

# Monitoring and reporting carbon stocks and fluxes in Dutch forests

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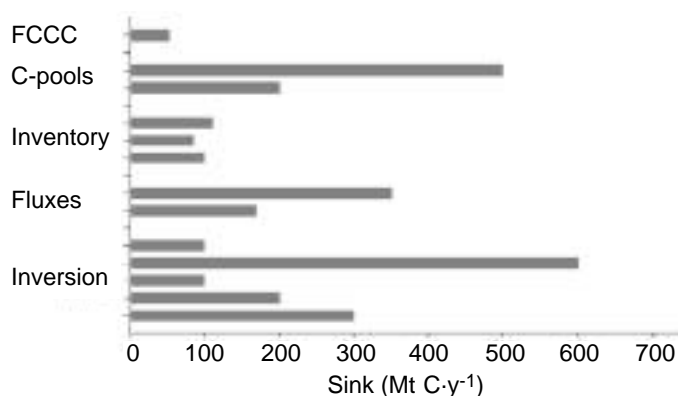
Global forests play an important role in the global carbon cycle. At this moment they absorb about 25% of the emission of carbon dioxide. This aspect has initiated research into the possibilities of enhancing and maintaining this role of global forests. Carbon sequestration in forests might be, also for the Netherlands, an option to compensate part of the carbon dioxide emissions. This paper describes the role of forests, gives a quantification of the present sink in Dutch and European forests and indicates for which compartments improvements of the reporting can be made.

**Keywords.** Forest carbon cycle, monitoring, Kyoto Protocol, The Netherlands.

## 1. INTRODUCTION

Monitoring the real sink strength of forests requires the careful integration of several complementary techniques. Our current understanding of where the carbon is sequestered is poor. At the global level, the inversion models show a Northern hemisphere sink; the precise longitudinal location of this sink is subject of much scientific and political debate (Ciais *et al.*, 1995). Direct monitoring of the Net Ecosystem Exchange of European forest show a sink strength of about 2 t C·ha<sup>-1</sup>·y<sup>-1</sup>. According to Valentini *et al.* (2000) there is considerable latitudinal variation in the sink capacity of European forest, with forest in the boreal regions sequestering almost no carbon, and forests in the Mediterranean up to 5 Mg C·ha<sup>-1</sup>·y<sup>-1</sup>. A comparison of the current techniques is shown in **figure 1**. Also shown are the amounts reported by the European countries to the Framework Convention on Climate Change (FCCC). There is a striking imbalance between the amounts reported to the FCCC and the estimates obtained by other techniques.

In terms of emission reduction, the European countries clearly miss an opportunity to report a much bigger sink. Phrased differently, the current way of reporting land use sequestration of carbon is inadequate. What is needed therefore is the development of a monitoring technique that will bring the actual reported amount up to the level where it would be in agreement with the other techniques. Such a technique would have to be generally applicable, spatially explicit and representative, verifiable, and efficient.



**Figure 1.** Estimates of the sink strength of European forests. The bars for inversions methods cover the sink strength of the whole European land area. FCCC estimate is based on various national communications to the UNFCCC. Other references are Martin *et al.* (1998), Ciais *et al.* (1995).

## 2. CURRENT METHOD APPLIED IN THE NETHERLANDS

The current method as applied in the Netherlands is not a full carbon accounting approach. It is a standing stock approach, based on the total yearly increase of woody biomass in the forests and trees outside the forests, corrected for the yearly extraction of wood. The factors that in practice influence the net growth are:

- the composition of the forests (deciduous/pinetrees/mixed forest);
- the growth as a function of tree species and age of the stand;
- the yearly extraction per tree species;
- the carbon content per tree species.

At this moment aggregated national numbers are used for the standing stock in the Netherlands, which are based on a report from the Stichting Bos en Hout (1994). 25% is added to the numbers for the biomass from branches, roots and treetops. **Table 1** gives an overview for 1992.

The net accumulation of biomass in Dutch forest is not constant due to changes in increment and fellings. In **table 2**, the average growth and extraction are given over the years. **Table 3** then gives some key numbers for the carbon balance of Dutch forests. **Figure 2** presents the relation between per capita area of forest in European countries and the fraction of total national emissions which is being compensated by those national forests present carbon sinks.

