The total amount of carbon held by vegetation in Great Britain is estimated to be 114 Mtonnes.

Woodlands and forests hold 80% of the G.B. total although they occupy only about 11% of the rural land area. Broadleaf species hold about 50% of the carbon in woodlands and forests.

A map of carbon in the vegetation of Great Britain at 1 km × 1 km resolution based on land cover identified in the I.T.E. Land Cover Map is presented. The predominant location of vegetation carbon is the broadleaved woodlands of southern England.

The amount of carbon in the soils of Great Britain is estimated to be 9838 Mt (6948 Mt in Scotland and 2890 Mt in England and Wales).

In Scotland, most soil carbon is in blanket peats, whereas most soil carbon is in stagnogley soils in England and Wales.

The carbon content of the soils of Great Britain is mapped at 1 km × 1 km resolution. Scottish peat soils have the greatest density of carbon and in total contain 4523 Mt of carbon, 46% of the G.B. total.

Keywords: soil, plant, vegetation, forest, carbon storage, land use, Great Britain.

1. Introduction

In support of the U.K.s commitment under the Framework Convention on Climate Change, the Institute of Terrestrial Ecology has, under contract from the Department of the Environment, been developing an inventory of carbon in the vegetation and soils of Great Britain. Forests and other vegetation are an important part of the pool of carbon and changes in size and productivity of the pool may act as a sink or source for carbon dioxide. U.K. policy aims to secure an annual increase in the net amount of carbon stored in these natural pools. The amount, and geographical distribution, of carbon in vegetation (especially forests) is of considerable importance to this policy. Soils contain much more carbon than vegetation and, although this pool is only able...
Table 1. Carbon density (tonnes per hectare) for vegetation in each Cover Type

<table>
<thead>
<tr>
<th>Cover Type</th>
<th>Vegetation carbon density (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal</td>
<td>1</td>
</tr>
<tr>
<td>Crops</td>
<td>1</td>
</tr>
<tr>
<td>Pasture, etc.</td>
<td>1</td>
</tr>
<tr>
<td>Fallow</td>
<td>0</td>
</tr>
<tr>
<td>Horticulture</td>
<td>1</td>
</tr>
<tr>
<td>Unimproved grass</td>
<td>1</td>
</tr>
<tr>
<td>Shrub</td>
<td>2</td>
</tr>
<tr>
<td>Heath</td>
<td>2</td>
</tr>
<tr>
<td>Bogs, etc.</td>
<td>2</td>
</tr>
<tr>
<td>Maritime</td>
<td>2</td>
</tr>
<tr>
<td>Broadleaf</td>
<td>see Table 3</td>
</tr>
<tr>
<td>Conifer woodland</td>
<td>see Table 3</td>
</tr>
<tr>
<td>Mixed woodland</td>
<td>see Table 3</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. Biomass to carbon conversion parameters for forest species of Great Britain. The conversion factor from standing timber volume to carbon biomass \( k_w \) (tonnes carbon per cubic metre of timber) = \( p \omega \phi \), where \( p \) is the specific gravity of wood, \( \omega \) is the ratio of the total volume of wood to the “standing volume” from the F.C. Census and \( \phi \) is the fraction of wood mass that is carbon. SAB refers to sycamore, ash and birch taken together.

<table>
<thead>
<tr>
<th>Species</th>
<th>( \rho )</th>
<th>( \phi )</th>
<th>( \omega ) (Age &lt;20 y)</th>
<th>( \omega ) (Age &gt;20 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scots pine</td>
<td>0.41</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Corsican pine</td>
<td>0.41</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>0.39</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Sitka spruce</td>
<td>0.35</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Norway spruce</td>
<td>0.34</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Larch</td>
<td>0.41</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Douglas fir</td>
<td>0.41</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
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<tr>
<td>All conifers</td>
<td>0.38</td>
<td>0.42</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Oak</td>
<td>0.56</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Beech</td>
<td>0.55</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>SAB</td>
<td>0.52</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Poplar</td>
<td>0.55</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Sweet chestnut</td>
<td>0.55</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Elm</td>
<td>0.55</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>All broadleaves</td>
<td>0.55</td>
<td>0.46</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

To change slowly, changes in land use have a major long-term effect on the carbon held in soils. Therefore, an inventory of soil carbon has also been developed. The Institute of Terrestrial Ecology, the Macaulay Land Research Institute and the Soil Survey and Land Research Centre collaborated in preparing the first version of this soil carbon database.

The publication “Climate Change—United Kingdom’s Report under the Framework
R. Milne and T. A. Brown 415

The carbon stored in the forest and non-forest vegetation of Great Britain (G.B.) was estimated by combining published studies of biomass partitioning, a census of forests, ecological surveys of sample areas, a land classification and a remotely sensed map of land cover.

**Table 3. Average carbon density (t/ha) of woodlands in each I.T.E. Land Class of G.B.** The data in columns 2, 3 and 4 were used in the Survey/Land Class method of estimating total vegetation carbon. The data in columns 2 and 5 were used in estimating carbon densities for use with the I.T.E. Land Cover Map for geographically disaggregating total carbon.

<table>
<thead>
<tr>
<th>I.T.E. Land Class</th>
<th>Conifers t/ha</th>
<th>Broadleaves t/ha</th>
<th>Mixed t/ha</th>
<th>Mixed combined with broadleaves t/ha</th>
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<td>52.3</td>
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<td>4</td>
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<td>55.3</td>
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<td>50.3</td>
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<td>6</td>
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<td>56.5</td>
<td>39.5</td>
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<td>46.3</td>
<td>46.3</td>
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<td>9</td>
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<td>10</td>
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<td>50.5</td>
<td>50.5</td>
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<td>35.4</td>
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<td>42.7</td>
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<tr>
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<td>25.9</td>
<td>57.4</td>
<td>30.7</td>
<td>37.4</td>
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<td>23.8</td>
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<td>38.4</td>
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<td>57.9</td>
<td>27.4</td>
<td>34.0</td>
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<tr>
<td>25</td>
<td>24.3</td>
<td>48.6</td>
<td>33.5</td>
<td>44.2</td>
</tr>
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<td>19.5</td>
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<td>28</td>
<td>19.7</td>
<td>57.3</td>
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<tr>
<td>30</td>
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<td>59.3</td>
<td>12.4</td>
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<td>31</td>
<td>32.1</td>
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<td>43.7</td>
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<td>32</td>
<td>20.2</td>
<td>54.8</td>
<td>28.9</td>
<td>34.1</td>
</tr>
</tbody>
</table>

Convention on Climate Change” (HMSO, 1994) describes the initial estimates of the total carbon in vegetation and soils and their geographical distribution. In this paper, the methods used to produce those estimates and recent improvements to the results are presented.

