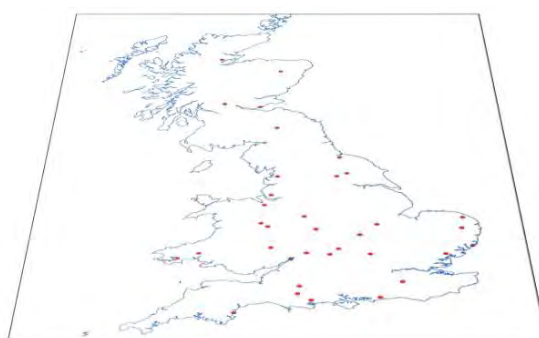


Tree cover outside woodland in Great Britain

National Forest Inventory

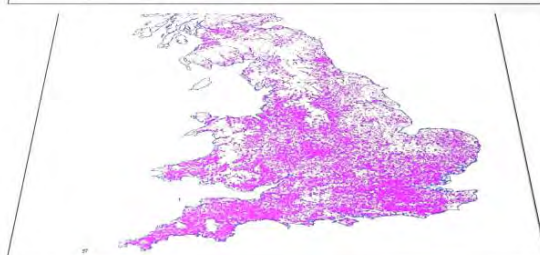
Fieldwork



Aerial photography
hand mapping



Tree map from image
analysis



Issued by: National Forest Inventory
Forest Research
231 Corstorphine Road
Edinburgh, EH12 7AT

Date: April 2017

Enquiries: Ben Ditchburn,
Tel. 0300 067 5064
NFI@forestry.gsi.gov.uk

Summary

The National Forest Inventory provides a record of the size and distribution of forests and woodlands in Great Britain and information on key forest attributes. This report provides the Forestry Commission's first estimates since 2002 of the amount of tree cover outside NFI woodland areas¹ in the form of small woods, groups of trees and lone trees. In addition, it provides estimates of sub-categories of these broad tree feature classes and estimates of hedgerow areas and lengths. It includes estimates for England, Scotland and Wales, broken down by both NFI Regions and urban and rural areas.

The report identifies that Britain has an estimated 742 thousand hectares of tree cover outside woodland, composed of small woods of over 0.1 hectare in size, groups of trees and lone trees. NFI woodland occupies just over 3 million hectares or 13.4 % of Britain's land area. If the additional 742 thousand hectares of tree cover outside woodland identified in this report is added to that woodland area, the total equates to circa 3.8 million hectares or 16.7% of Britain being under woodland area or tree cover outside woodland.

This is substantially more tree cover outside woodland than has previously been reported. This observation will in part be due to the tree planting schemes of the last few decades, but in the main represents assessing tree cover that was previously present, but not identified. Reporting the full extent of tree canopy outside woodland has been possible through the application of improved techniques and technologies in earth observation, Geographic Information Systems (GIS) and statistics.

Definitions of the terms used in this report can be found in the Definitions and terminology section and in the Glossary in the Appendix.

A companion *Summary Report* is also available at www.forestry.gov.uk/inventory.

¹ (over half a hectare in extent and greater than 20 metres in width)

Key findings

- There are 742 thousand hectares of tree cover outside areas NFI woodland in Britain as at January 2016²; 565 thousand hectares in England, 84 thousand hectares in Scotland and 93 thousand hectares in Wales.
- Rural³ tree cover outside woodland accounts for 546 thousand hectares of tree cover outside woodland in total, some (74%) and 196 thousand hectares (26%) are within urban areas. Non-woodland tree cover amounts to 11% of land area in urban areas and 3% in rural areas.
- Total tree cover, including both woodland tree cover and tree cover outside woodland, is 16.5% in urban areas and 16.7% in rural areas.
- Small woods of over 0.1 hectare in extent account for 390 thousand hectares in Britain; 295 thousand hectares in England, 46 thousand hectares in Scotland and 49 thousand hectares in Wales.
- Groups of trees less than 0.1 hectare in extent account for 255 thousand hectares of Britain; 193 thousand hectares in England, 29 thousand hectares in Scotland and 33 thousand hectares in Wales.
- There is estimated to be a total canopy cover of 97 thousand hectares associated with lone trees⁴ in Britain. By country there are 78 thousand hectares in England, 9 thousand hectares in Scotland and 10 thousand hectares in Wales. This represents 30.1 million lone trees in Britain; 22.2 million in England, 6.4 million in Scotland and 1.6 million in Wales.
- Of the 390 thousand hectares of small woods, 164 thousand hectares or 42% are in the form of linear features, such as those lining roads and rivers.
- The majority of small woods, groups and lone trees are found in the lowland areas of Britain, at an altitude of less than 200m, with 91% of features found below this height.
- There are 452 thousand kilometres (281 thousand miles) of hedgerows in Britain; 336 thousand kilometres (209 thousand miles) in England, 41 thousand kilometres (25 thousand miles) in Scotland and 76 thousand kilometres (47 thousand miles) in Wales⁵.

² Mid date of the fieldwork assessments, to which all other data is calibrated.

³ Rural and urban as defined by the Ordnance Survey Strategi[®] dataset.

⁴ Trees over 2 metres in height, unless in hedgerows, for which the minimum height is 3 metres.

⁵ 1 kilometre=0.621 miles.

**Table 1** Areas of woodland and tree cover outside woodland as a % of total land area

Region	Total land area	NFI woodland		Tree cover outside woodland			Total area of woodland and tree cover
	(000 ha)	(000 ha)	% of land area	(000 ha)	% of land area	SE%	% of land area
Great Britain	22,895.4	3,074.6	13.4	742.3	3.2	5	16.7
England	13,030.8	1,336.4	10.3	565.0	4.3	5	14.6
North West England	1,410.5	120.0	8.5	51.4	3.6	6	12.2
North East England	857.4	117.0	13.6	21.4	2.5	9	16.1
Yorkshire and the Humber	1,540.5	117.2	7.6	43.9	2.8	8	10.5
East Midlands	1,562.3	100.9	6.5	57.0	3.6	6	10.1
East England	1,911.9	156.4	8.2	80.4	4.2	6	12.4
South East and London	2,064.5	332.9	16.1	123.8	6.0	6	22.1
South West England	2,383.7	265.7	11.1	113.0	4.7	7	15.9
West Midlands	1,299.8	126.2	9.7	74.2	5.7	8	15.4
Scotland	7,791.0	1,429.0	18.3	84.5	1.1	13	19.4
North Scotland	1,744.4	237.4	13.6	10.8	0.6	42	14.2
North East Scotland	1,142.0	236.9	20.7	13.0	1.1	23	21.9
East Scotland	866.8	140.2	16.2	19.6	2.3	28	18.4
South Scotland	1,997.4	435.2	21.8	34.3	1.7	14	23.5
West Scotland	2,040.5	379.3	18.6	6.9	0.3	28	18.9
Wales	2,073.6	309.3	14.9	92.7	4.5	7	19.4

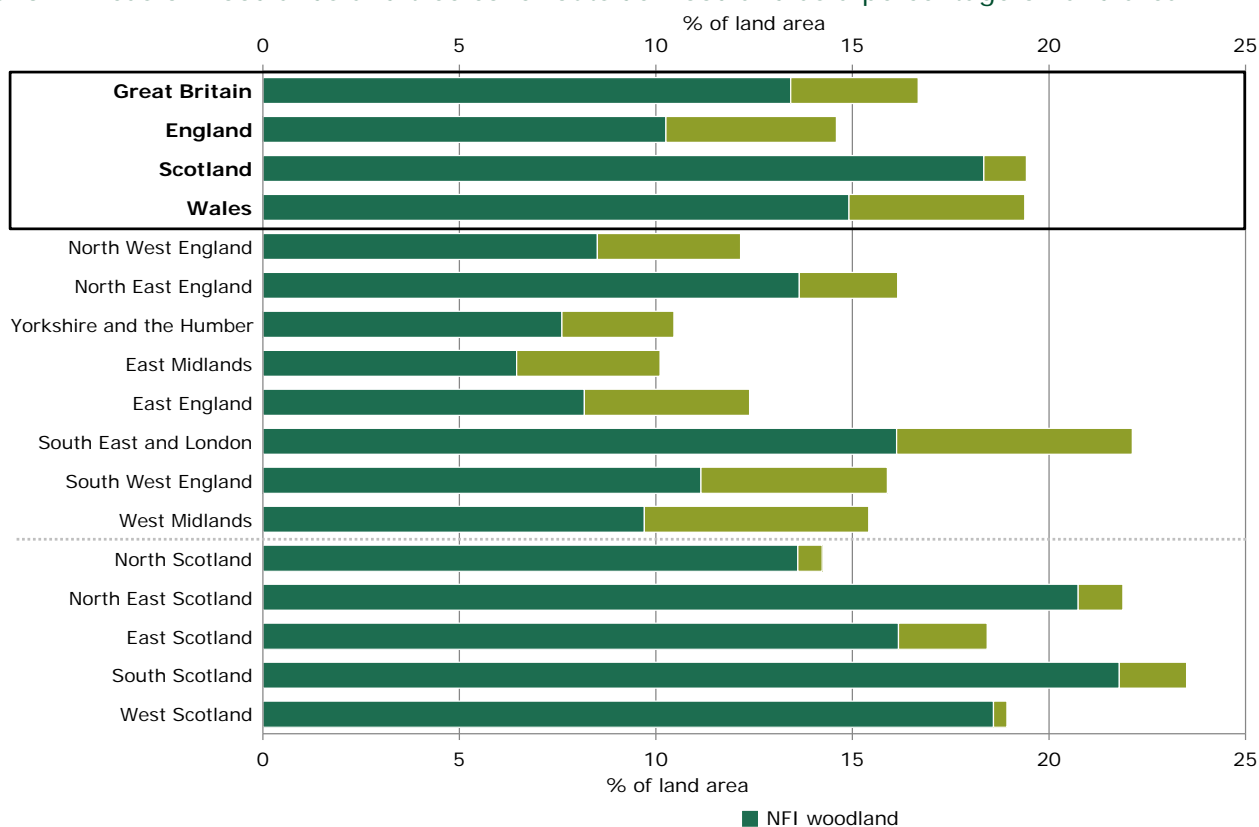
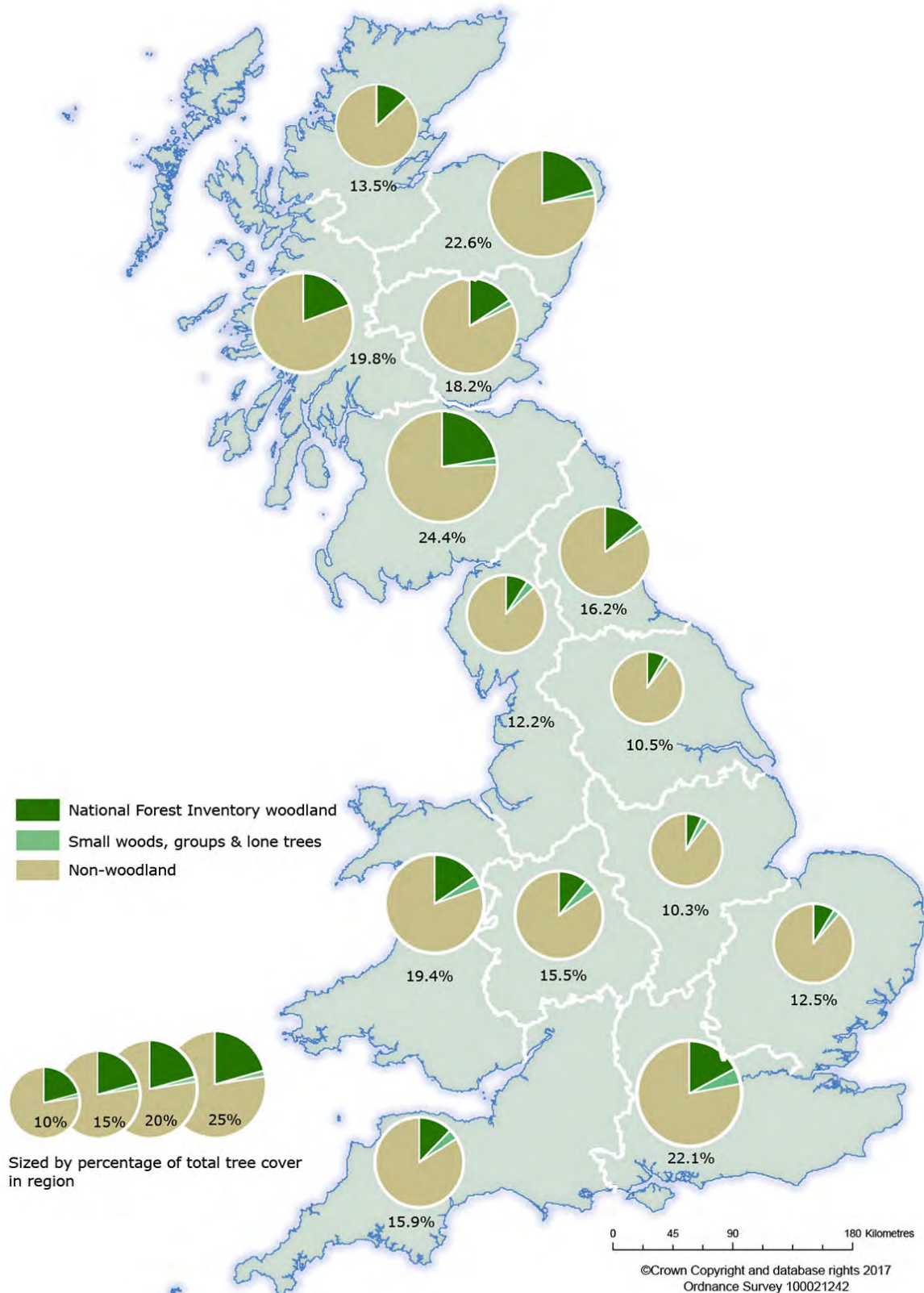
Figure 1 Areas of woodlands and tree cover outside woodland as a percentage of land area

Table 2 Summary area of woodlands and categories of tree cover outside woodland

Region	Total NFI woodland	Small woods		Groups of trees		Lone trees		Total area of woodland and tree cover	
	(000 ha)	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	3,074.6	390.2	7	255.4	6	97.1	6	3,817.4	1
England	1,336.4	294.8	6	192.6	6	78.2	7	1,901.9	1
North West England	120.0	24.2	8	18.5	8	8.9	12	171.7	2
North East England	117.0	12.1	13	6.6	10	2.7	15	138.5	1
Yorkshire and the Humber	117.2	22.8	12	12.7	10	8.4	10	161.2	2
East Midlands	100.9	25.8	10	23.8	8	7.8	11	158.3	2
East England	156.4	39.3	8	31.5	8	9.7	11	236.9	2
South East and London	332.9	65.3	9	43.5	8	14.9	13	456.6	2
South West England	265.7	64.7	11	34.7	8	13.3	10	378.5	2
West Midlands	126.2	40.7	12	21.1	9	12.4	11	200.3	3
Scotland	1,429.0	46.2	21	29.5	12	8.9	15	1,513.5	1
North Scotland	237.4	6.4	63	3.1	39	1.3	58	248.2	2
North East Scotland	236.9	6.8	34	5.2	28	1.0	34	249.9	1
East Scotland	140.2	10.4	45	6.7	27	2.5	32	159.8	3
South Scotland	435.2	18.9	21	11.9	15	3.5	16	469.4	1
West Scotland	379.3	3.8	38	2.7	39	0.5	36	386.2	0
Wales	309.3	49.2	8	33.4	9	10.1	17	401.9	1



Figure 2 Total percentage of land covered by woodland and tree cover outside woodland



Contents

Summary	2
Key findings	3
List of tables	11
Introduction	12
Background	13
History of Small Woods surveys	13
Definitions and terminology	15
<i>NFI woodland</i>	<i>19</i>
<i>New NFI woodland and extra NFI woodland</i>	<i>19</i>
<i>Small woods</i>	<i>20</i>
<i>Groups of trees</i>	<i>22</i>
<i>Lone trees</i>	<i>23</i>
<i>Hedgerows</i>	<i>25</i>
Data and methods overview	28
<i>Data used for England and Wales only</i>	<i>28</i>
<i>Data used for Scotland only</i>	<i>28</i>
<i>Data across Great Britain</i>	<i>30</i>
Results	34
<i>National Forest Inventory woodland</i>	<i>36</i>
NFI woodland and tree cover outside woodland	38
<i>Major categories of tree cover outside woodland</i>	<i>41</i>
<i>Breakdown of major categories of tree cover outside woodland</i>	<i>44</i>
Area of small woods	44
Number of small woods features	47
Size of small woods	48
<i>Groups of trees</i>	<i>49</i>
Area of groups of trees	49
Number of groups of trees	52
Sizes of groups of trees	54

<i>Lone trees</i>	55
Areas of canopies of lone trees	55
Number of lone trees	58
Sizes of lone trees	60
<i>Hedgerows</i>	61
Area of hedgerows	61
Trees within hedgerows	65
<i>Maps</i>	68
What the results tell us	73
Future work	74
Glossary	75
Appendices	76
<i>Appendix 1: Data and methodology</i>	76
(A) Data sources	76
(B) Statistical Analysis	83
<i>Appendix 2: Historical influences on tree cover</i>	93
<i>NFI national reports</i>	96

List of figures

Figure 1	Areas of woodlands and tree cover outside woodland as a percentage of land area ..	4
Figure 2	Total percentage of land covered by woodland and tree cover outside woodland.....	6
Figure 3	An example of woodland area and tree cover outside woodland	15
Figure 4	Illustrative map showing woodland and categories of trees outside woodland	16
Figure 5	NFI woodland features identified in the landscape	17
Figure 6	Tree cover outside woodland identified in the landscape	17
Figure 7	Tree cover outside woodland stratified into constituent categories	18
Figure 8	An example of NFI woodland over 0.5 hectare in extent	19
Figure 9	An example of a non-linear small wood	21
Figure 10	An example of a linear small wood	21
Figure 11	An example of a group of trees	22
Figure 12	An example of a linear group of trees	22
Figure 13	An example of a lone tree in open land	23
Figure 14	An example of lone trees on a boundary	24
Figure 15	An example of a hedgerow tree	24
Figure 16	An example of hedgerows	25
Figure 17	A one-by-one kilometre fieldwork square	29
Figure 18	Fieldwork and aerial photo hand mapping samples calibrate the 'tree map'	31
Figure 19	Schema of the double calibration process used to derive the estimates.....	33
Figure 20	NFI woodland area, extra NFI woodland and new NFI woodland areas	36
Figure 21	Areas of woodland and tree cover outside woodland	38
Figure 22	Rural areas of woodland and tree cover outside woodland	39
Figure 23	Urban areas of woodland and tree cover outside woodland	40
Figure 24	Areas of major categories of tree cover outside woodland	41
Figure 25	Number of features of major categories of trees outside woodland	42
Figure 26	How features are counted	43
Figure 27	Total area of small woods and sub-categories	44
Figure 28	Rural areas of small woods and sub-categories	46
Figure 29	Urban areas of small woods and sub-categories	46
Figure 30	Total number of small woods features including sub-categories	47
Figure 31	Number of small woods features including sub-categories in rural areas	48
Figure 32	Number of small woods features including sub-categories in urban areas	48
Figure 33	Total area of groups of trees and sub-categories	49
Figure 34	Rural areas of groups of trees and sub-categories	51
Figure 35	Urban areas of groups of trees and sub-categories	51
Figure 36	Number of groups of trees including linear and non-linear sub-categories	52
Figure 37	Number of features of groups of trees including sub-categories in rural areas.....	53
Figure 38	Number of features of groups of trees including sub-categories in urban areas	53
Figure 39	Areas of canopies of lone trees	55
Figure 40	Areas of canopies of lone trees in rural areas	57
Figure 41	Areas of canopies of lone trees in urban areas	57

Figure 42 Number of lone trees.....	58
Figure 43 Number of lone tree features in rural areas	59
Figure 44 Number of lone tree features in urban areas.....	59
Figure 45 Area of hedgerows	61
Figure 46 Length of hedgerows	63
Figure 47 Areas of canopies of hedgerow tree features	65
Figure 48 Area of canopies of hedgerow tree features in rural areas	67
Figure 49 Area of canopies of hedgerows tree features in urban areas	67
Figure 50 NFI woodland and tree cover outside woodland in Cumbria	69
Figure 51 Woodland and non-woodland tree cover in South Scotland.....	70
Figure 52 NFI woodland and tree cover outside woodland in South West England.....	71
Figure 53 NFI woodland and tree cover outside woodland in London and S.E. England	72
Figure 54 A one-by-one kilometre survey square in Devon	84
Figure 55 Population-level spatial relationship between primary and calibrating datasets	85
Figure 56 Sample-level spatial relationship.....	86

List of tables

Table 1 Areas of woodland and tree cover outside woodland as a % of total land area	4
Table 2 Summary area of woodlands and categories of tree cover outside woodland	5
Table 3 Definitions of NFI, categories of tree cover outside woodland, and hedgerows	26
Table 4 NFI woodland area, extra NFI and new NFI woodland by country, urban and rural ..	37
Table 5 Areas of woodland and tree cover outside woodland	38
Table 6 Rural areas of woodland and tree cover outside woodland	39
Table 7 Urban areas of woodland and tree cover outside woodland	40
Table 8 Areas of major categories of tree cover outside woodland	41
Table 9 Numbers of features of main categories of trees outside woodlands	42
Table 10 Mean sizes of non-woodland tree features	43
Table 11 Areas of small woods and sub-categories	45
Table 12 Total number of small woods features including sub-categories	47
Table 13 Small woods mean feature sizes	48
Table 14 Areas of groups of trees	50
Table 15 Number of groups of trees including linear and non-linear categories	52
Table 16 Mean sizes of groups of trees	54
Table 17 Areas of canopies of lone trees	56
Table 18 Number of lone trees	58
Table 19 Mean sizes of lone trees	60
Table 20 Areas of hedgerows by country and region	62
Table 21 Areas of hedgerows by country and rural and urban land categories	62
Table 22 Length of hedgerows	64
Table 23 Length of hedgerows by country and rural and urban land categories	64
Table 24 Area of canopies of hedgerow tree features	66
Table 25 Upland and lowland distribution of tree features outside woodland	68
Table 26 Numbers of hand mapped and fieldwork 1-by-1 Km sample squares	78
Table 27 Tree cover categories assessed and captured in the hand-mapping exercise	79
Table 28 Fieldwork woodland and non-woodland tree cover categories	82

Introduction

National forest inventories are carried out by the Forestry Commission to provide accurate, up-to-date information about the size, distribution, composition and condition of the forests and woodlands in Great Britain (GB). In tandem with the inventories of woodlands, the Forestry Commission has historically undertaken 'Small Woods' assessments to provide information on the amount and composition of tree cover outside woodlands, such as those associated with smaller woods, groups of trees and lone trees.

The current National Forest Inventory (NFI), which began in 2010 with the first cycle completed, and the second cycle started in 2015, involved the production of a forest and woodland map for GB and a continuing programme of field surveys of the mapped forest and woodland areas. Data collected by the National Forest Inventory is used for a number of purposes, including the reporting of current estimates and long-term forecasts of forest metrics such as:

- Standing volume and timber availability;
- Tree growth and increment;
- Carbon storage and biomass; and
- Biodiversity and social value of forests and woodlands.

This Inventory Report sets out the results (as at January 2016) for the current 'Small Woods' assessment and concerns the areas of tree cover outside woodland, broken down into areas of small woods, groups of trees and lone trees (see Figure 3). In addition, and as a by-product of the main work, the length and area of hedgerows in Britain are also provided.

The current assessment of 'Small Woods' began in 2012 and is based on a non-woodland tree map derived from the National Tree Map (NTM™) produced by Bluesky International Limited for England and Wales and a programme of field surveys and hand-mapping of non-woodland tree cover for the purposes of calibration of the map. The tree map covers most trees over 3 metres in height and was derived from national DTM, DSM, Aerial Photography and Colour Infrared data owned by Bluesky and some free mapping data. In addition to calibration and correction of the map, the field work, which was undertaken at a series of one-by-one kilometre squares across Britain, provides an assessment of trees under 3 metres. In Scotland no map product containing non-woodland trees was available and the estimates in this report are based solely on field work and hand-mapping of features at a series of one-by-one kilometre sample squares. The survey did not assess the composition of the non-woodland trees (tree species, age and tree health). Further information on this report and other National Forest Inventory outputs is available from www.forestry.gov.uk/inventory.

Background

Since 1924 Britain has monitored its woodlands and trees through a series of inventories, held at roughly 20-year intervals. These inventories have provided information on areas defined as woodland and also 'Small Woods' or trees outside woodland (e.g. those in small copses, lone trees, hedges etc.). Small woods have been defined in relation to the definition used as the threshold for larger woodland. This threshold has ranged from 1 acre to 2 hectares in past surveys and is currently set at 0.5 hectare, which is the minimum size of woodland under most international definitions of woodland⁶. The surveys reported not only the extent of these features, but also their tree species, composition and health, as well as basic mensuration data. Some surveys also assessed hedgerow extent.

The current National Forest Inventory (NFI) reports woodland areas in excess of 0.5 hectare, while trees outside woodland have been assessed in a separate exercise that is the subject of this report and is complementary to the mapping and surveying of NFI woodland.

History of Small Woods surveys

The history of modern censuses or surveys of woodlands and small woods started with the 1924 Census of Woodlands which used a minimum area of 2 acres (around 0.9 hectares) to define woodland. A similar survey was carried out in 1930 to update the 1924 figures but was less detailed. After the Second World War, work started on a new Census of Woodlands (i.e. the survey was not based on sampling) with a minimum woodland area of 5 acres (around 2 hectares). It was realised that further work would be required to complete the assessment of all trees and a further sample-based survey was undertaken to assess small woods.

This further survey entitled '*Hedgerow and Park Timber and Woods less than Five Acres 1951*' was based on the selection of every 100th map sheet at a scale of six inches to one mile (1:10,560). All woods on the map and any others subsequently found on ground inspection were assessed.

The results of the 1951 survey, when compared with the 1947 Census, showed that 21% of the nation's timber volume was to be found in hedgerow and park trees and a further 6% in woods of between one and five acres. This survey was considered to be very accurate and its findings are considered a reliable benchmark with which to compare other surveys.

A limited sample survey was carried out as part of the 1965 Census, to provide accurate timber production forecasts at a regional level. The information reported was utilised in the planning and development of the growing timber industry. For this survey the minimum

⁶ The United Nations Food and Agriculture Organisation (FAO), European Union and Forest Europe (MCPFE) define woodland as having a minimum area of 0.5 ha, whilst land use, land-use change and forestry (LULUCF) accounting uses a 0.1 hectare lower threshold for 'wooded land', which aligns to the small wood threshold used in this report.

allowable woodland size was set at one acre (0.4 hectare). A small woods and hedgerow survey was carried out south of the Mersey–Humber line contemporaneously with the main survey, using a similar method to the 1951 survey.

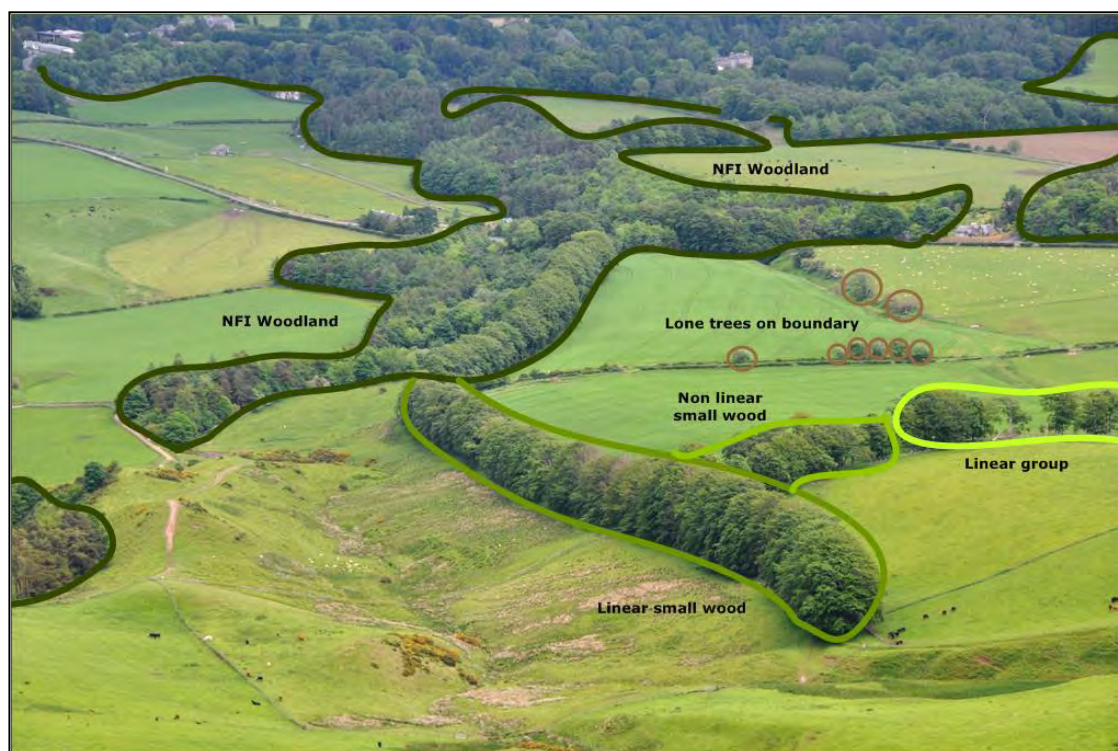
The next major survey was carried out between 1979 and 1982 and the results were published in 1987 as the *Census of Woodlands and Trees 1979-82*. The minimum area of woodland selected, at 0.25 hectare, was very much smaller than it had been in 1947 and therefore included within the main woodland survey the bulk of many areas that would have been termed small woods. The sample design for the survey of non-woodland trees was based on the assessment of strips in two stages, beginning with an assessment of the strip in smaller squares from aerial photography followed by a subsequent ground visit to two of the small squares. The size and numbers of the squares varied during the course of the survey but the basic strategy remained the same.

The results of the survey of non-woodland trees (derived from their component features of boundary trees, open-grown trees, clumps, linear features and individual coppices) showed that non-woodland trees contributed approximately 12% of the total timber volume in Britain. It should be noted that comparison with the 1951 survey cannot be made directly due to the change in the minimum woodland area.

The most recent survey, the *National Inventory of Woodlands and Trees (NIWT)*, was run in the 1990s and published in 2002. This main survey set a minimum woodland area threshold of 2 hectares and created a woodland map based upon aerial photography to identify these. A field survey was conducted across 34,000 one-hectare sample squares within this woodland. A complementary survey, the Survey of Small Woodland and Trees (SSWT) or ‘Small Woods’ survey covered trees in small woods, linear features, groups and lone trees. This comprised a desk-based analysis of 2,392 one-by-one kilometre sample squares across Britain, supported by field sampling 4,784 250 metres by 250 metres squares, to characterize the tree and small woods resource. This survey concluded that circa 1% to 2% of tree canopy by area was outside woodland, although urban areas and narrow linear features were excluded. The analysis also identified around 120,974 kilometres of narrow linear wooded features, but did not allocate an area to these. Results were published in 2002; the report is available at: www.forestry.gov.uk/inventory.

