixed woodlands' as opposed to those with mosaic-blocks of broadleaved and coniferous trees, are unusual.
2. Coniferous woodland	Coniferous woodland includes semi-natural stands and plantations. Cover should be >20%. The recognition of coniferous woodland is generally straightforward. Rare examples of open canopy semi-natural pinewoods may have been classified according to the dominant understorey class. The BH includes new plantation and recently felled areas (this is a class where the BH definition is based on land use, i.e. forestry, rather than cover). New plantations, predominantly heather and/or grass, for example, are recorded as such by the spectral classification of image data. New plantations are only be recorded as conifers when tree cover is sufficient to strongly influence the reflectance. LCM2000 includes newly felled areas. Once they are fully recolonised by rough grass, heath or scrub, they are recorded according to that cover. Deciduous larch is discernible from other deciduous trees and generally, correctly, included with other conifers.
3. Boundaries and linear features	Only the largest of linear features (e.g. shelter belts, motorways) might be mapped by the classification of satellite images. The field survey provides by far the best information on these BHs.
4. Arable and horticulture	This Broad Habitat includes annual crops, perennial crops such as berries and orchards, plus freshly ploughed land, annual leys and rotational setaside. Distinction of rotational setaside relies heavily upon the summer-winter composite images to demonstrate the seasonal characteristic and thereby help spectral distinction. Orchards with a ground flora are hard to distinguish and the class relies upon knowledge-based corrections using interpretations made for CORINE Land Cover mapping (Brown & Fuller, 1996). Setaside vegetated with ruderal weeds and rough grassland are included with the improved grass BH, but distinguished by LCM2000 at the subclass level.

6. Neutral grassland	The three semi-natural swards are the converse of the above and rely upon the assumptions as above. Where pH is known, separate field-identification, training and classification is used. However, a soil ‘acid sensitivity’ map is the deciding factor when distinguishing neutral from calcareous and acid grasslands. Under the final-stage ‘knowledge-based correction’ pH >4.5 and < 5.5 denotes ‘neutral’ soils. This range is not ideal tending towards the acid side of ‘neutral’; however, the acid sensitivity map only offers 3 classes and this range, described as ‘moderately sensitive’ to acidification, is the nearest category to neutral. Using this pH level will tend to over-estimate ‘neutral soils’ and identify them in borderline acid situations.
7. Calcareous grassland	The same details apply as did to neutral grass but with the pH > 5.5. Again, the range is far from ideal; the acid sensitivity map describes this pH range as having ‘low sensitivity’ to acidification. This will tend to over-estimate ‘calcareous soils’, including neutral examples; however, there was no better alternative available.
8. Acid grassland	As above, but pH <4.5 denotes ‘acid’ soils. This range is appropriate.
5. Improved grassland	Improved grasslands will be distinguished from semi-natural grass. The criteria used by field surveyors (dominance of palatable grasses) also gives the grasslands a distinct spectral signature. It is recognised that management practices (heavy grazing) can obscure this dominance and might cause mis-classifications with semi-natural swards. However, the field training course and trial reconnaissance surveys suggest separation is feasible. If accuracies are lower than the intended 90% per-parcel, then the target classification will be that of the Specification (without distinction between semi-natural and improved swards), but the distinction will be retained at the subclass level.
5. Improved grassland continued	Integration of the broad assessment with specific field estimates might prove especially powerful as a guide to the spatial distributions and quantities of the various agricultural grasslands. Setaside grass, though to be included in this category, may be confused with rough neutral grass once well-established.
6. Neutral grassland	The three semi-natural swards are the converse of the above and rely upon the same assumptions as above. Where pH is known, separate field-identification, training and classification is used. A soil ‘acid sensitivity’ map is the main way of distinguishing neutral from calcareous and acid grasses: under the final-stage ‘knowledge-based correction’ pH >4.5 and < 5.5 denotes ‘neutral’ soils.
7. Calcareous grassland	The same details apply as did to neutral grass but with the pH > 5.5.
8. Acid grassland	As above, but pH <4.5 denotes ‘acid’ soils.
9. Bracken	There were problems in the accurate mapping of bracken in 1990 so it was not written into the Specification as a ‘target class’. However, dense bracken is distinguished (excepting woodland stands) at the subclass level; it should be recognised that bracken often fails to offer stands sufficiently extensive for classification and training.
10. Dwarf shrub heath	This Widespread Habitat is essentially an aggregation of LCM1990's <i>Open</i> and <i>Dense Shrub Heaths</i> . This means that the Habitat could generally be identified on LCM2000 with no particular difficulties. However, the Broad habitat classification treats ericaceous vegetation on peat > 0.5 m depth as ‘bog’. A drift map showing peat-soils is used to distinguish heaths from ericaceous bogs.