2. Methods and results

2.1. Vegetation Carbon

The carbon stored in the forest and non-forest vegetation of Great Britain (G.B.) was estimated by combining published studies of biomass partitioning, a census of forests, ecological surveys of sample areas, a land classification and a remotely sensed map of land cover.
Table 4a. Estimated carbon density (tonnes/ha) of coniferous species in G.B. The average, weighted by the area distribution with age, for each species is also presented (Net).

<table>
<thead>
<tr>
<th>Species</th>
<th>0–10</th>
<th>10–20</th>
<th>20–30</th>
<th>30–40</th>
<th>40–50</th>
<th>50–60</th>
<th>60–70</th>
<th>70–80</th>
<th>80–120</th>
<th>&gt;120</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scots pine</td>
<td>3.4</td>
<td>8.1</td>
<td>16.9</td>
<td>31.6</td>
<td>49.1</td>
<td>58.6</td>
<td>64.9</td>
<td>68.9</td>
<td>65.7</td>
<td>71.3</td>
<td>30.3</td>
</tr>
<tr>
<td>Corsican pine</td>
<td>3.4</td>
<td>18.4</td>
<td>33.6</td>
<td>51.8</td>
<td>66.8</td>
<td>82.4</td>
<td>96.6</td>
<td>92.3</td>
<td>112.7</td>
<td>127.2</td>
<td>34.9</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>2.5</td>
<td>4.9</td>
<td>14.6</td>
<td>28.6</td>
<td>37.1</td>
<td>37.6</td>
<td>68.3</td>
<td>122.9</td>
<td>6.5</td>
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</tr>
<tr>
<td>Sitka spruce</td>
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<td>7.5</td>
<td>22.9</td>
<td>36.9</td>
<td>52.6</td>
<td>67.1</td>
<td>85.3</td>
<td>90.2</td>
<td>14.1</td>
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<tr>
<td>Norway spruce</td>
<td>2.9</td>
<td>7.2</td>
<td>19.7</td>
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<td>52.2</td>
<td>58.9</td>
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<td>61.6</td>
<td>69.2</td>
<td>68.4</td>
<td>32.3</td>
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<tr>
<td>Douglas fir</td>
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<td>31.8</td>
<td>54.2</td>
<td>78.9</td>
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<td>99.2</td>
<td>113.3</td>
<td>133.4</td>
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<tr>
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<td>22.1</td>
<td>37.6</td>
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<td>60.8</td>
<td>64.8</td>
<td>64.5</td>
<td>68.7</td>
<td>69.1</td>
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</tbody>
</table>

Table 4b. Estimated carbon density (tonnes/ha) of broadleaved species in G.B. The average, weighted by the area distribution with age, for each species is also presented (Net). SAB refers to sycamore, ash and birch taken together.

<table>
<thead>
<tr>
<th>Species</th>
<th>0–10</th>
<th>10–20</th>
<th>20–30</th>
<th>30–40</th>
<th>40–50</th>
<th>50–60</th>
<th>60–70</th>
<th>70–80</th>
<th>80–120</th>
<th>&gt;120</th>
<th>Net</th>
</tr>
</thead>
<tbody>
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<td>45.7</td>
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<td>63.6</td>
<td>68.8</td>
<td>73.2</td>
<td>90.1</td>
<td>88.3</td>
<td>73.9</td>
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<td>Beech</td>
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<td>104.3</td>
<td>123.1</td>
<td>124.3</td>
<td>78.2</td>
</tr>
<tr>
<td>SAB</td>
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<td>13.8</td>
<td>30.6</td>
<td>43.1</td>
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<td>59.3</td>
<td>64.3</td>
<td>66.7</td>
<td>75.5</td>
<td>93.9</td>
<td>46.6</td>
</tr>
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<td>62.1</td>
<td>82.7</td>
<td>74.8</td>
<td>95.8</td>
<td>79.9</td>
<td>111.3</td>
<td>103.5</td>
<td>36.4</td>
</tr>
<tr>
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<td>32.2</td>
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<td>122.8</td>
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<td>106.7</td>
<td>105.2</td>
<td>88.5</td>
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<td>27.7</td>
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<td>76.8</td>
<td>91.3</td>
<td>98.9</td>
<td>61.9</td>
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</tbody>
</table>
2.1.1. Non-forest carbon in each I.T.E. Land Class

The I.T.E. Countryside Surveys of 1984 and 1990 of land use in Great Britain (Barr et al., 1993) were stratified by using a land classification system developed by Bunce et al. (1981). This allocates each 1 km × 1 km square in G.B. to one of 32 Land Classes on the basis of combinations of environmental data which are already in mapped form, such as geology, climate and topography (Barr et al., 1993). In the 1984 Countryside Survey, 384 1 km × 1 km squares were visited in G.B. and the vegetation features were recorded in detail (Barr et al., 1993). These squares were revisited in the 1990 Countryside Survey and additional squares were visited up to a total of 512. Within this total, in 1990, the number of squares visited in each Land Class was generally in proportion to the occurrence of that class in G.B.