Definitions and terminology

Figure 3 An example of woodland area and tree cover outside woodland

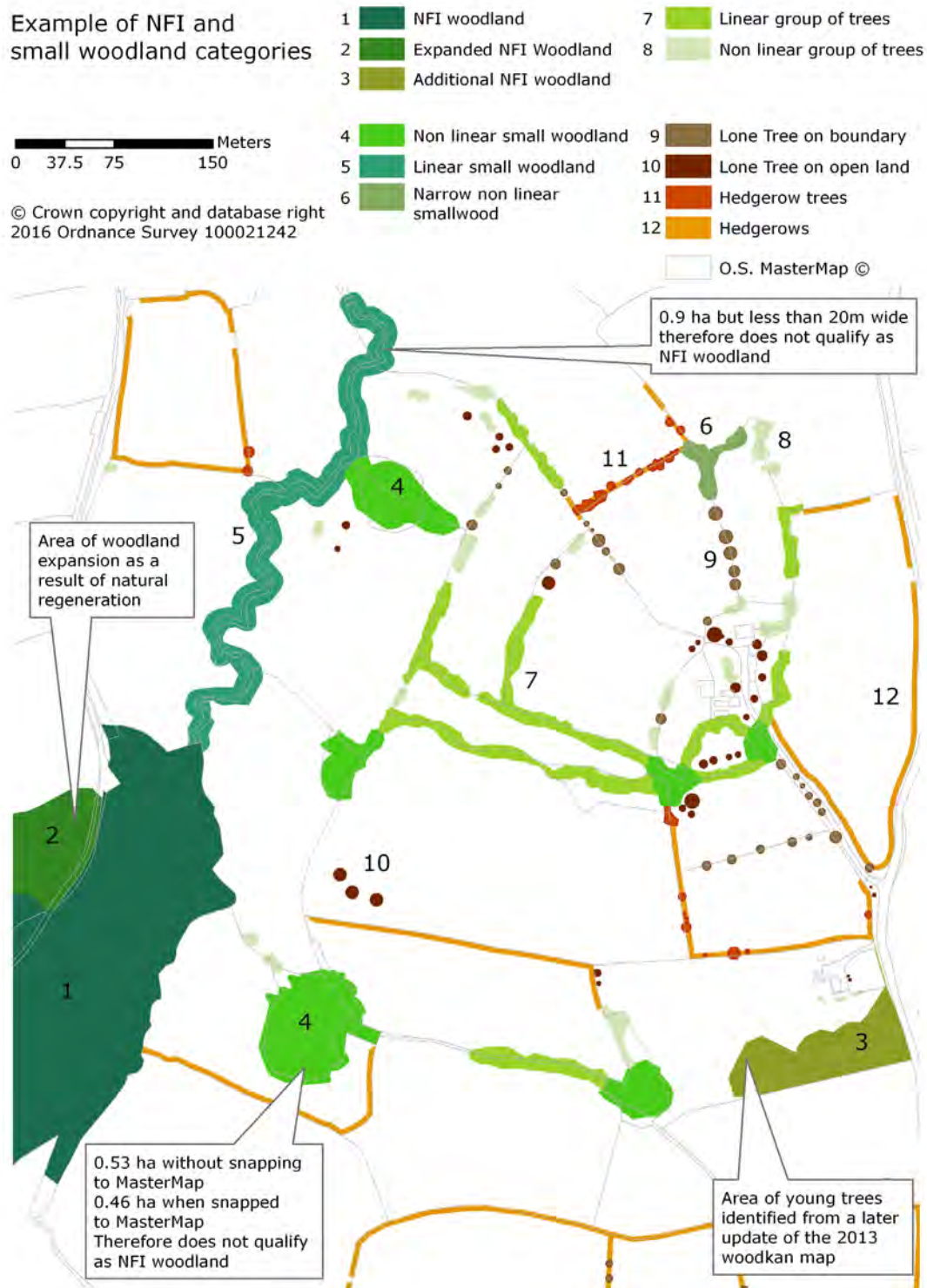


From a single tree in a field to an extensive forest, a continuum of different shapes and sizes of tree cover exist in the British landscape, some of which are defined as woodland while other features are regarded as non-woodland. This report has defined the elements of this continuum in the categories below. Figure 4 overleaf illustrates these categories:

- **NFI woodland** – woods over 0.5 hectare in extent and a minimum of 20 m wide;
- **Small wood** – wooded features exceeding 0.1 hectare and less than 0.5 hectare in extent or less than 20m in width that do not qualify as NFI woodland, further categorised as
 - linear and
 - non-linear;
- **Groups of trees** – clusters of trees less than 0.1 hectare, further categorised as
 - linear,
 - non-linear and
 - groups of trees within hedgerows;
- **Lone trees**, further categorised as
 - hedgerow trees,
 - other boundary trees and
 - trees in open land.



Figure 4 Illustrative map showing woodland and categories of trees outside woodland



Figures 5, 6 and 7 demonstrate the distinction between woodland and features of tree cover outside woodland and how they are identified within the landscape.

Figure 5 NFI woodland features identified in the landscape

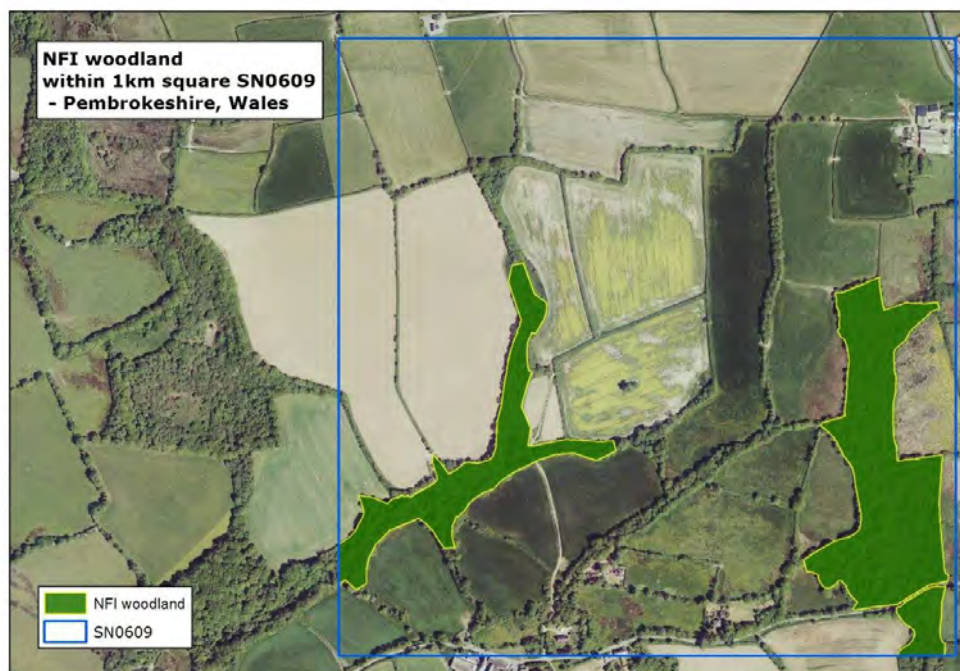


Figure 6 Tree cover outside woodland identified in the landscape

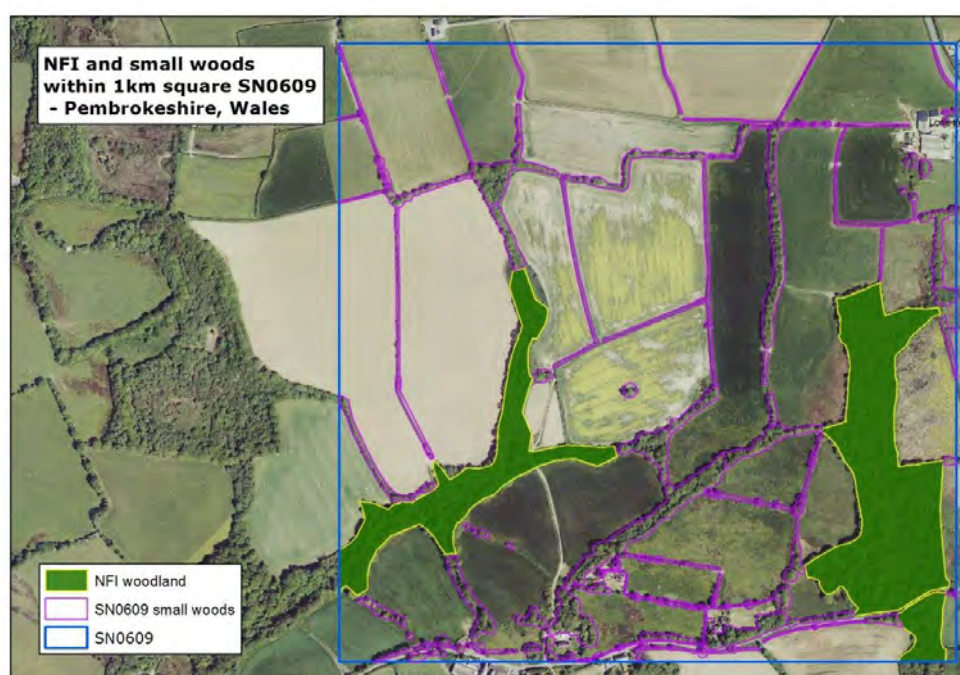
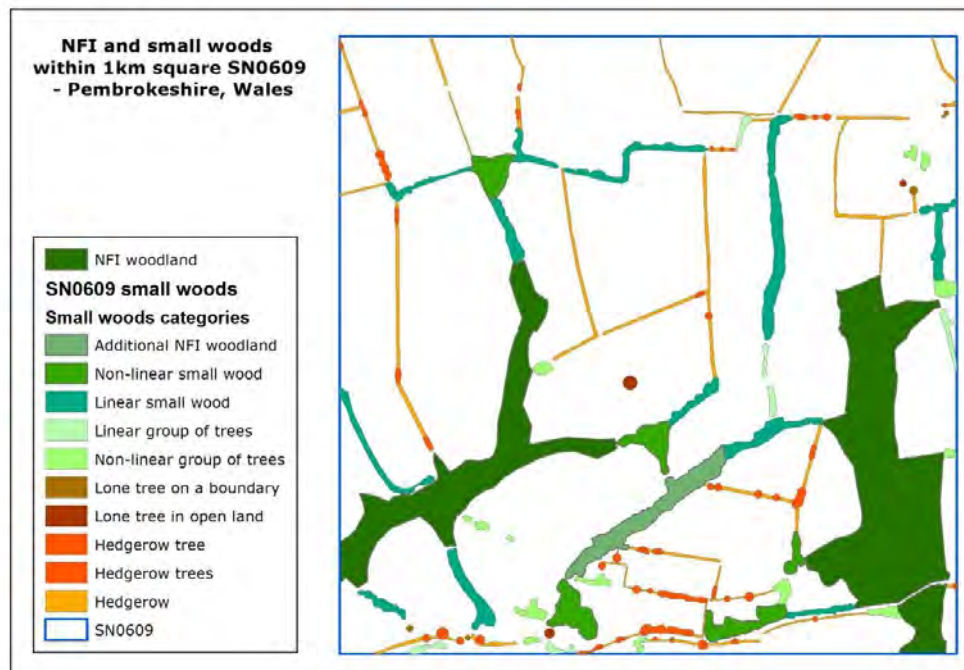




Figure 7 Tree cover outside woodland stratified into constituent categories



The definitions of non-woodland tree features used in this report are illustrated with photographs in Figures 8 to 16 and defined in detail in Table 3.

NFI woodland

NFI woodland is defined as areas of tree cover over 0.5 hectare in extent that have 20% or greater tree cover, or the potential to achieve it, and that are over 20 metres in width. This definition aligns with most aspects of the international definitions of woodland. The Forestry Commission publishes estimates of NFI woodland area annually in *Forestry Statistics*. Further information on these statistics is available at www.forestry.gov.uk/statistics. Figure 8 illustrates a typical NFI woodland.

Figure 8 An example of NFI woodland over 0.5 hectare in extent



New NFI woodland and extra NFI woodland

The areas of NFI woodland identified on the 2013 NFI woodland map are based principally on visual interpretation of aerial photography of older vintage (although annual updates of the map are informed by more contemporary satellite imagery and administrative information). In contrast, the estimates provided in this report are based on more recent aerial photography work, plus the field survey work conducted in 2015 and 2016. The recent aerial photography work supplied updates to the NFI map and these in combination with the fieldwork produced the estimates in this report. In the course of these field survey assessments, judgements have been made on the ages of the areas of NFI woodland found outside the 2013 NFI map to ascertain whether these areas are likely to have been established after the photography on which the NFI map is based. Areas of young trees that have been newly established since the photography used to construct the NFI map are classified in this report as 'New NFI woodland' while areas of older stands that were not identified in the 2013 NFI mapping exercise are referred to as 'Extra NFI woodland'.

A second classification of areas of NFI woodland identified outside the NFI map by the survey was also made, both are reported together as 'un-mapped' NFI area:

- a) Areas of NFI woodland that are spatially separate and have no common boundary with woodland areas identified on the NFI map. Such areas are referred to as 'Additional NFI woodland';
- b) Areas adjacent to and possessing a common boundary with woodland areas identified in the NFI map and therefore representing an expansion of existing areas of the map. Such areas are referred to as 'Expanded NFI woodland'.

Such areas that have been identified through comparison of the NFI map with the NTMTM map of tree cover have been incorporated into the 2015 version of the NFI woodland map improving the maps accuracy through increasing its area by circa 0.33%. These findings are reflected in the woodland area statistics published in *Forestry Statistics 2016*, although *Forestry Statistics* does not yet reflect the additional woodland identified by the sampling.

Small woods

If an area of tree cover is greater than 0.1 hectare in extent and is less than 0.5 hectare in size or less than 20 metres in width, it is classified as a small wood.

Small woods features come in a range of shapes and sizes, and are a common feature in the landscape of Britain. Over the years people have coined a range of terms to describe them, with a range of definitions. Names used to refer to such features include 'copse', 'spinney', 'dell' and many others. The meanings of most of these terms overlap and may or may not be linked to geographic features (such as 'dell') and have no precise definition. Thus, for the purposes of this report, and with the benefit of modern geographic sensing and measurement tools, two types of small woods are defined; linear small woods and non-linear small woods.

Areas of trees of greater than 0.1 hectare in extent with a mean width of less than 20 metres and an average length to width ratio of at least 4:1 are categorised as linear small woods. The distinction between linear and non-linear features has always formed part of Forestry Commission classifications of small woods, reflecting the high proportion of small woods that can be classed as linear features. These occur within Britain due to the high association of trees with land ownership boundaries, watercourses and transport routes.

Small woods that are greater than 20 metres in width form non-linear small woods, such as the example in Figure 9.

Figure 9 An example of a non-linear small wood

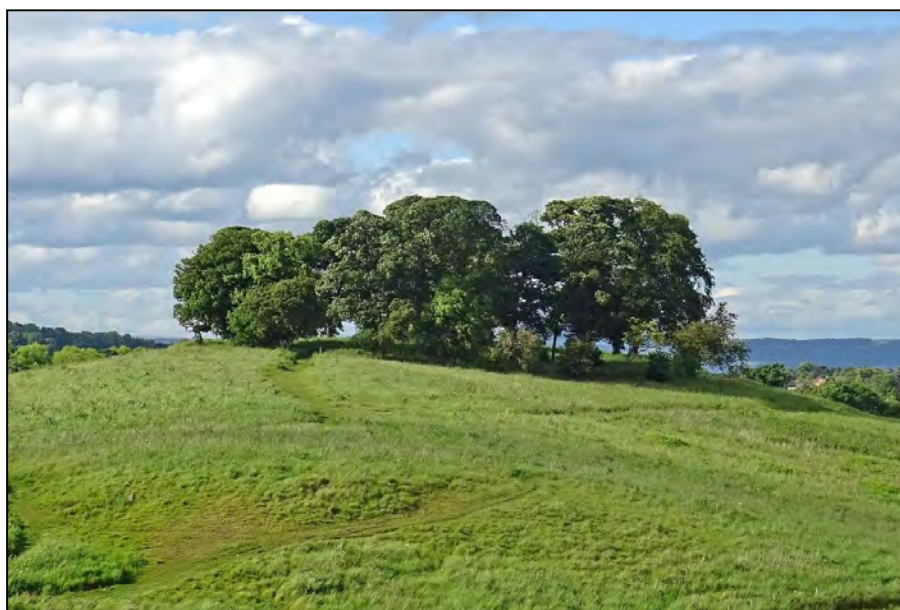


Figure 10 illustrates a linear small wood. Linear small woods form a large component of trees outside woodland and are found alongside watercourses, field boundaries, roads and railways.

Figure 10 An example of a linear small wood



Groups of trees

The smaller an area of tree cover is, the less it exhibits the properties of woodlands. This principle is reflected in the definitions used in this report and when the area of tree cover is less than 0.1 hectare the feature is classified as a 'group of trees'. In such areas, due to the small size, the understorey, ground cover and climate of the area are generally dominated by the adjacent land use. Figure 11 illustrates a small group of trees whose undertstorey reflects few woodland properties, taking on the character of the surrounding land use.

Figure 11 An example of a group of trees



Figure 12 illustrates a linear group of trees. These are defined as areas of two or more trees of up to 0.1 hectare in extent with a mean width of between 4 metres and 20 metres.

Figure 12 An example of a linear group of trees



The third sub-category of groups of trees are those within hedgerows. Such features are clusters of 2 or more trees with touching crowns that are integral to a hedgerow feature but have grown to a size of greater than 3 metres and are therefore considered to be a tree feature rather than a hedgerow feature.

Lone trees

Lone trees such as the example in Figure 13 are readily identifiable in the landscape. The NFI uses the criteria that their canopy must not be touching the canopy of another tree and the tree must be over 2 metres in height to qualify as a lone tree.

Figure 13 An example of a lone tree in open land



Many lone trees are associated with boundary features, such as hedges, fences or walls. These have been identified separately from lone trees in open land in this report and are further categorised into lone trees associated with hedgerows (see below) and lone trees associated with non-living boundaries such as walls and fences, as in Figure 14, which are classed as 'lone trees on a boundary'.

Figure 14 An example of lone trees on a boundary



Whether planted beside a hedgerow or growing from the hedge itself, hedgerow trees are notable throughout many parts of the British landscape. This report identifies any trees over 3 metres in height that are located within or immediately adjacent to a hedgerow. If there are groups of two or more such trees with touching crowns, they are classified as groups of trees within hedgerows (see above); otherwise they are registered as lone trees in hedgerows. In the landscape in Figure 15, mature lone hedgerow trees are connected by a network of hedgerows, which provide a living link between the hedgerow trees.

Figure 15 An example of a hedgerow tree



Hedgerows

Hedgerows form an important part of the British landscape, providing shelter and feedstock for many woodland and non-woodland species within otherwise low woodland cover areas. Hedgerows are often composed of high forest tree species such as beech, ash or oak, and also tree species that are often considered as shrubs, such as hawthorn. Many woodland fauna species rely upon hedgerows in landscapes with low woodland cover, using hedges for shelter, feed and crossing the landscape.

In the foreground of Figure 16, typical hedgerows composed of native species can be seen lining both sides of a minor road, delineating field boundaries. In the background a hedge marks the boundary of residential properties. Hedgerow areas and lengths are assessed from the dimensions of the polygons representing them in the hand-mapped and fieldwork data, and include the areas and lengths of the hedgerows that lie beneath the canopies of any hedgerow trees.

Figure 16 An example of hedgerows



Detailed definitions of the categories set out above are found in Table 3.

Table 3 Definitions of NFI, categories of tree cover outside woodland, and hedgerows

Category	Feature height
1. NFI woodland	
1a. NFI woodland For National Forest Inventory (NFI) reporting, NFI woodland is defined as areas with a canopy cover of 20% or more (or the potential to achieve this), with a minimum area of 0.5 hectare and minimum width of 20 metres. For the purposes of this report the 2013 version of the NFI woodland map has been used to represent currently identified areas of NFI woodland.	Any height
1b. New NFI woodland Areas of NFI woodland formed of young trees found outside the 2013 NFI woodland map which were established after the year of the photography used for the construction of the map.	Any height
1c. Extra NFI woodland Areas of NFI woodland found outside the 2013 NFI woodland map which were present in the photography used for the construction of the map but missed in the mapping exercise.	Any height
<i>Each of the categories 1b. and 1c. can be sub-divided into:</i>	
1b(i) or 1c(i) Expanded NFI woodland Areas of trees extending around the side(s) of, and additional to, NFI woodland included in the 2013 NFI woodland map as a result of re-positioning the physical boundary of mapped NFI woodland outwards from the boundary identified in the 2013 NFI woodland map.	Any height
1b(ii) or 1c(ii) Additional NFI woodland Areas of trees that meet the definition of NFI woodland and are isolated from, and additional to, areas of NFI woodland included in the 2013 NFI woodland map. Areas of additional NFI woodland therefore have no common boundary with existing woodland areas identified on the 2013 NFI woodland map.	Any height
2. Small woods	
2a. Linear small woods Areas of trees greater than 0.1 hectare in extent with a mean width of at least 4 metres and less than 20 metres, and length of at least 25 metres, with an average length to width ratio of at least 4:1. This includes such areas of trees on a boundary. There are no maximum area restrictions and some individual features in this class can therefore exceed 0.5 hectare in extent, but are not classified as NFI woodland since they do not meet the minimum width criteria in the definition of NFI woodland.	Any height
2b. Non-linear small woods Areas of trees with actual or potential canopy cover of greater than 0.1 hectare in extent that do not qualify as either linear small woods or as NFI woodland area. This therefore comprises areas of trees that are less than 0.5 hectare in extent, and with a mean width of greater than or equal to 20 metres and/or an average length to width ratio of less than 4:1.	Any height

Table 3 (cont'd) Definitions of NFI, categories of tree cover outside woodland, and hedgerows

Category	Feature height
3. Groups of trees	
3a. Linear groups of trees Areas of two or more trees of up to 0.1 hectare in extent with a mean width of at least 4 metres and less than 20 metres, and length of at least 25 metres, with an average length to width ratio of at least 4:1. This includes such areas of trees on a boundary. There are no explicit minimum area restrictions other than the minimum area implied by the minimum dimension restrictions (4m X 25m = 100m ² [0.01 hectare]).	Any height
3b. Non-linear groups of trees Two or more trees with a continuous canopy extent of less than or equal to 0.1 hectare (1,000m ²), and which do not qualify as Linear groups of trees or Hedgerow trees (but does include groups of trees on a boundary).	2 metres or more
3c. Hedgerow groups of trees Groups of two or more trees with touching crowns that are 3 metres or more in height and located within hedgerows.	3 metres or more
4. Lone trees	
5a. Lone trees in open land Single trees outside NFI woodland whose crowns have no contact with the crowns of any other tree crown and are not situated on a boundary.	2 metres or more
5b. Lone trees on a boundary Single trees outside NFI woodland whose crowns have no contact with the crowns of any other tree crown and are situated on a non-hedgerow boundary.	2 metres or more
3c. Hedgerow trees Single trees of 3 metres or more in height located within hedgerows, whose crowns have no contact with the crown of any other tree.	3 metres or more
6. Hedgerows	
Boundary lines of trees and shrubs over 20 metres long and less than 3 metres in height having a mean width of less than 4 metres at the base. Gaps of up to 20 metres count as hedgerow except if the gap forms a different intervening land use such as a road, track or gate.	Less than 3 metres

Data and methods overview

Preparation of the estimates in this report has involved a combination of analysis and processing of spatial datasets using Geographical Information Systems (GIS) application software, and subsequent statistical analysis of the outputs from these spatial analyses.

Multiple sources of information in the form of Earth Observation GIS spatial datasets have been utilised in this work, and the types of information available differed between England and Wales on the one hand and Scotland on the other hand. Consequently, not only did the available types of data differ between Scotland and the other countries, but the statistical estimation techniques applied to the data also differed. The overall results for Great Britain as a whole are composed of statistical estimates derived from partially different sources using a range of statistical approaches to their estimation. As a consequence, the relative precision of the estimates within the different countries varies to some extent. The different sources of information used in this work are listed and described in detail in Appendix 1. The various spatial datasets used were:

Data used for England and Wales only

The National Tree Map (NTM™) of England and Wales

A spatial dataset supplied to the Forestry Commission on licence by Bluesky International Limited.

'Hand-mapped' data for England and Wales

Results from identification of small woods, tree and hedgerow features from on-screen interpretation of aerial photography within a sample of 217 one-by-one kilometre squares randomly selected throughout England and Wales.

Data used for Scotland only

Native Woodland Survey of Scotland (NWSS) woodland map

The NWSS map is a spatial dataset of woodlands and small woods features of physical size of 0.1 hectare or more covering Scotland, produced from interpretation of aerial photography. This dataset was commissioned by Forestry Commission Scotland for NWSS and produced by Forest Research between 2006 and 2010.

'Hand-mapped' data for Scotland

Results from identification of small woods features from on-screen interpretation of aerial photography within a sample of 60 one-by-one kilometre squares randomly selected throughout Scotland.

Figure 17 A one-by-one kilometre fieldwork square



Data across Great Britain

'Fieldwork' data

Results from a sample of 35 one-by-one kilometre squares that were visited by NFI surveyors, who identified and plotted features on the ground within each sample square. The sample used was a subset of the 'hand-mapped' sample squares for England, Wales and Scotland. Figure 17 provides an example of the range of types of tree formations outside woodland.

The 2013 NFI woodland map

Used to identify and eliminate mapped NFI woodland areas from the analysis of tree cover outside woodland.

The Ordnance Survey Strategi[®] 1:250,000 scale spatial dataset

Provides a differentiation of land areas in Great Britain into urban and rural areas.

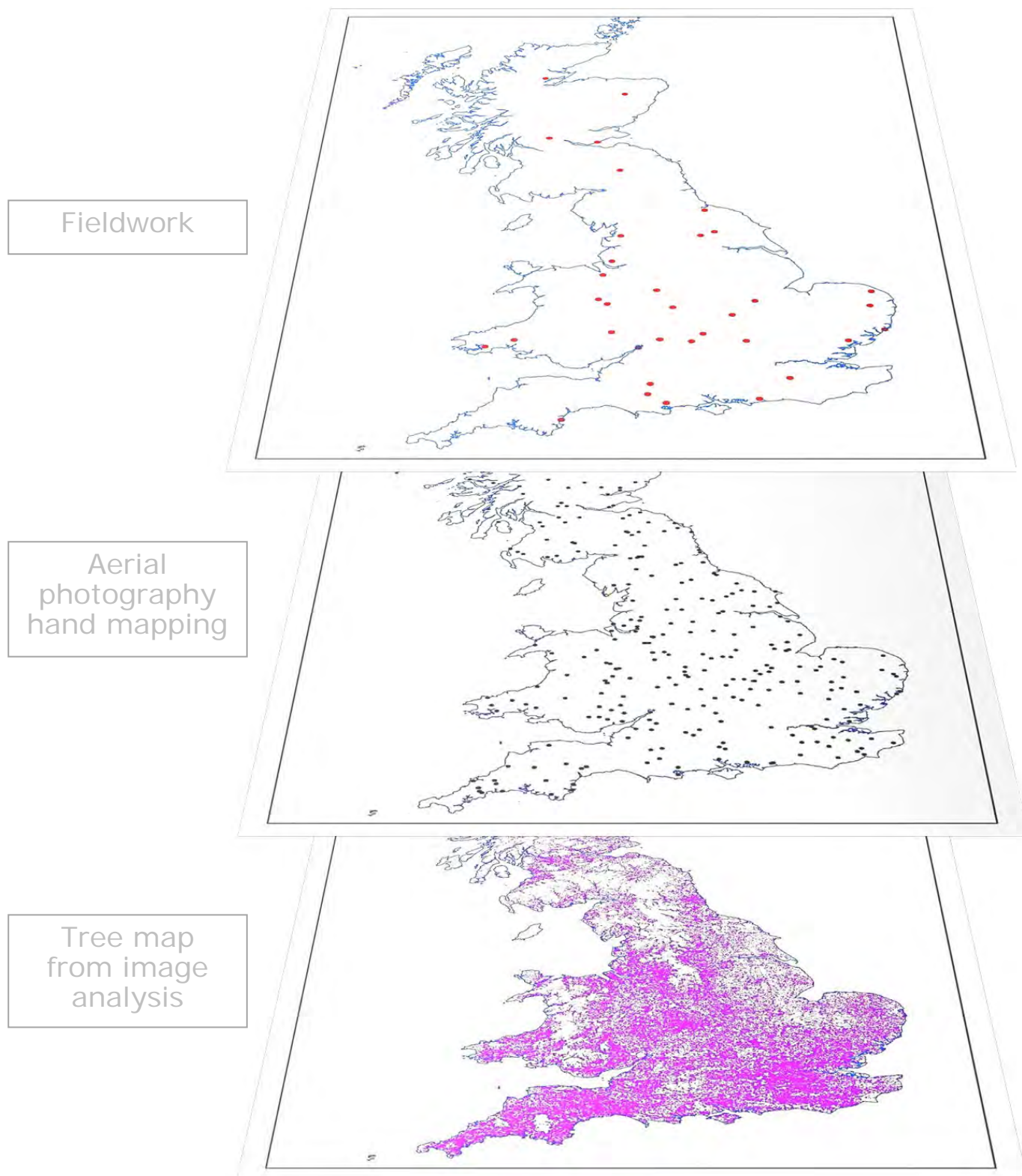
The spatial analysis work involved processing of some of these datasets from the 'raw' forms, supplied or initially available, into derived forms suitable for the estimation of the statistics contained in this report. It also involved, for those datasets generated internally (specifically the hand-mapped data and the fieldwork data), varying degrees of data checking and data cleaning in quality assurance activities.

After preparation of these spatial datasets, further spatial analyses involved super-imposing pairs of these datasets to identify their areas of intersection and non-intersection and recording the categories of features in each dataset that formed the intersections and non-intersections. In this way, data was generated on the relationships between spatial datasets which could then be subjected to statistical analysis. Other GIS analysis of these datasets involved:

- masking areas on the 2013 NFI woodland map so that the results of the analyses related to areas outside of NFI woodland areas;
- differentiating land areas into rural and urban land based on the Ordnance Survey Strategi[®] dataset;
- identifying tree and hedgerow features as being within either rural or urban areas and
- assigning various other attributes to the features identified in the datasets.

Figure 18 illustrates how the field work and hand mapping samples relate to the 'tree map' and NWSS data. These spatial relationships are the basis of the calibration of the 'tree map' data used to produce the area estimates contained in this report. A full explanation and specification of the spatial calibration procedure used to relate and analyse these datasets is contained in Appendix 1: Data and Methodology.

Figure 18 Fieldwork and aerial photo hand mapping samples calibrate the 'tree map'



As noted, the types of statistical analyses performed on the data derived from these spatial datasets varied according to the nature of the data:

Areas in England and Wales

Estimates of areas of small woods, groups and trees were derived from a double-calibration exercise, firstly using the hand-mapped sample data for England and Wales to calibrate the areas on the NTMTM map to the hand-mapped results, and secondly using the sub-sample of fieldwork data to calibrate the hand-mapped data to the results of the fieldwork, resulting in final estimates based upon fieldwork results. The schema of this double-calibration process, starting with areas on the NTMTM map, working through estimated areas based on hand-mapped data, to final estimates based on calibrated fieldwork data, is shown in Figure 19. In this figure, the blue items represent the data input to the process, which in some stages is a full dataset, or in other stages, is an extracted sub-sample; the green items represent estimates of population areas output at each stage; and the white boxes represent the two stages of the calibration process from NTMTM to calibrated fieldwork estimates.

Areas for Scotland

Initial estimates of areas of small woods, groups and trees utilised the hand-mapping sample within Scotland. The hand-mapped estimates were then calibrated to the fieldwork data using the spatial calibration procedure to give final estimates based upon calibrated fieldwork results.

Hedgerows

Hand-mapped estimates of the areas and lengths of hedgerows were obtained by direct scaling-up of the hand-mapped results from the areas covered by the sample to the population areas. The hand-mapped areas and lengths of hedgerows were then related to the fieldwork results for hedgerows to give final estimates of hedgerow areas and lengths based on fieldwork results.