11. Fen, marsh and swamp	This Habitat includes fen, fen meadows, rush pasture, swamp, flushes and springs. Apart from rush pasture, examples of the Habitat are relatively rare, and seldom extensive enough to map as pixels, let alone polygons and records for Britain are likely to be localised. Though there are indications that dominant rush cover influences the spectral characteristics of a parcel enough to make the distinction, the final accuracy with which rush pastures is distinguished will only be apparent after validation.
12. Bog	The bog category includes ericaceous, herbaceous and mossy swards in areas with a peat depth > 0.5 m. The peat drift maps are the final control over the bog category. Areas classified as 'bog' but with <0.5 m are corrected to grass moor or heath, according to dominant cover type.
13. Standing open water and canals	Water bodies > 0.5 ha are readily mapped. There will be few if any canals which can be mapped at satellite image scales - they effectively form linear features.
14. Rivers and streams	Only the widest of rivers (>50 m) are shown accurately, though such information might be drawn from other maps. They will not be distinguished from class 13. Standing water, except perhaps contextually (e.g. through use of digital maps of rivers).
15. Montane habitats	This class should be clearly identifiable by context and the presence of vegetation cover at a sparse level should distinguish Montane habitats from 26. Inland Rock.
16. Inland rock	This Habitat includes natural and man-made bare ground.
17. Built up areas and gardens	This Habitat is a combination of Suburban / rural development and Continuous urban categories of 1990. LCM2000 identifies these as subclasses. It records the heterogeneity of urban land, e.g. the vegetation cover in parks and larger gardens, bare urban ground and the tillage of allotments, in more detail than is required by the Broad Habitat classification.
18. Supra-littoral rock	Distinction between rock from sediment is done contextually, by defining a vector region encompassing rocky coastlines. Distinction of <u>supra</u> -littoral needs us to define a high water mark: this is only straightforward for major features. However, rarely are there extensive areas of supra-littoral rock.
19. Supra-littoral sediment	Sedimentary coasts are also defined interactively. Large areas of supra-littoral sediment occur as beaches, mudflats, dunes and shingle beaches. Distinction of the <u>supra</u> -littoral component uses the terrestrial mask, derived from LCMGB 1990, updated with changes, where appropriate.
20. Littoral rock	These classes are those in the maritime mask zone on a rocky coastline. They are generally more extensive than supra-littoral rock and thus more readily mappable from satellite images.
21. Littoral sediment	Littoral sediments are those in the maritime zone, on sedimentary coasts; they may be very extensive. Saltmarsh is included with this Broad Habitat but mapped as a separate subclass by LCM2000.
22. Inshore sublittoral sediment	All areas of sea and estuary class are assumed to be inshore and sublittoral sediment, without distinction of rocky substrata.
23. <i>Inshore sublittoral rock</i> , 24. <i>Offshore shelf sediment</i> , 25. <i>Offshore shelf rock</i> , 26. <i>Continental shelf slope</i> and 27. <i>Oceanic seas</i> are irrelevant in the context of a land cover map.	