The average area of 58 different Cover Types within each Land Class (Barr et al., 1993) is available from the Countryside Information System (CIS), a computer database developed by the I.T.E. (Merlewood) for the Department of the Environment. The 58 Cover Types were combined (Milne, 1994) into 14 Vegetation Groups and a carbon density of 0, 1 or 2 tC ha⁻¹ was selected for each non-woodland group on the basis of the values in Adger et al. (1991) and Olson et al. (1985) (Table 1).

2.1.2. Carbon content of woodlands

The volume of standing timber in stands of different age was estimated for 15 species or species groups using data from a Forestry Commission (F.C.) census of commercial woodlands in the state and private sectors (Locke, 1987). The standing volume of timber classified by species and forest age (in 10-year bands) was divided by the equivalent land area to provide a British average of timber volume per unit area (m³ ha⁻¹) for each age/species group (Milne, 1992). The data in the census did not include the volume in woodlands less than 10 years old, and the timber volume per unit area in these was estimated to be half that of the 10- to 20-year-old stands. Factors to convert from timber volume to woodland carbon density were calculated (Milne, 1992) by including a simple assessment of differences in biomass partitioning of young and old conifers (softwoods) and broadleaves (hardwoods) based on published productivity data (Cannell, 1980) and carbon flow modelling studies (Dewar and Cannell, 1992).

The carbon density (tonnes C ha⁻¹) of each age and species group was calculated using overall conversion factors \( k_{w} \) (tonnes carbon per cubic metre of timber) = \( \rho \omega \phi \), where \( \rho \) is the specific gravity of wood, \( \omega \) is the ratio of the total volume of wood to the standing volume from the F.C. Census and \( \phi \) is the fraction of wood mass that is carbon. Values for these parameters for the major tree species are given in Table 2 (Milne, 1992). The carbon densities were then weighted by the area in the country of each age for each species (\( A_{s} \)) to provide an estimate of the Great Britain average of carbon density for each species (\( CD_{s} \)):

\[ CD_{s} = \sum_{a} \left( CD_{wa} A_{sa} / A_{sT} \right) \]  

where \( CD_{wa} = k_{wa} VD_{wa} \) and \( VD_{wa} \) is the timber volume density of species \( s \) at age \( a \) and \( A_{sT} \) is the total area of species \( s \).

The species distribution data from the 1990 Countryside Survey were analysed to
produce, as an average for each Land Class, the area of each species relative to total woodland area \((RA_s)\). The average carbon density for conifer \((CD_c)\), broadleaf \((CD_b)\) and mixed \((CD_m)\) woodland for each Land Class was then calculated using the age-averaged density described above (based on F.C. data) with the species area distribution (from the 1990 Countryside Survey) and the area of woodland from the CIS databases (for 1990). Hence, the carbon masses for woodlands were calculated for 1990 as follows:

\[ RA_s = \frac{A_s}{\Sigma A_s} \]  
(2)

where \(A_s\) is area of species \(s\) recorded on average in Land Class \(c\) and \(RA_s\) is relative area of species \(s\) in Land Class \(c\).

\[ CD_c = X_c \sum_{\text{conifers}} (CD_i \times RA_s) \]  
(3)

\[ CD_b = X_b \sum_{\text{broad}} (CD_i \times RA_s) \]  
(4)

\[ CD_m = X_m (CD_i \times RA_{mix}) \]  
(5)

where \(X_c\) is area of conifer woodland in Land Class \(c\) from the CIS and hence \(CD_c\) is mass of carbon in conifer woodlands in Land Class \(c\). \(CD_b\) and \(CD_m\) are similarly the masses of carbon in broadleaf and mixed woodlands in Land Class \(c\) with \(CD_m\) and \(RA_{mix}\) referring to average values for all species to represent mixed woodland. The woodland carbon densities for each Land Class are shown in Table 3. The distribution with age of carbon density of British woodlands and the net value \((CD_i)\) for each species are presented in Tables 4a and 4b.

Sitka spruce has a low net carbon density (14.1 t/ha) due to the preponderance of young stands. Douglas fir, however, has the greatest estimated carbon density (41.3 t/ha) for conifers, due to older stands being more common. Sweet chestnut has the greatest estimated carbon density for broadleaved woodland (90.6 t/ha) and poplar the smallest (36.4 t/ha).

The national weighted average for the area of major species is presented in Table 5. Sitka spruce was the commonest species, occupying 21% of woodland in 1990. Scots

<table>
<thead>
<tr>
<th>Species</th>
<th>Area (%)</th>
<th>Carbon (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitka spruce</td>
<td>21.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Scots pine</td>
<td>10.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Larch</td>
<td>7.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Norway spruce</td>
<td>2.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Oak</td>
<td>9.0</td>
<td>16.1</td>
</tr>
<tr>
<td>Birch</td>
<td>7.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Ash</td>
<td>5.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Hawthorn</td>
<td>2.9</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Table 6. Area of vegetation cover groups in Great Britain and associated carbon in vegetation. Based on data on cover and species distribution in 512 1 km × 1 km squares visited in the 1990 Countryside Survey and scaled to G.B. using the I.T.E. Land Classification

<table>
<thead>
<tr>
<th>Cover group</th>
<th>Area (km²)</th>
<th>Area (% of G.B.)</th>
<th>Carbon (Mtonnes)</th>
<th>Carbon (% of G.B.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>110 547</td>
<td>49.3</td>
<td>10·77</td>
<td>9·6</td>
</tr>
<tr>
<td>Semi-natural</td>
<td>66 912</td>
<td>29.9</td>
<td>11·08</td>
<td>9·8</td>
</tr>
<tr>
<td>Woodland</td>
<td>24 965</td>
<td>11·1</td>
<td>91·97</td>
<td>80·1</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>21 586</td>
<td>9·6</td>
<td>0·00</td>
<td>0·0</td>
</tr>
<tr>
<td>Total</td>
<td>224 010</td>
<td></td>
<td>113·82</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Woodland type</th>
<th>Area (km²)</th>
<th>Area (% of G.B.)</th>
<th>Carbon (Mtonnes)</th>
<th>Carbon (% of G.B.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf</td>
<td>9 100</td>
<td>4·1</td>
<td>53·32</td>
<td>47·3</td>
</tr>
<tr>
<td>Conifer</td>
<td>13 646</td>
<td>6·1</td>
<td>29·02</td>
<td>24·8</td>
</tr>
<tr>
<td>Mixed</td>
<td>2 220</td>
<td>1·0</td>
<td>9·62</td>
<td>8·5</td>
</tr>
</tbody>
</table>

pine was the next most common coniferous species (10%). Amongst broadleaves, oak was the commonest species (9·0%), followed by birch (7·1%).

