Forestry Commission

Carbon in live woodland trees in Britain

National Forest Inventory Report

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 Inventory Report provides an estimate of the amount of carbon in living trees within British woodlands – including estimates for England, Scotland and Wales – broken down by principal species and by Forestry Commission and Private sector management.

- Total carbon in all forests and woodlands in Great Britain is estimated to be 213 million tonnes of carbon (780 million tonnes carbon dioxide equivalent ($MtCO_2e$)). For England this is 105 million tonnes, for Scotland 85 million tonnes and for Wales 22 million tonnes.
- Total carbon for the Forestry Commission estate is estimated to be 48 million tonnes.
- Total carbon for the Private sector estate is estimated to be 165 million tonnes.
- Total carbon for coniferous trees is estimated to be 109 million tonnes.
- Total carbon for broadleaved trees is estimated to be 104 million tonnes.

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). This information is essential for developing and monitoring policies and guidance to support sustainable forest management.

The current National Forest Inventory, which began in 2009 (the first cycle due for completion in 2014), is a multi-purpose operation that has 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. Information and data collected by the National Forest Inventory will be used for a number of purposes, including estimates and 25-year forecasts of forest metrics such as:

- Standing volume
- Timber availability
- Tree growth and increment
- Carbon storage
- Biomass

Estimates of aspects of the biodiversity and social value of forests and woodlands will also be provided by the Inventory.

This Inventory Report sets out the results (as at 31 March 2011) for the amount of carbon contained in living trees within all forests and woodlands in GB. Further information on this and other National Forest Inventory outputs is available from **www.forestry.gov.uk/inventory**.

Carbon

The last estimate of carbon stocks within forests and woodlands in GB was published by the Forestry Commission in the 2012 Research Report *Understanding the carbon and greenhouse gas balance of forests in Britain*. This new report, in addition to providing the latest overall estimates of total carbon stocks, gives a breakdown of carbon by species group, ownership type and by country and National Forest Inventory region (see map on page 11).

This assessment of woodland carbon stocks will form a new baseline for carbon accounting within British forests and woodlands and it will be used in the development of the forthcoming (2015) reporting on Land Use, Land-Use Change and Forestry (LULUCF) and more directly in reporting to the United Nations Food and Agriculture Organization (FAO) for the 2015 Forest Resources Assessment.

Carbon is defined as carbon stored in all living plant material in both the above and below ground parts of trees (including major roots, stumps, stems, branches, twigs and foliage) in stands with a mean diameter (at breast height) of 7 cm or more. The estimates do not include carbon in young stands that have not grown to this minimum mean diameter, nor, for example, carbon in the stems of coppice that are harvested before reaching this minimum mean diameter. Also excluded is carbon in standing dead trees, growing saplings and seedlings, shrubs (except shrubs growing with the morphology of trees), other ground layer vegetation, lying dead wood, litter, soil, harvested wood products and substitution effects (e.g. avoided emissions by using timber in place of steel). See the Glossary for further explanation of the terms used in this report.

How carbon is estimated

Estimates of total carbon are determined by:

- Woodland area.
- Woodland characteristics (e.g. tree height) within this area.
- Number and size of trees.

The estimates of carbon in this report have been derived separately for the Forestry Commission estate and for the Private sector estate. They are based on the same principles but use different data sources. For the Forestry Commission estate, information on woodland area and woodland characteristics has been extracted from the Forestry Commission's long-established Sub-compartment database. For the Private sector estate, the estimates were derived from results obtained to date from the National Forest Inventory.

Sub-compartment database

The Sub-compartment database (SCDB) is a record of all land managed by the Forestry Commission. Each stand of trees is represented spatially, together with information on individual stand characteristics (for example species, planting year, spacing and yield class) which is periodically updated. As new surveys of stands are conducted (e.g. for operational purposes), survey results are also recorded against the stands. In addition, the SCDB contains details of how the stands are being managed – in particular, the planned frequency and type of thinning operations and a 'due date' for felling.

National Forest Inventory

The National Forest Inventory is composed of two elements: a woodland map and a field survey. The woodland map covers all forests and woodlands over 0.5 hectares with a minimum of 20% canopy cover (or the potential to achieve it), including new planting, clearfelled sites and restocked sites. It is based upon 25 cm resolution colour aerial photography for England and Scotland and 40 cm resolution aerial photography for Wales. The map was validated and updated using satellite imagery, which gave an independent crosscheck of woodland present. Satellite imagery was also used to identify areas of recently felled forests and woodland. Particular attention was paid to identifying areas of woodland loss verified as being due to the establishment of windfarms or the restoration of habitats.

Field survey work is used to refine the map-based estimates of woodland and clearfelled areas and to measure detailed aspects of the forest. The results in this report were derived from field surveys carried out between 2009 and 2012. This involved the ground surveying of one-hectare sample squares that were partially or entirely covered by forest, including clearfelled areas, according to the woodland map. Further details of the mapping work and the derivation of forested areas can be found in the 2010 Woodland Area reports at **www.forestry.gov.uk/inventory**.

Carbon estimates

The stand attributes derived from data from the SCDB and the National Forest Inventory are used to estimate the amount of biomass contained in the living trees of the stand. Estimates exclude biomass contained in other vegetation associated with the stand (e.g. shrubs and herbs). The derivation involves the application of allometric relationships of the volume of tree components to the size and shape of trees, and species-specific estimates of wood density that convert volume to weight of biomass.* By this means, separate biomass estimates are obtained for the various components of the trees of the stand in roots, stems, branches and leaves. For the purposes of estimation, it is assumed broadleaves are in full leaf. Estimates of total carbon in the trees are derived by multiplying the biomass estimates by a value for the carbon content of tree biomass.**

Estimates for the Forestry Commission estate

Information from the SCDB was used to estimate carbon in living trees at the reference date of 31 March 2011 on a stand-by-stand basis. This was then aggregated to produce the estimated total across a defined geographic area for particular types of stand (classified, for example, by species, tree age or tree size class). For each stand, if an operational survey had been carried out close to the reference date, information from that survey was used to estimate total carbon. Otherwise, an estimate was made of the state of the stand, normally involving the application of standard Forestry Commission growth and yield models that take into account the past management of the stand. Estimated carbon is then modelled from the output of this stand modelling process.

