tree carbon using basic wood density figures, a stem biomass to total biomass conversion factor (e.g. Cannell 1982) and a carbon content of 50% (Ajtay et al. 1977). Stem dry weight increment was not coverted to whole tree dry weight increment because the forest is already of considerable age at which it can be assumed that net increase in the compartments branches, foliage and roots is negligible. The stock of carbon in the forest floor and in the stable humus was derived from standard Dutch soil descriptions (Beuving 1984) and from available literature data on dry weight of the forest floor (e.g. Cannell 1982).

3. RESULTS

The average age of the Dutch forest amounts to 50-60 years and the standing volume is small and still increasing. The HOSP-inventory showed an average standing volume of 170 m^3 ha^{-1} and an average current volume increment of 9.0 m^3 ha^{-1} yr^{-1} for all species (HOSP 1991). Half of the current increment is harvested annually and the wood is mainly used for paper, packing wood and particle board. The standing forest of Scots pine is by far the most important forest ecosystem in the Dutch forest when carbon stock is concerned (see Figure 1).

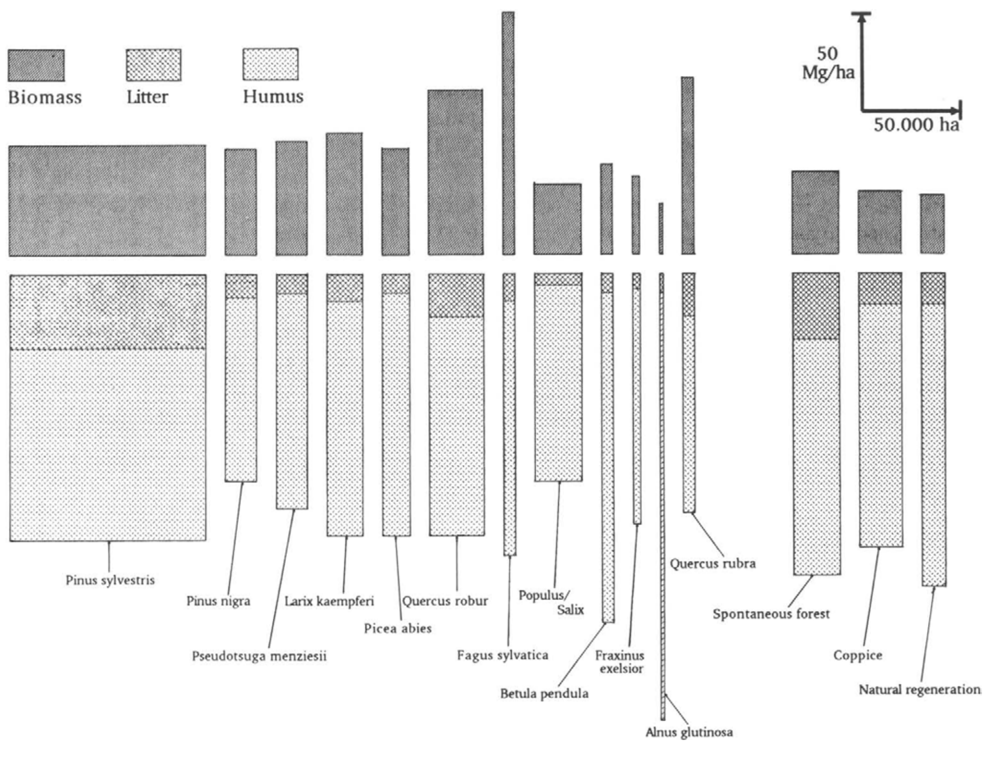

Figure 1. Carbon stocks for three compartments of fifteen forest types of the Dutch forest. The horizontal axis gives the area for each forest type, and the vertical axis the amount of carbon per ha.

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Carbon relations of Dutch forests

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Abstract

Present stock of carbon in living biomass, stable humus and litter and annual accumulation of carbon in stems of fifteen forest types of the Netherlands was quantified. Estimates were based on the most recent forest inventory, yield tables, biomass measurements and soil profile descriptions.

The present stock of carbon in the living biomass, soil stable humus and forest floor of the Dutch forest amounts to 64 Mt C. 58% of this is stored in the soil stable humus. The average carbon stock in the living biomass amounts to some 59 Mg C ha^{-1}. The net annual carbon sink was roughly estimated at 0.33 Mt C yr^{-1}. Due to variation in annual growth of the forest caused by e.g. climatic variability, net annual sequestration may vary between 0.2 and 0.4 Mt C yr^{-1} for the entire area.