2.1.3. Total mass of carbon in G.B. vegetation

The total mass of carbon in vegetation on land in each I.T.E. Land Class was calculated by summing the products of carbon density and total area for each Cover Type. The average density for each Land Class was then calculated by dividing by the total area of land in each Land Class. Total mass of carbon in the vegetation of Great Britain was estimated to be 113·8 Mtonnes (Table 6) by adding the 32 Land Class totals. Woodland held 80% of this, although occupying only 11·1% of the rural land area. Broadleaf woodland accounted for 47·3% and conifer woodlands 24·8% of the total G.B. carbon.

Bunce et al. (1983) estimated total woodland cover in Britain, using the I.T.E. Land Classification and field surveys carried out in 1978 to be 9·4% compared to 8·6% calculated from data supplied by the Forestry Commission. Bunce et al. (1983) pointed out that Forestry Commission surveys did not consider small blocks of woodland or riverine strips. In addition Bunce et al. (1983) carried out a test of the land classification method by selecting 5234 areas of 1 km on 1:50 000 Ordnance Survey maps and measuring the area of woodland marked. On scaling these measurements to the land area of Great Britain, a figure of 9·3% woodland cover was found, in remarkably good agreement with the land classification estimate. A similar percentage was found by the 1980 Forestry Commission (Locke, 1987) census.

Adger et al. (1991) estimated that “High Forests” in Great Britain contain 30·4 Mtonnes in coniferous stands and 50·5 Mtonnes in broadleaf woodlands. These estimates are similar to those in Table 3 but Adger et al. (1991) used greater carbon densities than the averages derived here and in the case of broadleaved woodlands excluded about 4000 km² by limiting their study to “High Forests”.
TABLE 7. Equivalent Target Classes and Key Cover Types for Landsat Imagery (Land Cover Map) with Key Cover Types of the 1990 Countryside Survey and the selected carbon densities for these types

<table>
<thead>
<tr>
<th>Target Classes</th>
<th>Landsat Imagery Type</th>
<th>Key Cover Type</th>
<th>Carbon density (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous urban</td>
<td>Continuous urban</td>
<td>Communications</td>
<td>0</td>
</tr>
<tr>
<td>Suburban</td>
<td>Suburban</td>
<td>Built up</td>
<td>0</td>
</tr>
<tr>
<td>Tilled land</td>
<td>Tilled land</td>
<td>Tilled land</td>
<td>1</td>
</tr>
<tr>
<td>Mown/grazed turf</td>
<td>Managed grassland</td>
<td>Managed grass</td>
<td>1</td>
</tr>
<tr>
<td>Meadow/verge</td>
<td>Managed grassland</td>
<td>Managed grass</td>
<td>1</td>
</tr>
<tr>
<td>Ruderal weed</td>
<td>Rough grass/marsh</td>
<td>Rough grass/marsh</td>
<td>2</td>
</tr>
<tr>
<td>Felled forest</td>
<td>Rough grass/marsh</td>
<td>Rough grass/marsh</td>
<td>2</td>
</tr>
<tr>
<td>Rough grass/marsh</td>
<td>Rough grass/marsh</td>
<td>Rough grass/marsh</td>
<td>2</td>
</tr>
<tr>
<td>Bracken</td>
<td>Bracken</td>
<td>Dense bracken</td>
<td>2</td>
</tr>
<tr>
<td>Grass heath</td>
<td>Heath/moor grass</td>
<td>Moorland grass</td>
<td>1</td>
</tr>
<tr>
<td>Moorland grass</td>
<td>Heath/ moor grass</td>
<td>Moorland grass</td>
<td>1</td>
</tr>
<tr>
<td>Open shrub heath moor</td>
<td>Open shrub heath/ moor</td>
<td>Open heath</td>
<td>2</td>
</tr>
<tr>
<td>Open shrub moor</td>
<td>Open shrub heath/ moor</td>
<td>Open heath</td>
<td>2</td>
</tr>
<tr>
<td>Dense shrub heath moor</td>
<td>Dense shrub heath/ moor</td>
<td>Dense heath</td>
<td>2</td>
</tr>
<tr>
<td>Dense shrub moor</td>
<td>Dense shrub heath/ moor</td>
<td>Dense heath</td>
<td>2</td>
</tr>
<tr>
<td>Lowland bog</td>
<td>Bog</td>
<td>Wet heaths and saturated bogs</td>
<td>2</td>
</tr>
<tr>
<td>Upland bog</td>
<td>Bog</td>
<td>Wet heaths and saturated bogs</td>
<td>2</td>
</tr>
<tr>
<td>Scrub/orchard</td>
<td>Deciduous/mixed woods</td>
<td>Broadleaved/mixed woods</td>
<td>10</td>
</tr>
<tr>
<td>Deciduous woodland</td>
<td>Deciduous/mixed woods</td>
<td>Broadleaved/mixed woods</td>
<td>see Table 3</td>
</tr>
<tr>
<td>Coniferous woods</td>
<td>Coniferous woods</td>
<td>Coniferous woods</td>
<td>see Table 3</td>
</tr>
<tr>
<td>Inland bare ground</td>
<td>Inland bare</td>
<td>Inland bare</td>
<td>0</td>
</tr>
<tr>
<td>Saltmarsh</td>
<td>Saltmarsh</td>
<td>Saltmarsh</td>
<td>0</td>
</tr>
<tr>
<td>Coastal bare</td>
<td>Coastal bare</td>
<td>Coastal bare</td>
<td>0</td>
</tr>
<tr>
<td>Inland water</td>
<td>Inland water</td>
<td>Inland water</td>
<td>0</td>
</tr>
<tr>
<td>Sea/estuary</td>
<td>Sea/estuary</td>
<td>Sea/estuary</td>
<td>0</td>
</tr>
</tbody>
</table>