Number of features

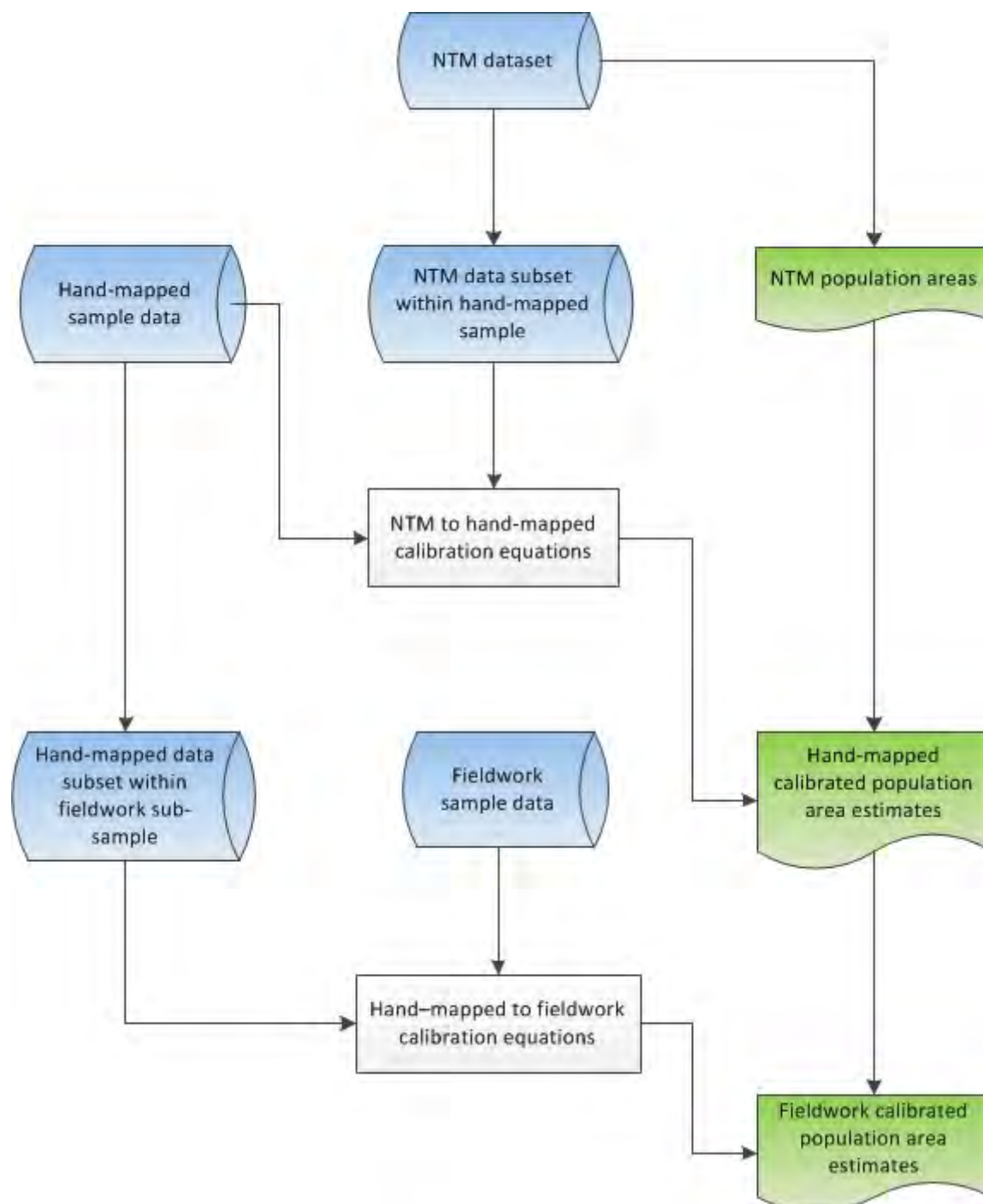
Initial estimates of the number of features were derived from the hand-mapped dataset, and final estimates were obtained by relating hand-mapped data to fieldwork data, giving final estimates based on fieldwork.

Mean sizes of features

Mean sizes of small woods, groups and tree features were obtained by direct calculations of the mean areas of features in the hand-mapped data.

A fuller description of the various statistical analyses performed is given in the Statistical Analysis section (B) of Appendix 1.

Figure 19 Schema of the double calibration process used to derive the estimates



Results

This report provides the results from investigations by the NFI on the location, extent and characteristics of tree cover and hedgerows outside areas of full NFI woodland as identified on the 2013 version of the NFI woodland map. All results have a reference date of January 2016. The features found in these areas fall into three broad classes:

1. Areas that qualify as NFI woodland that are located outside the boundaries of woodland areas identified on the 2013 NFI woodland map. These are partly areas of new woodland that have become established since the photography used to construct the map, and partly areas that existed but were not identified as woodland in the original mapping exercise. Some of this newly-identified area extends from the boundaries of the existing mapped woodland and therefore represents expansion of existing mapped areas, while other areas are separate with no common boundary with existing mapped NFI woodland, representing additional areas of NFI woodland.
2. Areas of small woods, groups and individual trees that do not qualify as NFI woodland due either to the minimum size and canopy density requirements for areas of NFI woodland, or are excluded from the NFI woodland map on the basis of the mapping conventions used in the mapping exercise, such as a minimum width of 20 metres and the OS MasterMap[®] rules (see Glossary). These features have been sub-divided into a number of categories principally on the basis of size and shape characteristics. The categories based on size range from small woods with physical size exceeding 0.1 hectare, groups of trees of physical feature sizes of up to 0.1 hectare, and individual trees whose canopies are not touching the canopies of other trees. These three broad classes are further sub-divided on the basis of shape and, in the case of individual trees, their location with respect to other landscape features.
3. The investigation also recorded and evaluated hedgerows. These are regarded as a separate class of features from woodland and trees since they are often wholly or partly made up of shrub species and do not therefore qualify as tree cover. Trees within hedgerows that had grown to a significant height above the hedgerow (a minimum of 3 metres tall) were included in the tree cover categories.

A full description of these classes and sub-categories can be found in the previous Definitions and terminology section.

The results provide estimates of total areas and, for appropriate categories, the numbers of features within Great Britain, individual countries (England, Scotland and Wales), and individual NFI regions within countries. The mean sizes of observed features within each category were calculated the mean sizes of the features identified in the hand-mapping sample. Hedgerows are reported in terms of their estimated total areas and lengths. For NFI woodland, mapped areas of woodland on the 2013 NFI woodland map are presented along with areas of NFI woodland found outside of the map to provide revised estimates of total

areas of NFI woodland in NFI regions, countries and GB. Within each geographical administrative area, estimates are presented separately for urban and rural areas, as identified in the OS Strategi[®] spatial dataset. To assist in interpretation and to demonstrate regional and geographic differences in the distribution of small woods features, maps of the distributions are provided (see Figures 2, 50, 51, 52 and 53).

Apart from the areas of NFI woodland defined on the 2013 NFI woodland map and feature sizes, all estimates presented in this report have been derived using data obtained from NFI hand-mapped and fieldwork sample surveys. The estimates provided have been calibrated to the results of the fieldwork exercises (see Appendix 1 – Data and Methodology for technical details). These fieldwork exercises were conducted in late 2015 and early 2016 and therefore the results presented in this section have a reference date of January 2016, being the mid-date of the fieldwork.

Having been derived from sample survey data, the estimates presented in this section are subject to sampling errors and in all cases (apart from the areas derived from the 2013 NFI woodland map and the mean feature sizes) the precision of the estimates is shown in percentage terms as relative standard errors, being the standard error of the estimate expressed as a ratio of the value of the estimate. The standard errors in relative terms are generally low and at an acceptable level for estimates at country and GB level, although the estimates for Scotland and Wales are mostly higher than those for England due to the different nature of the underlying data available for deriving the Scottish estimates and the smaller sample area of Wales. At NFI regional level the estimates are less precise in relative terms, particularly for less prevalent categories and sub-categories. For estimates with high relative standard errors (of over 25% as an indication), caution needs to be applied in their interpretation. Such estimates cannot be relied upon as providing a value close to the actual value in the population reported on, and should be regarded as indicative values of the general level of the actual areas or numbers of features and with such are marked amber in the tables. More precise estimates in such sub-populations and categories of small woods, trees and hedgerows would require further data collection focused on the particular population of interest.

In the following tables of results, the value of each estimate is individually rounded and, as a result, the values in the body of the tables may not sum to the marginal totals shown. In some cases, the marginal totals and the values in the body of the tables are independently estimated from the data and this may also result in discrepancies between the sum of the individual estimates in the body of the tables and the estimates of their marginal totals.

National Forest Inventory woodland

Forestry Commission publishes the definitive estimates of woodland area for Great Britain. Figure 20 and Table 4 show that, according to the 2013 NFI map, there were 3,014.3 thousand hectares of NFI woodland in Britain as at 2013. Of this, England had 1,298.2 thousand hectares, Scotland had 1,410.7 thousand hectares, and Wales had 305.4 thousand hectares.

In addition to the mapped woodland area in 2013, an area of NFI woodland outside the 2013 NFI woodland map has been identified by the tree map and the sampling activities. This is composed of 'new' woodland that has become established between the date of the NFI map primary imagery data sources (aerial photography, satellite data) and the date of field survey 2015 to 2016, and 'extra' woodland that was established at the time of the imagery but was not identified in the imagery. These are recorded as 'total unmapped area' in Figure 20 and Table 4.

Figure 20 NFI woodland area, extra NFI woodland and new NFI woodland areas

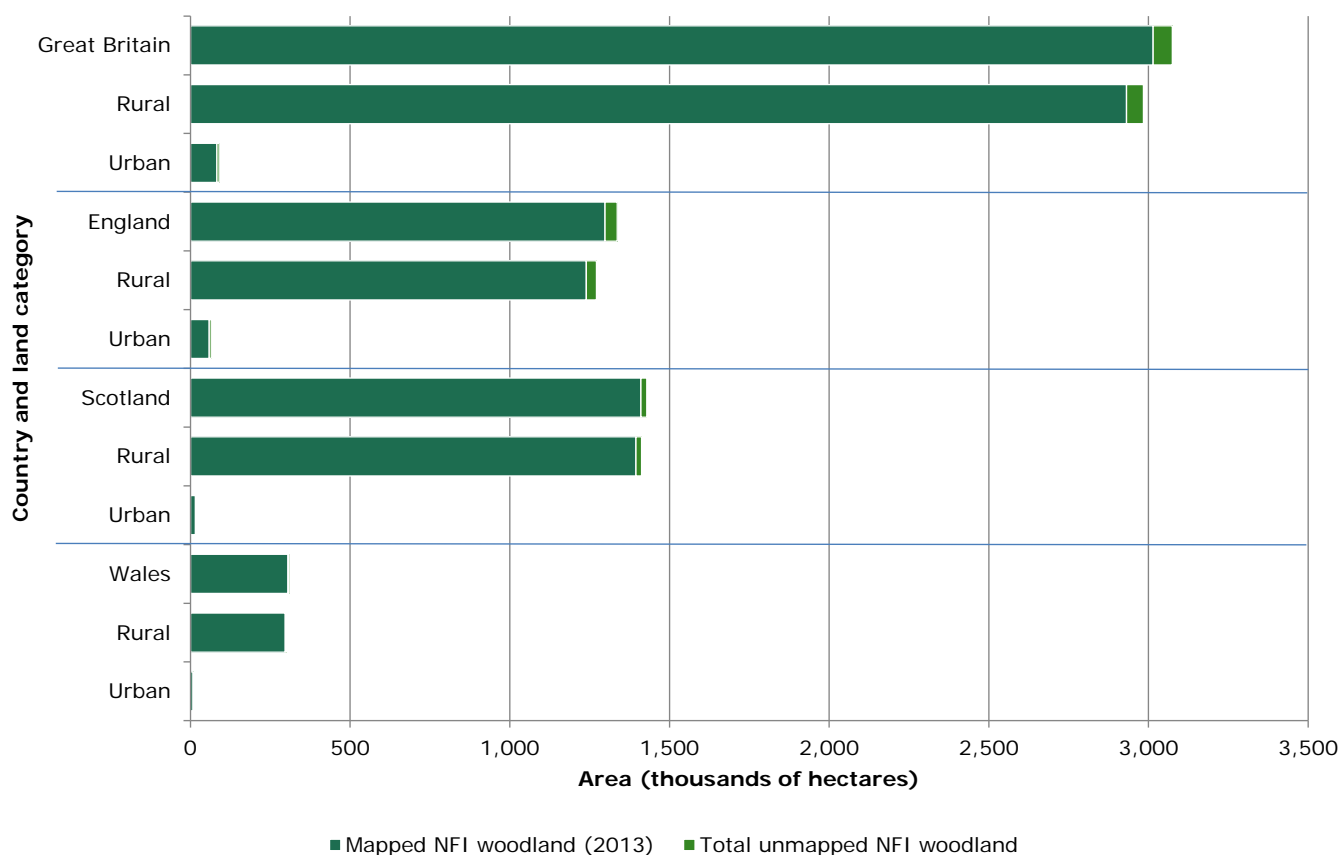


Table 4 NFI woodland area, extra NFI and new NFI woodland by country, urban and rural

Land category	Mapped NFI (2013)	Total unmapped NFI area		Total woodland area	
	(000 ha)	(000 ha)	SE%	(000 ha)	SE%
Great Britain	3,014.3	60.3	36	3,074.6	1
Rural	2,931.4	53.0	41	2,984.4	1
Urban	82.9	7.3	43	90.2	4
England	1,298.2	38.2	35	1,336.4	1
Rural	1,239.3	32.0	41	1,271.3	1
Urban	58.9	6.2	45	65.1	4
Scotland	1,410.7	18.3	46	1,429.0	1
Rural	1,395.1	17.8	48	1,412.9	1
Urban	15.5	0.5	60	16.0	2
Wales	305.4	3.8	41	309.3	1
Rural	297.0	3.2	48	300.2	1
Urban	8.4	0.6	60	9.1	4

Notes for Table 4 and Figure 20:

1. There are small differences in the woodland area estimates reported in Table 4 and those reported in *Forestry Statistics 2016*. This is because the 2016 woodland area estimates in *Forestry Statistics 2016* were based on the 2015 NFI woodland map and estimates of new planting in 2015-16. Whereas this report uses more up-to-date information arising from the assessment than was available to *Forestry Statistics*.
2. Unmapped NFI area is composed of New and Extra NFI woodland (see Definitions and Terminology section). The same area is also subdivided by the categories Expanded and Additional woodland. This data is used to update and inform the derivation of woodland area.

The overwhelming majority of NFI woodland in Great Britain is located in rural areas (97%) compared to 3% in urban areas. The pattern is similar across England, Scotland and Wales. Table 8 provides a breakdown of rural to urban woodland area.



NFI woodland and tree cover outside woodland

Figure 21 Areas of woodland and tree cover outside woodland

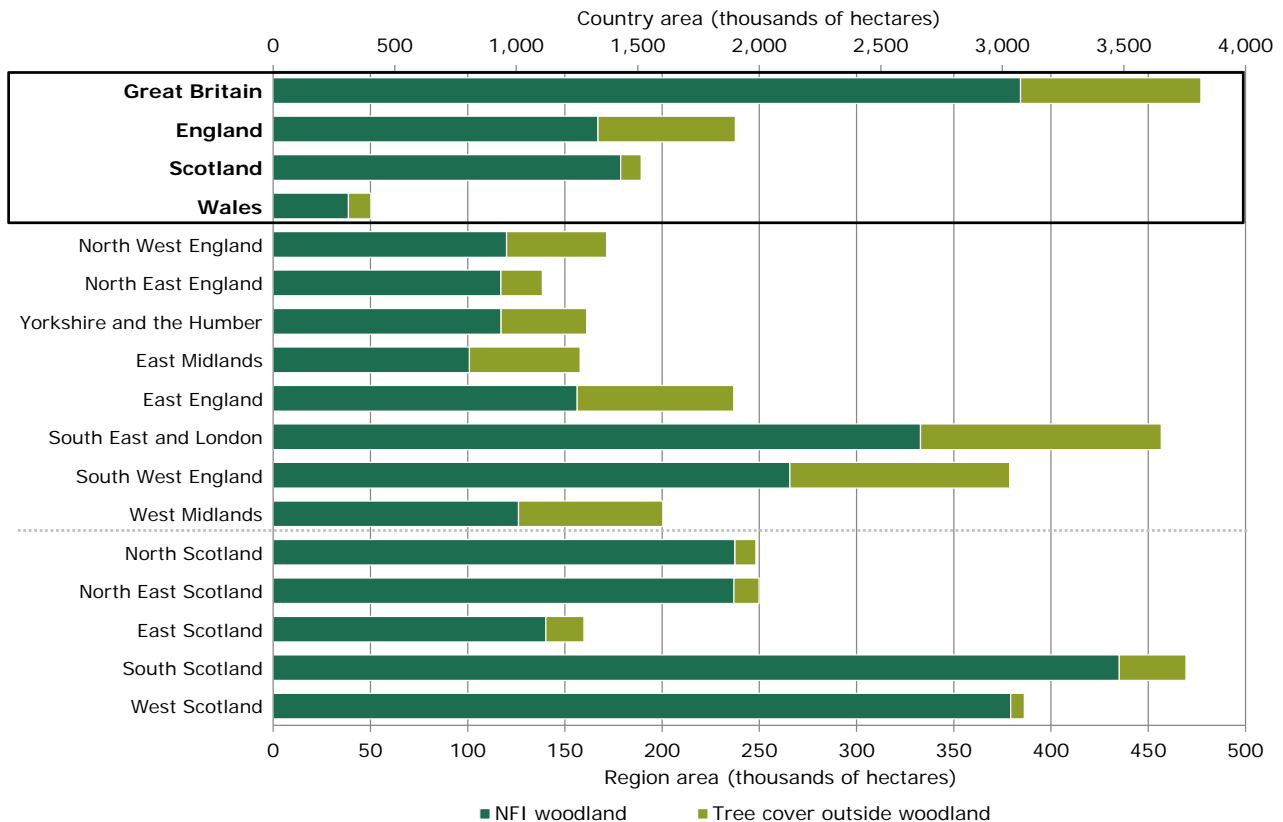
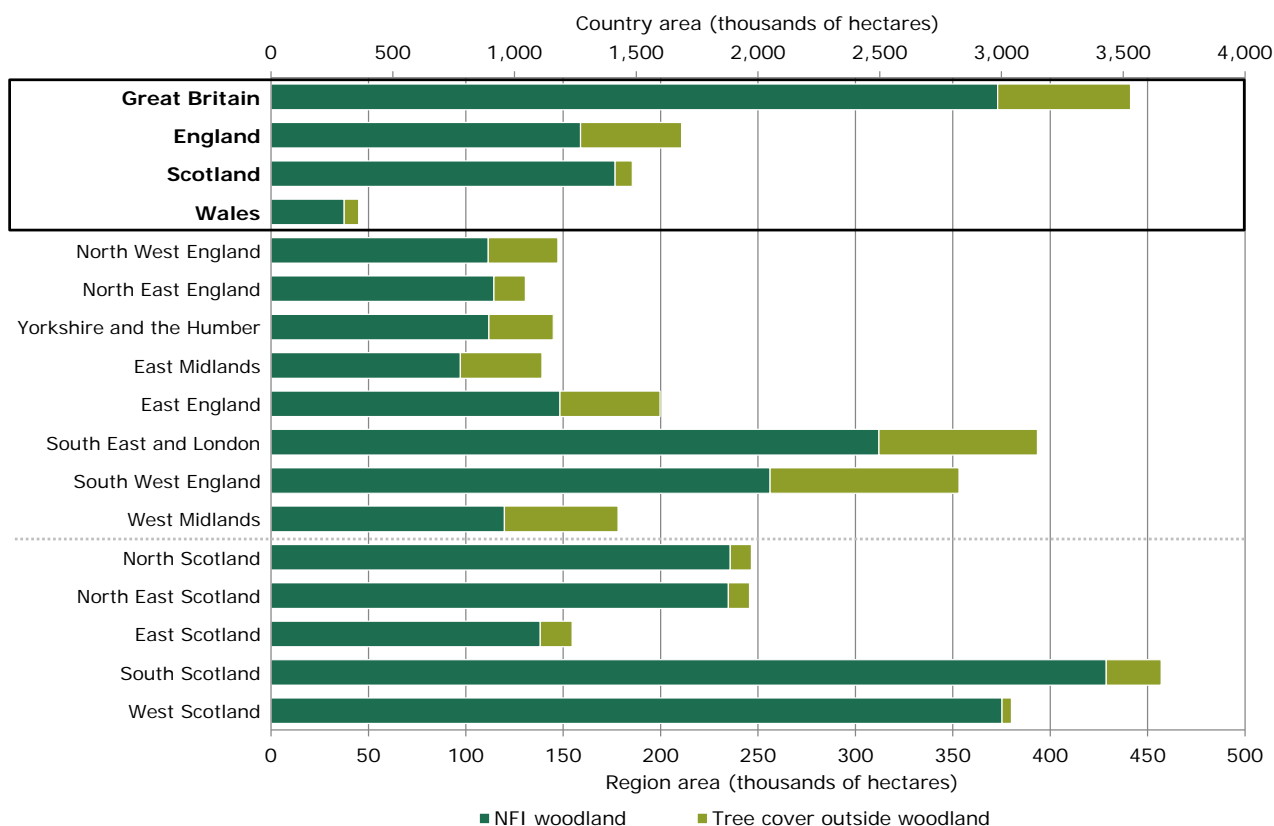


Table 5 Areas of woodland and tree cover outside woodland

Region	Total land area	NFI woodland	Tree cover outside woodland		Total area of woodland and tree cover	Total area of woodland and tree cover
	(000 ha)	(000 ha)	(000 ha)	SE%	(000 ha)	% of land area
Great Britain	22,895	3,075	742	5	3,817	16.7
England	13,031	1,336	565	5	1,901	14.6
North West England	1,411	120	51	6	171	12.2
North East England	857	117	21	9	138	16.1
Yorkshire and the Humber	1,541	117	44	8	161	10.5
East Midlands	1,562	101	57	6	158	10.1
East England	1,912	156	80	6	237	12.4
South East and London	2,064	333	124	6	457	22.1
South West England	2,384	266	113	7	379	15.9
West Midlands	1,300	126	74	8	200	15.4
Scotland	7,791	1,429	85	13	1,513	19.4
North Scotland	1,744	237	11	42	248	14.2
North East Scotland	1,142	237	13	23	250	21.9
East Scotland	867	140	20	28	160	18.4
South Scotland	1,997	435	34	14	469	23.5
West Scotland	2,041	379	7	28	386	18.9
Wales	2,074	309	93	7	402	19.4

**Figure 22** Rural areas of woodland and tree cover outside woodland**Table 6** Rural areas of woodland and tree cover outside woodland

Region	Total land area	NFI woodland	Tree cover outside woodland		Total area of woodland and tree cover	Total area of woodland and tree cover
	(000 ha)	(000 ha)	(000 ha)	SE%	(000 ha)	% of land area
Great Britain	21,159.2	2,984.4	546.0	6	3,530.4	16.7
England	11,591.8	1,271.3	415.1	5	1,686.3	14.5
North West England	1,229.7	111.5	35.8	6	147.3	12.0
North East England	788.0	114.4	16.2	11	130.6	16.6
Yorkshire and the Humber	1,395.6	111.8	33.1	9	144.9	10.4
East Midlands	1,419.5	97.2	41.8	7	139.0	9.8
East England	1,716.2	148.3	51.4	7	199.7	11.6
South East and London	1,703.3	312.1	81.4	7	393.5	23.1
South West England	2,199.6	256.2	97.1	8	353.3	16.1
West Midlands	1,139.9	119.8	58.3	9	178.1	15.6
Scotland	7,610.4	1,412.9	71.0	15	1,484.0	19.5
North Scotland	1,723.6	235.8	10.8	42	246.6	14.3
North East Scotland	1,120.1	234.8	10.8	27	245.6	21.9
East Scotland	840.6	138.2	16.4	33	154.6	18.4
South Scotland	1,913.4	428.8	28.2	16	457.0	23.9
West Scotland	2,012.6	375.3	4.8	33	380.1	18.9
Wales	1,957.0	300.2	59.9	7	360.1	18.4

Figure 23 Urban areas of woodland and tree cover outside woodland

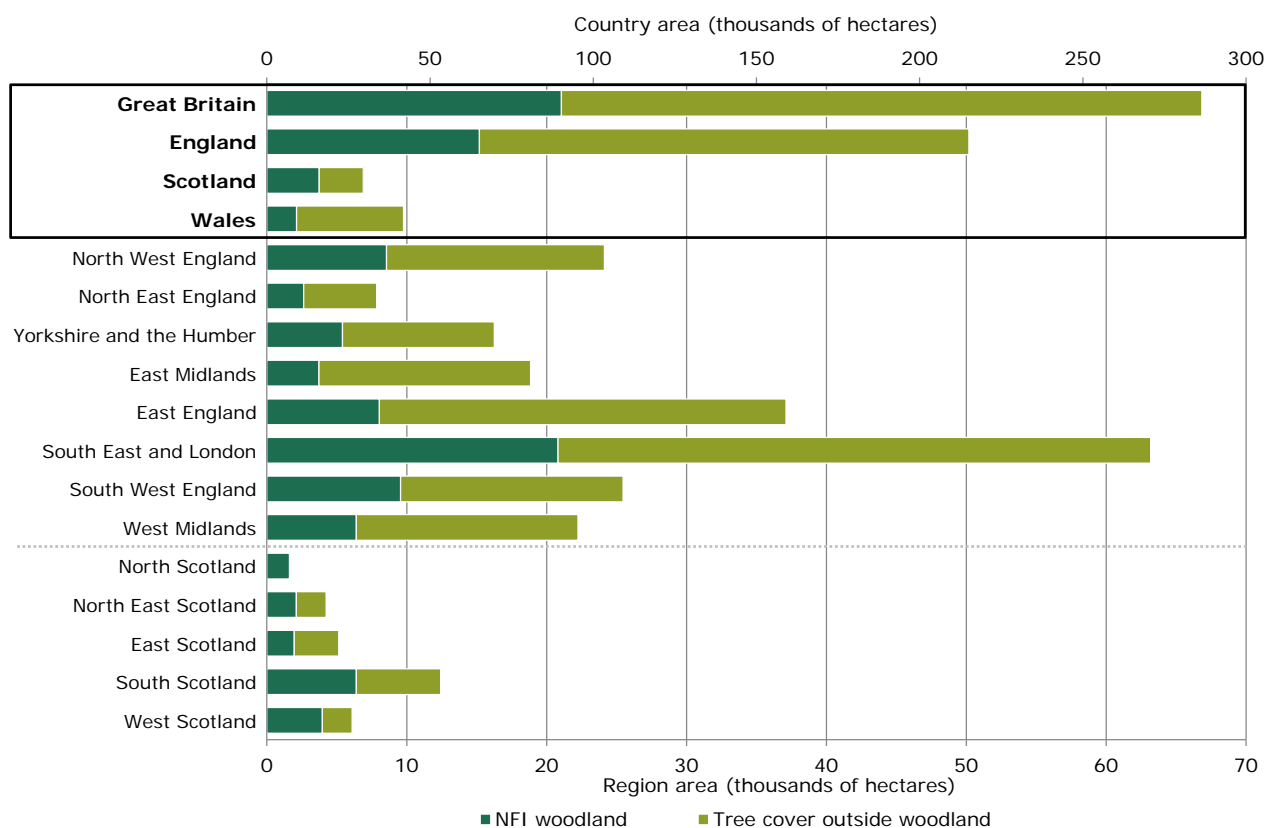


Table 7 Urban areas of woodland and tree cover outside woodland

Region	Total land area	NFI woodland	Tree cover outside woodland		Total area of woodland and tree cover	Total area of woodland and tree cover
	(000 ha)	(000 ha)	(000 ha)	SE%	(000 ha)	% of land area
Great Britain	1,736.2	90.2	196.3	10.3	286.5	16.5
England	1,438.9	65.1	150.0	10.7	215.1	14.9
North West England	180.9	8.6	15.6	13.8	24.1	13.3
North East England	69.4	2.6	5.2	15.1	7.9	11.3
Yorkshire and the Humber	145.0	5.4	10.8	15.1	16.3	11.2
East Midlands	142.8	3.7	15.1	12.5	18.8	13.2
East England	195.7	8.0	29.1	10.7	37.1	19.0
South East and London	361.1	20.8	42.4	13.1	63.2	17.5
South West England	184.1	9.6	15.9	17.5	25.5	13.8
West Midlands	159.9	6.4	15.9	12.5	22.2	13.9
Scotland	180.7	16.0	13.5	18.2	29.5	16.3
North Scotland	20.8	1.6	-	-	1.6	7.8
North East Scotland	21.9	2.1	2.1	43.5	4.2	19.4
East Scotland	26.2	2.0	3.2	29.1	5.1	19.6
South Scotland	84.0	6.4	6.0	24.3	12.4	14.8
West Scotland	27.9	4.0	2.1	50.6	6.1	21.9
Wales	116.6	9.1	32.8	13.7	41.9	35.9

Major categories of tree cover outside woodland

Figure 24 Areas of major categories of tree cover outside woodland

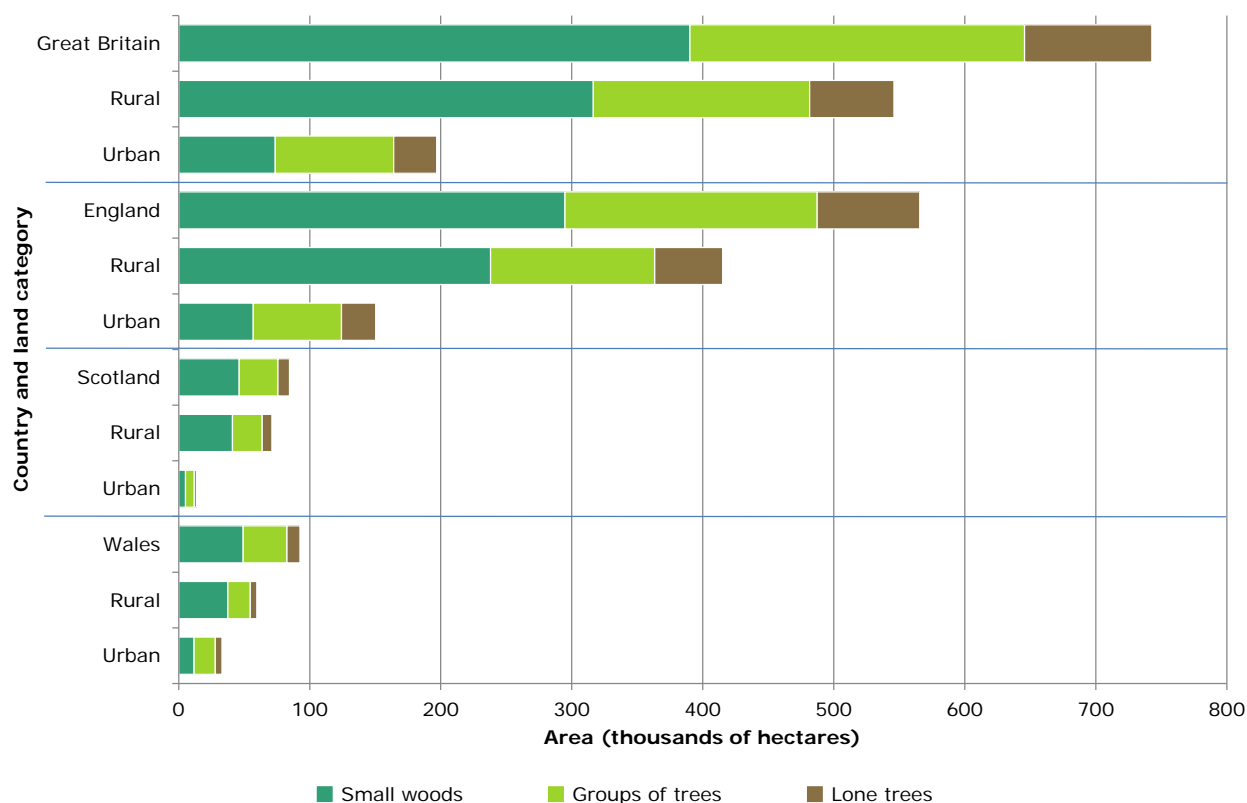


Table 8 Areas of major categories of tree cover outside woodland

Land category	Total NFI woodland	Small woods		Groups of trees		Lone trees		Total area of woodland and tree cover	
	(000 ha)	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	3,074.6	390.2	7	255.4	6	97.1	6	3,816.9	5
Rural	2,984.4	316.5	8	165.1	6	64.3	6	3,530.4	6
Urban	90.2	73.7	12	90.3	13	32.8	15	286.5	10
England	1,336.4	294.8	7	192.6	6	78.2	7	1,901.4	5
Rural	1,271.3	238.0	8	125.2	9	52.0	6	1,686.3	5
Urban	65.1	56.8	12	67.3	13	26.2	15	215.1	11
Scotland	1,429.0	46.2	21	29.5	12	8.9	15	1,513.5	13
Rural	1,412.9	41.0	24	22.7	14	7.3	17	1,484.0	15
Urban	16.0	5.2	24	6.7	26	1.6	31	29.5	18
Wales	309.3	49.2	8	33.4	9	10.1	17	402.0	7
Rural	300.2	37.5	9	17.1	8	5.0	11	360.1	7
Urban	9.1	11.7	20	16.3	17	5.0	32	41.9	14