1. INTRODUCTION

The biosphere plays an important role in the regulation of the global carbon cycle. Especially forests are important as a storage pool of atmospheric carbon and as regulator of the carbon cycle although the precise role of temperate and boreal forests remains one of the largest unsolved questions in the global carbon budget. Forests of the temperate and boreal zone may play a substantial role in sequestering the missing carbon (Sampson et al. 1993). Although Dutch forests are insignificant in the temperate forest carbon cycle, determining the magnitude of its present source/sink activity is relevant from the point of view of national climate policy and for improved understanding of vegetation-atmosphere interaction.

2. METHODS

For each forest type and tree species, the following parameters were quantified: carbon stock in the living biomass, forest floor and soil stable humus and current annual accumulation of carbon through stem volume increment per site class. Harvesting data were gained from the last inventory and product decomposition was roughly estimated.

Major source of information was the latest forest volume and growth inventory which covered the period 1984-1989 (HOSP 1991). To assess growth for three site classes, available yield tables (Janssen and Sevenster 1991) were used in combination with the forest inventory data. Standing wood volume figures were converted to whole

The total stock of carbon stored in the forest biomass, forest floor and soil organic matter equals (see Table 1) 54.2 Mt. 58% of the carbon is stored in the stable humus, which makes this compartment rather important. Assuming that the 85% of the Dutch forest which was covered in this study, is representative for the total afforested area (approx. 330,000 ha), the total stock of carbon can be estimated at 64 Mt.

The carbon pool in the living biomass, totaling 16.5 Mt, is small, both because of the limited area of forest in The Netherlands and because of the young average age. The average carbon stock per hectare in the living biomass amounts to about 59 Mg C ha^{-1}. Of the forest types considered, beech stands have the highest average stock with 125 Mg C ha^{-1}. Figure 1 presents the results for each forest type.

Table 1. Total stock of carbon in living biomass, forest floor and stable humus of 85% of the Dutch forest.

	Area (ha)	Living biomass (Mt C)	Forest floor (Mt C)	Stable humus (Mt C)
Standing forest:				
Scots pine	98 213	5.44	3.80	9.5
Austrian and Corsican pine	16 302	0.87	0.18	1.5
Douglas-fir	15 722	0.92	0.15	1.7
Japanese larch	18 015	1.11	0.26	2.1
Norway spruce	13 262	0.72	0.13	1.6
indigenous oak	27 084	2.26	0.74	3.0
beech	7 150	0.89	0.10	0.9
poplar and willow	15 280	0.55	0.11	1.5
ash	3 411	0.13	0.03	0.4
alder	967	0.03	0.01	0.2
birch	5 506	0.25	0.06	0.9
red oak	7 856	0.70	0.11	0.5
Other forest types:				
spontaneous forest	23 970	0.93	0.80	2.8
coppice	22 250	0.70	0.36	2.7
natural regeneration forest	13 084	0.38	0.20	2.0
Total stock of carbon		15.87	7.04	31.3

The present gross annual carbon accumulation through stem volume increment for the total area was estimated to be 0.66 Mt C yr^{-1}. Through harvesting and decomposition of woody products, about half of this is immediately returned to the atmosphere. The resulting net annual accumulation amounts to 0.33 Mt C yr^{-1} (see Nabuurs and Mohren 1993 for more details). The average net rate of carbon sequestration for all forest types equals some 0.97 Mg C ha^{-1}yr^{-1}. The gross values per forest type varied from 0.8 to 4.6 Mg C ha^{-1} yr^{-1}. Of the forest types considered, beech forests appeared to have the highest net carbon flux density.

4. DISCUSSION

At present, forests in the Netherlands appear to act as a carbon sink. This in accordance with other studies reporting a noticable sink activity of the temperate forests (Kauppi et al. 1992). In the Netherlands, total sequestration amounts to 0.7% of the annual emission of carbon.

These results are based on growth measurements over the period 1984-1989. More recent data indicate an average annual volume increment of 7.8 $m^3ha^{-1}yr^{-1}$ instead of 9 m^3 $ha^{-1}yr^{-1}$ as was previously reported. As a consequence, the net storage rate as reported here, will decrease accordingly. This indicates that these results strongly depend on year-to-year variation in growth of the forest as caused by e.g. climatic variability. Due to this, the net annual carbon sequestration rate is expected to vary between 0.2 and 0.4 Mt C yr^{-1}.

The reported volume increments are much higher than could be expected from earlier inventories and available yield tables. This discrepancy is most likely due to underestimation of growth in the yield tables and due to an overall growth increase because of enhanced nitrogen availability. However, from analysis of growth data of long-term yield-plots, no obvious increase in growth rate could be detected.

It can be expected that the rate of carbon accumulation will continue for several decades because of the young age and limited standing volume at present.

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