Because the resulting estimates are based on a full record of data from the SCDB, there is no sampling error involved in the estimation process, therefore no sampling standard error is calculated. However, the nature of the estimation process within each individual stand does introduce estimation error, with variable contributions from stand to stand, due to the type, age and accuracy of the information held in the SCDB. In addition to these estimation errors, the reported carbon estimates have been derived from predictive models that estimate the amount of carbon present in stands of a given state. Application of these models introduces modelling errors in addition to estimation errors.* These estimation and modelling errors have not been quantified in this report.

*Details of the BSORT model are available from **www.forestry.gov.uk/forecast.** **Details are available in Forestry Commission Technical Paper 4: *The carbon content of trees.*

Estimates for the Private sector estate

Forests on the National Forest Inventory woodland map were first separated into Forestry Commission estate and Private sector estate holdings using Forestry Commission spatial records of management boundaries. Estimates of carbon on the Private sector estate used a woodland area obtained from the map updated to 31 March 2011 (published in May 2012). This map contained a larger area (around 2.2 million hectares) of Private sector woodland than has been estimated by previous forest inventories.

Data from 4036 surveyed sample squares from the National Forest Inventory field survey were used to produce the results in this report. These sample squares represent a sub-sample of a planned 15000 statistically representative squares covering all GB woodland that will be surveyed during this first cycle of the National Forest Inventory survey (due for completion in 2015).

At each sample square, the forest was stratified into different woodland types or stands, where information on species, age, management and a range of other parameters was collected. An average of around two stands per square was found, resulting in 8052 stands being assessed. Within each stand, field-based computer systems were used to locate two or three 100 m^2 (0.01 hectare) circular plots, within which all trees of greater than or equal to 4 cm diameter at breast height (DBH) were mapped, species identified and diameters measured. A total of 228311 trees were measured in the sample used for this report. For 59334 of these trees, additional measurements of tree height and crown dimensions were taken. The resulting data were used to estimate total carbon in the living trees. All squares were marked on the ground with metal pegs and GPS data of their location recorded for checking and future measurement. At least 3% were re-measured by an independent quality assurance team to ensure standards. Further details of the methodology are available from **www.forestry.gov.uk/forecast**.

The results for individual surveyed squares were aggregated and scaled up to the areas identified by the woodland map, using standard statistical survey methodology, to produce the estimates in this report. Along with these estimates, associated sampling standard errors have also been calculated and reported in relative terms as percentages of the estimate. The sampling standard error will account for random variation arising from the selection of the sample, and random measurement errors.

It should be emphasised that, for the Private sector estimates, while large sampling standard errors indicate less reliability in the quoted estimates due principally to relatively small numbers of samples available for estimation purposes, the converse of a small sampling standard error does not in itself imply that the quoted estimate is subject to a small amount of error. This is because, as described above, the derivation of carbon estimates at the stand and component level is based on the application of a series of modelled relationships and calculation parameters that convert the field measurements and observations in the sample squares to total tree carbon estimates. The errors and biases that may be present in these series of models and calculation parameters are not accounted for in the quoted sampling standard errors and are therefore additional, unquantified errors that may have a significant impact on the overall accuracy of the carbon estimates. More precise estimates for this sector, derived from a larger sample, will become available when the first cycle of the National Forest Inventory field survey is completed in 2015.

Results for carbon

This section provides the estimates of total carbon stocks in living trees in forests and woodlands in GB. Estimates are also provided at individual country level and at National Forest Inventory region level (see map on page 11), with breakdowns for the Forestry Commission and Private sector estates; coniferous trees and broadleaved trees; and principal tree species.

All estimates are of total carbon stocks in living trees in forests and woodlands as at 31 March 2011. The estimates are given in millions of tonnes of carbon, which should not be confused with the alternative measure of carbon storage: megatonnes carbon dioxide equivalent ($MtCO_2e$). The figures in the tables may not add to the totals shown as they have been individually rounded or, in some cases for Private sector estimates, because the estimates have been independently calculated per species from slightly different samples within the survey. Sampling standard errors (SE) attached to Private sector estimates are expressed in relative terms (%) to the right of the relevant estimate. Standard errors do not include any errors arising from modelling errors (empirical and allometric) and conversion factors (volume to biomass to carbon content).

The estimate of total carbon stocks in living trees in woodlands in Great Britain is 213 million tonnes (Table 1). Of this, 48 million tonnes (23%) is estimated to be on the Forestry Commission estate and 165 million tonnes (77%) on the Private sector estate. The estimate of total carbon stocks is composed of an estimate of 109 million tonnes (51%) in coniferous trees and 104 million tonnes (49%) in broadleaved trees. These results are illustrated in Figures 1a and 1b.

Tables 2, 3 and 4 provide the equivalent estimates for England, Scotland and Wales respectively, and these are illustrated in Figures 2a, 2b, 3a, 3b, 4a and 4b.

Table 1 Total carbon stocks in principal woodland tree species in Great Britain.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
Great Britain				
All conifers	**42 012**	**67 154**	**2**	**109 165**
Sitka spruce	23 870	31 129	3	**54 999**
Scots pine	4 716	13 084	4	**17 800**
Corsican pine	1 935	1 691	11	**3 626**
Norway spruce	1 839	3 580	8	**5 418**
Larches	3 064	8 165	5	**11 229**
Douglas fir	1 811	3 314	10	**5 125**
Lodgepole pine	3 767	3 128	9	**6 895**
Other conifers	1 009	3 007	12	**4 016**
All broadleaves	**5 996**	**97 961**	**2**	**103 957**
Oak	1 922	28 945	4	**30 867**
Beech	1 546	12 892	7	**14 439**
Sycamore	89	10 713	6	**10 802**
Ash	218	13 823	5	**14 041**
Birch	845	9 650	4	**10 495**
Sweet chestnut	61	3 010	10	**3 071**
Hazel	34	3 029	6	**3 063**
Hawthorn	0	1 710	7	**1 710**
Alder	64	3 848	8	**3 912**
Willow	0	2 394	10	**2 394**
Other broadleaves	1 217	8 416	6	**9 633**
All species	**48 008**	**164 964**	**1**	**212 972**