Figure 25 Number of features of major categories of trees outside woodland

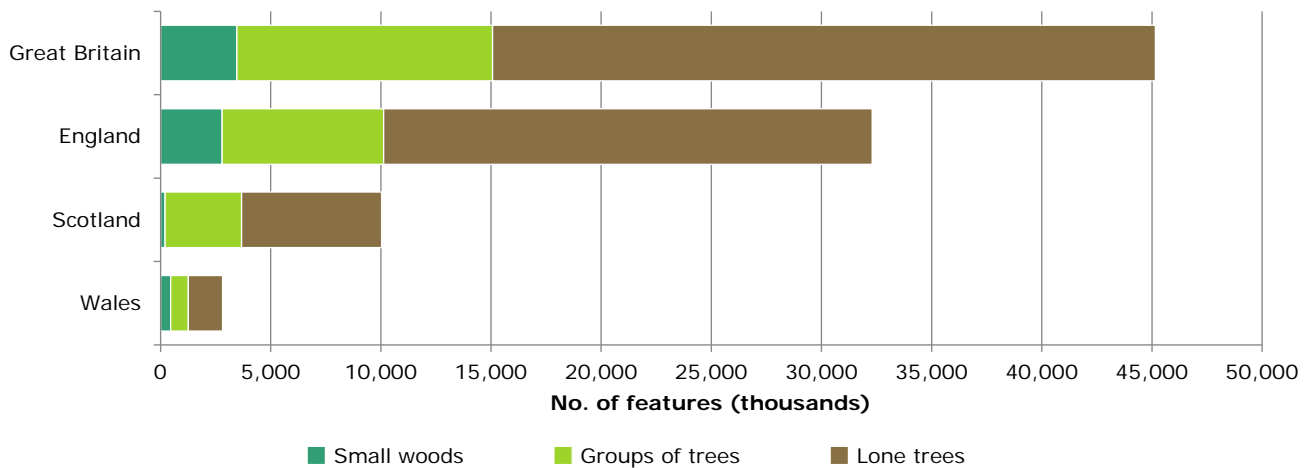
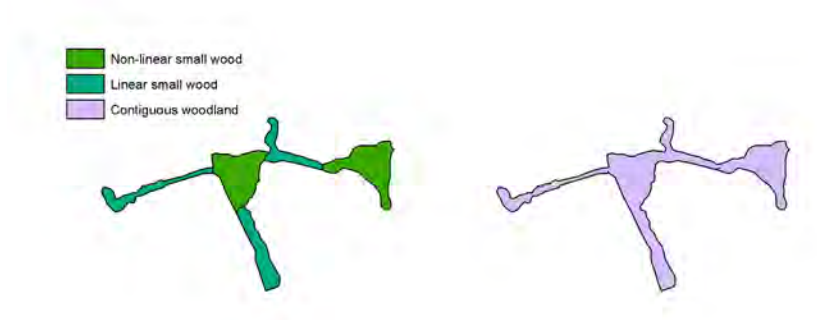


Table 9 Numbers of features of main categories of trees outside woodlands

Land category	Small woods		Groups of trees		Lone trees		Total number of features	
	No. of features '000	SE%	No. of features '000	SE%	No. of features '000	SE%	No. of features '000	SE%
Great Britain	3,465	15	11,602	20	30,092	13	45,159	10
England	2,800	17	7,324	29	22,177	16	32,300	13
Scotland	202	29	3,479	29	6,359	23	10,040	18
Wales	464	45	799	52	1,556	33	2,819	25

Figure 26 How features are counted



Note for Figure 25, 26 and Table 9:

The feature counts represent individual features, which may be contiguous with other features. For example in Figure 26 five individual features would be counted not one.

Table 10 Mean sizes of non-woodland tree features

Land category	Linear small woods	Non-linear small woods	Linear groups	Non-Linear groups	Hedgerow groups	Lone trees in open land	Lone boundary trees	Hedgerow trees
	m ²	m ²	m ²	m ²	m ²	m ²	m ²	m ²
Great Britain	2,073	1,744	388	227	281	34	34	59
Rural	2,127	1,835	424	265	301	44	43	62
Urban	1,860	1,581	325	193	168	25	29	34
England	2,064	1,728	384	238	254	34	34	57
Rural	2,124	1,832	419	275	266	43	43	58
Urban	1,854	1,571	328	208	160	26	30	41
Scotland	1,836	1,909	332	146	192	18	32	28
Rural	1,821	2,104	385	186	246	23	44	41
Urban	1,854	1,595	277	118	143	15	24	18
Wales	2,183	1,740	463	280	385	74	36	96
Rural	2,189	1,742	472	295	386	80	46	98
Urban	2,015	1,723	399	220	365	42	23	70

Note for Table 10:

Areas derived from hand mapped sample data only.



Breakdown of major categories of tree cover outside woodland

Area of small woods

Figure 27 Total area of small woods and sub-categories

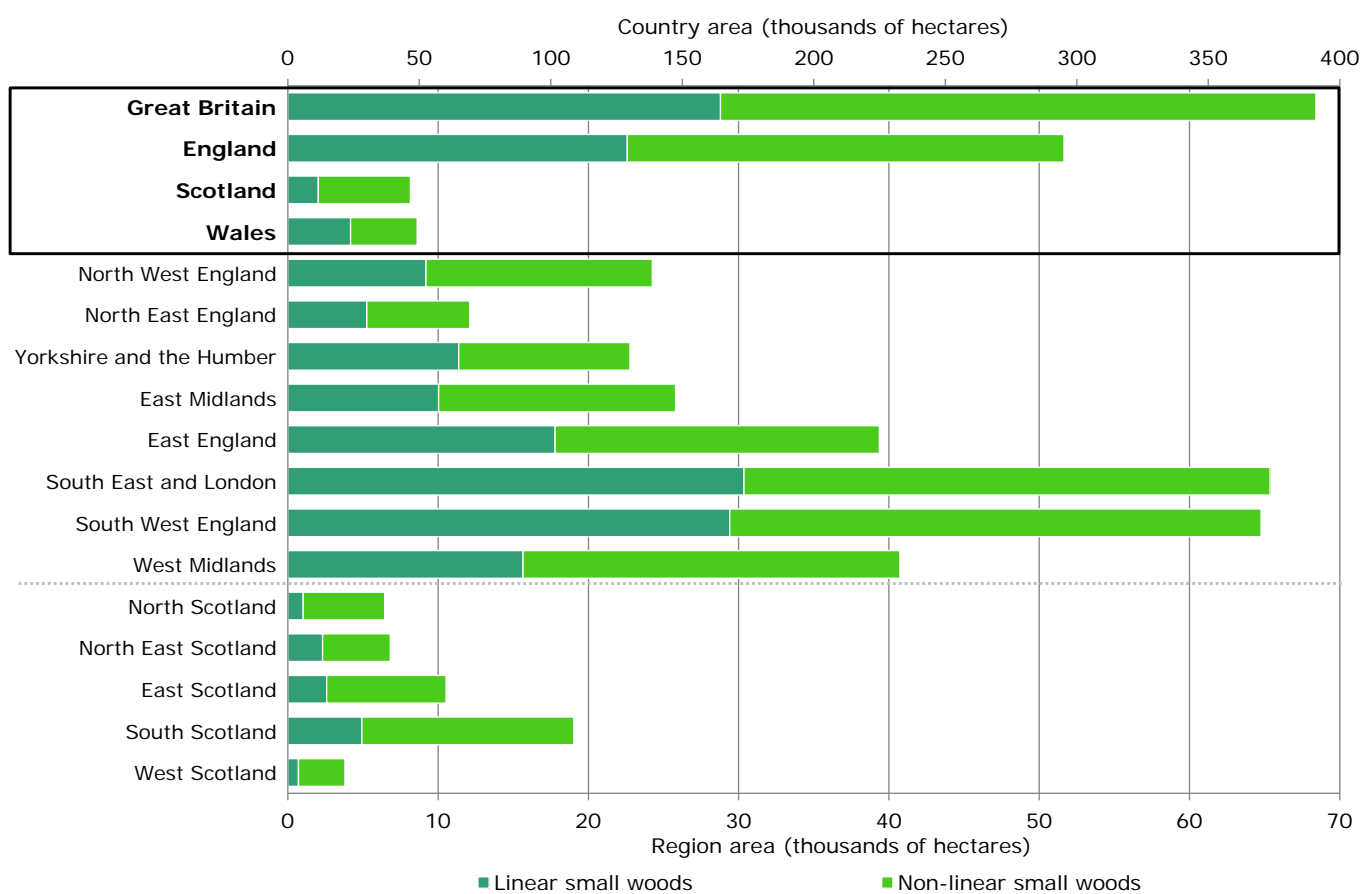




Table 11 Areas of small woods and sub-categories

Region	Linear small woods						Non-linear small woods					
	Rural		Urban		Total		Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	138.7	10	25.8	16	164.5	9	178.3	13	48.1	17	226.4	11
England	109.8	10	19.3	16	129.1	8	128.4	11	37.7	18	166.0	10
North West England	6.9	13	2.3	26	9.2	12	10.4	10	4.7	22	15.1	10
North East England	4.2	24	1.1	33	5.3	20	5.2	17	1.6	25	6.8	15
Yorkshire and the Humber	9.9	16	1.5	31	11.4	14	7.8	21	3.6	27	11.4	17
East Midlands	8.6	19	1.4	27	10.0	17	11.9	13	3.9	18	15.8	11
East England	14.2	14	3.5	25	17.8	12	17.4	12	4.2	24	21.6	10
South East and London	24.5	11	5.8	24	30.4	10	24.7	16	10.3	26	35.0	13
South West England	27.6	13	1.8	41	29.4	12	30.8	18	4.6	25	35.4	16
West Midlands	14.0	15	1.7	18	15.7	13	20.2	20	4.9	18	25.1	16
Scotland	9.4	27	2.2	32	11.6	22	32.0	29	3.1	32	35.0	26
North Scotland	1.0	67	-	-	1.0	67	5.4	67	-	-	5.4	67
North East Scotland	2.1	41	0.3	59	2.3	37	4.1	48	0.4	1	4.5	45
East Scotland	1.8	46	0.8	54	2.6	36	7.0	59	0.9	50	7.9	53
South Scotland	3.9	27	1.0	45	4.9	24	13.2	29	0.9	33	14.1	27
West Scotland	0.6	56	< 0.1	68	0.7	50	2.2	51	0.9	68	3.1	41
Wales	19.5	12	4.4	40	23.8	12	18.0	13	7.3	19	25.3	10

Region	Total small woods					
	Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	316.5	8	73.7	12	390.2	7
England	238.0	7	56.8	13	294.8	6
North West England	17.2	8	7.0	17	24.2	8
North East England	9.4	16	2.7	21	12.1	13
Yorkshire and the Humber	17.7	14	5.1	21	22.8	12
East Midlands	20.5	12	5.3	16	25.8	10
East England	31.6	9	7.6	18	39.3	8
South East and London	49.3	10	16.1	19	65.3	9
South West England	58.3	12	6.4	22	64.7	11
West Midlands	34.0	14	6.6	15	40.7	12
Scotland	41.0	24	5.2	24	46.2	21
North Scotland	6.4	63	-	-	6.4	63
North East Scotland	6.2	38	0.6	1	6.8	34
East Scotland	8.7	53	1.7	40	10.4	45
South Scotland	16.9	23	1.9	31	18.9	21
West Scotland	2.8	46	1.0	66	3.8	38
Wales	37.5	9	11.7	20	49.2	8



Figure 28 Rural areas of small woods and sub-categories

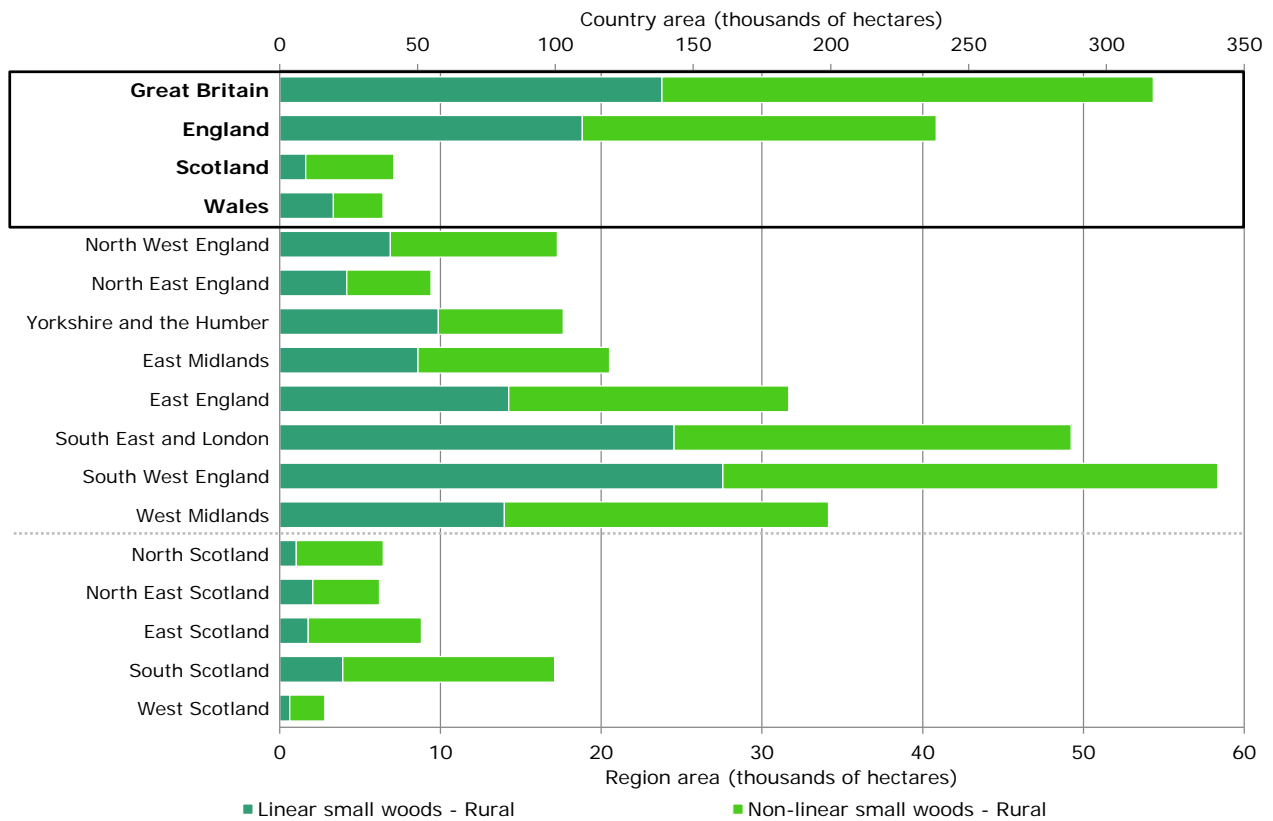
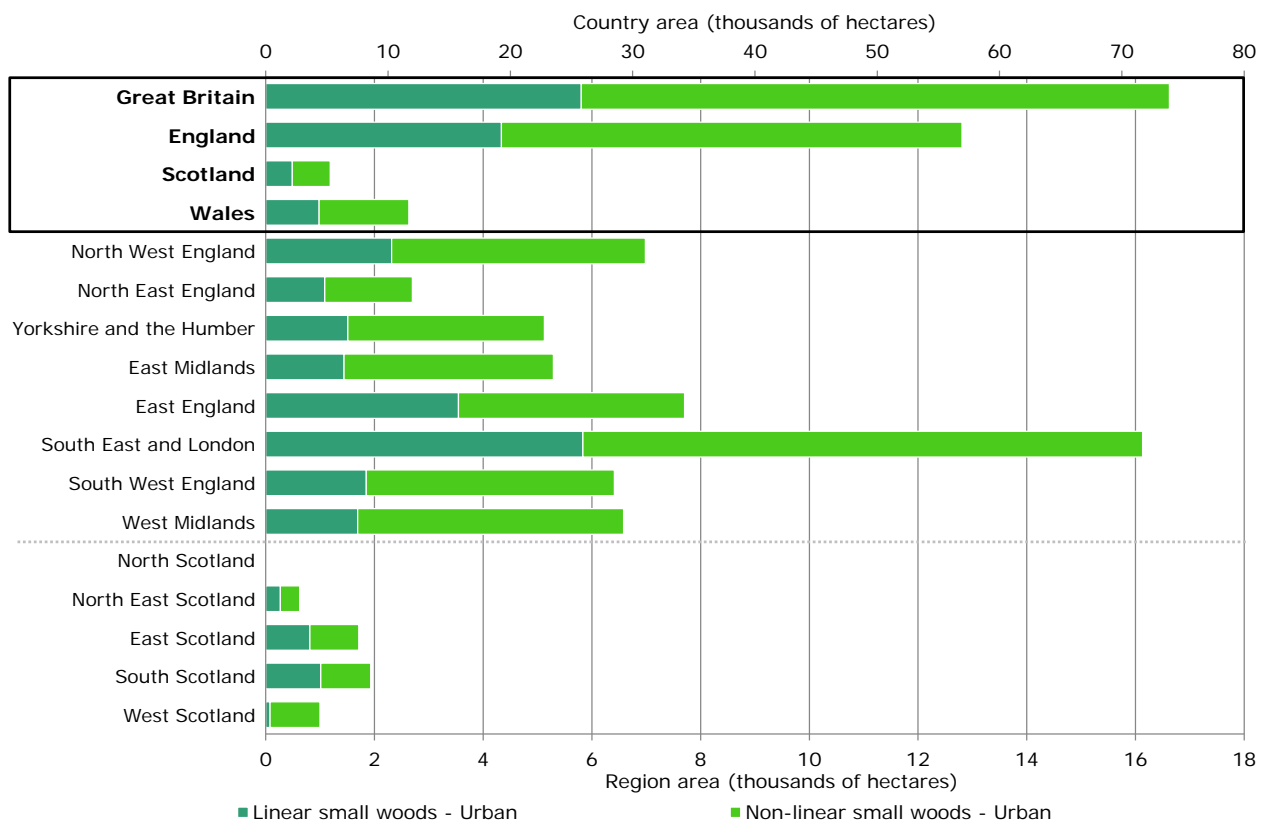


Figure 29 Urban areas of small woods and sub-categories





Number of small woods features

Figure 30 Total number of small woods features including sub-categories

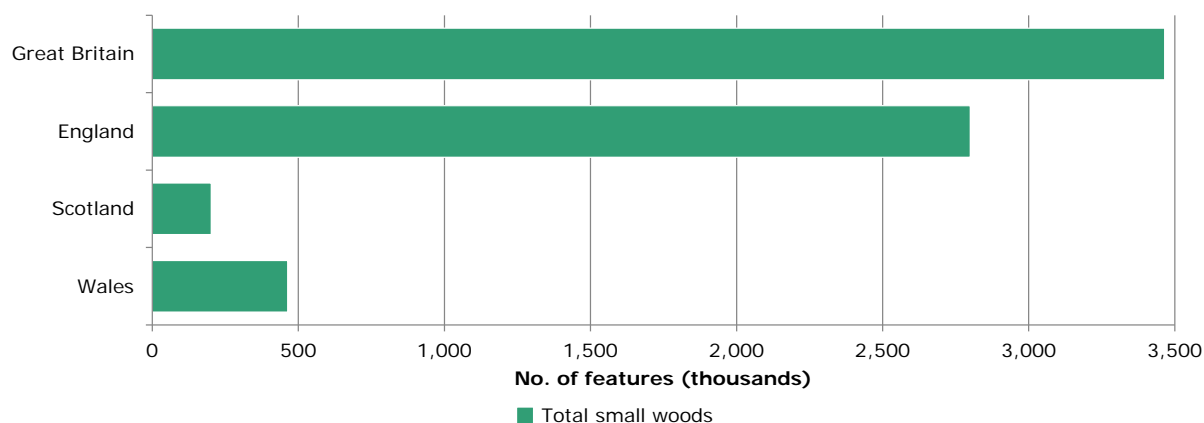


Table 12 Total number of small woods features including sub-categories

Region	Total small woods					
	Rural		Urban		Total	
	No. of features '000	SE%	No. of features '000	SE%	No. of features '000	SE%
Great Britain	2,474	17	992	34	3,465	15
England	1,872	19	928	36	2,800	17
Scotland	177	32	25	64	202	29
Wales	425	49	39	90	464	45

Note for Table 12:

Small woods features and group features are sometimes contiguous, forming single compound features containing more than one small wood and/or group feature. These components are counted separately for the statistics presented.

Figure 31 Number of small woods features including sub-categories in rural areas

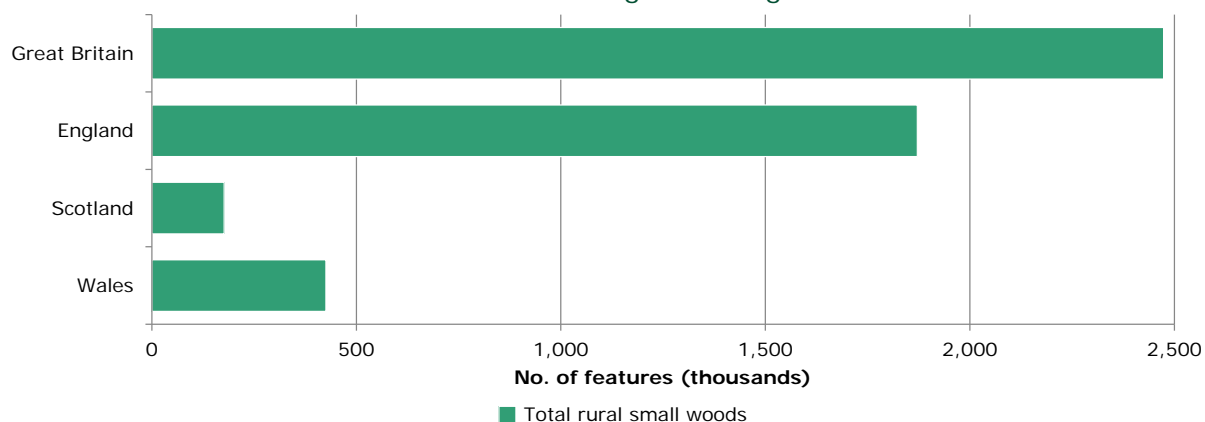
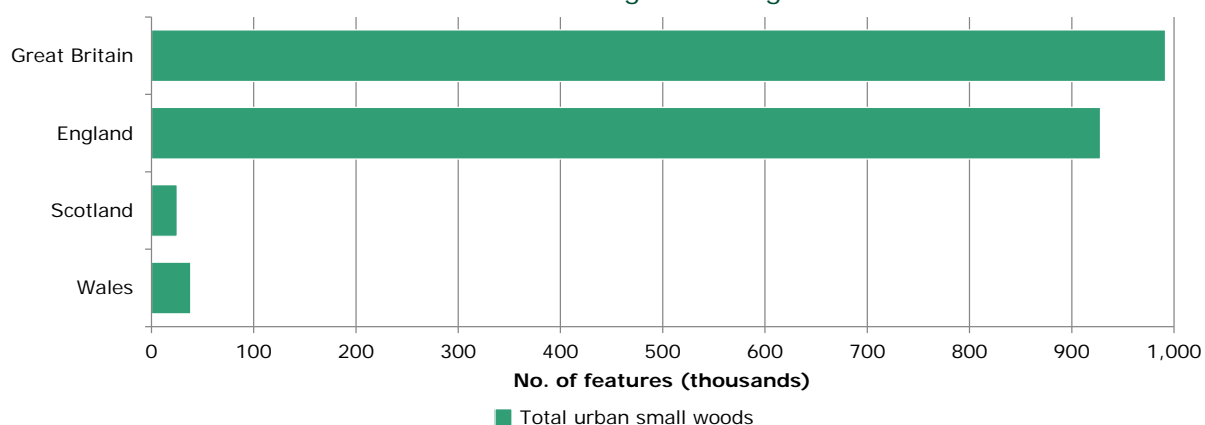


Figure 32 Number of small woods features including sub-categories in urban areas



Size of small woods

Table 13 Small woods mean feature sizes

Region	Linear small woods			Non-linear small woods		
	Rural	Urban	Total	Rural	Urban	Total
	ha	ha	ha	ha	ha	ha
Great Britain	0.19	0.21	0.21	0.16	0.18	0.17
England	0.19	0.21	0.21	0.16	0.18	0.17
North West England	0.16	0.18	0.17	0.17	0.15	0.16
North East England	0.26	0.16	0.22	0.20	0.16	0.19
Yorkshire and the Humber	0.20	0.19	0.20	0.16	0.19	0.17
East Midlands	0.18	0.19	0.18	0.17	0.17	0.17
East England	0.19	0.18	0.19	0.19	0.16	0.18
South East and London	0.25	0.18	0.23	0.20	0.15	0.17
South West England	0.21	0.24	0.21	0.19	0.15	0.18
West Midlands	0.26	0.18	0.24	0.19	0.17	0.18
Scotland	0.19	0.18	0.18	0.16	0.21	0.19
North Scotland	-	-	-	< 0.1	-	< 0.1
North East Scotland	0.23	0.15	0.19	0.27	0.13	0.19
East Scotland	0.15	0.23	0.20	0.19	0.28	0.23
South Scotland	0.18	0.16	0.17	0.22	0.10	0.18
West Scotland	0.23	-	0.23	0.15	0.16	0.16
Wales	0.22	0.20	0.22	0.17	0.17	0.17



Groups of trees

Area of groups of trees

Figure 33 Total area of groups of trees and sub-categories

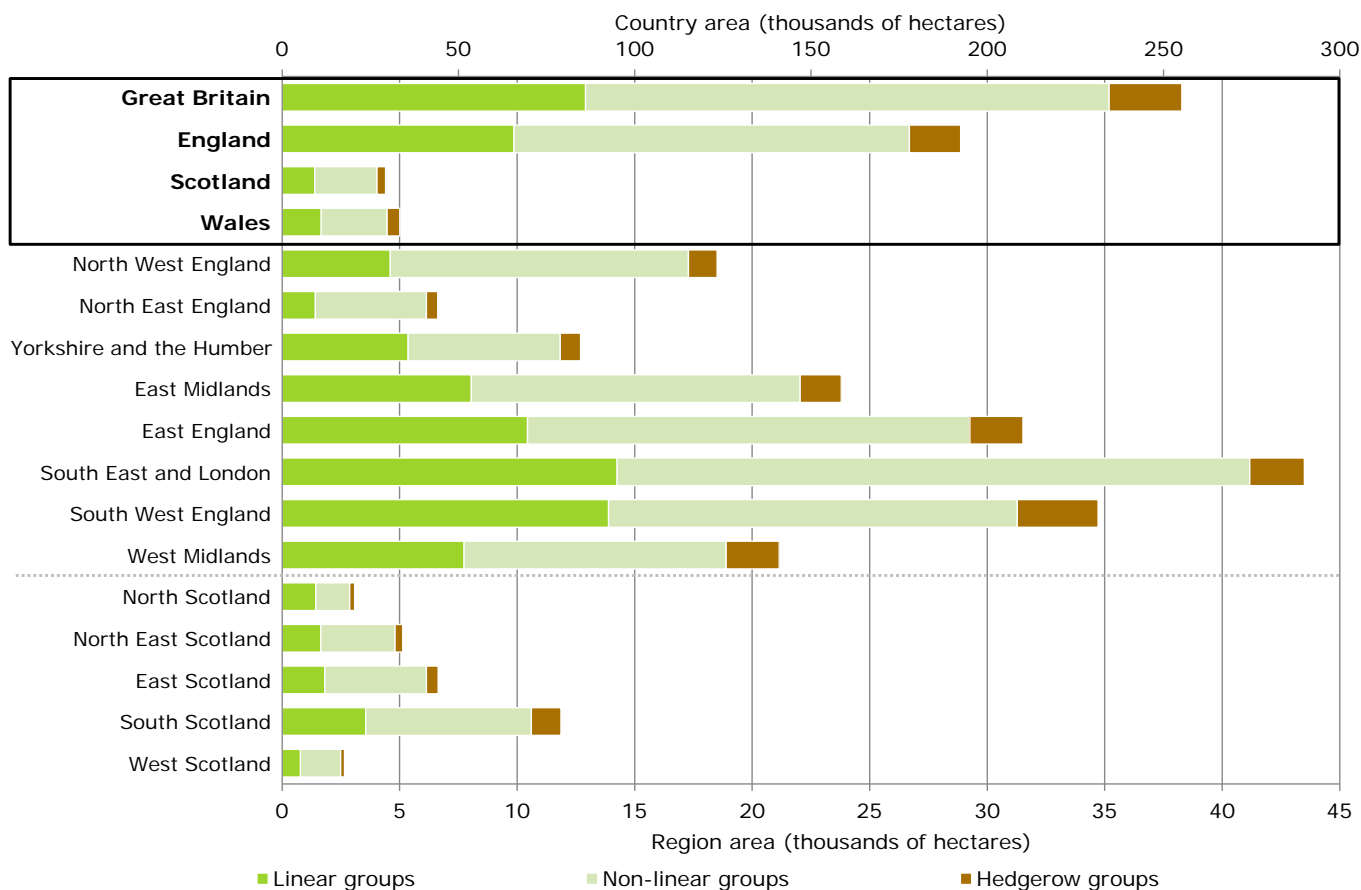


Table 14 Areas of groups of trees

Region	Linear groups						Non-linear groups					
	Rural		Urban		Total		Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	62.7	9	23.4	18	86.1	8	83.2	7	65.3	13	148.5	7
England	48.9	9	16.8	18	65.7	8	62.3	7	49.9	13	112.2	7
North West England	3.4	18	1.2	25	4.6	15	7.9	9	4.7	17	12.7	9
North East England	1.1	15	0.3	29	1.4	13	3.2	13	1.6	16	4.7	10
Yorkshire and the Humber	4.0	17	1.4	17	5.4	14	4.5	13	2.0	21	6.5	11
East Midlands	6.4	11	1.7	25	8.0	10	8.0	9	6.0	16	14.0	9
East England	6.3	12	4.2	25	10.4	12	6.9	10	11.9	12	18.8	9
South East and London	9.5	12	4.7	20	14.2	11	12.1	11	14.9	15	26.9	9
South West England	12.1	11	1.7	26	13.9	10	12.8	11	4.6	28	17.4	11
West Midlands	6.1	13	1.6	19	7.7	11	7.0	16	4.2	16	11.2	12
Scotland	7.5	18	1.8	27	9.2	15	12.9	17	4.8	31	17.7	15
North Scotland	1.4	55	-	-	1.4	55	1.4	47	-	-	1.4	47
North East Scotland	1.4	35	0.3	64	1.6	31	2.3	39	0.8	1	3.2	35
East Scotland	1.4	30	0.4	42	1.8	25	3.5	38	0.9	50	4.3	32
South Scotland	2.7	23	0.9	35	3.6	19	4.7	20	2.3	43	7.0	20
West Scotland	0.5	47	0.2	67	0.8	39	1.0	55	0.8	86	1.7	49
Wales	6.3	12	4.8	19	11.1	11	8.0	10	10.7	20	18.6	12