2.1.4. The geographical distribution of vegetation carbon

The value of 113.8 Mt for vegetation carbon based on the I.T.E. Land Classification and Countryside Survey is a statistically sound estimate of the total pool size due to the stratified sampling in the Survey. A geographical distribution of vegetation carbon density can be shown (Figure 1) by plotting for each 1 km × 1 km square the average vegetation carbon density of the Land Class of the square. However, plotting the Land Class average of carbon density in this way does not give a good geographical disaggregation. This can be seen by the apparent lack of carbon in the map of Figure 1 where forests are known to be present, for example at Thetford Forest in East Anglia.

Cannell and Milne (1995) presented a map of vegetation carbon density in 10 km × 10 km blocks based on the distribution of the 25 Target Cover Classes of the
Figure 1. Distribution of vegetation carbon in Great Britain based on the I.T.E. Land Classification, i.e. each 1 km × 1 km square has the mean vegetation carbon density of the I.T.E. Land Class of that square. The data mapped is the average vegetation carbon density (tonnes carbon per hectare) across the 1 km × 1 km square.
Comparison of areas of different Cover Types in Great Britain as estimated from (a) 1990 Countryside Survey/I.T.E. Land Classification method and (b) Landsat Imagery (I.T.E. Land Cover Map)

<table>
<thead>
<tr>
<th>Field Survey</th>
<th>Landsat Imagery</th>
<th>Field Survey area ('00 km²)</th>
<th>Landsat area ('00 km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
<td></td>
</tr>
<tr>
<td>Communications</td>
<td>Continuous urban</td>
<td>48</td>
<td>26</td>
</tr>
<tr>
<td>Built up</td>
<td>Suburban</td>
<td>160</td>
<td>137</td>
</tr>
<tr>
<td>Tilled land</td>
<td>Tilled land</td>
<td>481</td>
<td>513</td>
</tr>
<tr>
<td>Managed grass</td>
<td>Managed grassland</td>
<td>682</td>
<td>657</td>
</tr>
<tr>
<td>Rough grass/marsh</td>
<td>Rough grass/marsh</td>
<td>107</td>
<td>43</td>
</tr>
<tr>
<td>Dense bracken</td>
<td>Bracken</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Moorland grass</td>
<td>Heath/moor grass</td>
<td>120</td>
<td>302</td>
</tr>
<tr>
<td>Open heath</td>
<td>Open shrub heath/moor</td>
<td>146</td>
<td>279</td>
</tr>
<tr>
<td>Dense heath</td>
<td>Dense shrub heath/moor</td>
<td>45</td>
<td>72</td>
</tr>
<tr>
<td>Wet heaths and saturated bogs</td>
<td>Bog</td>
<td>166</td>
<td>43</td>
</tr>
<tr>
<td>Broadleaved/mixed woods</td>
<td>Deciduous/mixed woods</td>
<td>130</td>
<td>123</td>
</tr>
<tr>
<td>Coniferous woods</td>
<td>Coniferous woods</td>
<td>137</td>
<td>77</td>
</tr>
<tr>
<td>Inland bare</td>
<td>Inland bare</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Saltmarsh</td>
<td>Saltmarsh</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Coastal bare</td>
<td>Coastal bare</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Inland water</td>
<td>Inland water</td>
<td>29</td>
<td>17</td>
</tr>
</tbody>
</table>

remotely sensed I.T.E. Land Cover Map to improve on the spatial accuracy of the mapping. In this paper we explain the method used in detail and extend it to a 1 km x 1 km resolution map. Links between the Target Cover Classes and the cover types used here (Table 1) exist through the 17 Key Cover Types defined for the Countryside Survey (Barr et al., 1993; Wyatt et al., 1994). Hence, a carbon density can be estimated for each of the Key Cover Types and Target Classes. The class equivalencies and the appropriate carbon densities are shown in Table 7. The data in the Land Cover Map used for this study consisted of the percentage of each Target Class occurring in each 1 km x 1 km square in Great Britain.

The Land Cover Map data were found to produce significantly different estimates, compared to the I.T.E. Land Class/Survey method, for the area of several Key Cover Types in Great Britain, and in certain I.T.E. Land Classes. Table 8 shows the comparison of the areas for Great Britain estimated by the two methods (Barr et al., 1993). The ratio of the areas from the two methods for each Key Cover Type for each Land Class was therefore calculated. Within each Land Class an adjusted carbon density was calculated for each Key Cover Type using these ratios. Combining the adjusted densities with areas from the Land Cover Map for each Key Cover Type produced a total carbon for the Land Class equal to that obtained using the Land Class/Survey approach. The adjusted densities were multiplied by the area of each Key Cover Type in each 1 km x 1 km square to calculate the total carbon in that square. The calculated carbon stored in the soil of each square in Great Britain is mapped in Figure 2. This method therefore combined the best estimate of total carbon from the Land Class/Survey approach with the best estimate of the locations of different land types from the Land Cover Map. The improved location of major pools of carbon can be seen, for example, by the ease of identifying Kielder Forest on the Scottish/English border.
Figure 2. Distribution of carbon in vegetation based on allocating the total vegetation carbon in all the squares of an I.T.E. Land Class, estimated from survey data, proportionally to each square using the relative occurrence and location of different vegetation cover types from the I.T.E. Land Cover Map.
Figure 3. Distribution of main cover groups from the I.T.E. Land Cover Map used in estimating soil carbon for Great Britain.
Figure 4. Distribution of soil carbon in Great Britain based on soil data from MLURI soil data for Scotland, SSLRC soil data for England and Wales, Forestry Authority bulk density data for Scottish peats and the I.T.E. Land Cover Map.
2.2. SOIL CARBON