Table 2 Total carbon stocks in principal woodland tree species in England.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
England				
All conifers	**8 593**	**19 104**	**3**	**27 697**
Sitka spruce	2 902	2 977	9	**5 879**
Scots pine	1 381	5 191	7	**6 572**
Corsican pine	1 645	1 502	11	**3 147**
Norway spruce	489	1 955	10	**2 444**
Larches	563	3 367	7	**3 930**
Douglas fir	881	1 940	13	**2 821**
Lodgepole pine	302	411	25	**713**
Other conifers	430	1 792	10	**2 222**
All broadleaves	**3 804**	**73 900**	**2**	**77 704**
Oak	1 498	22 994	5	**24 492**
Beech	1 308	9 679	7	**10 987**
Sycamore	65	7 942	8	**8 007**
Ash	171	10 614	5	**10 785**
Birch	187	5 239	6	**5 426**
Sweet chestnut	57	2 901	10	**2 959**
Hazel	16	2 440	7	**2 456**
Hawthorn	0	1 416	8	**1 416**
Alder	26	2 443	10	**2 468**
Willow	0	1 797	12	**1 797**
Other broadleaves	476	6 771	6	**7 247**
All species	**12 397**	**92 991**	**2**	**105 388**

Figure 1a Total carbon stocks in conifer and broadleaved woodland trees in Great Britain.

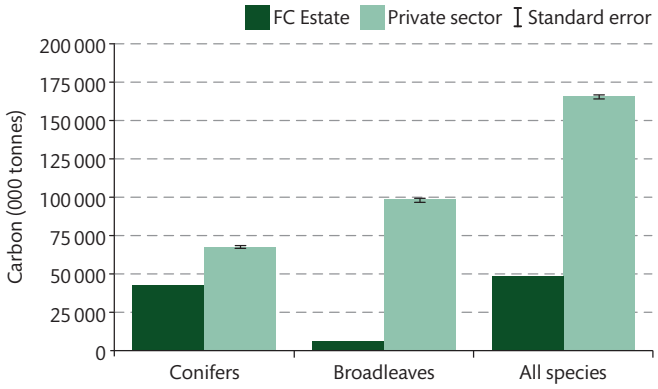


Figure 2a Total carbon stocks in conifer and broadleaved woodland trees in England.

Figure 1b Share of total carbon stocks in principal woodland tree species in Great Britain.

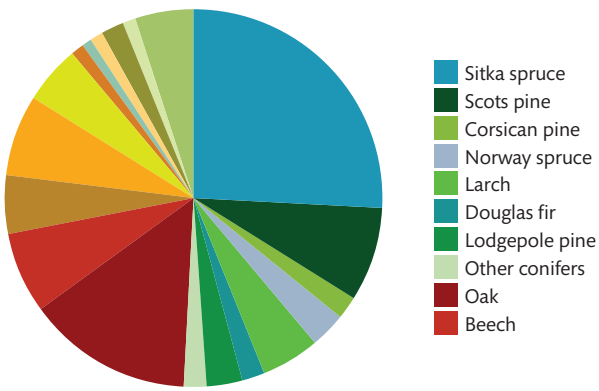


Figure 2b Share of total carbon stocks in principal woodland tree species in England.

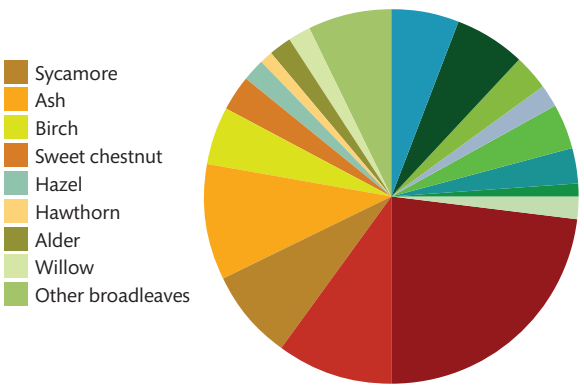


Table 3 Total carbon stocks in principal woodland tree species in Scotland.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
Scotland				
All conifers	**27 316**	**42 638**	**2**	**69 955**
Sitka spruce	17 480	25 247	3	**42 727**
Scots pine	3 153	7 781	6	**10 934**
Corsican pine	107	108	49	**215**
Norway spruce	954	1 400	14	**2 354**
Larches	1 608	3 845	8	**5 453**
Douglas fir	488	762	23	**1 249**
Lodgepole pine	3 242	2 567	10	**5 809**
Other conifers	284	853	34	**1 137**
All broadleaves	**1 517**	**14 112**	**5**	**15 630**
Oak	258	2 784	14	**3 042**
Beech	67	2 244	17	**2 311**
Sycamore	19	1 629	14	**1 648**
Ash	18	1 148	23	**1 166**
Birch	632	3 883	5	**4 514**
Sweet chestnut	0	0	-	**0**
Hazel	17	170	22	**187**
Hawthorn	0	126	21	**126**
Alder	31	724	23	**755**
Willow	0	229	15	**229**
Other broadleaves	476	1 197	18	**1 673**
All species	**28 834**	**56 607**	**2**	**85 441**

Table 4 Total carbon stocks in principal woodland tree species in Wales.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
Wales				
All conifers	**6 102**	**5 411**	**6**	**11 513**
Sitka spruce	3 488	2 905	11	**6 393**
Scots pine	182	112	46	**294**
Corsican pine	184	81	43	**265**
Norway spruce	396	225	42	**621**
Larches	892	953	20	**1 845**
Douglas fir	442	612	25	**1 054**
Lodgepole pine	223	150	35	**373**
Other conifers	295	362	38	**657**
All broadleaves	**675**	**9 948**	**6**	**10 623**
Oak	167	3 167	14	**3 334**
Beech	171	969	26	**1 141**
Sycamore	5	1 142	22	**1 148**
Ash	29	2 061	16	**2 090**
Birch	26	529	17	**555**
Sweet chestnut	3	109	85	**112**
Hazel	1	419	19	**420**
Hawthorn	0	167	24	**167**
Alder	8	681	17	**689**
Willow	0	368	27	**368**
Other broadleaves	265	447	20	**712**
All species	**6 777**	**15 365**	**5**	**22 143**

Figure 3a Total carbon stocks in conifer and broadleaved woodland trees in Scotland.