**Table 1.** Overview of woody biomass in forests and trees in the Netherlands (1992).

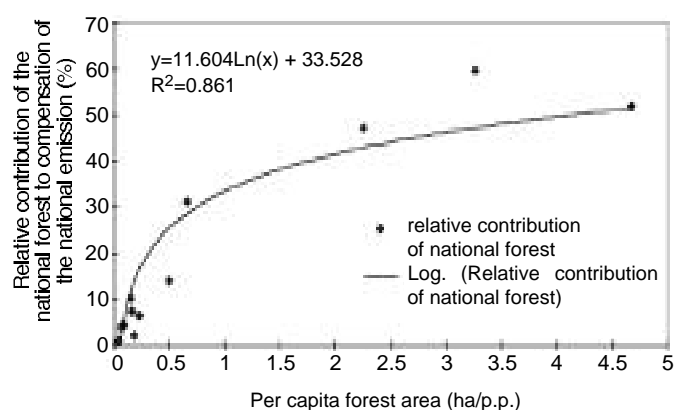
	Area
<b>Forest</b>	
Total exploited forest	266,000 ha
Total not-exploited forest	71,000 ha
Other forest	10,000 ha
<b>Other standing stock</b>	
Trees planted in rows	66,000 ha
Single trees	2,000 ha
<b>Total growing area (1992)</b>	<b>415,000 ha</b>
Municipal gardens NOT growing	non assessed
Fruittrees NOT growing	23,000 ha
Nurseries NOT growing	7,000 ha
<b>Total area in the Netherlands</b>	<b>445,000 ha</b>
Increase by planting	1,000 ha·y <sup>-1</sup>
Average growth	7.88 m <sup>3</sup> ·ha <sup>-1</sup>
Average extraction	4.45 m <sup>3</sup> ·ha <sup>-1</sup>
Correction for branches, roots and treetops	25%
Specific carbon content	250 kg·m <sup>-3</sup>

**Table 2.** Net annual increment and fellings in Dutch forests from 1990 to 1995.

	Unit	1990	1991	1992	1993	1994	1995
Growth	m <sup>3</sup> ·ha <sup>-1</sup>	8.12	7.97	7.82	7.85	7.88	7.90
Extraction	m <sup>3</sup> ·ha <sup>-1</sup>	5.12	4.63	4.63	4.52	4.45	4.40
Net	Mm <sup>3</sup>	1.58	1.76	1.68	1.75	1.81	1.84

**Table 3.** Carbon stocks and sequestration in the Dutch forests (Nabuurs, Mohren, 1993).

Total C stock in forests and forest soils	64 Mt C
Carbon stock in forest biomass	19.7 Mt C
Estimated C stock in harvested wood products	15.1 Mt C
Average C stock in forest biomass per ha	59 Mg C·ha <sup>-1</sup>
Annual net C sequestration	0.33 Mt C
Annual Dutch emissions of carbon	53 Mt C



**Figure 2.** Relation between per capita area of forest in European countries and the fraction of total national emissions which is being compensated by those forests (Nabuurs *et al.*, 1997).

### 3. MANAGEMENT OPTIONS

Under the Kyoto Protocol, article 3.3, only afforestation, reforestation and deforestation (ARD) activities after 1990 may be reported. Afforestation in the period 1990–1998 is about 1,000 ha per year, maximum afforestation until the commitment period (2008–2012) will be 45–55,000 ha. Deforestation is estimated at 300 ha per year until 2008.

This means that sinks due to accumulation of forest growing stock in existing forests (A), accumulation of carbon in forest soils (B) or an increasing wood products pool (C) will not be reportable, unless these will be taken into account under article 3.4.

**A. In case carbon accumulation in existing forests** is acknowledged under article 3.4, possible measures for influencing the carbon balance of the forest standing stock could include:

- forest fire prevention,
- fighting forest diseases and pests,
- forest conservation,
- advanced regeneration,
- longer rotation periods,
- integrated forest management,
- fertilisation,
- tree species composition,
- water management.

**B. In case carbon accumulation in soil** is acknowledged under article 3.4, possible measures for influencing the carbon balance of forest soils could include:

- slash (and dead wood) treatment (possible source for bio-energy),
- water management,
- fertilisation,
- forest fire prevention.