Region	Hedgerow groups						Total groups of trees					
	Rural		Urban		Total		Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	19.0	22	1.6	42	20.6	21	165.1	6	90.3	13	255.4	6
England	13.8	23	0.8	44	14.6	22	125.2	7	67.3	13	192.6	6
North West England	1.2	29	< 0.1	48	1.2	27	12.6	9	6.0	17	18.5	8
North East England	0.5	31	< 0.1	63	0.5	30	4.7	12	1.9	17	6.6	10
Yorkshire and the Humber	0.8	34	< 0.1	62	0.9	33	9.4	12	3.4	17	12.7	10
East Midlands	1.6	23	0.2	60	1.7	21	15.9	8	7.9	16	23.8	8
East England	2.1	21	0.2	50	2.3	20	15.3	9	16.2	14	31.5	8
South East and London	2.2	29	0.2	56	2.3	27	23.8	9	19.7	15	43.5	8
South West England	3.4	25	< 0.1	52	3.4	24	28.3	9	6.4	24	34.7	8
West Midlands	2.2	24	< 0.1	54	2.3	24	15.2	12	5.9	16	21.1	9
Scotland	2.3	31	0.2	50	2.4	29	22.7	14	6.7	26	29.5	12
North Scotland	0.2	56	-	-	0.2	56	3.1	39	-	-	3.1	39
North East Scotland	0.3	45	< 0.1	96	0.3	44	4.0	31	1.1	1	5.2	28
East Scotland	0.5	46	< 0.1	56	0.5	45	5.4	32	1.3	41	6.7	27
South Scotland	1.1	32	0.1	58	1.3	29	8.6	16	3.3	35	11.9	15
West Scotland	0.1	57	< 0.1	83	0.2	50	1.6	44	1.0	72	2.7	39
Wales	2.9	20	0.7	62	3.6	20	17.1	8	16.3	17	33.4	9



Figure 34 Rural areas of groups of trees and sub-categories

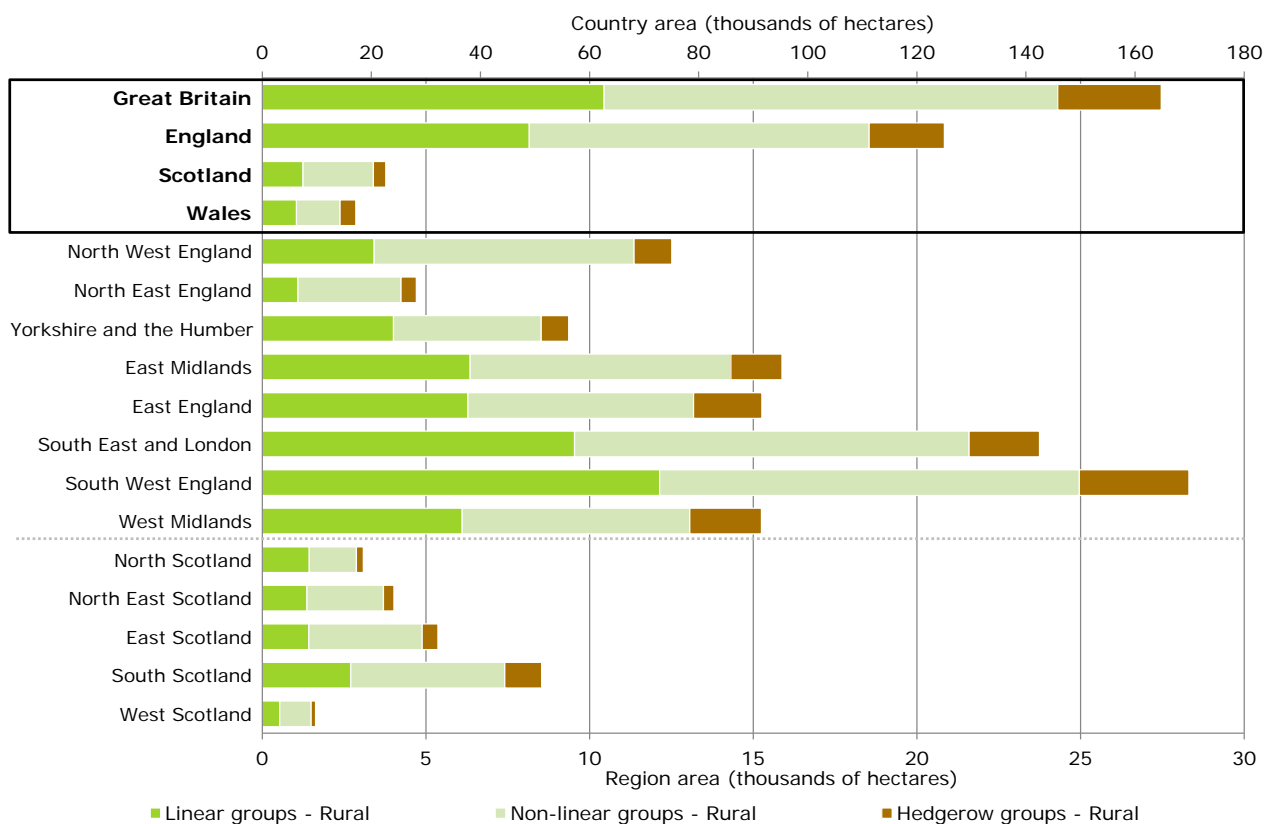
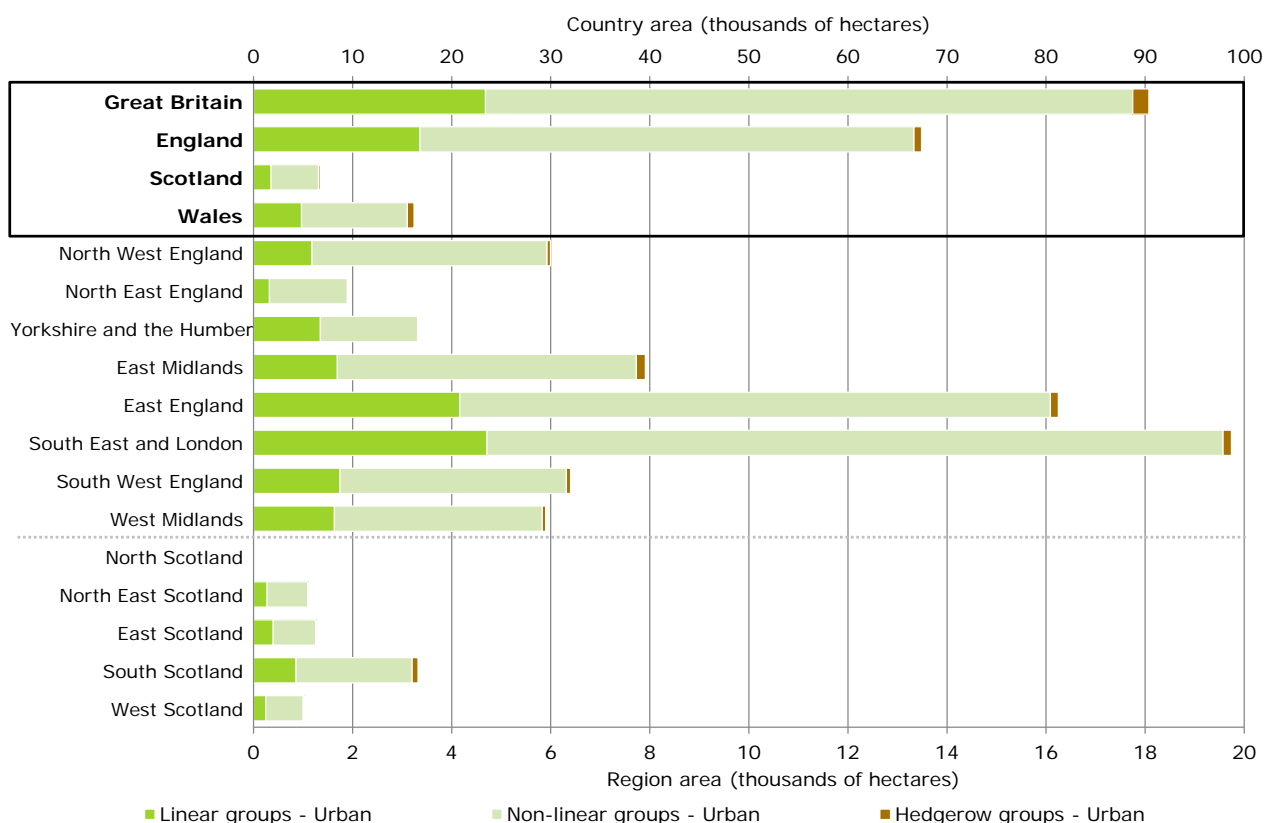


Figure 35 Urban areas of groups of trees and sub-categories





Number of groups of trees

Figure 36 Number of groups of trees including linear and non-linear sub-categories

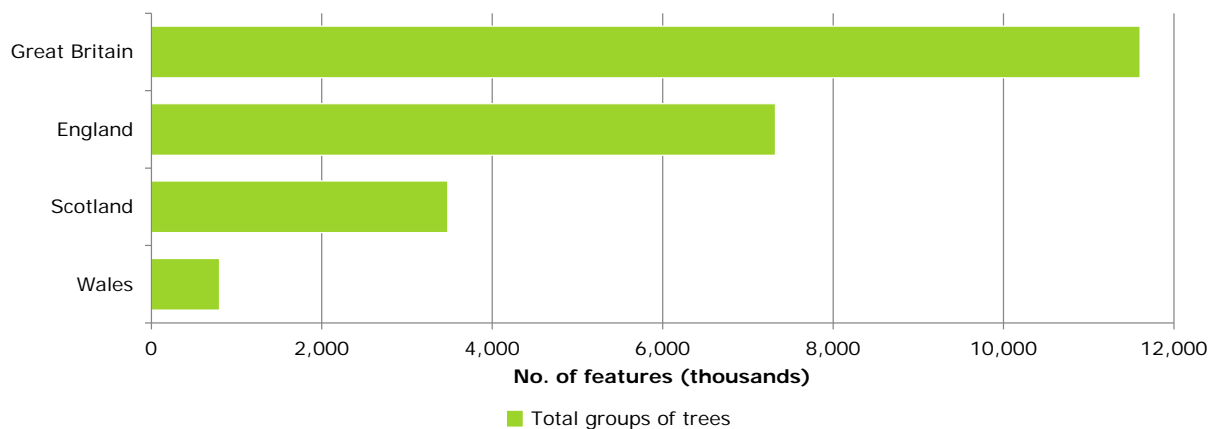


Table 15 Number of groups of trees including linear and non-linear categories

Region	Total groups of trees					
	Rural		Urban		Total	
	No. of features '000	SE%	No. of features '000	SE%	No. of features '000	SE%
Great Britain	6,878	18	4,724	43	11,602	20
England	3,391	22	3,933	50	7,324	29
Scotland	2,800	31	679	82	3,479	29
Wales	687	58	112	115	799	52

Note for Table 15:

Small woods features and group features are sometimes contiguous, forming single compound features containing more than one small wood and/or group feature. These components are counted separately for the statistics presented.



Figure 37 Number of features of groups of trees including sub-categories in rural areas

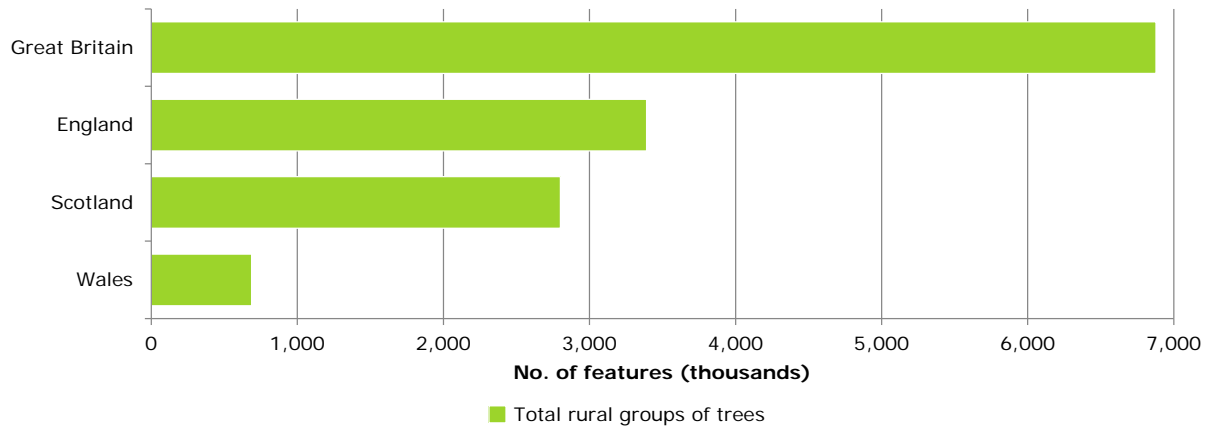
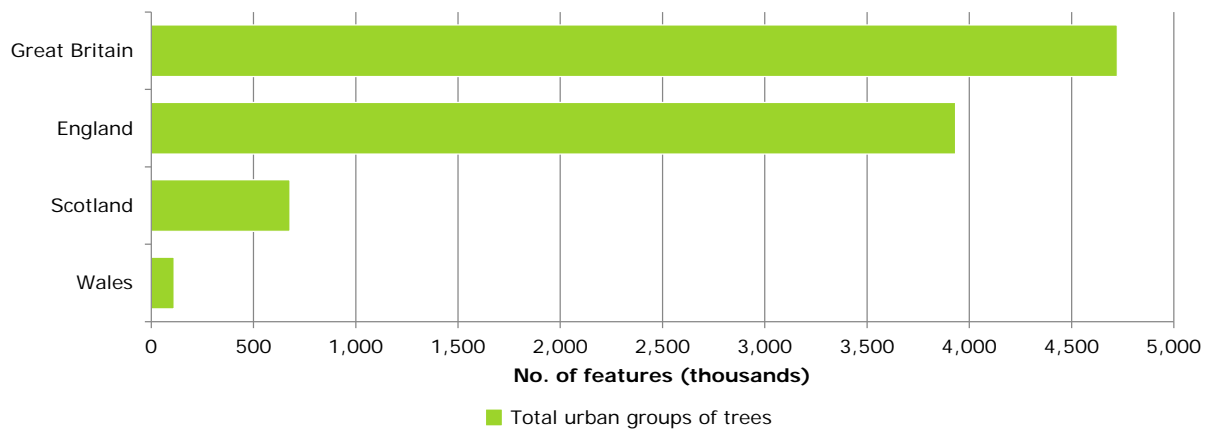


Figure 38 Number of features of groups of trees including sub-categories in urban areas



Sizes of groups of trees

Table 16 Mean sizes of groups of trees

Region	Linear groups			Non-linear groups		
	Rural	Urban	Total	Rural	Urban	Total
	m ²	m ²	m ²	m ²	m ²	m ²
Great Britain	325	424	388	193	265	227
England	328	419	384	208	275	238
North West England	399	278	358	294	178	241
North East England	409	409	409	251	180	229
Yorkshire and the Humber	422	417	420	242	286	258
East Midlands	423	254	387	237	196	220
East England	405	285	349	262	173	199
South East and London	424	349	384	302	218	239
South West England	442	323	414	297	173	249
West Midlands	414	359	395	255	452	327
Scotland	277	385	332	118	186	146
North Scotland	451	-	451	145	-	145
North East Scotland	342	242	295	152	90	111
East Scotland	355	293	323	210	115	165
South Scotland	424	273	343	201	134	158
West Scotland	261	461	350	141	140	141
Wales	472	399	463	295	220	280

Region	Hedgerow groups		
	Rural	Urban	Total
	m ²	m ²	m ²
Great Britain	168	301	281
England	160	266	254
North West England	138	145	140
North East England	176	-	176
Yorkshire and the Humber	199	48	162
East Midlands	199	500	231
East England	299	95	278
South East and London	214	96	186
South West England	260	128	247
West Midlands	327	375	328
Scotland	143	246	192
North Scotland	-	-	-
North East Scotland	223	-	223
East Scotland	106	117	112
South Scotland	267	150	206
West Scotland	33	102	85
Wales	386	365	385



Lone trees

Areas of canopies of lone trees

Figure 39 Areas of canopies of lone trees

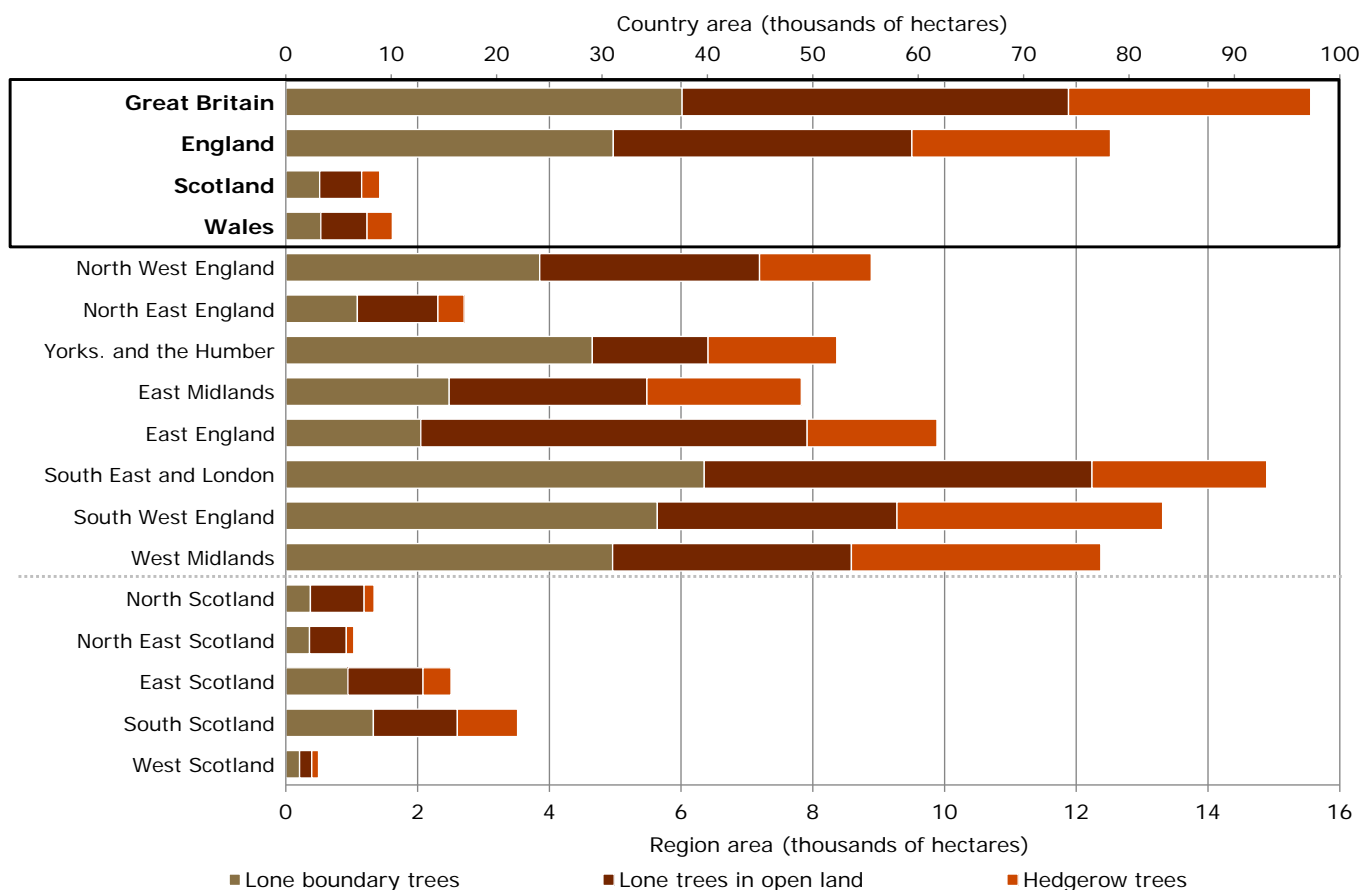


Table 17 Areas of canopies of lone trees

Region	Lone boundary trees						Lone trees in open land					
	Rural		Urban		Total		Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	21.2	18	16.4	21	37.6	14	21.6	11	15.0	17	36.7	10
England	17.4	18	13.7	21	31.1	14	16.5	11	11.8	17	28.3	9
North West England	2.2	26	1.6	28	3.9	19	2.5	17	0.8	28	3.3	15
North East England	0.7	28	0.3	52	1.1	25	1.0	18	0.3	25	1.2	15
Yorks. and the Humber	2.9	24	1.7	21	4.7	17	1.2	17	0.5	19	1.8	13
East Midlands	1.5	22	1.0	38	2.5	20	2.0	17	1.0	27	3.0	15
East England	1.0	22	1.1	33	2.0	20	1.6	18	4.3	18	5.9	14
South East and London	2.7	24	3.6	34	6.4	22	2.9	15	3.0	27	5.9	16
South West England	3.6	21	2.0	35	5.6	18	2.7	19	1.0	34	3.6	16
West Midlands	2.8	21	2.2	24	5.0	16	2.5	17	1.1	37	3.6	16
Scotland	2.6	23	0.6	43	3.2	20	3.1	26	0.8	41	4.0	22
North Scotland	0.4	56	-	-	0.4	56	0.8	66	-	-	0.8	66
North East Scotland	0.2	35	0.2	74	0.4	39	0.3	42	0.2	1	0.6	47
East Scotland	0.9	37	< 0.1	43	0.9	35	1.0	50	0.2	54	1.1	43
South Scotland	1.0	26	0.4	59	1.3	25	0.9	24	0.4	59	1.3	24
West Scotland	0.2	57	< 0.1	70	0.2	49	0.1	48	< 0.1	90	0.2	44
Wales	1.2	19	2.1	53	3.3	34	2.0	16	2.4	39	4.4	22

Region	Hedgerow trees						Total for all lone and hedgerow trees					
	Rural		Urban		Total		Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	21.4	12	1.6	27	23.0	11	64.3	6	32.8	15	97.1	6
England	18.0	12	0.9	30	18.8	12	52.0	6	26.2	15	78.2	7
North West England	1.5	22	0.2	57	1.7	20	6.3	15	2.6	21	8.9	12
North East England	0.4	27	< 0.1	45	0.4	26	2.1	16	0.6	35	2.7	15
Yorks. and the Humber	1.9	21	< 0.1	45	2.0	20	6.1	12	2.3	17	8.4	10
East Midlands	2.3	17	< 0.1	34	2.3	16	5.8	12	2.0	26	7.8	11
East England	1.8	22	0.2	29	2.0	20	4.3	13	5.4	16	9.7	11
South East and London	2.5	20	0.2	40	2.6	19	8.1	12	6.7	24	14.9	13
South West England	3.9	17	< 0.1	42	4.0	16	10.2	11	3.1	28	13.3	10
West Midlands	3.7	21	< 0.1	41	3.8	21	9.0	12	3.3	22	12.4	11
Scotland	1.6	22	0.1	37	1.7	20	7.3	17	1.6	31	8.9	15
North Scotland	0.2	53	-	-	0.2	53	1.3	58	-	-	1.3	58
North East Scotland	0.1	37	< 0.1	64	0.1	34	0.6	33	0.4	70	1.0	34
East Scotland	0.4	35	< 0.1	46	0.4	34	2.3	35	0.2	46	2.5	32
South Scotland	0.8	23	0.1	44	0.9	21	2.7	16	0.9	41	3.5	16
West Scotland	< 0.1	47	< 0.1	70	0.1	45	0.4	42	< 0.1	68	0.5	36
Wales	1.8	17	0.6	48	2.4	18	5.0	11	5.0	32	10.1	17



Figure 40 Areas of canopies of lone trees in rural areas

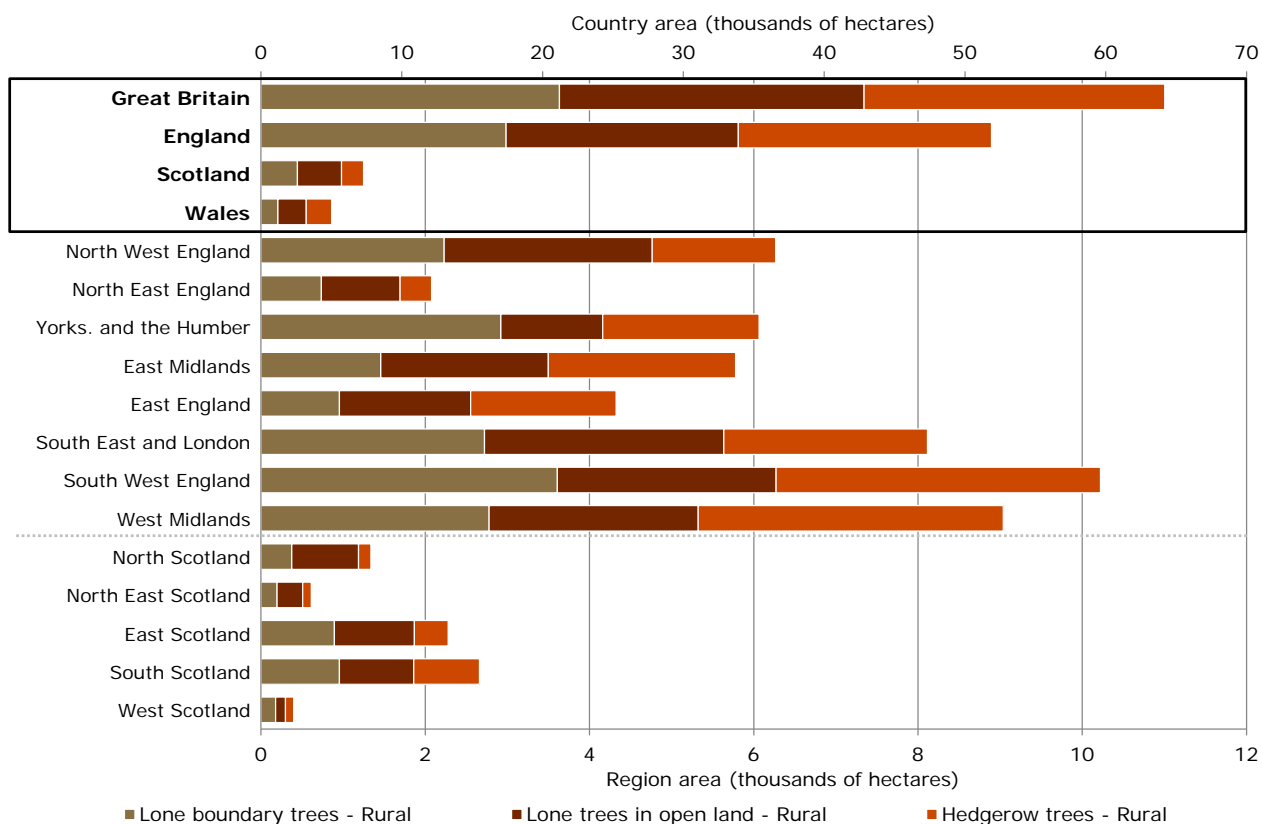
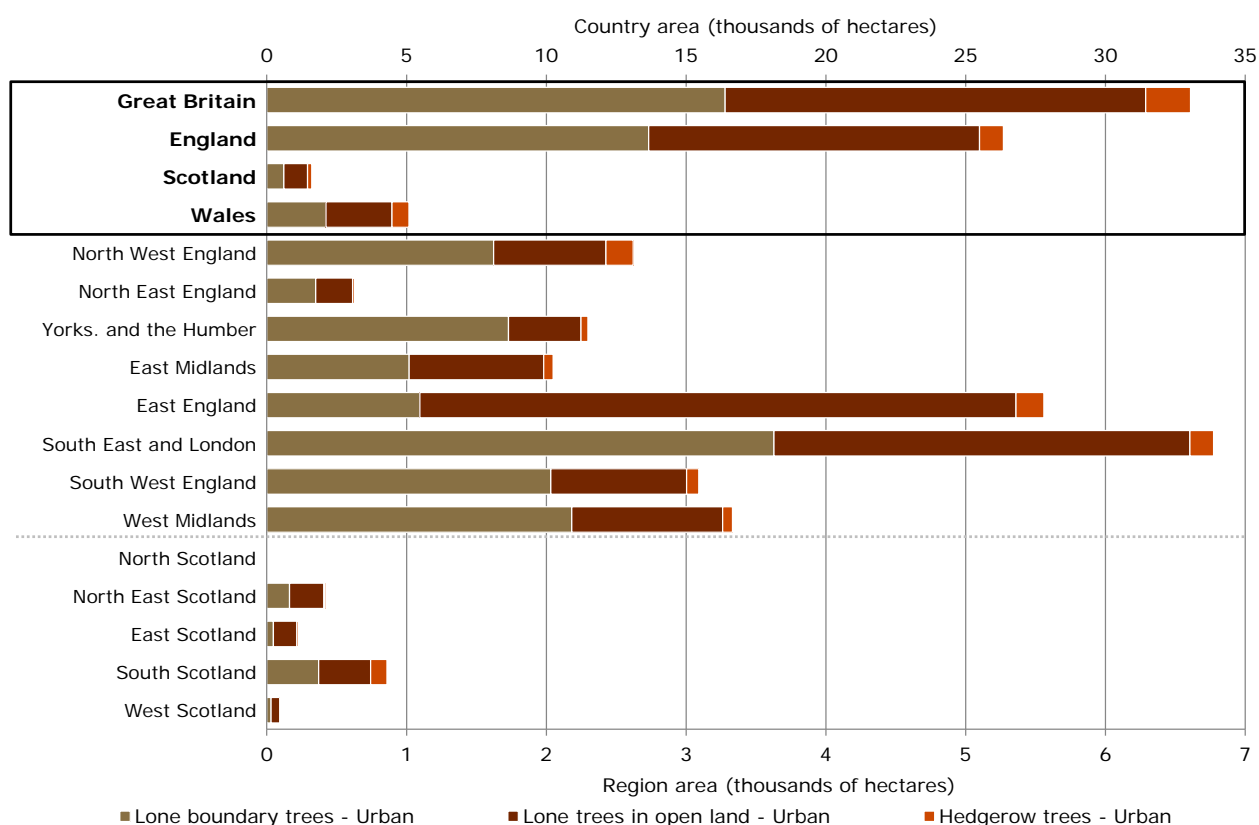


Figure 41 Areas of canopies of lone trees in urban areas





Number of lone trees

Figure 42 Number of lone trees

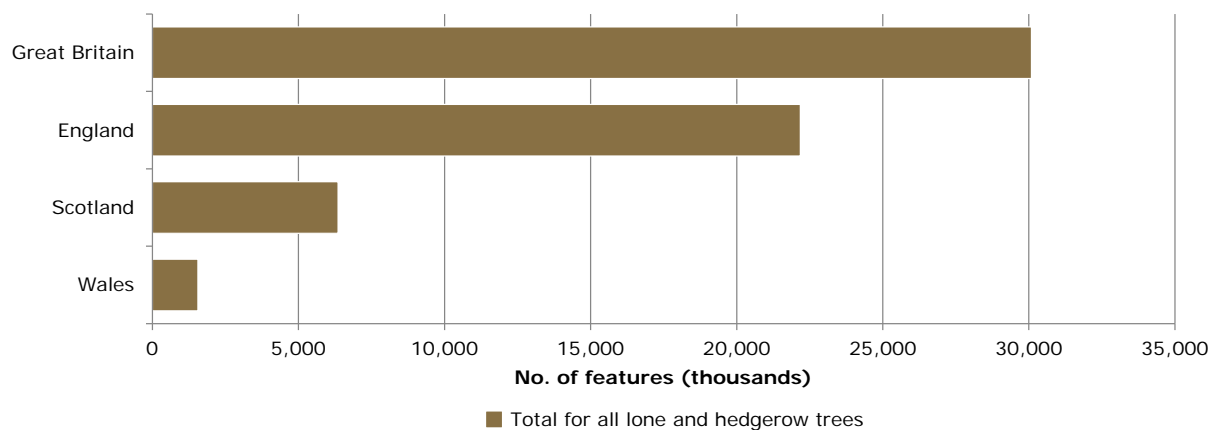


Table 18 Number of lone trees

Region	Total for all lone and hedgerow trees					
	Rural		Urban		Total	
	No. of features '000	SE%	No. of features '000	SE%	No. of features '000	SE%
Great Britain	18,772	11	11,320	28	30,092	13
England	11,922	13	10,255	30	22,177	16
Scotland	5,514	25	845	62	6,359	23
Wales	1,337	35	219	98	1,556	33

Note for Table 18:

Small woods features and group features are sometimes contiguous, forming single compound features containing more than one small wood and/or group feature. These components are counted separately for the statistics presented.