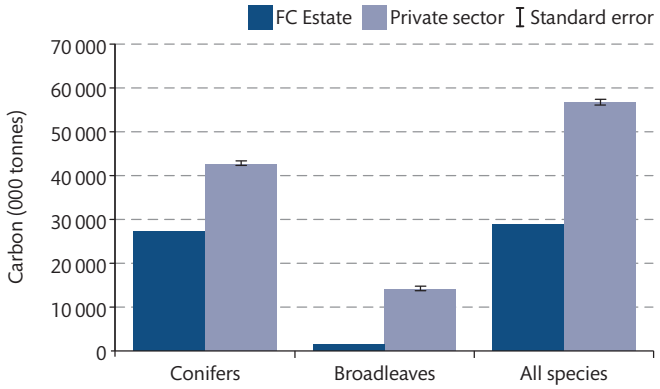


Figure 4a Total carbon stocks in conifer and broadleaved woodland trees in Wales.

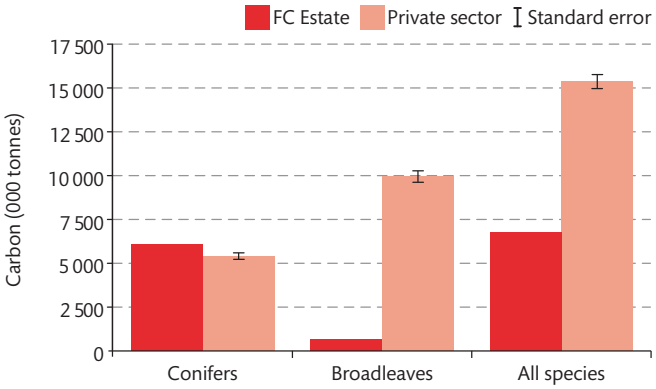


Figure 3b Share of total carbon stocks in principal woodland tree species in Scotland.

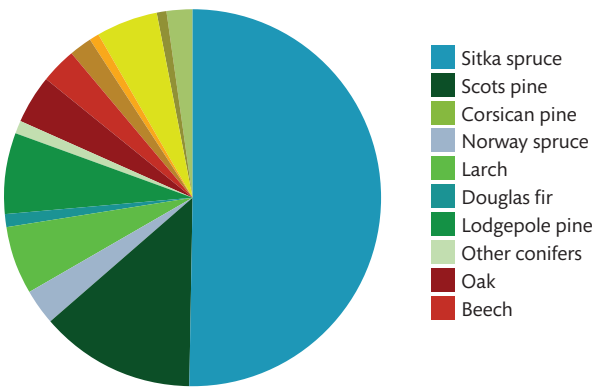


Figure 4b Share of total carbon stocks in principal woodland tree species in Wales.

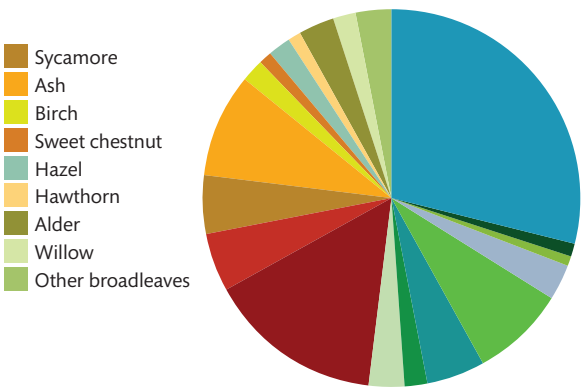
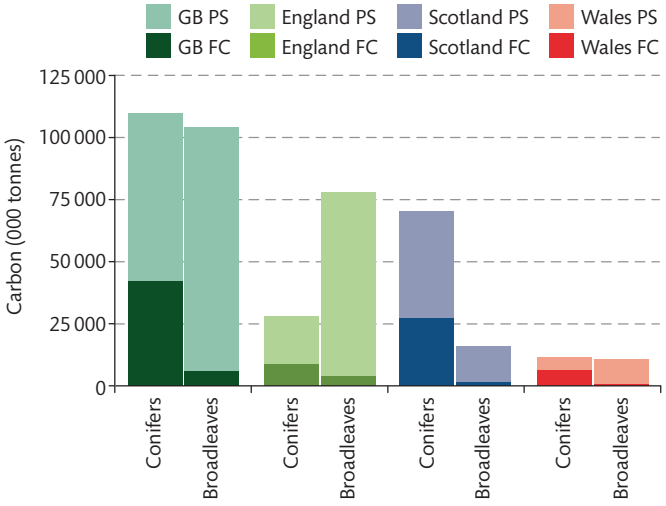


Table 5 and Figure 5 provide a comparative representation of the estimated amount of carbon in living woodland trees in Great Britain and in each of the three individual countries. They show that England is estimated to have a total of 105 million tonnes of carbon in living trees (50% of the total for Great Britain); Scotland is estimated to have 85 million tonnes (40% of GB); and Wales is estimated to have 22 million tonnes (10% of GB).

Table 5 Total carbon stocks in conifer and broadleaved woodland trees in GB and countries.

Country	FC	Private sector		Total
	000 t	000 t	SE%	
England				
All conifers	8 593	19 104	3	**27 697**
All broadleaves	3 804	73 900	2	**77 704**
All species	**12 397**	**92 991**	**2**	**105 388**
Scotland				
All conifers	27 316	42 638	2	**69 955**
All broadleaves	1 517	14 112	5	**15 630**
All species	**28 834**	**56 607**	**2**	**85 441**
Wales				
All conifers	6 102	5 411	6	**11 513**
All broadleaves	675	9 948	6	**10 623**
All species	**6 777**	**15 365**	**5**	**22 143**
Great Britain				
All conifers	42 012	67 154	2	**109 165**
All broadleaves	5 996	97 961	2	**103 957**
All species	**48 008**	**164 964**	**1**	**212 972**

Figure 5 Total carbon stocks in conifer and broadleaved woodland trees in GB and countries.



Tables 6 and 7 provide the estimates of total carbon stocks in living trees in forests and woodlands for each of the National Forest Inventory regions in England and Scotland respectively (Wales is not split into separate regions in the Inventory). These results are illustrated in Figures 6 and 7.