Howard et al. (1994a,b) estimated that the soils of Scotland contain 19 000 Mt and those of England and Wales 2773 Mt carbon. They mapped the geographical distribution of the soil carbon pool in 10 km × 10 km blocks. Their estimates were based on data for each 1 km × 1 km square in Great Britain from several sources. The Soil Survey and Land Research Centre (SSLRC) LandIS database provided the dominant soil series for each square and the bulk density and carbon content for each series from representative soil core data for England and Wales. The Macaulay Land Use Research Institute (MLURI) National Soils Database provided equivalent data for Scotland. For a given soil series the carbon content of the soil is dependent on the vegetation or other cover. In Howard et al. (1994a,b) and the U.K. Climate Change Report (HMSO, 1994) this data came from the I.T.E. 1990 Countryside Survey with the cover for non-survey squares estimated using the I.T.E. Land Classification. Two problems have been identified in these estimates:

1. The estimates of soil carbon in Howard et al. (1994a,b) suggest that Scottish peatlands contain 75% of the soil carbon of G.B. but this very large mass is directly dependent on the bulk density of peat used in the calculation. No data was available for the bulk density on Scottish peats so an estimate for the surface layer of peat of 0.35 g/cc was made from published information on lowland English peats (Burton and Hodgson, 1987). This value is large compared to other published values for the bulk density of peat, which tend to be about 0.1 g/cc (e.g. Miller et al., 1973; Clymo, 1983; Hulme, 1986). This discrepancy led to a recalculation of the mass of carbon in Scottish peats on the basis of a bulk density of 0.11 g/cc to provide an estimate of 9500 Mt for the soil carbon in G.B. for the U.K. Climate Change Report (HMSO, 1994).

2. The carbon in any given soil type will depend on the vegetation cover. The soil carbon estimates in Howard et al. (1994a,b) assumed the dominant vegetation type in each 1 km × 1 km square to be the dominant vegetation in the I.T.E. Land Class of the square estimated from Countryside Survey data. This does not reflect the detailed geographical variation of vegetation and hence may introduce error into the values of soil carbon which were estimated from soil series on a square by square basis. In fact some I.T.E. Land Classes are estimated to be dominantly uncovered with vegetation and hence would be expected to have no soil carbon. The SSLRC found that in some of these locations their database indicated a soil type unlikely to have no vegetation.

Solutions to these two problems are reported below and improved estimates of the size and geographical distribution of soil carbon in G.B. are presented.

2.2.1. The bulk density and carbon content of Scottish peats

The Forestry Authority Research Division carried out a peat forest soil survey between 1974 and 1981 which sampled 302 cores of peat (Pyatt et al., 1979; Pyatt and Anderson, pers. comm.). The peats sampled were greater than 0.45 m deep and were mostly in Scotland and for semi-natural cover. Sections from 10 cm and 35 cm down each core were analysed. The data relevant to bulk density for each of these cores were obtained from the Forestry Authority and used to calculate an improved estimate of carbon in Scottish peats.
Table 9. Bulk density and carbon content of Scottish peats from Forestry Authority peat survey. Blanket peat values are average of data from 202 cores and basin peat the average from 22 cores

<table>
<thead>
<tr>
<th>Peat type</th>
<th>Bulk density (g/cc)</th>
<th>Carbon (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanket peat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 cm</td>
<td>0·1</td>
<td>46</td>
</tr>
<tr>
<td>35 cm</td>
<td>0·1</td>
<td>48</td>
</tr>
<tr>
<td>Average</td>
<td>0·1</td>
<td>47</td>
</tr>
<tr>
<td>Basin peat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 cm</td>
<td>0·1</td>
<td>51</td>
</tr>
<tr>
<td>35 cm</td>
<td>0·1</td>
<td>38</td>
</tr>
<tr>
<td>Average</td>
<td>0·1</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 10. Carbon content of Scottish peats. (a) Estimate presented in Howard et al. (1994a,b), (b) estimate adjusted using bulk densities of Table 9. Vegetation type: S—semi-natural, P—permanent grass, A—agriculture. N.B. Change of bulk density with increasing depth taken into account in depth calculations so carbon per metre depth is different for different total depths

<table>
<thead>
<tr>
<th>Peat type</th>
<th>Vegetation</th>
<th>Depth of peat (m)</th>
<th>Carbon (a) (kt per km²)</th>
<th>Carbon (b) (kt per km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanket</td>
<td>S</td>
<td>1</td>
<td>182</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1·3</td>
<td>234</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1·5</td>
<td>286</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1·8</td>
<td>338</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>2</td>
<td>390</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>2·5</td>
<td>507</td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>3·5</td>
<td>780</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>4</td>
<td>910</td>
<td>263</td>
</tr>
<tr>
<td></td>
<td>P or A</td>
<td>not stated</td>
<td>200</td>
<td>58</td>
</tr>
<tr>
<td>Basin</td>
<td>S</td>
<td>3</td>
<td>420</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>P or A</td>
<td>2</td>
<td>200</td>
<td>72</td>
</tr>
</tbody>
</table>

The grid reference of each sample point in the peat survey was used to determine the MLURI soil series of each core. Of the 302 cores, 202 were identified as blanket peat (Soil Code 60660) and 22 cores were basin peat (Soil Code 60610). The bulk densities, expressed as dry mass per fresh volume, of the cores were averaged and the mean bulk density for blanket peat was found to be 0·1 g/cc and for basin peat 0·09 g/cc (Table 9).