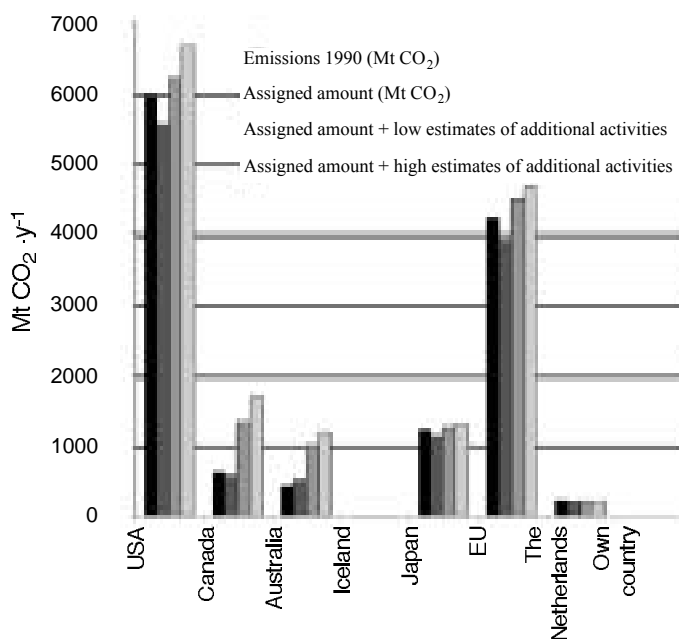
**C. In case carbon accumulation in wood products** is acknowledged under article 3.4, possible measures for influencing the carbon balance of forest products could include:

- stimulation of long term wood products,
- recycling of wood products.

#### 4. AVAILABILITY OF DATA AND ACCURACY

Many datasets are available through different organisations. However, these possible sources of information are very scattered and have never been linked before. Possible sources of information could be:

- Survey on Forest Area (available from CBS),
- Forest Inventory on Growth and Yield (available from Bosdata),
- Land use Databases,
- Dense sample grid from former soil inventories,
- ICP Forest Health Monitoring,
- Central Agency for Statistics (CBS),
- Institute for Forestry and Forest Products several databases (SBH),
- Food and Agricultural Organisation (FAO),
- European Forest Institute (EFI),
- Future monitoring system on function fulfilling,
- Euroflux-site data,
- Long term forest plots,
- Forest reserves.



**Figure 3.** Contribution of additional activities under Article 3.4. to achievement of the commitment for 7 countries (groups). From Nabuurs *et al.* (1999). Emissions 1990, assigned amount without additional activities, and with inclusion of low and high estimates of additional activities as calculated by Access to Country Specific Data (ACSD) for your chosen set of activities (Mt CO<sub>2</sub>-eq).

#### 5. CONCLUDING

The government of the Netherlands is very active in the Kyoto discussions despite its own very small biospheric options. This very active position is shown through international collaboration in research in the field of climate change and carbon sequestration. The Dutch forests are intensively monitored, but still there is quite large uncertainty over the present role of Dutch forests, the forest soils, wood products and management and land use options. A full greenhouse gas balance of different land use management or land use change options has never been done. A full carbon accounting and operational method should be developed and may consist of an operational combination of forest inventory, eddy flux measurements and remote sensing data.

#### Acknowledgement

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#### Bibliography

- Ciais P., Tans PP., Trolier M., White JWC., Francey RJ. (1995). A large northern hemispheric terrestrial CO<sub>2</sub> sink indicated by the 13C/12C ratio of atmospheric CO<sub>2</sub>. *Science* **269**, p. 1098–1102.
- Martin PH., Valentini R., Kennedy P., Folving S. (1998). New estimate of the carbon sink strength of EU forests integrating flux measurements, field surveys and space observations: 0.17 - 0.35 Gt (C). *Ambio* **27**, p. 582–584.
- Nabuurs GJ., Mohren GMJ. (1993) Carbon in Dutch forest Ecosystems. *Neth. J. Agric. Sci.* **41** (4), p. 309–326.
- Nabuurs GJ., Paivinen R., Sikkema R., Mohren GMJ. (1997). The role of European forests in the global Carbon cycle. A review. *Biomass Bioenergy* **13**, p. 345–358.
- Nabuurs GJ., Kuikman PJ., van Diepen CA. (1999). *Kyoto article 3.4. Insights from access to country specific data (ACSD)*. Leaflet. Alterra, A Band European Forest Institute, 4 p.
- Valentini R., Matteucci G., Dolman AJ., Schulze ED., Rebmann C., Moors EJ., Granier A., Gross P., Jensen NO., Pilegaard K., Lindroth A., Grelle A., Bernhofer C., Gruenwald P., Aubinet M., Ceulemans R., Kowalski AS., Vesala T., Rannik U., Berbigier P., Loustau D., Gudmundsson J., Thorgeirsson H., Ibrom A., Morgenstern K., Clement R., Moncrieff J., Montagnini L., Minerbi S., Jarvis PG. (2000). Respiration as the main determinant of carbon balance in European forests. *Nature* **404**, p. 861–865.