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Biotechnol. Agron. Soc. Environ. 2000 **4** (4), 259–262

Calculation on the impacts of forestation, afforestation and reforestation on the C-sequestration potential in Belgian forests ecosystems

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Belgium submitted two National Communications (NC) to the UNFCCC: NC1 in January 1997 and NC2 in August 1997. The Belgian climate policy is formulated at the federal level, requiring co-operation between regional and federal administrations. Around a fifth of the total area of Belgium is covered by forests. Around 80% of the productive forests are in the Walloon region. Reported values for LUCF categories give a potential of 2,057 kt eq. $CO_2 \cdot y^{-1}$. Given the existing Regional Forest Inventories (RFI): RFI1 for 1984 and RFI2 for 1999, an estimate has been made to consolidate reported data. Afforestation, deforestation and reforestation activities are calculated according the IPCC special report on land use, land-use change and forestry.
Keywords. Forest inventory, C-sink, C-accounting, Belgium.

1. INTRODUCTION

Belgium ratified the United Nation Framework Convention on Climate Change (UNFCCC) on 16 January 1996. The Regions (Flanders, Brussels Capital and Wallonia) have responsibility for these matters. The Federal State is responsible for environmental questions of a general nature and reports to the UNFCCC. Belgian climate policy is formulated through an extensive consultative process, with the involvement of all the key agents through the mechanisms of inter-ministerial conferences and working groups under the umbrella of the Ministry for Social Affairs, Public Health and the Environment (MSAPHE)[1]. The National Communications (NC) are prepared by its Greenhouse Effect Co-ordination Group. The NC1 was send in January 1997 (MSAPHE, 1997a) and the NC2 in August 1997 (MSAPHE, 1997b). At the beginning of 1997, a decision was taken to give regions the political mandate to negotiate. Given the complex distribution of these responsibilities, strenghtening of the co-ordination and cooperation between regions and the Federal State is required.

Belgium has a temperate maritime climate, with moderate temperature variability, prevailing westerly winds, heavy cloud cover and regular rain. The area under agricultural production represents about 13,560 km^2. The distribution of forests in Belgium is shown in **table 1**.

[1] In French: Ministère des Affaires sociales de la Santé publique et de l'Environnement (MASSPE).
In Flemish: Ministerie van Sociale Zaken, Volksgezondheid en Leefmilieu (MSZVL).

2. REFERENCE VALUES FOR GREENHOUSE GAS INVENTORIES

The most important greenhouse gas of anthropogenic origin – as far as quantities emitted are concerned – is CO_2. The total emissions for energy, industry and waste, for the base year 1990 in Belgium, amount to 113,997 $kt \cdot y^{-1}$ and were reported as 126,288 $kt \cdot y^{-1}$ for 1997 (MSAPHE, 1999).

Both NC 1 and 2 reported "Changes in forest and other woody biomass stocks" (5A) as –2,057 $kt \cdot y^{-1}$ "Wood growth" (5D1) as –7,126 $kt \cdot y^{-1}$ and "Wood harvest" (5D2) as 5,070 $kt \cdot y^{-1}$. The same figures were

Table 1. Forest cover in Belgium.

Region	Area (km^2)	Forest area (km^2)	% of the area	% of the total forest area
Flanders	13,521	1,352	9.9	19.9
Brussels capital	162	20	12.3	0.3
Wallonia	16,845	5,448	32.3	79.9
Belgium	30,528	6,820	22.3	100

used for all the years under consideration (from 1990 until 1996) because the statistics underlying these calculations were not available. It can be deduced from these data that the annual net CO_2 fixation is only equivalent to 1.7–1.8 % of the annual anthropogenic CO_2 emissions.

Apart from the calculation of the annual net CO_2 fixation based on statistical data in accordance with the calculation method proposed by the IPCC (1997), a vegetation model of the Montheith type (Belfix), which had been calibrated with remote sensing data, has also been applied for 1990 (Veroustraete *et al.*, 1994). The model calculates the annual net CO_2 fixation by all vegetation types and gives an estimate of 1,837 $kt \cdot y^{-1}$. The difference of 10% compared with the results obtained with the IPCC method assumes that the Belfix method, in which the model is calibrated with measured data, provides a more accurate calculation than the IPCC method, which relies on statistics and averaged factors.

3. WORKING GROUP 1 RELATED ACTIVITIES (Inventory of C sinks and sources)

The Walloon Forest Inventory was set up as a permanent process by decree of the Walloon government (Moniteur Belge, 1995). The first inventory was conducted between 1980–1984 at the University of Gembloux (Lecomte, Rondeux, 1994). The inventory is drawn up by sampling to determine the surfaces by categories of property (Private or Public: State, Province, Community), type of forest, species, age, size and quality. It also provides estimates of the volume of standing timber and of the growth of these volumes, harvests and future potential yield for species of economic relevance. The sampling points are selected according to a 1,000 m × 500 m grid directed from the East to the West on the National Geographic Institute maps at a scale of 1/25,000. Each grid intersection, located in the forests according to the map, is subject to measurement in the field.

If we consider that the Walloon forest area is about 550,000 ha, the sampling strategy includes around 11,000 measurement points (1 point per 50 ha). The rectangular grid has the advantage of going against the orientation of the relief elements oriented along a SW–NW axis and against ecological and geological gradients predominant in the N-S orientation.