APPENDIX III. LCM2000 CLASS VARIANTS MAPPED ONTO BROAD HABITATS, WITH CODES, CODE NUMBER, APPROXIMATE COLOUR AND THE ACTUAL RED-GREEN-BLUE COLOUR MIX (0-255) USED ON MAPS

BH (name abbreviated)	Variants	Alpha-code	Number	R	G	B
22. Inshore sublittoral	sea	We	22.1.1	0	0	128
13. Standing water/canals	water (inland)	W	13.1.1	0	0	255
20. Littoral rock	rock	Lr	20.1.1	255	255	128
	rock with algae	Lra	20.1.2			
21. Littoral sediment	mud	Lm	21.1.1			
	sand	Ls	21.1.2			
	sand with algae	Lsa	21.1.3			
	saltmarsh	Lsm	21.2.1	128	102	255
	saltmarsh (grazed)	Lsg	21.2.2			
18. Supra-littoral rock	rock	Sr	18.1.1	204	179	0
19. Supra-littoral sediment	shingle (vegetated)	Sh	19.1.1			
	shingle	Shv	19.1.2			
	dune	Sd	19.1.3			
	dune shrubs	Sds	19.1.4			
12. Bog	bog (shrub)	Bh	12.1.1	0	128	115
	bog (grass/shrub)	Bhg	12.1.2			
	bog (grass/herb)	Bg	12.1.3			
	bog (undifferentiated)	Bo	12.1.4			
10. Dwarf shrub heath	dense (ericaceous)	H	10.1.1	128	26	128
	gorse	Hg	10.1.2			
	open	Hea	10.2.1	230	140	166
15. Montane habitats	montane	Z	15.1.1	0	180	190
1. Broad-leaved woodland	deciduous	D	1.1.1	255	0	0
	mixed	Dm	1.1.2			
	open birch	Db	1.1.3			
	scrub	Ds	1.1.4			
2. Coniferous woodland	conifers	C	2.1.1	0	102	0
	felled	Cf	2.1.2			
	new plantation	Cn	2.1.3			
4. Arable & horticultural	barley	Ab	4.1.1	102	0	0
	maize	Am	4.1.2			
	oats	Ao	4.1.3			
	wheat	Aw	4.1.4			
	cereal (spring)	Acs	4.1.5			
	cereal (winter)	Acw	4.1.6			
	arable bare ground	Aba	4.2.1			
	carrots	Ac	4.2.2			
	field beans	Af	4.2.3			
	horticulture	Ah	4.2.4			
	linseed	Al	4.2.5			
	potatoes	Ap	4.2.6			
	peas	Aq	4.2.7			
	oilseed rape	Ar	4.2.8			
	sugar beet	As	4.2.9			
	unknown	Au	4.2.10			
	mustard	Ax	4.2.11			
	non-cereal (spring)	Ans	4.2.12			
	orchard	Ado	4.3.1			
	arable grass (ley)	Agl	4.3.2			
	setaside (bare)	Asb	4.3.3			
	setaside (undifferentiated)	Ase	4.3.4			
5. Improved grassland	intensive	Gi	5.1.1	0	255	0
	grass (hay/ silage cut)	Gih	5.1.2			
	grazing marsh	Gim	5.1.3			
	grass setaside	Gis	5.2.1	255	177	0
6. Neutral	rough grass (unmanaged)	Grn	6.1.1			
	grass (neutral / unimproved)	Gn	6.1.2			
7. Calcareous	calcareous (managed)	Gc	7.1.1	180	255	180
	calcareous (rough)	Grc	7.1.2			
8. Acid	acid	Ga	8.1.1	153	128	0
	acid (rough)	Gra	8.1.2			
	acid with <i>Juncus</i>	Gaj	8.1.3			
	acid <i>Nardus/Festuca/Molinia</i>	Gam	8.1.4			
9. Bracken	bracken	Gbr	9.1.1	255	100	60
11. Fen, marsh and swamp	swamp	Fs	11.1.1	255	255	0
	fen/marsh	Fm	11.1.2			
	fen willow	Fw	11.1.3			
17. Built up areas, gardens	suburban/rural developed	Us	17.1.1	128	128	128
	urban residential/commercial	U	17.2.1	0	0	0
	urban industrial	Ui	17.2.2			
16. Inland rock	despoiled	Id	16.1.2			
	semi-natural	Ib	16.1.1	210	210	255
20 BHs	72 target/subclasses/variants					

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