Table 6 Total carbon stocks in principal woodland tree species in National Forest Inventory regions. England.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
North West England				
All conifers	**943**	**1 978**	**8**	**2 921**
Sitka spruce	656	861	17	**1 517**
Scots pine	53	257	20	**310**
Corsican pine	24	24	99	**47**
Norway spruce	23	185	27	**208**
Larches	94	485	16	**579**
Douglas fir	32	8	64	**40**
Lodgepole pine	46	97	60	**143**
Other conifers	16	63	53	**80**
All broadleaves	**162**	**5 238**	**8**	**5 401**
Oak	52	1 525	13	**1 577**
Beech	19	673	39	**692**
Sycamore	5	1 165	22	**1 170**
Ash	12	418	20	**430**
Birch	23	618	19	**641**
Sweet chestnut	2	31	82	**34**
Hazel	10	64	25	**74**
Hawthorn	0	71	25	**71**
Alder	2	419	19	**422**
Willow	0	80	28	**80**
Other broadleaves	36	144	25	**181**
All species	**1 105**	**7 237**	**6**	**8 343**

Table 6 (continued) England.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
North East England				
All conifers	**2 268**	**2 364**	**8**	**4 632**
Sitka spruce	1 677	676	20	**2 354**
Scots pine	133	767	18	**900**
Corsican pine	17	16	85	**33**
Norway spruce	177	223	36	**400**
Larches	70	429	28	**499**
Douglas fir	24	71	54	**95**
Lodgepole pine	149	132	48	**281**
Other conifers	22	50	50	**72**
All broadleaves	**55**	**2 378**	**9**	**2 433**
Oak	4	431	28	**435**
Beech	10	204	25	**214**
Sycamore	3	375	27	**378**
Ash	0	240	23	**240**
Birch	8	486	22	**494**
Sweet chestnut	0	0	-	**0**
Hazel	0	113	26	**113**
Hawthorn	0	15	32	**15**
Alder	3	267	32	**270**
Willow	0	130	59	**130**
Other broadleaves	27	109	17	**136**
All species	**2 324**	**4 761**	**6**	**7 085**
Yorkshire and the Humber				
All conifers	**769**	**1 935**	**6**	**2 704**
Sitka spruce	211	562	17	**773**
Scots pine	234	414	14	**648**
Corsican pine	35	88	37	**123**
Norway spruce	26	142	21	**168**
Larches	146	468	12	**614**
Douglas fir	31	75	39	**107**
Lodgepole pine	60	122	32	**182**
Other conifers	26	63	27	**90**
All broadleaves	**137**	**5 342**	**5**	**5 478**
Oak	24	1 271	15	**1 295**
Beech	23	706	17	**729**
Sycamore	18	1 355	14	**1 373**
Ash	12	681	13	**693**
Birch	22	436	12	**458**
Sweet chestnut	0	39	58	**39**
Hazel	0	39	24	**39**
Hawthorn	0	107	15	**107**
Alder	1	232	21	**233**
Willow	0	109	21	**109**
Other broadleaves	36	376	12	**412**
All species	**906**	**7 269**	**4**	**8 175**

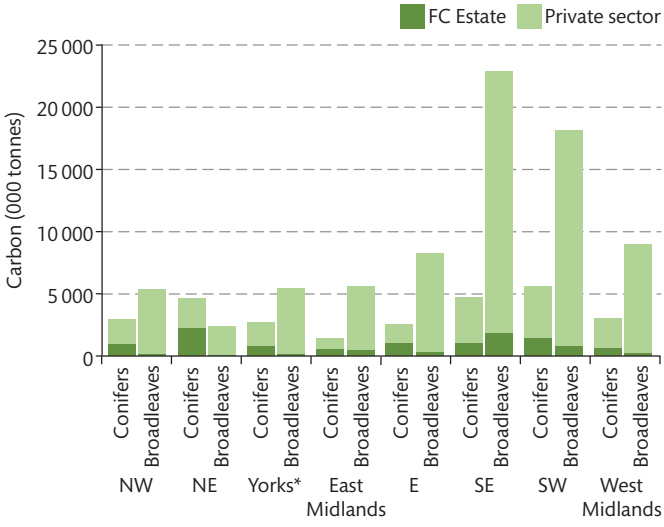
Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
East Midlands				
All conifers	**563**	**858**	**16**	**1 421**
Sitka spruce	19	2	110	**21**
Scots pine	167	519	26	**686**
Corsican pine	280	122	33	**403**
Norway spruce	22	72	36	**94**
Larches	16	105	26	**121**
Douglas fir	7	23	81	**30**
Lodgepole pine	24	0	-	**24**
Other conifers	27	15	59	**42**
All broadleaves	**430**	**5 201**	**7**	**5 631**
Oak	224	1 399	15	**1 623**
Beech	38	67	32	**105**
Sycamore	11	766	21	**777**
Ash	61	1 354	20	**1 415**
Birch	29	245	21	**274**
Sweet chestnut	4	167	50	**171**
Hazel	0	97	22	**98**
Hawthorn	0	224	20	**224**
Alder	1	51	63	**52**
Willow	0	131	41	**131**
Other broadleaves	63	698	18	**761**
All species	**993**	**6 058**	**6**	**7 051**
East England				
All conifers	**1 053**	**1 497**	**9**	**2 550**
Sitka spruce	0	12	70	**12**
Scots pine	261	669	16	**931**
Corsican pine	710	371	23	**1 081**
Norway spruce	4	101	33	**105**
Larches	11	178	25	**190**
Douglas fir	38	79	37	**117**
Lodgepole pine	1	0	-	**1**
Other conifers	26	87	33	**113**
All broadleaves	**245**	**8 052**	**6**	**8 297**
Oak	69	2 324	15	**2 393**
Beech	74	718	22	**792**
Sycamore	6	1 050	21	**1 056**
Ash	16	1 015	18	**1 031**
Birch	24	454	21	**478**
Sweet chestnut	6	411	30	**417**
Hazel	1	123	26	**124**
Hawthorn	0	60	19	**60**
Alder	4	229	53	**232**
Willow	0	263	48	**263**
Other broadleaves	46	1 406	18	**1 452**
All species	**1 298**	**9 549**	**5**	**10 847**