Figure 43 Number of lone tree features in rural areas

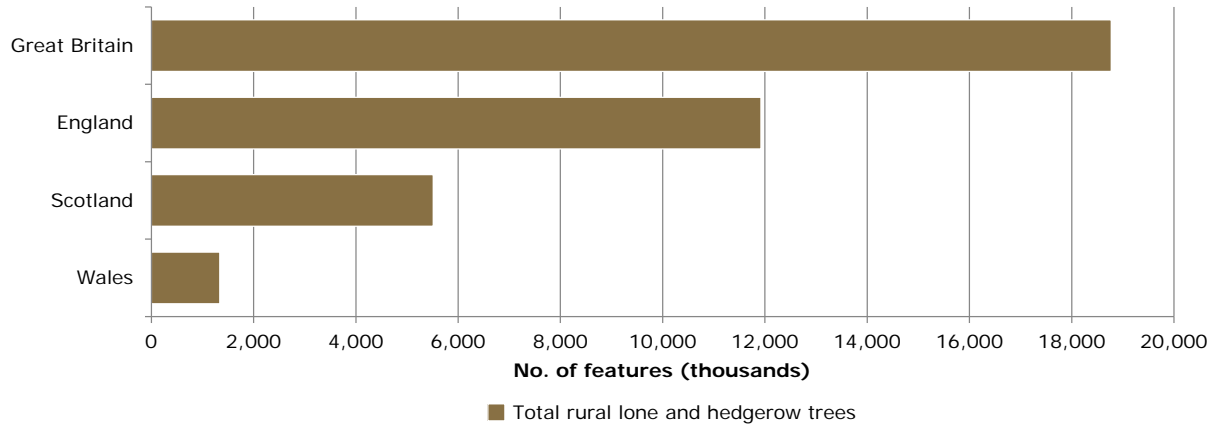
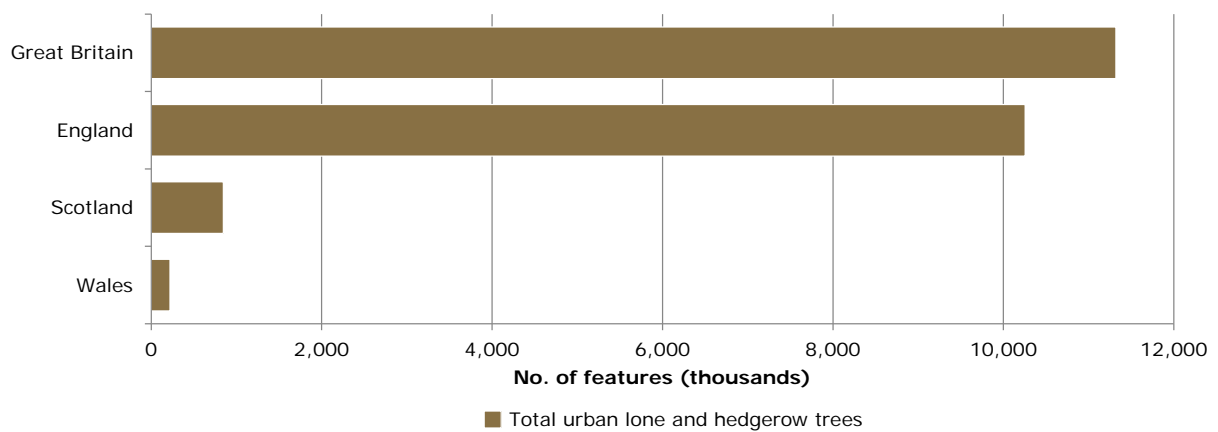


Figure 44 Number of lone tree features in urban areas



Sizes of lone trees

Table 19 Mean sizes of lone trees

Region	Lone boundary trees			Lone trees in open land		
	Rural	Urban	Total	Rural	Urban	Total
	m ²	m ²	m ²	m ²	m ²	m ²
Great Britain	29	43	34	25	44	34
England	30	43	34	26	43	34
North West England	44	27	33	41	26	37
North East England	30	19	28	36	32	34
Yorkshire and the Humber	40	23	30	36	25	31
East Midlands	37	24	30	43	26	38
East England	33	25	29	49	24	31
South East and London	63	33	38	48	30	35
South West England	45	31	38	44	16	30
West Midlands	45	34	37	44	32	38
Scotland	24	44	32	15	23	18
North Scotland	66	-	66	17	-	17
North East Scotland	19	16	16	16	14	14
East Scotland	48	24	46	30	13	22
South Scotland	50	35	41	23	17	20
West Scotland	27	13	20	24	15	19
Wales	46	23	36	80	42	74

Region	Hedgerow trees		
	Rural	Urban	Total
	m ²	m ²	m ²
Great Britain	34	62	59
England	41	58	57
North West England	71	75	72
North East England	62	40	59
Yorkshire and the Humber	57	25	55
East Midlands	56	35	55
East England	64	27	60
South East and London	64	49	63
South West England	54	14	51
West Midlands	56	27	55
Scotland	18	41	28
North Scotland	-	-	-
North East Scotland	-	6	6
East Scotland	26	20	24
South Scotland	44	20	31
West Scotland	23	12	18
Wales	98	70	96



Hedgerows

Area of hedgerows

Figure 45 Area of hedgerows

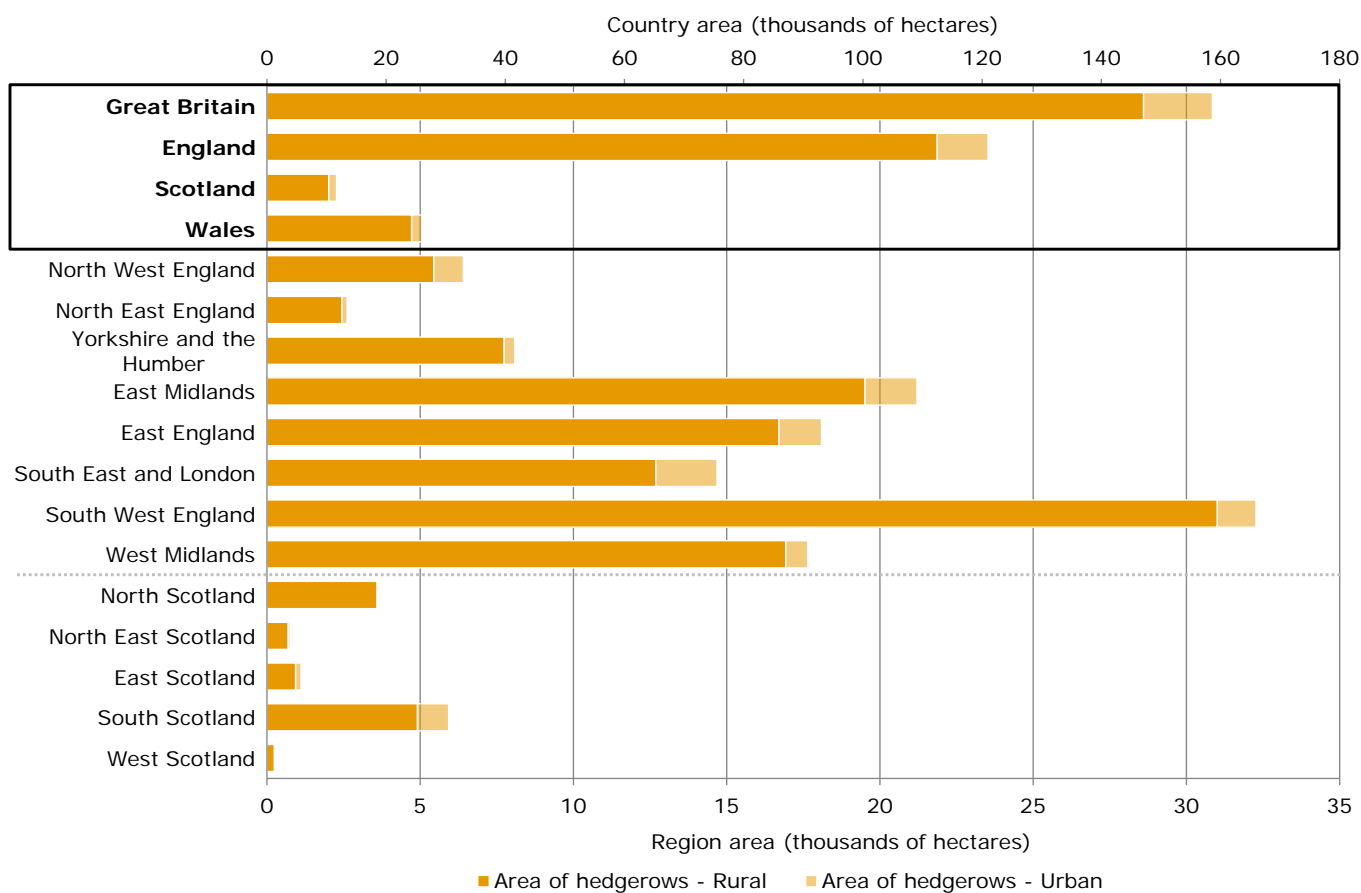


Table 20 Areas of hedgerows by country and region

Region	Area of hedgerows	
	(000 ha)	SE%
Great Britain	158.6	9
England	121.0	11
North West England	6.4	24
North East England	2.6	36
Yorkshire and the Humber	8.1	26
East Midlands	21.2	16
East England	18.1	18
South East and London	14.7	15
South West England	32.3	19
West Midlands	17.6	16
Scotland	11.6	36
North Scotland	3.6	100
North East Scotland	0.7	59
East Scotland	1.1	47
South Scotland	5.9	31
West Scotland	0.3	82
Wales	26.0	19

Table 21 Areas of hedgerows by country and rural and urban land categories

Region	Area of hedgerows					
	Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	147.1	10	11.5	16	158.6	9
England	112.5	11	8.5	18	121.0	11
Scotland	10.4	40	1.3	16	11.6	36
Wales	24.3	20	1.7	54	26.0	19

Notes for Table 20 and 21:

Hedgerow estimates are based upon fieldwork and hand-mapping only (see methodology).



Length of hedgerows

Figure 46 Length of hedgerows

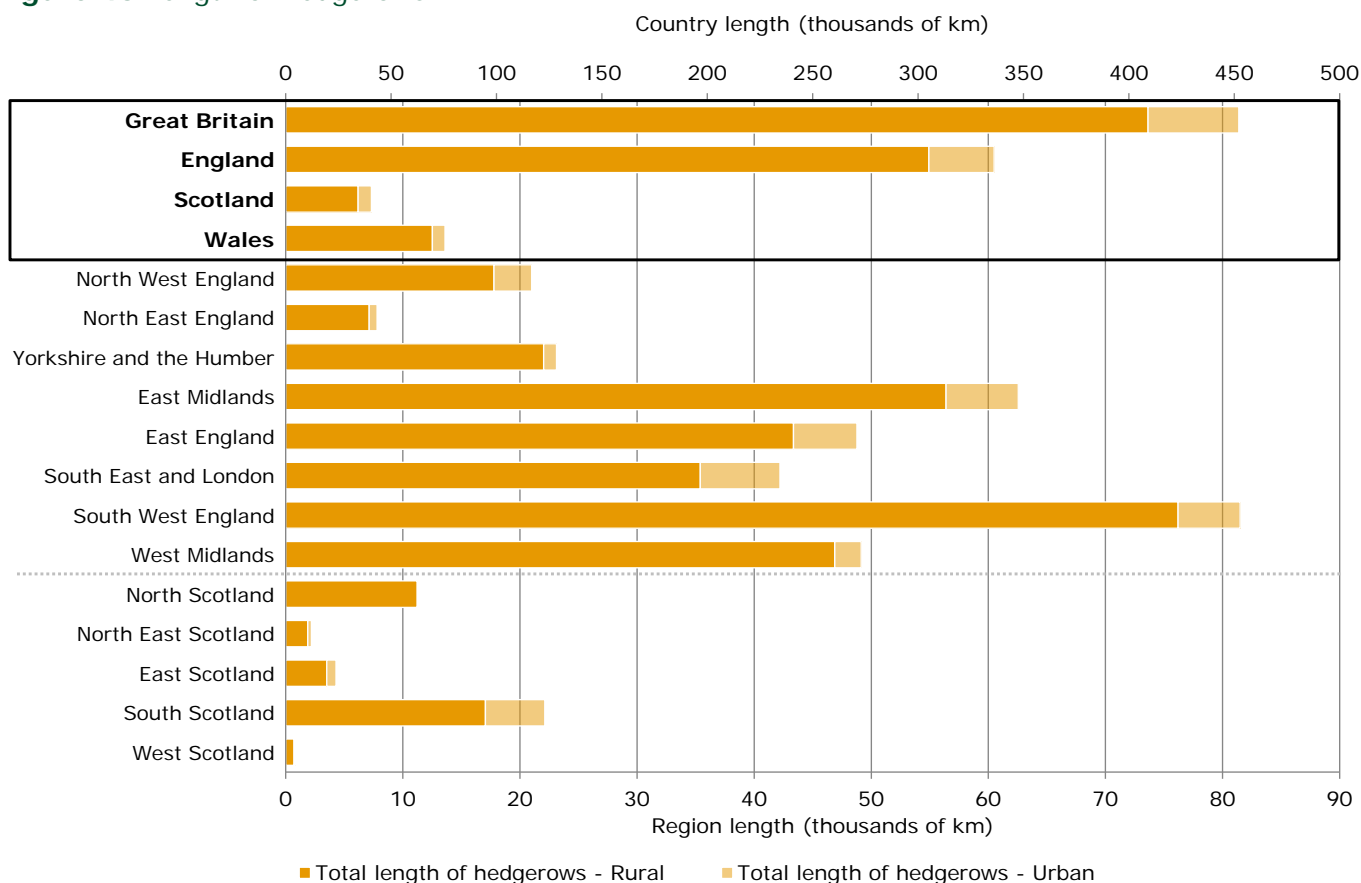


Table 22 Length of hedgerows

Region	Total length of hedgerows	
	(000 km)	SE%
Great Britain	452.2	6
England	336.1	8
North West England	21.0	24
North East England	7.8	35
Yorkshire and the Humber	23.1	25
East Midlands	62.6	13
East England	48.8	14
South East and London	42.2	12
South West England	81.5	16
West Midlands	49.1	14
Scotland	40.6	25
North Scotland	11.2	100
North East Scotland	2.2	38
East Scotland	4.3	38
South Scotland	22.1	21
West Scotland	0.8	38
Wales	75.5	16

Table 23 Length of hedgerows by country and rural and urban land categories

Region	Total length of hedgerows					
	Rural		Urban		Total	
	(000 km)	SE%	(000 km)	SE%	(000 km)	SE%
Great Britain	409.1	7	43.1	15	452.2	6
England	305.1	8	31.0	18	336.1	8
Scotland	34.3	38	6.3	16	40.6	25
Wales	69.6	17	5.9	48	75.5	16

Notes for Table 22 and 23:

1. Hedgerow estimates are based upon fieldwork and hand-mapping only (see methodology).
2. The estimates in this table equate to 281,000 miles of hedgerow in Britain; 208,800 miles in England, 25,200 miles in Scotland and 46,900 miles in Wales.
3. Estimates are broadly comparable to the *Countryside Survey 2007* estimates (Centre for Hydrology and Ecology), but will vary due to methodological and sampling differences. In particular in how hedgerows are defined in relation to the discerning line between hedgerow and linear tree features.



Trees within hedgerows

This sub-section presents estimates of areas and numbers of tree features within hedgerows. Estimates of the areas and numbers of groups of trees in hedgerows are tabulated and displayed in the section on groups of trees in Tables 14 and 16 and Figures 34, 35 and 39, and estimates of areas and numbers of lone trees in hedgerows are tabulated and displayed in the section on lone trees in Tables 17 and 19 and Figures 39, 40 and 41.

Tables 22, 23 and 24 and Figures 47-49 below summarise these estimates and show the total areas of tree features within hedgerows to provide complementary information to the estimates of areas and lengths of hedgerows themselves.

Figure 47 Areas of canopies of hedgerow tree features

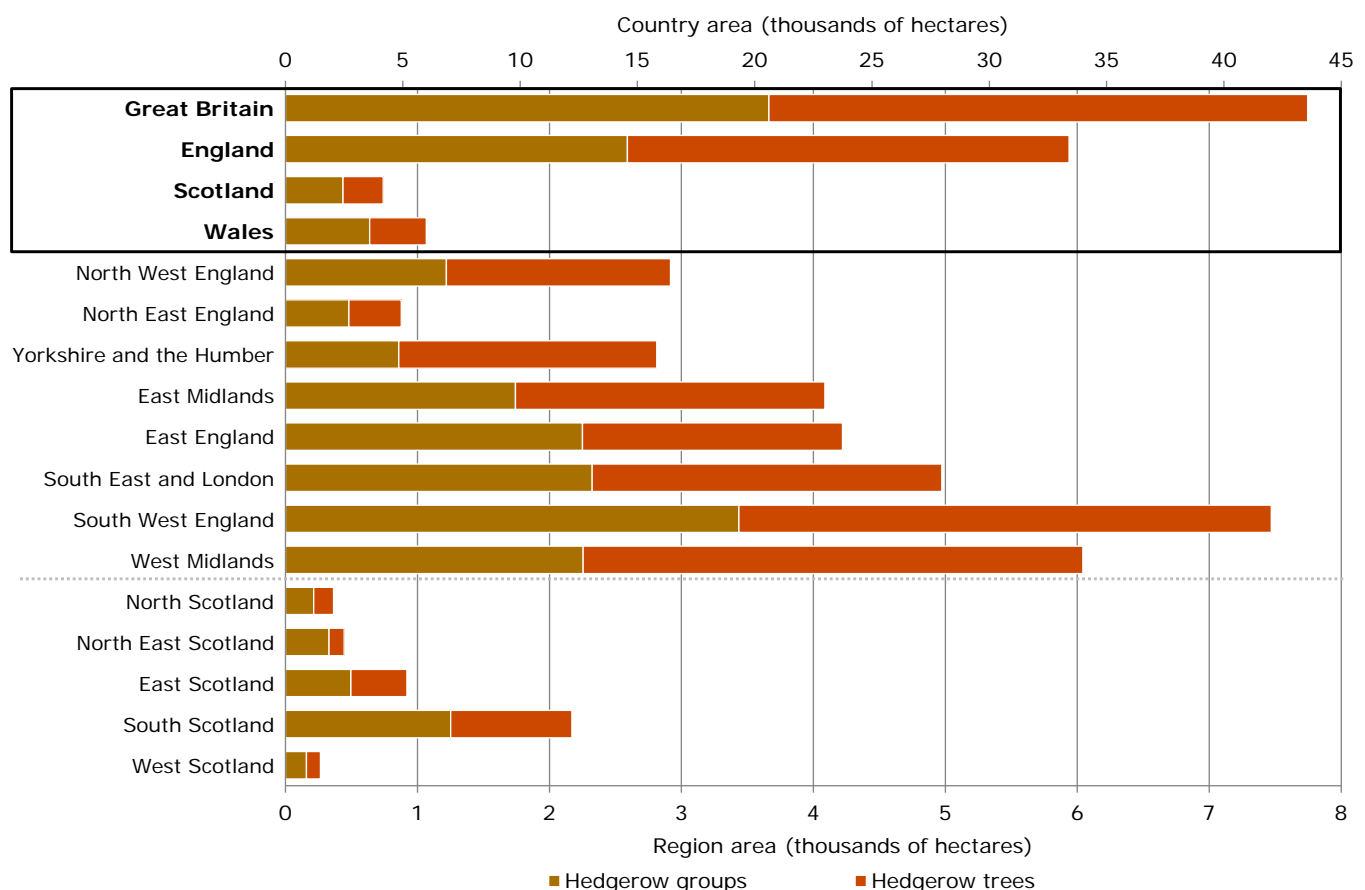


Table 24 Area of canopies of hedgerow tree features

Region	Total hedgerow tree features					
	Rural		Urban		Total	
	(000 ha)	SE%	(000 ha)	SE%	(000 ha)	SE%
Great Britain	40.3	14	3.2	28	43.6	13
England	31.8	14	1.6	30	33.4	13
North West England	2.7	20	0.3	48	2.9	19
North East England	0.8	24	< 0.1	45	0.9	24
Yorkshire and the Humber	2.7	21	< 0.1	41	2.8	21
East Midlands	3.8	15	0.2	48	4.1	14
East England	3.9	17	0.4	31	4.2	15
South East and London	4.6	19	0.3	39	5.0	18
South West England	7.3	16	0.2	38	7.5	16
West Midlands	5.9	18	0.1	39	6.0	18
Scotland	3.8	23	0.3	34	4.2	22
North Scotland	0.4	45	-	-	0.4	45
North East Scotland	0.4	39	< 0.1	61	0.4	38
East Scotland	0.9	34	< 0.1	41	0.9	33
South Scotland	1.9	23	0.2	38	2.2	21
West Scotland	0.2	43	< 0.1	69	0.3	39
Wales	4.7	15	1.3	42	6.0	15



Figure 48 Area of canopies of hedgerow tree features in rural areas

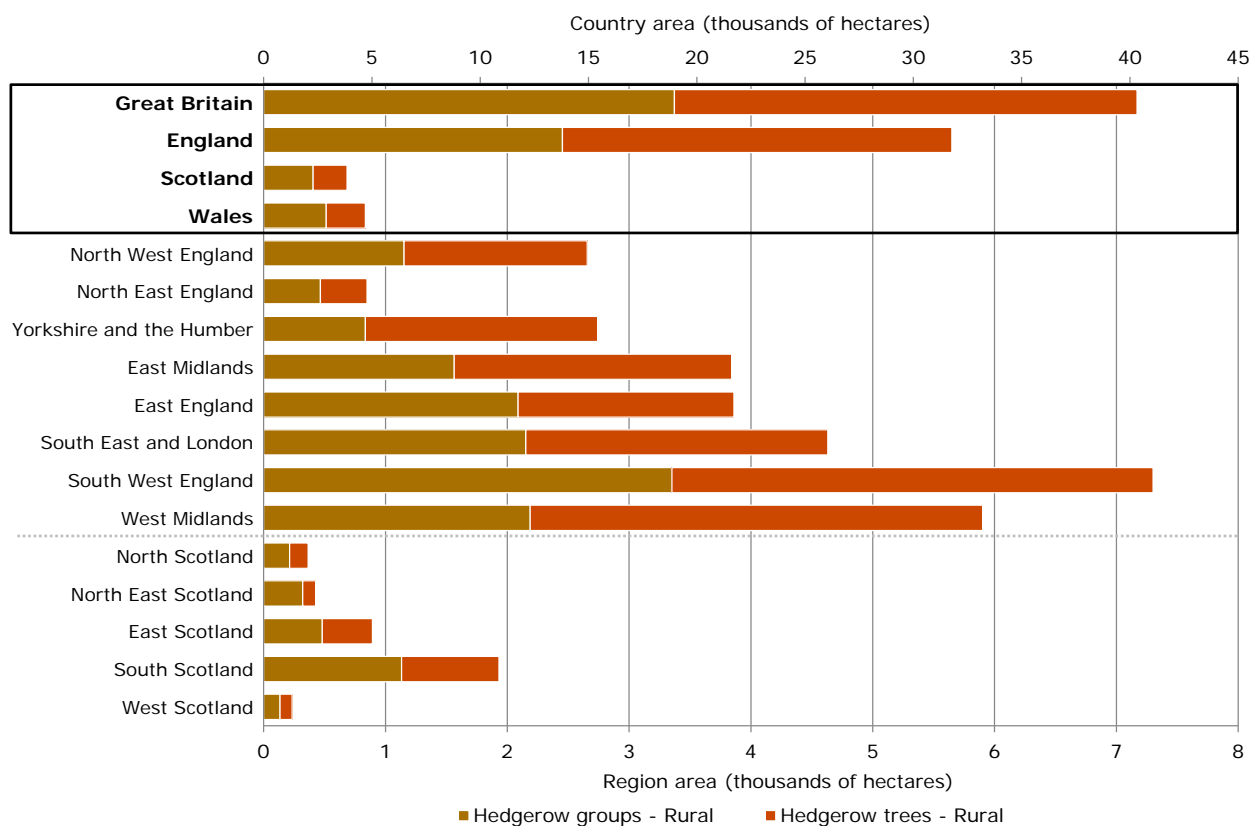


Figure 49 Area of canopies of hedgerows tree features in urban areas

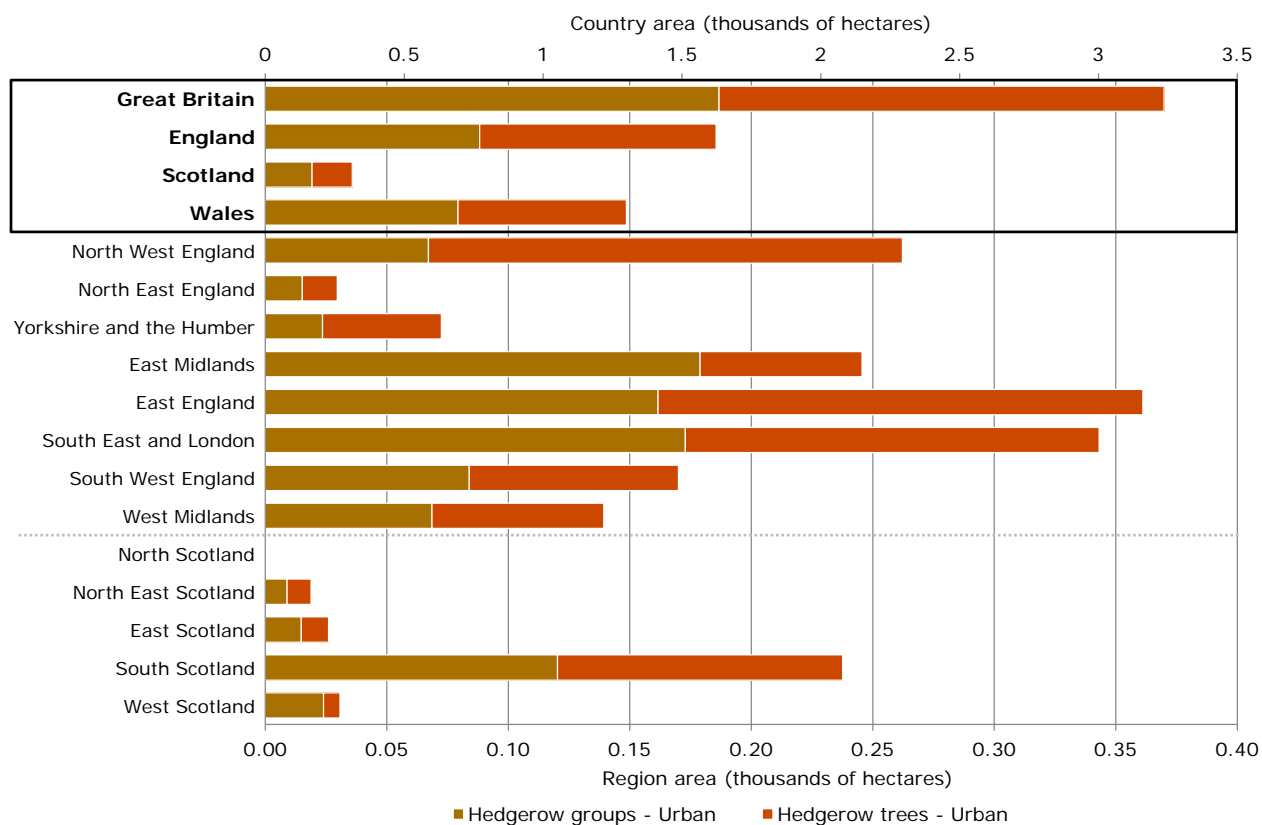


Table 25 Upland and lowland distribution of tree features outside woodland

Region	Area of features on land over 200m	Area of features on land below 200m
	%	%
Great Britain	9.0	91.0
England	5.6	94.4
North West England	4.6	95.4
North East England	11.5	88.5
Yorkshire & the Humber	22.4	77.6
East Midlands	0.2	99.8
Eastern England	0.0	100.0
S.E. England & London	0.0	100.0
South West England	8.6	91.4
West Midlands	12.5	87.5
Scotland	15.2	84.8
North Scotland	20.2	79.8
North East Scotland	12.7	87.3
East Scotland	4.8	95.2
South Scotland	22.4	77.6
West Scotland	0.0	100.0
Wales	26.5	73.5

Maps

The following maps are provided to show aspects of the present spatial distributions of woodland and tree cover outside woodland. Figure 50 shows how tree cover outside woodland is predominantly located in valleys and plains and less so on steep slopes or at greater altitude, in this instance in Cumbria. Figure 51 shows the strong association between urban areas, lower altitudes and trees outside woodland in South Scotland. Figure 52 shows the widespread nature of tree cover outside woodland in the landscape, and their lower representation on land at higher altitude, such as Dartmoor, Exmoor, Bodmin Moor and Salisbury Plain. Figure 53 shows that there are a large number of small woods features in South East England and that they are widely spread and represented across this area, including in Greater London. A full suite of 14 A3 regional maps and two A1 national maps (images only as opposed to GIS data) are available for download from the Forestry Commission / Forest Research / NFI website at www.forestry.gov.uk/inventory.