Howard et al. (1994a,b) assumed that bulk density increased from about 0·35 g/cc to 0·5 g/cc at 5 m depth due to the compression of the peat. The ratios of bulk density at different depths relative to that at the surface was retained here but the bulk densities in the top 1 m from Table 9 were used to adjust the earlier estimates of soil carbon for Scottish peats (Howard et al., 1994a,b). The carbon fraction of dried samples was available from the MLURI data and combining these with the new bulk densities provided improved values for the carbon content of fresh peat. These new estimates are compared with the original in Table 10. For comparison, the carbon content of the
Table 11. Carbon content of 1 m depth of peat soil in England and Wales from Howard et al. (1994a,b)

<table>
<thead>
<tr>
<th>Avery Soil Group</th>
<th>Vegetation carbon content (kt per km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>10.1</td>
<td>92</td>
</tr>
<tr>
<td>10.2</td>
<td>83</td>
</tr>
</tbody>
</table>

PEATS in the SSLRC database for England and Wales, which were based on better bulk density data, are shown in Table 11. The depth of peat in different locations in Scotland was estimated by MLURI for their original carbon database resulting in a range of carbon contents when expressed on a “per area” basis (Table 10).

2.2.2. Size of soil carbon pool and its geographical distribution

The dominant vegetation cover in each 1 km × 1 km square of Great Britain was estimated using the 25 Target Classes of the Landsat Satellite-derived I.T.E. Land Cover Map (Barr et al., 1993). The 25 Target Classes were grouped into five dominant vegetation types (P—permanent grass, A—other agriculture, S—semi-natural, T—woodland, W—inland water) using equivalencies with the Cover Types used in the previous estimates based on the I.T.E. Land Class and Countryside Survey. This provides a more realistic description (Figure 2) of the geographical distribution of vegetation than that used in Howard et al. (1994a,b).

The database of soil series is as used previously but some squares now have a different dominant vegetation. For the England and Wales data 84 037 out of 155 314 squares had an altered cover, for Scotland 32 139 out of 84 929 altered. Fortunately, many of the soil series/vegetation combinations had already been assigned a carbon content in the original work. However, 565 in England and Wales and 535 in Scotland of the new soil series/vegetation combinations still did not have a carbon content available from the old database. This was particularly the case for woodlands, as no I.T.E. Land Class has woodland as a dominant vegetation. The carbon content of the required soil series/vegetation combinations was estimated from similar combinations in the old database, using the following rules:

1. soil under woodlands will have the same carbon content as the same soil series under semi-natural vegetation;
2. for Scotland, the carbon content of a given combination will be equal to the mean value of all the available data for the same soil type (i.e. peaty podzol, brown forest soil, etc.) under the same vegetation;
3. for England and Wales, the carbon content of a given combination will be equal to the mean value of all the available data for the same Avery Soil Group under the same vegetation;
4. for England and Wales, where the soil database indicates that soil is present but the Land Cover Map disagrees, permanent grass vegetation will be assumed (this approach was adopted by SSLRC for the original estimates);
5. for Scotland, where the Land Cover Map indicates no vegetation, then a soil carbon value of zero is used;
The range of soil carbon content within any Avery Group or Scottish soil type was assessed to be about 20% of the mean for the group. Hence, substitution of actual contents for the mean values used here would be unlikely to bring a major improvement. For places where woodland is dominant no actual data was available from the old database so the carbon content of the same type under semi-natural vegetation was used. Actual values for woodland soils would be preferable but apparently few measurements under trees have been made by any soil survey organization.

The resulting values of soil carbon are summarized in Table 12. The total size of the soil carbon pool for Scotland is 6948 Mt, and for England and Wales it is 2890 Mt, giving a total for Great Britain of 9838 Mt. Scottish peats hold 46% of this total. These values are similar to those presented in the U.K. Climate Change Report (HMSO, 1994). In Scotland, most carbon is in blanket peats whereas in England and Wales stagnogley soils cover the largest area and have the largest proportion of carbon. In England and Wales peat soils have about the same carbon total as brown earths (Tables 13 and 14).

The carbon content of each 1 km×1 km square of Great Britain is mapped in Figure 3. The importance of Scottish peatlands to the soil carbon pool is easily seen from this map and the main features are similar to those in the map published in the U.K.’s Report for the Framework Convention on Climate Change (HMSO, 1994).

3. Discussion

The carbon stored in vegetation of Great Britain has been estimated to be 113.8 Mt (Table 6) and in soils to be 9838 Mt (Table 12). These values can be considered as the sum of the products of an area and a mean carbon density for each land cover group and each soil group. A standard error was assigned to each of the areas and mean densities as shown in Table 15.

The standard errors for the vegetation group areas were calculated from data in the Countryside Information System. For the uncertainty in the mean vegetation carbon densities, values were assigned by consideration of the possible variation in carbon densities across the constituent crop and forest conditions. Uncertainty in the woodland carbon estimates is the controlling factor for vegetation. The assumption of a standard error of ±10 ha⁻¹ in the mean woodland density is likely to be an overestimate, given the amount of data from different species and ages of woodland contributing to the estimate of the mean. The variance of the components of the equation to calculate the

### Table 12. Total soil carbon in Great Britain

<table>
<thead>
<tr>
<th></th>
<th>Soil carbon (Mt)</th>
<th>Soil carbon (% of G.B. total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland (peat)</td>
<td>4523</td>
<td>46</td>
</tr>
<tr>
<td>Scotland (non-peat)</td>
<td>2425</td>
<td>25</td>
</tr>
<tr>
<td>Scotland (total)</td>
<td>6948</td>
<td>71</td>
</tr>
<tr>
<td>England and Wales</td>
<td>2890</td>
<td>29</td>
</tr>
<tr>
<td>Great Britain</td>
<td>9838</td>
<td></td>
</tr>
</tbody>
</table>
Carbon in British vegetation and soils