Table 6 (continued) England.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
South East England and London				
All conifers	**993**	**3 766**	**6**	**4 759**
Sitka spruce	4	64	43	**68**
Scots pine	305	1 430	13	**1 735**
Corsican pine	259	395	21	**653**
Norway spruce	76	386	16	**462**
Larches	43	538	15	**581**
Douglas fir	167	313	23	**479**
Lodgepole pine	2	6	107	**8**
Other conifers	137	651	17	**788**
All broadleaves	**1 855**	**21 259**	**3**	**23 114**
Oak	805	6 390	7	**7 195**
Beech	821	4 170	10	**4 992**
Sycamore	9	742	20	**750**
Ash	27	2 627	9	**2 653**
Birch	47	1 871	8	**1 917**
Sweet chestnut	18	1 290	13	**1 307**
Hazel	1	918	11	**919**
Hawthorn	0	440	14	**440**
Alder	9	426	26	**435**
Willow	0	294	17	**294**
Other broadleaves	119	2 160	10	**2 280**
All species	**2 848**	**24 972**	**3**	**27 820**
South West England				
All conifers	**1 390**	**4 263**	**6**	**5 653**
Sitka spruce	305	685	20	**990**
Scots pine	120	501	18	**621**
Corsican pine	199	199	29	**398**
Norway spruce	124	485	18	**610**
Larches	113	748	14	**861**
Douglas fir	384	1 098	19	**1 482**
Lodgepole pine	11	3	105	**14**
Other conifers	132	558	17	**690**
All broadleaves	**741**	**17 564**	**5**	**18 305**
Oak	253	6 131	10	**6 384**
Beech	281	2 524	15	**2 804**
Sycamore	9	1 521	13	**1 529**
Ash	35	3 044	8	**3 078**
Birch	20	655	13	**675**
Sweet chestnut	24	664	24	**688**
Hazel	2	762	13	**764**
Hawthorn	0	330	20	**330**
Alder	4	546	20	**551**
Willow	0	644	19	**644**
Other broadleaves	114	1 036	13	**1 150**
All species	**2 131**	**21 815**	**4**	**23 946**

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
West Midlands				
All conifers	**615**	**2 443**	**12**	**3 058**
Sitka spruce	30	115	64	**145**
Scots pine	108	634	27	**742**
Corsican pine	121	288	33	**408**
Norway spruce	37	362	30	**398**
Larches	69	417	24	**486**
Douglas fir	199	273	37	**472**
Lodgepole pine	9	50	73	**60**
Other conifers	43	304	32	**347**
All broadleaves	**178**	**8 867**	**8**	**9 045**
Oak	67	3 523	16	**3 590**
Beech	42	617	35	**659**
Sycamore	4	969	36	**973**
Ash	10	1 236	21	**1 246**
Birch	15	474	25	**490**
Sweet chestnut	3	299	35	**302**
Hazel	1	325	25	**326**
Hawthorn	0	169	20	**169**
Alder	2	272	34	**274**
Willow	0	147	28	**147**
Other broadleaves	34	842	25	**877**
All species	**792**	**11 330**	**6**	**12 123**

Figure 6 Total carbon stocks in conifer and broadleaved woodland trees in National Forestry Inventory regions of England.



*Yorks = Yorkshire and the Humber

Table 7 Total carbon stocks in principal woodland tree species in National Forest Inventory regions. Scotland.

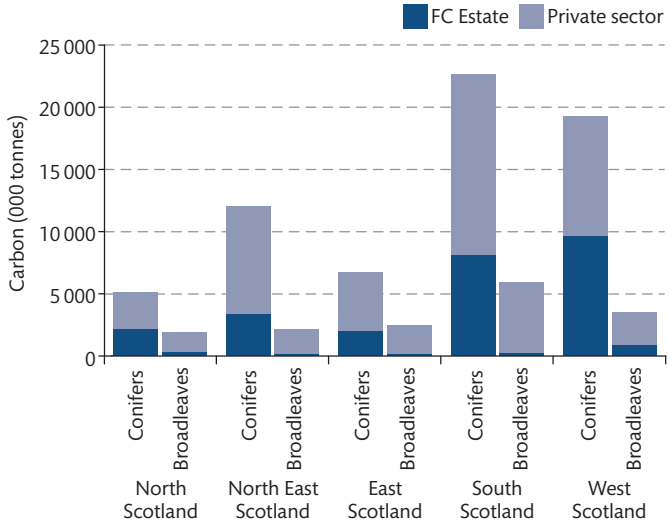
Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
North Scotland				
All conifers	**4 341**	**5 093**	**5**	**9 434**
Sitka spruce	1 028	1 908	11	**2 936**
Scots pine	1 291	1 080	19	**2 371**
Corsican pine	3	37	108	**40**
Norway spruce	110	88	53	**199**
Larches	240	307	28	**547**
Douglas fir	198	279	43	**477**
Lodgepole pine	1 422	1 376	12	**2 798**
Other conifers	48	0	-	**48**
All broadleaves	**274**	**1 536**	**14**	**1 809**
Oak	14	27	59	**41**
Beech	4	278	67	**282**
Sycamore	0	32	91	**33**
Ash	0	35	65	**36**
Birch	214	892	12	**1 106**
Sweet chestnut	0	0	-	**0**
Hazel	3	31	61	**34**
Hawthorn	0	0	-	**0**
Alder	4	110	42	**114**
Willow	0	23	56	**23**
Other broadleaves	34	106	24	**140**
All species	**4 615**	**6 589**	**5**	**11 204**
North East Scotland				
All conifers	**3 302**	**8 694**	**4**	**11 997**
Sitka spruce	1 167	1 757	15	**2 925**
Scots pine	1 110	4 689	7	**5 799**
Corsican pine	64	0	-	**64**
Norway spruce	156	330	31	**486**
Larches	258	995	17	**1 253**
Douglas fir	97	316	38	**413**
Lodgepole pine	410	422	27	**833**
Other conifers	40	158	62	**198**
All broadleaves	**108**	**1 951**	**10**	**2 059**
Oak	4	243	59	**246**
Beech	15	213	41	**227**
Sycamore	2	86	51	**88**
Ash	1	5	88	**6**
Birch	39	1 190	10	**1 229**
Sweet chestnut	0	0	-	**0**
Hazel	0	13	88	**13**
Hawthorn	0	0	58	**0**
Alder	4	15	45	**20**
Willow	0	30	53	**30**
Other broadleaves	44	142	26	**185**
All species	**3 410**	**10 613**	**4**	**14 024**