Figure 50 NFI woodland and tree cover outside woodland in Cumbria

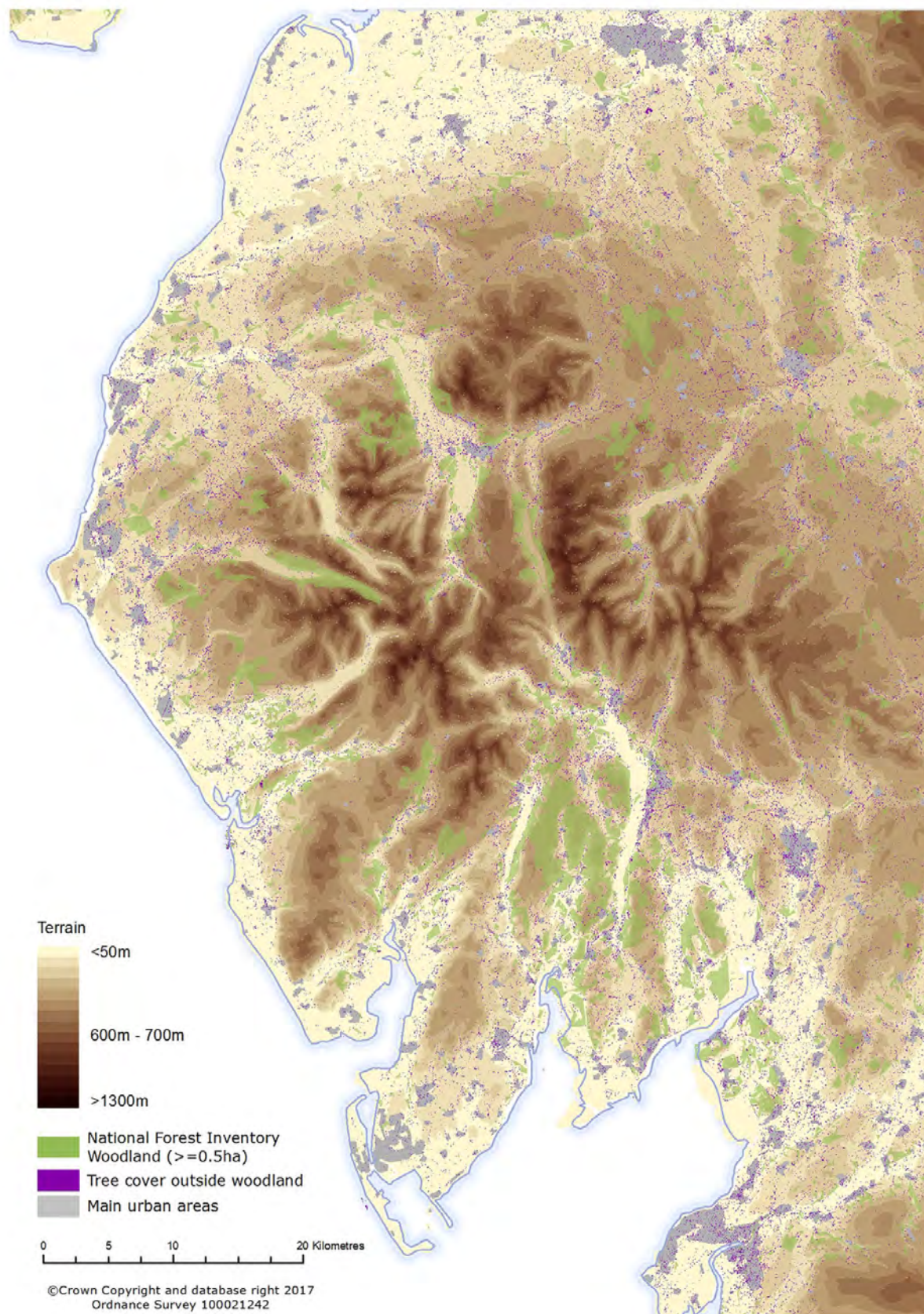


Figure 51 NFI woodland and tree cover outside woodland in South Scotland

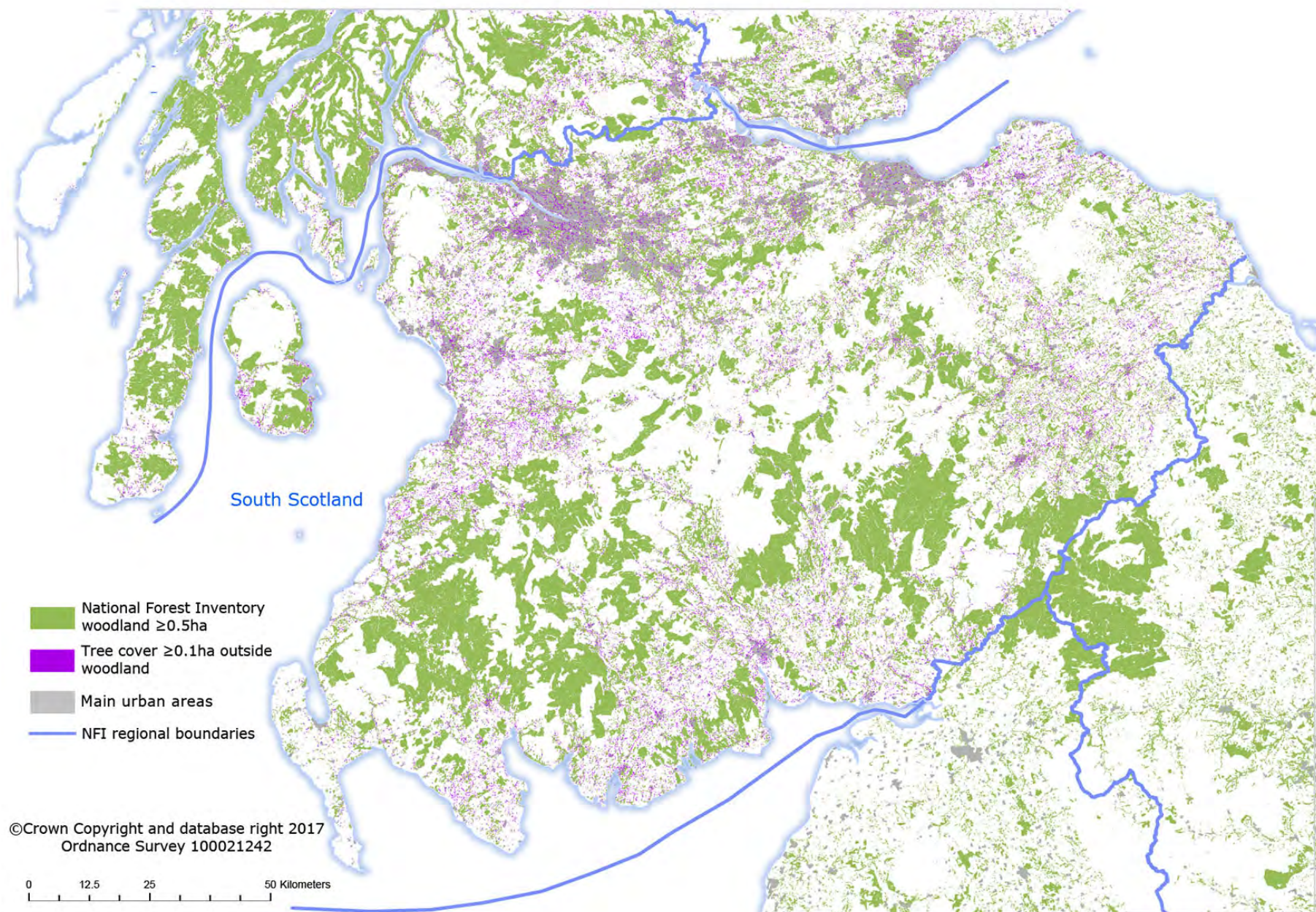


Figure 52 NFI woodland and tree cover outside woodland in South West England

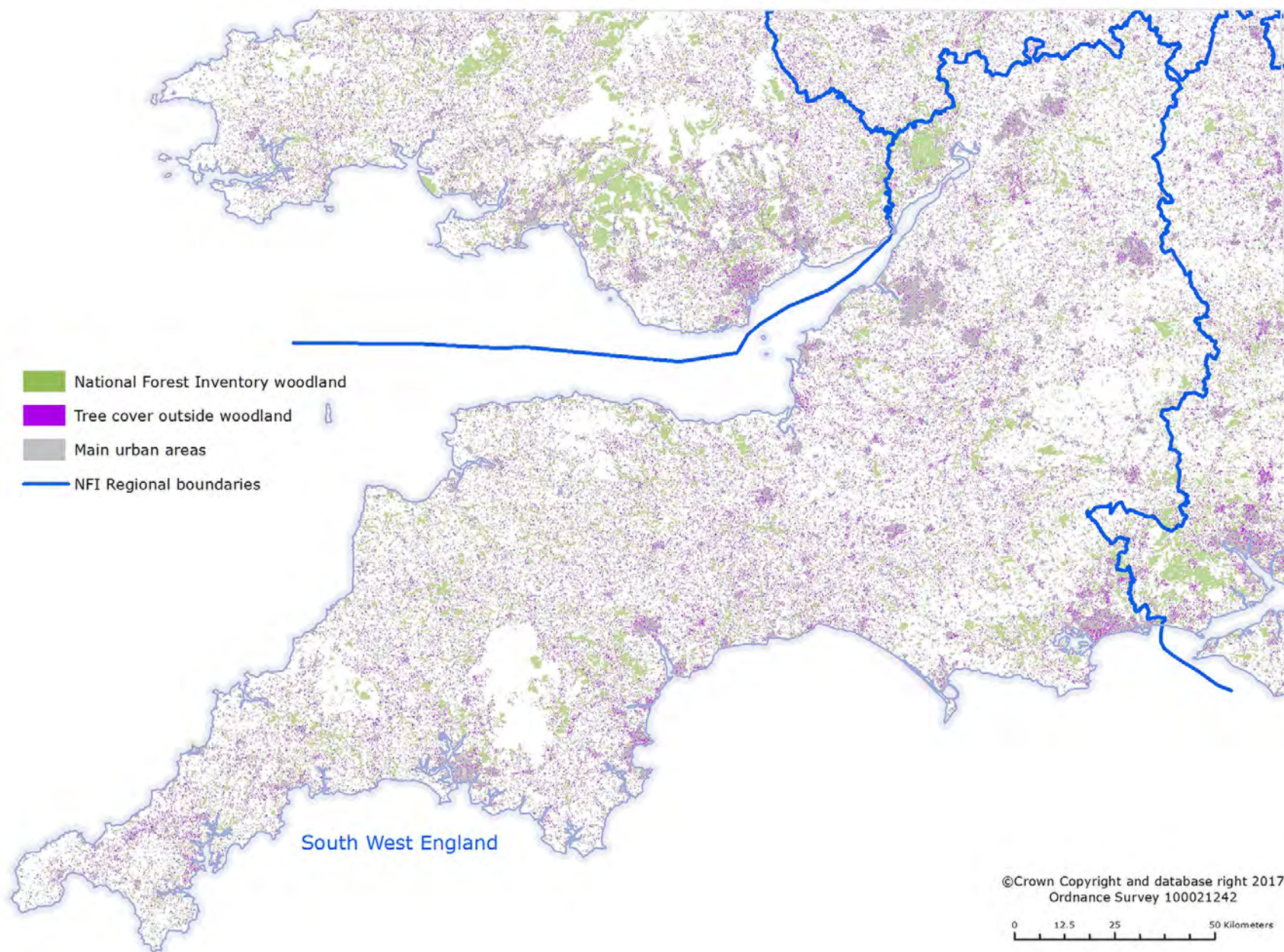
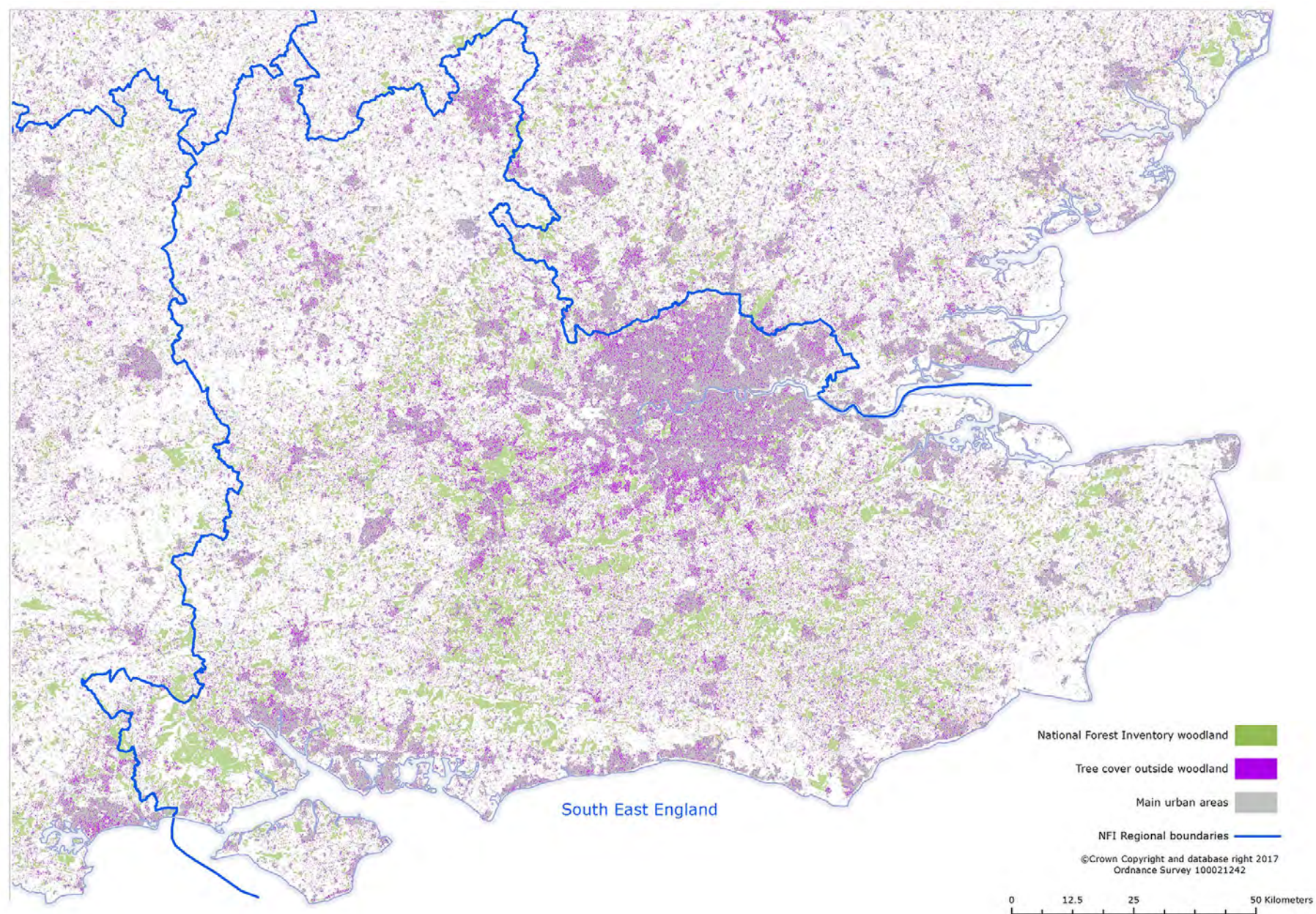


Figure 53 NFI woodland and tree cover outside woodland in London and South East England



What the results tell us

The results show that there are more trees and tree cover outside woodlands in Great Britain than previous evaluations had reported. There are 742 thousand hectares of tree cover outside woodland in total, representing 19% of all tree cover (both woodland and outside of woodland) and 3.2% of all land area. The report also quantifies non-woodland tree features in terms of numbers of features and characterises these features in terms of their sizes, shapes and locations. This locational work identifies that the distribution of tree cover outside woodland varies considerably across Britain, ranging from 4.5% of land area in Wales to 1.1% in Scotland.

The increased area of non-woodland tree cover observed in this work will include long established tree cover, small scale and non-grant aided tree planting arising over recent decades and natural regeneration on abandoned farmland and brownfield land. Tree establishment alongside transport routes and built developments will also have contributed. Improved detection and reporting of these features has become possible through the application of new techniques and technologies in earth observation, Geographic Information Systems and statistics. In essence these new techniques are much more capable of identifying and quantifying smaller features such as lone trees and small groups of trees. This extra accuracy has resulted in more coverage of non-woodland tree features being identified within the landscape. Although the findings of the 1947 and 1951 surveys, known at the time as the modern Domesday assessment and based upon a full census of woods (see Background section), found a similar ratio of woodland to non-woodland trees (one in five trees were non-woodland trees or 21% of all trees were outside woodland).

The results show that the distribution of tree cover outside woodland is highly uneven across Britain, displaying strong patterns with very different amounts and proportions of tree cover outside woodland found between the rural and urban land categories, upland and lowland environs and between the east and west of Britain. Urban landscapes contain higher levels of tree cover than rural, lowlands have much more tree cover outside woodlands than the uplands and the west has much higher levels of non-woodland tree cover than the east. There is also a significant association with trees and linear features such as watercourses and land boundaries, with 37% of non-woodland tree cover features being linear in nature. The survey establishes that non-woodland tree features and tree features as a whole are more concentrated in urban areas than rural areas, demonstrating that trees are an integral part of the immediate human environment in Britain.

It is of note that tree coverage in urban areas is 16.5% across Britain. This pattern is remarkably persistent across British urban areas and evident in the estimate that 34% of lone trees in Britain are found in urban areas.

The distribution of tree cover outside woodland is a result of a history of woodland clearance, historic land husbandry, land use economics, boundary marking and the planting and establishment of trees, the latter in particular in the 20th century. This history helps to explain the uneven distribution of non-woodland tree cover found across Britain and is explored in more depth in Appendix 2 on the Historical influences on tree cover. Exactly how the trees identified in this report were originally established is uncertain without further field surveys.

Future work

The findings in this report can inform those areas of policy and practice that involve small woods, groups of trees and lone trees, such as plant health management, landscape ecological network planning, habitat restoration, carbon accounting and urban planning.

The results presented are primarily based upon earth observation techniques supported by limited fieldwork and assess only the area and number of tree features outside woodland. The results do not include estimates of the composition and nature of these trees, covering parameters such as:

- Tree species
- Tree age
- Tree health

Obtaining such data would require a more extensive fieldwork programme with more detailed assessment of the trees forming non-woodland features.

A future NFI report, planned for release in 2018, will report on the change in woodland and non-woodland tree cover between 1924 and 2016, comparing NFI findings to those of previous Forestry Commission woodland censuses.

Glossary

Forest (and woodland)	National Forest Inventory (NFI) woodland is defined as land with a minimum area of 0.5 hectare under stands of trees, and tree crown cover of at least 20%, or the potential to achieve this. The minimum width for woodland is 20 metres.
Forestry Commission (FC)	The government department responsible for the regulation of forestry, implementing forestry policy and management of state forests in England and Scotland. Forestry policy, regulation and management is devolved, with the exception of common issues addressed on a GB or UK basis.
Group	A configuration of two or more trees less than 0.1 ha in extent.
Hectare (ha)	Unit of area equivalent to 100 metres x 100 metres = 10,000 square metres. 1 ha = 2.47 acres.
Hedgerow group	A group of trees that span a hedgerow.
Boundary tree	A lone tree on a boundary, such as a wall or fence.
Hedgerow tree	A lone tree within a hedgerow greater than 3 metres in height.
Lone tree	A single tree of over 2 metres in height (or over 3 metres in height in hedgerows) whose crown is not in contact with that of any other trees.
Urban and rural areas	Urban areas in this report are the areas mapped as the urban land category in the Ordnance Survey (OS) 1:250,000 Strategi [®] spatial dataset. All land areas of Britain outside this category are taken to be rural areas.
Linear group	A group of trees with a width of less than 20 metres.
Lowland and Upland Britain	For the purposes of this report, land at an altitude below 200 metres is defined as lowland and above 200 metres as upland (based on Bartholomew 1:200,000 Contour Data).
National Forest Inventory (NFI)	An inventory run by the Forestry Commission, set up in 2009, to provide a record of key information about GB forests and woodlands.
Ordnance Survey (OS) MasterMap	A mapping product that delineates features of the United Kingdom landscape.
Small woods	Wooded area of greater than 0.1 hectare in extent that does not qualify as NFI woodland.
Tree cover	The area of land covered by the crowns of trees.

Appendices

Appendix 1: Data and methodology

(A) Data sources

The estimates of areas and incidences of small woods features published in this report have been derived from a number of data sources. Statistical calibration models have been employed to produce estimates from the combined information in these sources. The various spatial datasets that have been utilised in this process are listed in the Method overview section of the main report. A more detailed description of each spatial dataset is provided here, separated into the reference datasets that are defined across the land areas of Great Britain or of whole countries, and sample datasets defined within randomly selected one-by-one kilometre sample squares.

Reference datasets

National Tree Map (NTM™)

This is a spatial product produced and marketed by Bluesky International Limited comprising the estimated presence and location of tree canopies with complete coverage of all land area. It was generated from a combination of aerial photography, colour infra-red imagery and digital terrain and surface models. These were processed using an automated algorithm that attempted to identify areas of tree cover from this information by means of bespoke image-processing techniques.

The product licensed for use by the Forestry Commission covered the whole land area of England and Wales and differentiated the area into tree cover and non-tree cover based upon the interpretation algorithm used. Examination of the quality of the product showed that the differentiation is good but not perfect; it contains some mis-identification of non-tree features as tree cover, misses some features of tree cover, and successfully identifies but has locational and size inaccuracies of some tree cover features (sometimes due to problems with the inclusion of ground shadow as tree cover). The product is specified as identifying the canopies of trees that have attained a height of 3 metres or more, but a proportion of trees of less than 3 metres in height were successfully identified and included in the map.

The product supplied by Bluesky and used in this study represented individual tree canopies as seamless differentiated (non-overlapping) polygons. This was post-processed by the NFI team by 'dissolving' adjacent individual tree canopy representations into integrated combined polygons, then categorising the polygons resulting from this process into four classes of apparent tree cover from the properties of these polygons:

1. Individual trees with canopies not touching the canopies of other trees;
2. Groups of trees of an integrated canopy area of less than 0.05 hectare in extent (labelled 'groups');
3. Areas of apparent integrated tree canopy between 0.1 hectares and 0.5 hectare in extent (labelled 'small woods'); and
4. Areas of apparent integrated tree canopy of over 0.5 hectare in extent (labelled 'NFI missed' or 'un-mapped').

Native Woodland Survey of Scotland (NWSS) dataset

This dataset was originally commissioned by Forestry Commission Scotland for the Native Woodland Survey of Scotland project⁷. It consists of a spatial dataset of all woodland areas in Scotland of a minimum size of 0.1 hectares identified by interpretation of aerial photography. It was produced between 2006 and 2010 using aerial photography taken over the period 1999 to 2009. Masking out NFI woodland areas according to the 2013 NFI woodland map provides information on wooded areas of over 0.1 hectare in extent outside the NFI map.

The 2013 NFI woodland map

The NFI woodland map is a spatial product of the NFI that is updated annually and maps and classifies areas of NFI woodland (by Interpreted Forest Types – 'IFT's') that have been identified from aerial photography, satellite imagery and administrative sources. It is used in this study to eliminate areas identified as NFI woodland from the analysis, so that the estimates in this report relate to areas outside of mapped NFI woodland areas.

The Ordnance Survey Strategi[®] 1:250,000 scale map

This is a spatial product from Ordnance Survey that differentiates the land area of Great Britain into several infrastructure layers, including urban land, with urban land being identified as areas containing a concentration of buildings and other structures. It has been used in this study as a stratification factor in the design of the survey work and to provide a breakdown of overall results into those pertaining to rural and urban areas separately.

⁷ The final report of this project can be found at <http://scotland.forestry.gov.uk/supporting/strategy-policy-guidance/native-woodland-survey-of-scotland-nwss/national-nwss-report>

⁸ The map published by NWSS utilised polygons of 0.5 hectare and over from this work, and was limited to native, nearly native and plantations on ancient woodland sites (PAWS) sites in Scotland.

Sample datasets

These datasets have been generated by the NFI with hand-mapping and ground survey exercises within randomly selected one-by-one kilometre sample squares. The numbers of such samples selected for each survey within each NFI region, country and GB is shown in Table 26. In many cases these sample squares contained both rural and urban areas, as identified in the Ordnance Survey Strategi® map, and the statistical units used in the analysis of the various datasets were defined as either the rural and urban areas within these sample squares. Consequently, those squares that contain both rural and urban areas contributed two separate units of information to the analyses. Table 26 shows the numbers of sample squares in total and also the number of squares containing rural areas and urban areas. The sum of the latter two categories therefore generally exceeds the total number of surveyed squares.

Table 26 Numbers of hand mapped and fieldwork one-by-one kilometre sample squares

Region	Hand-mapped sample			Fieldwork sub-sample		
	No. of sample squares containing:		Total no. of sample squares	No. of sample squares containing:		Total no. of sample squares
	Rural	Urban		Rural	Urban	
Great Britain	271	101	277	33	16	35
England	185	78	190	24	13	26
North West England	22	15	23	2	2	2
North East England	13	6	13	1	1	1
Yorkshire and the Humber	22	6	22	2	1	2
East Midlands	24	8	24	2	2	2
East England	25	11	26	4	1	4
South East and London	28	15	31	5	1	5
South West England	33	11	33	5	3	6
West Midlands	18	6	18	3	2	4
Wales	27	9	27	4	1	4
England and Wales	212	87	217	28	14	30
Scotland	59	14	60	5	2	5
North Scotland	6	1	6	1	0	1
North East Scotland	9	2	10	1	1	1
East Scotland	10	3	10	1	0	1
South Scotland	24	7	24	1	1	1
West Scotland	10	1	10	1	0	1

England and Wales hand-mapped data

The hand-mapping exercise involved visual interpretation of aerial photography to identify and plot the location of the boundaries of tree cover and hedgerows within a sample of 217 one-by-one kilometre squares in England and Wales and to classify the identified features into a number of different categories. The exercise was confined to land areas outside the woodland areas identified in the 2013 NFI woodland map.

The sample of 217 squares selected for England and Wales comprised an initial 17 squares that were previously assessed in a pilot study on the quality of the NTMTM product, augmented by a further 200 samples that were subsequently selected and hand-mapped. This sample of 200 was stratified by NFI region and by urban and rural areas, with the latter classification defined and identified by the OS Strategi[®] map. The results of this hand-mapping exercise were used to relate to and calibrate the information in the NTMTM map. Since the pilot study found that the NTMTM product was more accurate in identifying tree features in rural areas compared to urban areas, urban areas were sampled more intensively in the hand-mapping exercise in order to compensate for these observed differences in accuracy attained by the NTMTM product. Accordingly, in the selection of the sample of 200 squares, the probability of selection of urban areas was weighted by a factor of 2.6 in comparison to rural areas.

The mechanism of selection of the sample involved enumerating the rural and urban land areas outside NFI woodland (according to the 2013 NFI woodland map) within each NFI region. The proportion of the sample squares allocated to each NFI region was assigned *pro-rata* to a 'weighted' total land area within each region, calculated as $(\text{rural land area}) + 2.6 * (\text{urban land area})$. Selection of the sample of squares within each NFI region was made with probability of selection of a square proportionate to the 'size' of the square, where the 'size' of a square was calculated as $(\text{rural land area}) + 2.6 * (\text{urban land area})$, after excluding areas of woodland according to the 2013 NFI woodland map.

Within each selected square, after masking out areas of NFI woodland according to the 2013 NFI map, the aerial photography interpreters plotted the boundaries of each individual tree or wooded feature identified in the photography, and classified each feature as belonging to one of the categories listed in Table 27.

Table 27 Tree cover categories assessed and captured in the hand-mapping exercise

Feature name	Description
NFI missed	Extension of NFI woodland or area of woodland >0.5 hectare in extent and >20 metres in width
Small woods	Wooded area between 0.05 hectare and 0.5 hectare in extent and >20 metres in width
Linear group	Wooded area <20 metres in width and with a length to width ratio of at least 4:1
Clustered group	Groups of trees of <0.05 hectare in extent that do not qualify as a linear group and are not growing within a hedgerow
Hedgerow group	Groups of trees growing within a hedgerow
Boundary tree	Single tree growing on a boundary (and not in a hedgerow)
Hedgerow tree	Single tree growing within a hedgerow
Lone tree	Single tree not on a boundary or in a hedgerow

Post-processing of the hand-mapped data was undertaken to more closely align the categories in the processed dataset to those used in this report, as defined in Table 3. Accordingly:

- 'Non-linear groups of trees' were formed by pooling 'Clustered groups' with 'Small wood' features of less than 0.1 hectare;
- 'Linear groups of trees' were formed of 'Linear groups' of less than 0.1 hectare;
- 'Non-linear small woods' were formed of 'Small wood' features of greater than or equal to 0.1 hectare; and
- 'Linear small woods' were formed of 'Linear groups' of greater than or equal to 0.1 hectare.

In addition to identifying and plotting tree and woodland features, the hand-mapping exercise also identified and plotted hedgerows within the sample squares (composed of shrubs and/or small trees), from which the area and length of hedgerows were assessed.

Scotland hand-mapped data

In Scotland, a total of 60 one-by-one kilometre squares were selected for hand-mapping which, as with the England and Wales exercise, involved interpretation of aerial photography to identify and plot tree features, individual trees and hedgerows within the sample squares.

The sample was stratified by NFI regions within Scotland and by urban and rural areas, the latter according to the Ordnance Survey Strategi[®] mapping product. For the distribution of the sample, an analysis was first undertaken to identify and enumerate the areas of polygons in the NWSS dataset of less than 0.5 hectare outside NFI woodland areas and within urban and rural areas of each NFI region. Using the results of this analysis, the proportion of the total sample assigned to each combination of NFI region and land category (urban or rural) was allocated *pro-rata* to these areas.

Within each NFI region, selection of representative sample squares in rural areas was made by assigning the probability of selection of a square to be proportional to the amount of rural area within the square outside the 2013 NFI woodland map. A similar procedure was used for the selection of sample squares in urban areas. This resulted in an overall sample within each NFI region with probability of selection proportional to the amount of non-NFI land area within the square.

As with the England and Wales hand-mapping exercise, within each selected square, after masking out areas of NFI woodland according to the 2013 NFI map, the aerial photography interpreters plotted and categorised each individual tree, woodland feature and hedgerow identified in the photography. However, in Scotland, the categories of woodland features described in Table 27 included a differentiation of the 'NFI missed'

category used in England and Wales into two separate categories, labelled 'NFI edge' and 'NFI missed'. Included in 'NFI edge' were areas of canopy extending from the NFI map that had not been included within the map due to the mapping rules used, while the 'NFI missed' category contained identified areas of woodland of >0.5 hectare in extent and >20 metres in width not adjacent to mapped NFI woodland, and also areas attached to woodland areas on the NFI map that qualify as part of NFI woodland according to the NFI mapping rules.

As with the England and Wales hand-mapped dataset, the linear groups and small woods categories were post-processed into separate sub-categories according to feature sizes of less than or greater than 0.1 hectare, and small woods features of less than 0.1 hectare were pooled with the clustered group features into 'non-linear groups of trees'. As noted for England and Wales, the Scotland hand-mapping exercise also identified and plotted hedgerows within the sample squares (composed of shrubs and/or small trees), from which the area and length of hedgerows were assessed.

Fieldwork data

A sub-sample of the one-by-one kilometre hand-mapped squares in England, Scotland and Wales were visited by NFI surveyors to ground-truth the hand-mapped results obtained from aerial photography interpretation and to provide an assessment of the heights of trees in tree and woodland features.

The sub-sample subjected to fieldwork assessments consisted of a total of 35 squares, comprising 30 squares from the selection of 217 hand-mapped samples in England and Wales and 5 squares from the selection of 60 hand-mapped samples in Scotland. The distribution of the sub-sample across NFI regions, and rural and urban areas, is shown in Table 26.