Table 13. Carbon in Scottish soils grouped by soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Area (km²)</th>
<th>Carbon (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial soil (undiﬀ)</td>
<td>1 161</td>
<td>27 438</td>
</tr>
<tr>
<td>Alpine podzol</td>
<td>601</td>
<td>24 786</td>
</tr>
<tr>
<td>Brown calcareous soil</td>
<td>435</td>
<td>2 309</td>
</tr>
<tr>
<td>Brown forest soil</td>
<td>10 851</td>
<td>251 248</td>
</tr>
<tr>
<td>Brown forest soil with gleying</td>
<td>3 628</td>
<td>72 570</td>
</tr>
<tr>
<td>Brown magnesian soil</td>
<td>19</td>
<td>731</td>
</tr>
<tr>
<td>Calcareous gle (GW)</td>
<td>294</td>
<td>2 019</td>
</tr>
<tr>
<td>Complex—not applicable</td>
<td>9 315</td>
<td>359 547</td>
</tr>
<tr>
<td>Humus—iron podzol</td>
<td>253</td>
<td>3 711</td>
</tr>
<tr>
<td>Iron podzol</td>
<td>127</td>
<td>3 500</td>
</tr>
<tr>
<td>Magnesian gle (SW)</td>
<td>91</td>
<td>2 051</td>
</tr>
<tr>
<td>Non-calcareous gle</td>
<td>1 437</td>
<td>36 352</td>
</tr>
<tr>
<td>Non-calcareous gle (GW)</td>
<td>10</td>
<td>199</td>
</tr>
<tr>
<td>Non-calcareous gle (GW)?</td>
<td>32</td>
<td>516</td>
</tr>
<tr>
<td>Non-calcareous gle (SW)</td>
<td>7 456</td>
<td>179 896</td>
</tr>
<tr>
<td>Non-calcareous regosol</td>
<td>5</td>
<td>41</td>
</tr>
<tr>
<td>Peat, basin</td>
<td>612</td>
<td>81 090</td>
</tr>
<tr>
<td>Peat, blanket</td>
<td>25 641</td>
<td>4 442 038</td>
</tr>
<tr>
<td>Peaty gle</td>
<td>4 620</td>
<td>363 846</td>
</tr>
<tr>
<td>Peaty gle (GW)</td>
<td>13</td>
<td>270</td>
</tr>
<tr>
<td>Peaty gle (SW)</td>
<td>2 998</td>
<td>229 961</td>
</tr>
<tr>
<td>Peaty podzol</td>
<td>8 850</td>
<td>704 306</td>
</tr>
<tr>
<td>Peaty ranker</td>
<td>656</td>
<td>46 617</td>
</tr>
<tr>
<td>Podzolic ranker</td>
<td>78</td>
<td>4 560</td>
</tr>
<tr>
<td>Saline alluvial soil</td>
<td>43</td>
<td>424</td>
</tr>
<tr>
<td>Saline gle</td>
<td>90</td>
<td>317</td>
</tr>
<tr>
<td>Subalpine podzol</td>
<td>2 900</td>
<td>101 584</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>127</td>
<td>5 800</td>
</tr>
<tr>
<td>No data</td>
<td>1 101</td>
<td>0</td>
</tr>
<tr>
<td>Not soil</td>
<td>1 408</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>84 929</strong></td>
<td><strong>6 948 230</strong></td>
</tr>
</tbody>
</table>

G.B. total were then appropriately combined. The resulting overall standard error in the total carbon in vegetation estimate of 113.8 Mt was found to be $\pm 2.7 \text{ t ha}^{-1}$.

For the soil group areas, it was assumed that there could be a 20% error in the area estimated for the Scottish peat group. This group contains most carbon and the areas of the other Scottish soils and the area of England and Wales would have negligible error, as these could be estimated from geographical data. A standard error of $\pm 20\%$ of the mean soil carbon density was also assumed for the non-peat Scottish soils and the soils of England and Wales. This error reflects the observed variability in the carbon densities of the different series making up a group within the soils database. A greater standard error of $\pm 80 \text{ kt km}^{-2}$ (about 50% of mean) was assumed for the carbon density of Scottish peats. This reflects the uncertainty in the bulk density and in the peat depth variation across the country. On these assumptions, a standard error of $\pm 2463 \text{ Mt}$ was calculated in the total G.B. soil carbon of 9838 Mt.

Existing databases have proved to be a valuable data source in calculating estimates for the size and distribution of the carbon pools in the vegetation and soils of Great
Britain. However, existing databases do not always have all the required information and further work is necessary to provide this. In carbon sequestration studies relevant to the U.K.’s commitment to the Framework Convention on Climate Change, the next need is for information on the geographical distribution of sources and sinks of carbon in vegetation and soils. Forests are the main sink of carbon but their density, age and productivity varies throughout the country. Changes in land use due to new government policies and schemes, e.g. set aside, may also result in particular places becoming significant sources or sinks for carbon. Therefore, the challenge now is to extend the work on the pool size to include rates of change of stored carbon. This is a complex question and will only be amenable to solution by limiting the changes examined to
Uncertainty of estimates of total carbon in vegetation and soils of Great Britain

<table>
<thead>
<tr>
<th>Vegetation group</th>
<th>Area (km²)</th>
<th>Mean carbon density (t ha⁻¹)</th>
<th>Total carbon (Mt)</th>
<th>Std error (calculated) Std error combined (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>110 547</td>
<td>0.97</td>
<td>10.77</td>
<td>3.00</td>
</tr>
<tr>
<td>Semi-natural</td>
<td>66 912</td>
<td>1.66</td>
<td>11.08</td>
<td>0.50</td>
</tr>
<tr>
<td>Woodland</td>
<td>24 965</td>
<td>36.84</td>
<td>97.97</td>
<td>10.00</td>
</tr>
<tr>
<td>No vegetation</td>
<td>21 586</td>
<td>0</td>
<td>0</td>
<td>n.i.</td>
</tr>
<tr>
<td>Total</td>
<td>113 82</td>
<td>113.82</td>
<td>25.58</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Area (kt km⁻²)</th>
<th>Mean density (kt km⁻²)</th>
<th>Total (kt)</th>
<th>Std error (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scottish peat</td>
<td>26 253</td>
<td>172</td>
<td>4523</td>
<td>80</td>
</tr>
<tr>
<td>Scottish non-peat</td>
<td>58 676</td>
<td>41</td>
<td>2425</td>
<td>10</td>
</tr>
<tr>
<td>England and Wales</td>
<td>140 049</td>
<td>21</td>
<td>2890</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>98 38</td>
<td>2463</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n.i. = Not investigated.

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References