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
East Scotland				
All conifers	**1 986**	**4 691**	**5**	**6 676**
Sitka spruce	912	2 249	10	**3 162**
Scots pine	454	985	14	**1 438**
Corsican pine	24	0	-	**24**
Norway spruce	117	266	22	**383**
Larches	127	892	16	**1 020**
Douglas fir	58	72	33	**130**
Lodgepole pine	261	65	40	**326**
Other conifers	32	146	42	**178**
All broadleaves	**86**	**2 348**	**9**	**2 434**
Oak	8	265	34	**272**
Beech	13	622	28	**635**
Sycamore	5	284	23	**289**
Ash	1	158	43	**159**
Birch	33	586	11	**619**
Sweet chestnut	0	0	-	**0**
Hazel	0	15	32	**15**
Hawthorn	0	24	66	**24**
Alder	1	173	52	**174**
Willow	0	99	25	**99**
Other broadleaves	25	187	34	**212**
All species	**2 072**	**7 021**	**4**	**9 093**
South Scotland				
All conifers	**8 090**	**14 494**	**4**	**22 583**
Sitka spruce	6 738	11 637	5	**18 375**
Scots pine	100	749	21	**850**
Corsican pine	10	13	69	**23**
Norway spruce	230	622	23	**852**
Larches	460	1 022	15	**1 482**
Douglas fir	71	92	37	**162**
Lodgepole pine	430	220	32	**650**
Other conifers	50	137	33	**187**
All broadleaves	**195**	**5 694**	**10**	**5 889**
Oak	45	1 309	22	**1 354**
Beech	14	876	26	**890**
Sycamore	7	1 038	17	**1 046**
Ash	4	840	29	**844**
Birch	27	612	13	**638**
Sweet chestnut	0	0	-	**0**
Hazel	0	22	44	**22**
Hawthorn	0	95	22	**95**
Alder	3	184	24	**187**
Willow	0	61	22	**61**
Other broadleaves	95	658	29	**753**
All species	**8 285**	**20 175**	**4**	**28 460**

Table 7 (continued) Scotland.

Principal species	FC	Private sector		Total
	000 t	000 t	SE%	
West Scotland				
All conifers	**9 597**	**9 667**	**5**	**19 265**
Sitka spruce	7 634	7 696	5	**15 330**
Scots pine	197	278	32	**475**
Corsican pine	6	58	58	**64**
Norway spruce	341	93	64	**434**
Larches	524	628	20	**1 152**
Douglas fir	63	3	84	**67**
Lodgepole pine	718	484	24	**1 203**
Other conifers	114	412	63	**526**
All broadleaves	**854**	**2 584**	**13**	**3 438**
Oak	187	941	22	**1 128**
Beech	21	256	65	**277**
Sycamore	4	188	70	**193**
Ash	12	108	45	**121**
Birch	319	603	13	**922**
Sweet chestnut	0	0	-	**0**
Hazel	14	90	31	**104**
Hawthorn	0	7	77	**7**
Alder	18	242	50	**260**
Willow	0	16	37	**16**
Other broadleaves	278	104	43	**382**
All species	**10 452**	**12 208**	**5**	**22 660**

Figure 7 Total carbon stocks in conifer and broadleaved woodland trees in National Forest Inventory regions of Scotland.



The National Forest Inventory regions.

The Wales area is treated as both a country and a region in the Inventory.

What the results tell us

This is the first National Forest Inventory estimate of the amount of carbon contained in living woodland trees in Great Britain. The combination of National Forest Inventory data and Forest Research models has provided the most accurate estimate of carbon produced to date in Great Britain. The results provide a snapshot, as at March 2011, of both the total amount of carbon and its geographic distribution.

The results show that, of the National Forest Inventory regions* in England, the largest carbon stocks in living woodland trees are contained within forests and woodlands in South East England and London with an estimated 28 million tonnes of carbon, and in South West England with an estimated 24 million tonnes.

Of the National Forest Inventory regions in Scotland, the largest carbon stocks in living woodland trees are contained within forests and woodlands in South Scotland with an estimated 28 million tonnes of carbon, and West Scotland with an estimated 23 million tonnes.

The results also show that there is a significantly higher amount of carbon in forests and woodlands in Great Britain than previous reported estimates. For example, there is around 30% more carbon than the upper boundary of those estimated in 2012 in the Forestry Commission Research Report *Understanding the carbon and greenhouse gas balance of forests in Britain*, although this report did point to the likely revision and improvement of those estimates when National Forest Inventory data were available. The estimated carbon stocks are also over 50% higher than those reported to the United Nations Food and Agriculture Organization (FAO) for the 2010 Forest Resources Assessment. Again, the text was similarly qualified in anticipation of the forthcoming Inventory data.

The principal source of the difference between estimates is an improvement in the inventory data upon which the estimates were based (for example due to the application of more advanced technology such as satellite imagery, geographic information systems and computer models, all of which have improved the accuracy of estimates). It is now evident that previous inventories, such as the National Inventory of Woodlands and trees (NIWT), under-estimated both forest area and numbers of trees, which therefore led to an under-estimate of associated carbon stocks. There are also differences in scope between the National Forest Inventory and the previous NIWT surveys; the former, for example, includes woods found in urban areas that the latter excluded.

However, while improved methodology and more accurate tools account for the majority of the difference between the National Forest Inventory and the previous NIWT surveys, the results are, to some extent, a reflection of the real growth and increment of forest and woodland trees in Britain and the fact that Britain currently harvests less than that annual tree growth (see the National Forest Inventory Reports *GB 25-year forecast of standing coniferous volume and increment*, *50-year forecast of hardwood timber availability* and *Forestry Facts and Figures 2013*). The average age and average size of trees will have increased between the inventories and as a consequence carbon stocks will also have risen. The evidence of this can be seen from the age class and mean stand diameter data reported in the Inventory Reports *Standing timber volume for coniferous trees in Britain* and *Preliminary estimates of quantities of broadleaved species in British woodlands, with a special focus on ash*. The age class data in the reports show that most trees in Britain are currently relatively immature and, by comparing their current age to the average duration of tree crop rotations, it can be deduced that the majority of trees were younger and smaller at the time of the NIWT survey.

Differences such as these are particularly relevant when trying to make comparisons between this Inventory Report and *Land Use, Land-Use Change and Forestry* (LULUCF) reporting to the United Nations Climate Change Secretariat. As LULUCF reports place particular emphasis on changes in balances in carbon stocks arising from direct human-induced land-use impacts, the differences in reported stocks arising from the National Forest Inventory methodology are not directly applicable to LULUCF reporting. Nevertheless the new figures reported here represent a substantive improvement in our knowledge of forest and woodland carbon stocks and how they are changing over time. The new figures will be used in the development of the 2015 LULUCF reports and more directly in reporting to the FAO for the 2015 Forest Resources Assessment.