In all cases the field surveyors were given the results of the hand-mapping exercise to verify or correct the existence, location and classification of the hand-mapped polygons and to identify and plot any additional features that were not captured in the hand-mapped data. This included the identification of temporarily unstocked areas, such as areas of clearfell. The surveyors were instructed to plot the boundaries of all features to the dripline of the trees. At most sample sites the mean heights of the trees of each feature were assessed into classes of below 2 metres, 2 metres to less than 3 metres, and 3 metres and over, although at 10 of the sites, coarser assessments were used of less than 2 metres and 2 metres and over.

The various woodland, tree and hedgerow features identified by the ground surveyors in areas outside the 2013 NFI woodland map were classified by the surveyors into the categories described in Table 28.

Table 28 Fieldwork woodland and non-woodland tree cover categories

Category	Area	Minimum tree height	Maximum tree height	Minimum width	Maximum width	Temporary unstocked to be mapped
NFI missed (a polygon of trees that should have been included in the NFI tree layer and will effectively extend the NFI area)	n/a for the new polygon. Total area with the NFI polygon/s must be ≥ 0.5 hectare	0 metre	n/a	n/a	n/a	Yes
Small wood (a woodland too small to be part of the NFI)	0.05 - <0.5 hectare	0 metre	n/a			Yes
Group linear (length of at least 25 metre, with a length: width ratio of roughly 4:1)	n/a	0 metre	n/a	4 metre	19 metre	No
Group clustered (>1 tree in a group, crowns must be touching)	>1 tree to 0.05 hectare	2 metres	n/a	0 metre	19 metre	No
Group hedgerow (A group of trees within a hedgerow)	>1 tree with touching crowns	3 metres	n/a	n/a	n/a	No
Individual tree – Boundary (tree is on the boundary of a field. Also includes urban trees along a boundary e.g. street trees)	n/a	2 metres	n/a	n/a	n/a	No
Individual tree – Middle (tree is within a field)	n/a	2 metres	n/a	n/a	n/a	No
Individual tree – Hedgerow (trees ≥ 3 metre tall within a hedgerow are mapped as individual trees)	n/a	3 metres	n/a	n/a	n/a	No
Hedgerows (any boundary line of trees and shrubs over 20 metre long and less than 3 metre height and maximum width of 4 metre at base, maximum allowable gap 20 metre but break if different intervening land use such as road, track, gate)	n/a	n/a	3 metres (any tree ≥ 3 metres to be mapped as an individual tree)	0 metre	4 metre	No

The field surveyors' assessments were latterly subjected to quality assurance checks, including visits to a sub-sample of the sample sites by quality assurance assessors, and desk examination and correction of any faulty assessments with the aid of aerial photography. The identified features were then post-processed using GIS software, with the aid of aerial photography, to classify all identified features into the classes and groups described in Table 3:

- 'NFI missed' features were sub-classified into 'New NFI woodland' or 'Extra NFI woodland' on the basis of the apparent age of the trees in the aerial photography,

with features composed of young or undetectable trees in the photography assigned to 'New NFI woodland';

- 'NFI missed' features were also sub-classified into 'Expanded NFI woodland' if the feature extended from areas of woodland on the NFI map, or as 'Additional NFI woodland' if the feature was detached from mapped woodland areas on the NFI map;
- 'Small wood' features were classed as either 'Non-linear small woodlands' or 'Non-linear groups of trees' according to whether the size of the feature was greater than, or less than or equal to, 0.1 hectare respectively;
- 'Group linear' features were classified as either 'Linear small woodlands' or 'Linear groups of trees' according to whether the size of the feature was greater than, or less than or equal to, 0.1 hectare respectively; and
- 'Group clustered' features were identified as 'Non-linear groups of trees'

The resulting derived dataset provided the information from which estimated areas and numbers of features classified into the categories described in Table 3 were calculated and reported.

(B) Statistical Analysis

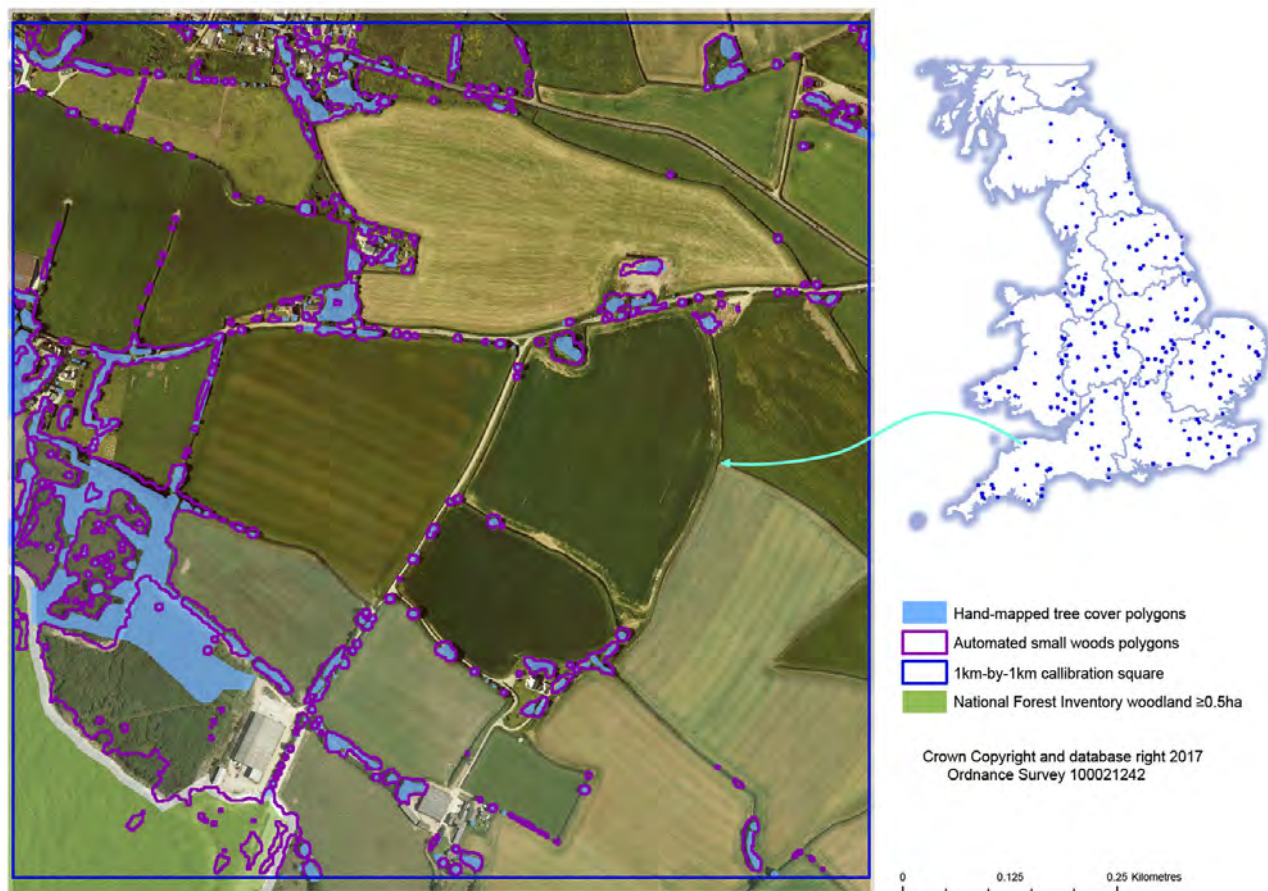
A number of different approaches were used in the statistical analysis of the data to produce estimates of areas of tree cover, numbers of features and mean feature sizes, according to the nature and structure of the data available and the output metric required. These approaches are described in detail in this section. The estimation of areas of tree cover made use of a bespoke technique to "spatially calibrate" between pairs of spatial datasets and this technique is described with illustrations in the following sub-section.

The spatial calibration procedure for the estimation of areas of tree cover

This technique has been developed to use the spatial relationships between two spatial datasets to 'calibrate' the known or previously estimated areas at population level of one dataset (the "primary" dataset) for the purpose of estimating the population areas of the other dataset (the "calibrating" dataset).

Taking as an example the calibration of NTMTM areas to the hand-mapping results (the data for which are described in the previous section), the situation within a particular one-by-one kilometre sample square is shown in Figure 54, where both the NTMTM data and the hand-mapped data are plotted in the form of polygons representing identified features, and the two spatial datasets are overlaid. Within this sample square, areas covered by both NTMTM and hand-mapped polygons can be observed (i.e. intersecting areas) and other areas can be observed that are covered only by NTMTM polygons or only by hand-mapped polygons (non-intersecting areas).

Figure 54 A one-by-one kilometre survey square in Devon

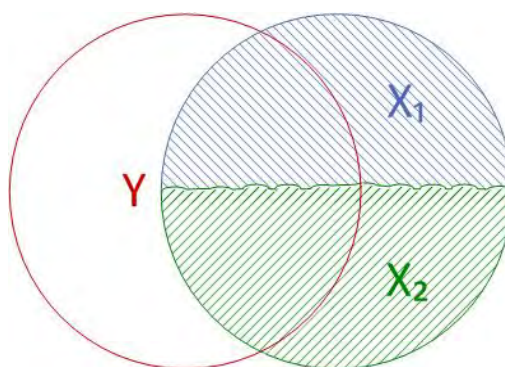


In general, because the NTMTM product has plotted the whole population, both the total area covered by NTMTM polygons in the population, and the total areas of particular categories of NTMTM polygons, are known through GIS evaluation and summing of polygon areas across the population. (In the context of this work, “population” here refers to the total area of such features within a geographically defined region, such as, for example, rural areas within an NFI region or country.) The hand-mapped data, on the other hand, has only been observed and evaluated within a random sample of one-by-one kilometre sample squares.

The procedure described here uses the spatial relationships between the two datasets, in the form of intersections and non-intersections, to construct estimates of the population values of areas based on hand-mapped data (i.e. what the hand-mapped areas would be if the hand-mapping operation had covered the whole area of the population). In this instance, the NTMTM dataset is the “primary” dataset and the hand-mapped dataset is the “calibrating” dataset.

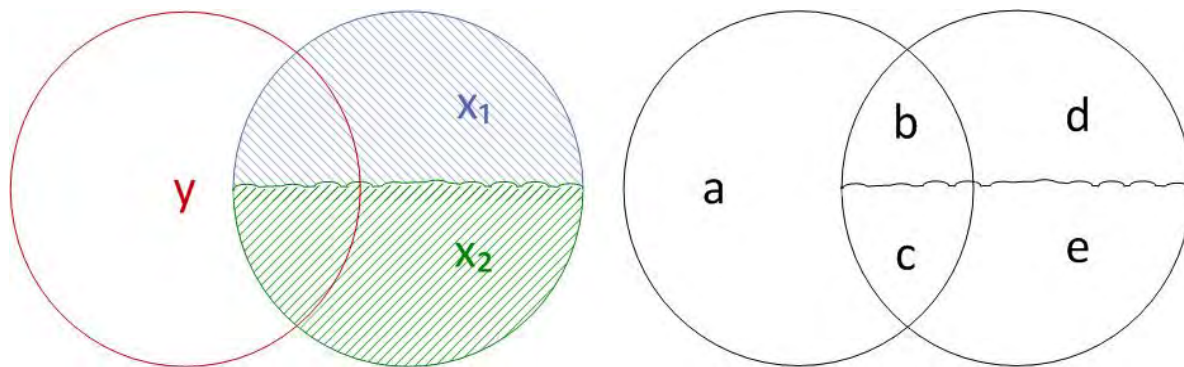
The situation at population level is denoted conceptually in Figure 55 for a simplified example in which the primary dataset is split into just two categories with population areas X_1 and X_2 which can be calculated directly from the dataset, and an unknown population area Y of the calibrating dataset. X_1 , X_2 and Y each represent the areas of many individual polygons of plotted features across the population and the intersections of Y with X_1 and X_2 represent the common intersecting areas of these respective sets of polygons. In practice, Y represents the area of a particular category of features or group of such categories in the calibrating dataset, such as, for example, the total area of features in the linear small woods category of the hand-mapped data. The area Y at population level is the unknown value that we wish to estimate.

Figure 55 Population-level spatial relationship between primary and calibrating datasets



The information available for estimating Y consists of the results from a sample survey in which, within the geographic sample units of this survey, areas of features of the calibrating dataset have been plotted using GIS software. The geographic units in the context of this work are rural or urban areas within randomly selected one-by-one kilometre sample squares. Additionally, the mapped features of the primary dataset lying within the geographic units of the sample survey can be extracted from the full primary dataset. The spatial data from the two datasets can now be plotted together and can be spatially compared within the sample areas, as shown, for example, for a particular sample square in Figure 54. The situation across the sample as a whole, comprising all sample squares, is conceptually shown in Figures 56a and 56b.

Figure 56 Sample-level spatial relationship



(a) Sample-level schematic relationship between primary and calibrating spatial datasets

(b) Decomposition of (a) into areas of intersection and non-intersection

Note to Figures 55 and 56:

The convention is used of denoting population areas with upper case letters and areas within a sample with lower case letters.

In Figure 56a the area labelled 'y' represents the physical area covered by features of a particular category, or group of categories, of the calibrating dataset. (In practice this will be composed of many individually plotted features across the survey.) Areas 'x₁' and 'x₂' represent areas of the two categories of features in the primary dataset (which likewise will in practice represent many individually plotted areas). There will be intersecting areas between the area 'y' and those of 'x₁' and 'x₂' and also areas of non-intersection between the primary and calibrating datasets. The areas of intersection and non-intersection are decomposed in Figure 56b, in which, across the sample as a whole:

- 'a' represents the areas of the features in the calibrating dataset not intersecting with the primary dataset;
- 'b' represents the area of intersections of the features in the calibrating dataset with the first category of features of the primary dataset;
- 'c' represents the area of intersections of the calibrating dataset with the second category of features of the primary dataset;
- 'd' represents the areas of non-intersection of the first category of features of the primary dataset with the features of the calibrating dataset; and
- 'e' represents the areas of non-intersection of the second category of features of the primary dataset with the features of the calibrating dataset.



The following identities hold between the areas shown in Figures 56a and 56b:

$$y = a+b+c$$

$$x_1 = b+d$$

$$x_2 = c+e$$

Then, across the sample, we can define:

$r_1 = b/(b+d)$ as the proportion of the area x_1 intersecting with area y ;

$r_2 = c/(c+e)$ as the proportion of the area x_2 intersecting with area y ;

$s = (a+b+c)/(b+c)$ as the inverse of the proportion of area y intersected by areas x_1 and x_2

Applied across the sample as a whole, these parameters express the relationship between area y and those of x_1 and x_2 of Figure 56a in the identifying equation:

$$y = s * (r_1 * x_1 + r_2 * x_2) \dots\dots\dots(1)$$

These sample-based calibration parameter estimates are then used at population level by substituting X_1 and X_2 of Figure 55 for x_1 and x_2 of Figure 56a respectively to provide the estimate Y' for area Y , thus:

$$Y' = s * (r_1 * X_1 + r_2 * X_2) \dots\dots\dots(2)$$

Relationship (1) can be generalised to any number of mutually exclusive categories of the primary dataset and expressed at individual sample plot level with the introduction of random plot-level errors:

$$y_{i,j} = s_i * \sum_k (r_{i,k} * x_{i,k}) + \varepsilon_{i,j} \dots\dots\dots(3)$$

where:

$y_{i,j}$ is the area of calibrating dataset features of category i in sample square j

$x_{i,k}$ is the area of primary dataset features of category k in sample square j

$\varepsilon_{i,j}$ are random errors associated with areas of calibrating dataset category i in sample square j

$r_{i,k}$ and s_i and are the calibration parameters calculated across the sample as a whole.

The example calibrating equation (2) can be generalised in like manner from equation (3) to give the calibration estimate for category i of the calibrating dataset using any number of mutually exclusive categories in the primary dataset:

$$Y'_i = s_i * \sum_k (r_{i,k} * X_k) \dots\dots\dots(4)$$

where the X_k are the total areas of features of category k of the primary dataset in the population.

Y' is a sample-based estimate and is therefore subject to sampling error. The scale of this error is indicated by the degree to which the relative areas of a to e of Figure 56b in individual sample units vary from the relationships between them across the sample as a

whole. The accuracy of the estimate Y' is also related to the degree of coincidence between the two datasets: in a case where there are no physical intersections between the primary and calibrating datasets, no information about the area Y can be determined from this calibration method, and alternative methods of estimation of Y would need to be used. At the other extreme, if the two datasets were exactly coincident then the identity $Y = X_1 + X_2$ would hold, so the area Y would be known to the same extent that the areas X_1 and X_2 are known.

The sampling standard error of the estimate Y' can be calculated asymptotically by considering the estimate to be a function of random variables defined across the sample. This then involves application of the formula for the asymptotic variance of a function of random variables which takes the general form:

$$\text{Var}(Y') = \mathbf{f}'\mathbf{V}\mathbf{f} \dots\dots\dots (5)$$

where \mathbf{f} is a vector of partial derivatives of the estimator with respect to each of the component variables involved in the calibrating equation, evaluated at the mean values of the component variables, and \mathbf{V} is the sample variance-covariance matrix of the component variables. The asymptotic standard error of the estimate is the square root of its variance $[\sqrt{\text{Var}(Y')}]$.

The above description of the spatial calibration procedure has used the calibration from NTMTM to hand-mapped data as part of the illustration. In the analysis of available data to produce area estimates, the same procedure has been used several times to also calibrate hand-mapped to fieldwork data. In these cases, the population values for the hand-mapped dataset (which becomes the 'primary' dataset) are themselves estimates rather than known values (as is the case with the NTMTM dataset) so the calibrating equation (4) uses the population area estimates X'_k of the primary dataset in place of actual values X_k . This introduces a second source of error in the resulting calibration estimates, in addition to those deriving from the calibration procedure itself. The general formula for asymptotic variance given by equation (5) incorporates both sources of error in the estimated standard error of the calibration estimates.

Areas of tree cover in England and Wales

The derivation of the estimates of areas of tree cover in England and Wales utilised data and information from:

- the National Tree Map (NTMTM);
- the NFI hand-mapping exercise in England and Wales;
- the fieldwork data across GB;
- the 2013 NFI woodland map;
- the Ordnance Survey Strategi[®] spatial dataset.

The estimation process consisted of a double calibration analysis relating NTMTM polygons to the hand-mapped polygons, then relating the hand-mapped polygons to the results of the fieldwork. The schema of this double-calibration process is represented in Figure 19 of the main report. The 2013 NFI woodland map was used to exclude NFI woodland from these analyses, while the OS Strategi[®] product was used to separate the analysis and resulting estimates into areas within rural and urban land categories. In the first stage calibration, a spatial calibration analysis was performed within the 217 one-by-one kilometre hand-mapped samples to relate the NTMTM polygons to the hand-mapped polygons. Intersecting areas of the two datasets were identified and the categories of both the NTMTM polygons and the hand-mapped polygons forming the areas of intersection were recorded. Additionally, within each sample square, the total areas of each category of NTMTM polygon that did not intersect hand-mapped polygons, and the areas of each category of hand-mapped polygon that were not intersected by NTMTM polygons, were also recorded.

This analysis produced sample datasets of results from the sample squares within each NFI region and within rural and urban areas within NFI regions. Results in sample squares that were intersected by boundaries on the OS Strategi[®] map between rural and urban areas were separated into the results pertaining to each land category. For each combination of NFI region and land category, the NTMTM data was calibrated to the hand-mapped sample using the spatial calibration procedure.

In the second stage of the analysis, a spatial calibration of the hand-mapped results to the fieldwork results was undertaken. The sub-sample used for the fieldwork exercise was too small to partition into individual samples for each NFI region, and in this analysis the total of 35 fieldwork sample squares throughout GB are partitioned only into rural and urban subsets, resulting in separate calibration models applying across GB to each land category. (As with the first stage calibration exercise, sample squares that are dissected by boundaries on the OS Strategi[®] map between rural and urban areas contribute the relevant data in the square to the analyses of each of the land categories.)

Standard errors of the final fieldwork-based estimates accounted for sampling error contributions from each of the two applications of the spatial calibration procedure, as explained in the description of the procedure. In the implementation of these calculations, when there were no intersections throughout the sample between polygons of a fieldwork category with those of a hand-mapped category, the hand-mapped category was omitted from the calculation of the variance and standard error of the fieldwork-calibrated estimate.

Hedgerow areas and lengths in England and Wales

The NTMTM product relates only to trees and therefore does not include data on hedgerows. The NFI hand-mapping and fieldwork exercises, on the other hand, identified and plotted hedgerows as well as tree features, so this data was used independently to estimate the areas and lengths of hedgerows.

In the case of hedgerows, therefore, the first stage hand-mapped estimates of areas and lengths were made by means of a simple ratio calculator on the results for hedgerows in the hand-mapped sample squares. Within each subsample pertaining to an NFI region and rural or urban land category, the total area and lengths of hedgerows within the sample were divided by the total non-NFI land area of the relevant land category within the sample squares to give the area and lengths of hedgerows per hectare within the sample. These were then multiplied by the total non-NFI land area of the NFI region and land category to give the estimates of total hedgerow areas and lengths in the combination of NFI region and land category. The variances of these estimates used the standard formula for the variances of ratio estimators.

The hand-mapped results for hedgerows were then calibrated to the fieldwork results for hedgerows by means of further ratio estimators, in this case relating the total areas and lengths of hand-mapped hedgerows within the fieldwork sub-sample to the total areas and lengths of hedgerows identified in the fieldwork. Separate ratio estimators were calculated for rural and urban areas across Great Britain and applied to the hand-mapped estimates for each NFI region and land category within region. The variances and standard errors of the fieldwork-based final estimates contain sources of sampling error associated with each of the two stages of the overall estimation process.

Areas of tree cover and hedgerow areas and lengths in Scotland

The data and information available for estimating tree cover and hedgerows in Scotland was of a different form to that for England and Wales. In particular, the product available for Scotland that provided information on tree cover in areas outside woodland, with full coverage across the whole country, was the NWSS dataset. This contains, from interpretation of aerial photography, all woodland polygons greater than 0.1 hectare in extent, from which the subset of polygons of sizes 0.1 hectare to 0.5 hectare could be extracted. In England and Wales, the dataset giving full coverage across the whole area was the NTMTM map.

As noted in the description of the hand-mapped sample in Scotland, the distribution of the sample was determined by the relative total areas of NWSS polygons within NFI regions and land categories, and within a NFI region and land category combination, samples were selected using overall probabilities of selection proportional to non-NFI



rural and urban areas within the squares. Within an NFI region, this gave an overall probability of selection of any particular square to be:

$$p_i = a_i / \langle \text{Total NWSS area within the region} \rangle$$

where a_i is given by:

$$a_i = u_i * (U_N / U_T) + r_i * (R_N / R_T)$$

where:

u_i is the non-NFI urban area in square i ;

r_i is the non-NFI rural area in square i ;

U_N is the total area of non-NFI NWSS polygons in urban areas of the region;

U_T is the total non-NFI urban area in the region;

R_N is the total area of non-NFI NWSS polygons in rural areas of the region; and

R_T is the total non-NFI rural area in the region

For areas of any hand-mapped category of small woods or individual trees, and for hedgerow areas and lengths, the probability proportional to size estimator of total areas or lengths is given by:

$$Y = (\sum_i y_i / p_i) / N$$

In which y_i is the total area or length of the relevant features found in sample square i and N is the sample size.

The variance of these estimators are then given by:

$$\text{var}(\hat{y}_i) / N$$

where \hat{y}_i is the 'density' of the category in sample square i , calculated as y_i divided by the non-NFI land area in the square.

This provided estimates of areas and their variances based on the hand-mapped data for Scotland. These were then used to produce estimates calibrated to fieldwork results. In the case of tree features, this involved applying the hand-mapped to fieldwork spatial calibration procedure to derive final estimates, while in the case of hedgerows, a single ratio estimator for each of rural and urban land categories was applied, in the same way as for hedgerows in England and Wales.

Numbers of features and mean feature sizes

Hand-mapped estimates for numbers of features were obtained by scaling-up the hand-mapping counts using physical areas within the sample squares and scaling the results up to the total land area of the population. Features that straddled the sample square boundary were counted as belonging to that square if the majority of its area was contained within the square.

Accordingly, for each hand-mapped category within each combination of NFI region and land category, the estimated number of features per hectare was obtained by dividing the number of features in the sample by the non-NFI area of the relevant land category in the sample. The product of this result with the total non-NFI land area of the land category within the NFI region gave the estimated total area of the hand-mapped category in the NFI region.

For each of rural and urban land categories, the numbers of fieldwork features in the fieldwork sub-sample was related to the numbers of hand-mapped features in the sub-sample. The ratios of these numbers of features were then used to adjust the hand-mapped estimates to values based on fieldwork results. Standard errors of the resulting estimates took into account the sampling errors introduced in the two stages of this estimation process.

Mean feature sizes were calculated directly from the hand-mapped dataset and represent the mean areas of polygons of each category of features found within the sample squares covering the relevant geographic areas. Polygons that were not contained entirely within a sample square were excluded from these calculations.

Appendix 2: Historical influences on tree cover

Considering the history of land use in Britain, it is not particularly surprising that such a high proportion of trees are in small woods, groups or stand alone. Britain was a largely wooded island 8,000 years ago, which was progressively deforested through successive waves of clearance of trees for agriculture and for sourcing timber. Woodland clearance initially concentrated on areas composed of more fertile and accessible soils, land that would produce better agricultural land. As the population grew the need for agricultural land increased and less productive land was also brought into agriculture. This clearance occurred over several thousand years and involved many actors, acting for different reasons and at different scales. This clearance tended to be sporadic, unplanned and generally small-scale in nature, reflecting the impacts of a range of socio-economic and environmental factors over time. This pattern of removal would logically leave many small remnants of the pre-existing woodland between the woodland cleared and this pattern is reflected in the estimates. Rackham *et al.* (1987) in *The History of the Countryside* explains how the larger woodland expanses present in the Neolithic period were denuded over the millennia through a process of slow attrition to leave Britain with a woodland cover of circa 5 % in 1900. The remaining woodland was mostly composed of small fractions of remaining ancient woodland, with a few notable exceptions of larger woods such as the Forest of Dean, the New Forest and remnants of the Caledonian Pinewood. This pattern is reflected in the results in this report and previously published NFI data on the distribution of woodland sizes, with many more small woods than larger woods (see *NFI Woodland Area Report 2011* www.forestry.gov.uk/inventory).

Superimposed on this landscape of remnant fragments of the pre-existing woodland, people have made efforts to both retain and to put trees back into the landscape. Many small woods were retained or established to supply raw materials to communities in the medieval period and the retention of much of the ancient woodland in lowland Britain occurred in this way. Changes in land use and land ownership over history have also necessitated the marking out of land ownership through the establishment of boundaries in many forms. This includes the establishment of hedges and lone boundary trees alongside boundaries, walls, fences and ditches. From the establishment of the first field boundaries in the Bronze Age, to the marking of the 'Hundreds' and 'Frithes' under the Anglo-Saxons and to the Enclosures Acts 1604 to 1914, trees and hedges were planted to mark boundaries. The impact of this deeper history in land ownership law and boundary marking appears to be reflected in the results, with a high proportion of small woods and group features being classified as linear in nature or associated with linear features (37%).

The impact of different land law can be seen clearly where much higher levels of tree cover outside woodland are found in England and Wales per unit area (with similar rates of cover of 4.3% and 4.5% respectively) as compared to Scotland, with 1.1%. This goes beyond a solely upland / lowland impact, with Wales having both a high proportion of upland and a higher amount of boundary features and non-woodland tree cover than Scotland. England and Wales have similar and distinct land ownership histories as compared to Scotland, resulting in more boundary marking with trees and hedgerows. Scotland experienced a different land-use and land-law history and, through this, lower levels of boundary marking, which in combination with the relatively low ratio of lowland to upland, its northerly latitude and the lower population levels of the uplands, it has resulted in the lower areas and numbers of small woods features identified in Scotland. Land law will also have added to the high level of linear wooded features, as trees are often associated with these though other factors have driven the high level of linear features. Many features are associated with watercourses where the difficulties posed in clearing trees from watercourse banks, which are often steep and inaccessible to both humans and livestock has added to the linear features total. Also, from ancient times to recent, the establishment of trees alongside thoroughfares, from drove roads to motorways, has formed many linear tree features across Britain

Higher levels (91%) of tree cover outside woodland are found in the lowland areas of Britain as compared to the uplands. This is likely to reflect how less productive upland areas were generally formed into larger fields or management units than more productive lowland areas. Upland areas thus have fewer boundaries and boundary trees per unit area. Other factors, such as local culture, are also likely to have also played a role in the levels of tree cover outside of woodland. Rackham (1986) cites how historic land-use approaches divided the English countryside into two zones, one of 'ancient countryside' and one of 'planned countryside'. In the 'ancient' the land use practices of the Bronze-Age resulted in many small fields, small woods and field boundaries that have persisted through to the modern age. These tended to be retained in the western, Celtic parts of Britain, which resulted in more non-woodland tree cover features in these areas. This is as opposed to the eastern areas of Britain, where the Anglo Saxons and in turn the Georgians and Victorians, in an attempt to increase agricultural productivity, rationalised boundary structures, especially so under the 'Enclosure Acts' 1604 to 1914, and with such reduced wooded boundary features and resulted in a 'planned' countryside. This pattern can be seen distinctly in the results, with many more non-woodland features in the western lowlands of Britain as opposed to the eastern areas. Even in the western uplands of England and Wales there are more features than in lowland eastern areas.

Since 1920, Government policy has been to re-afforest, generally through larger-scale planting, although a notable amount of planting has occurred over areas of less than 0.5 hectare through successive woodland grant schemes. For example, around 40% of

discrete wooded areas within English Woodland Grant Schemes established between 1990 and 2012 were under 0.5 hectare in extent (see *2011 NFI report on Woodland Area*). Also, tree planting has often been a key component of the planning of built developments and has been delivered through schemes such as the tree planting on motorway verges, roundabouts and other transport infrastructure, as well as that of planting alongside building developments. The more organic establishment of trees, through the public's planting of trees in gardens has contributed significantly to the total amount of tree cover in urban areas. This will have been added to by charities and other non-government bodies organising planting on other urban ground. All these latter factors will have led to the report's findings that tree cover in urban areas is 16.5%.

NFI national reports

This report provides information on the size and structure of tree and hedgerow features outside woodland in Great Britain. NFI reports that contain related information are:

- NFI Woodland Area Statistics, Great Britain, England, Scotland, Wales (2011)
- Preliminary estimates of the changes in canopy cover in British woodlands between 2006 and 2015 (2016)

A number of other NFI reports have been produced to date:

- 25-year forecast of softwood timber availability (2012)
- 50-year forecast of softwood timber availability (2014)
- 50-year forecast of hardwood timber availability (2014)
- 25-year forecast of softwood timber availability (2016)

These and NFI data can be found on the NFI website www.forestry.gov.uk/inventory.

Official Statistics

This is an Official Statistics publication. More information about Official Statistics and the UK Statistics Authority is available at www.statisticsauthority.gov.uk

National Forestry Inventory Statistician: Alan Brewer

Survey design

B. Ditchburn and A. Brewer

Authors

A. Brewer, B. Ditchburn, D. Cross, E. Whitton and A. Ward

Publication support

V. Correia, D. Ross and L. Halsall

Reviewers

For a list of those who assisted in the quality assurance of these statistics, please see the Forestry Commission website www.forestry.gov.uk/forestry/infid-83mfrz.

References

Rackham, O. (1986) *The history of the countryside*, J.M. Dent & Sons Ltd.