A direct measure of changes in carbon stocks will be available when the second cycle of the National Forest Inventory Reports in 2020.

*It should be noted that National Forest Inventory regions are not equal in area and these rankings are not established on a per unit area basis.

Glossary

Age class: a grouping of trees into specific age ranges for classification purposes.

Allometric relationship: a mathematical relationship explaining the change in size (growth) of one or more parts of an organism. Allometric relationships are often used in forestry to estimate a difficult-to-measure variable, such as volume, from an easily measured attribute, such as diameter at breast height (DBH).

Area (forest/woodland): forest and woodland area is divided into net forest area – the land area actually covered by trees (in the National Forest Inventory defined to the drip line of the canopy), and gross forest area – which includes both the area covered by trees and the small open spaces (of less than 0.5 hectares) within the forest boundary (e.g. rides, glades, ponds).

Biomass: all of the material making up a tree, or one of its components, such as the stem or branches.

Broadleaves: trees and shrubs that belong to the angiosperm division of the plant kingdom (as distinct from the gymnosperm division that includes conifers). Most in the UK have laminar leaves and are deciduous. Sometimes referred to as 'hardwoods' but not all produce hardwood timber.

Canopy: the mass of foliage and branches formed collectively by the crowns of trees.

Carbon dioxide equivalent: equivalent CO_2 (CO_2e) is the concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas. The conversion factor for carbon to carbon dioxide equivalent is 44/12.

Carbon stock: a quantity of carbon forming a reservoir, generally as part of terrestrial or marine systems. Examples include the carbon in biomass of marine plants, in organic matter of terrestrial soils and in reserves of fossil fuels. For living trees forming forests, the biomass of the trees constitutes a carbon stock.

Clearfelling: cutting down of an area of woodland (if it is within a larger area of woodland it is typically a felling greater than 0.25 hectares). Sometimes a scatter or small clumps of trees may be left standing within the felled area.

Conifers: trees and shrubs that belong to the gymnosperm division of the plant kingdom (as distinct from the angiosperm division that includes broadleaves). Conifers mostly have needles or scalelike leaves and, with the exception of larch, all are evergreen. Sometimes referred to as 'softwoods', they produce softwood timber.

DBH (diameter at breast height): the diameter of a tree (overbark) at breast height, which is usually defined as 1.3 m along the axis of the stem from the ground.

Forest (and woodland): land predominately covered in trees (defined as land under stands of trees with a canopy cover of at least 20%, or the ability to achieve this, and with a minimum area of 0.5 hectares and minimum width of 20 m), whether in large tracts (generally called forests) or smaller areas known by a variety of terms (including woods, copses, spinneys or shelterbelts).

Forestry Commission: the government department responsible for the regulation of forestry, implementing forestry policy and management of state forests in Great Britain as at 31 March 2014. Forestry policy is devolved, with the exception of common issues addressed on a GB or UK basis, such as international forestry, plant health and forestry standards.

Forestry Commission estate: forests, woodlands, open land and other property managed by the Forestry Commission as at 31 March 2014.

Great Britain (GB): England, Scotland and Wales.

Overbark: a term used in measurements of wood volume that include the bark.

Private sector estate: forests and woodlands in GB not managed by the Forestry Commission. In the context of the National Forest Inventory, 'Private sector' is used for convenience although it includes land owned or managed by bodies such as local authorities and charities.

Production forecast: a forecast of softwood availability from the Forestry Commission (GB), the Forest Service, an agency within the Department of Agriculture and Rural Development in Northern Ireland) and potential softwood availability from the Private sector (UK).

Softwood: wood of coniferous trees or the conifers themselves.

Stand: a relatively uniform collection of trees (from either planting or natural regeneration) composed, for example, of a single species or a single age class.

Standard error (SE): the measure of the margin of error associated with an estimate as a result of sampling from a population with statistical variability. Larger standard errors indicate less precision in the estimate. Standard errors in this report are quoted in relative terms (i.e. as percentages of the value of the estimate).

Standing volume: a measurement of timber volume within standing trees. Usually expressed as cubic metres overbark standing (m^3 obs). In the Production forecast, standing coniferous volume is defined as live coniferous stemwood and useable branchwood (to 7 cm top diameter and at least 3 m in length). It excludes roots, below-ground stump material, small branches, foliage and deadwood. For Private sector woodland only, it also excludes standing volume in trees in woodlands less than 0.5 hectares.

Stemwood: the volume of wood in stems, with stems being defined internationally as the above-ground part of the main shoot (or offshoots) with apical dominance. In GB stemwood includes wood from the stump up to 7 cm top diameter of the main stem and sometimes branchwood at least 3 m in length with a minimum top diameter of 7 cm.

Stocked area: the area stocked with living trees. The stocked areas in this report are quoted in gross terms for the Forestry Commission estate and in net terms for the Private sector estate (see **definitions of Area above**).

Sustainable forest management: the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity and vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions at local, national and global levels, and that does not cause damage to other ecosystems.

Thinning: the removal of a proportion of trees in a forest after canopy closure, usually to promote growth and greater value in the remaining trees.

Top diameter: diameter of the smaller (top) end of a log, often used to define different categories of wood products (e.g. sawlogs, roundwood, pulp) and merchantable timber.

Top height: the mean total height of the 100 largest DBH trees per hectare.

Yield class (YC): a classification based on tree species, height growth (top height) and tree age, used to assess the volume production of a stand of trees. It reflects the potential productivity of the site for the tree species growing on it.

This report is one of a series of Inventory Reports that will report on the outputs from the Forestry Commission National Forest Inventory. See **www.forestry.gov.uk/inventory** for more information. The woodland map and areas calculated from it can be found in the 'National Forest Inventory Woodland Area Statistics' for Great Britain, England, Scotland and Wales, which can also be downloaded here.

The National Forest Inventory supports sustainable forest management in Great Britain. For more information see The UK Forestry Standard and its supporting Guidelines on:

- Forests and Biodiversity
- Forests and Climate Change
- Forests and Historic Environment
- Forests and Landscape
- Forests and People
- Forests and Soil
- Forests and Water

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