A ten-year period was adopted to carry out all the measurements. In order not to favour a given region, it was decided to cover the whole territory each year. The grid sampled each year is always the same as the previous years. By increasing the number of sampling points by 10% each year, the original mesh is narrowed from year to year: 1 measurement per 500 ha in 1994, the first year of the inventory, to 250 ha in 1995, to 100 ha in 1999, etc.

The sample plots are circles of 10 ares, for which the following information is collected: administrative data, topography, soil and vegetation, age, circumference at 1.5 m, total and dominant heights, commercial quality for broadleaf species bigger than 120 cm circumference, and as qualitative information: the regeneration technique, structure and development stage, quality, damage caused by game and the health and condition for harvest. For plots with edges or borders, the plot centre is moved towards the inside of the plantation.

The first forest inventory was completed in 1984, using a slightly different protocol than the one described here. By the end of 1999, 50% of the sample points of the second inventory had been measured, the data presented here represents a mesh of 100 ha over the whole territory. Walloon Forest Inventory data were processed using the conversion factors listed in **table 2**.

We have fitted a linear regression between 1984 and 1999 to derive the values for the reference year presented in **table 3**.

The carbon stocks in the biomass, as given in **table 4**, are calculated using the forest inventories and the conversion factors presented in **table 2**. Figures for soil carbon content in the Walloon forest soils date back to the sixties – seventies. We preferred using reference values for France (79 $t\ C \cdot ha^{-1}$, as a minimum value) and Germany (108.9 $t\ C \cdot ha^{-1}$ as a maximum value) as given in Arrouays *et al.*, (1999) and Dupouey *et al.*, (1999), in order to demonstrate the range and uncertainty.

Table 5 gives the annual potential carbon sequestration, according to the IPCC methodologies

Table 2. Conversion factors used to derive forest inventory data for deciduous and coniferous forests, their units and sources.

	Unit	Deci-duous	Coni-ferous
Above ground biomass/ total solid wood	$(t \cdot t^{-1})$	1.4	1.3(1)
Below ground biomass/ above ground biomass	$(t \cdot t^{-1})$	0.2	0.2(1)
Density of above ground biomass	$(t \cdot m^{-3})$	0.55	0.4(1)
Density of below ground biomass	$(t \cdot m^{-3})$	0.5	0.4(1)
C in biomass	(/)	0.5	0.5(2)
C content in soil (Min)	$(t \cdot ha^{-1})$	79	79(3)
C content in soil (Max)	$(t \cdot ha^{-1})$	108.6	108.6(3)
Wood growth	$(m^3 \cdot ha^{-1} \cdot y^{-1})$	5.15	15.2(2)

Source: (1) (FAO/CEE, 1986); (2) Lecomte (personal communication); (3) Arrouays *et al.*, 1999; Dupouey *et al.*, 1999.

Table 3. Forested areas in the Walloon region, productive areas and solid wood volumes, based on the 1984 forest inventory (completed grid of 50 ha) and the 1999 forest inventory (50% of the sample points, grid of 100 ha) and estimates for 1990, the reference year using a linear regression.

Year	**Forested areas** (ha)	**Productive areas** (ha)			**Solid wood volumes** (m^3)		
		Total	**Deciduous**	**Coniferous**	**Total**	**Deciduous**	**Coniferous**
1984	539,539	495,839	248,186	247,653	95,487,395	50,195,870	45,291,525
1990	541,643	488,623	249,032	239,592	104,385,677	53,906,842	50,478,835
1999	544,800	477,800	250,300	227,500	117,733,100	59,473,300	58,259,800

Table 4. Carbon stocks in the Walloon forest ecosystems.

Year	(t)	**Carbon in total biomass** ($t \cdot ha^{-1}$)		**Carbon in soil** ($t \cdot ha^{-1}$)	
		(1)	(2)	Min	Max
1984	36,970,077	75	69	42,623,581	58,593,935
1990	40,277,010	82	74	42,789,829	58,822,473
1999	45,237,409	95	83	43,039,200	59,165,280

(1) Productive areas; (2) total forested areas

(IPCC, 1997) and our working hypothesis of a linear trend in forest areas and overall biomass increase between 1998 and 1999. A distinction was made between the deciduous and coniferous species allocation respectively 5.15 and 15.2 $m^3 \cdot y^{-1} \cdot ha^{-1}$. Lecomte (personal communication) extrapolates the annual solid wood harvests for harvests in the public forests and gives an estimate of 3,350,000 m^3. No statistics were considered acceptable, whether from the National Statistics Institute, the Ministry of Economic Affairs, the wood industry unions or the trade sector.

Table 5. Annual carbon sequestration potential in the Walloon forests according to the IPCC methodology.

Year	**Annual wood growth** (m^3)	**Wood harvest** (m^3)	**Annual biomass change**	
			kt C	kt eq. CO_2
1991	4,924,308	3,350,000	436	1,600
1992	4,904,612	3,350,000	496	1,818
1993	4,884,916	3,350,000	512	1,876
1994	4,865,220	3,350,000	527	1,933
1995	4,845,525	3,350,000	521	1,911
1996	4,825,829	3,350,000	515	1,889
1997	4,806,133	3,350,000	509	1,867
1998	4,786,437	3,350,000	503	1,845
1999	4,766,741	3,350,000	497	1,823

Lecomte (personal communication) also estimates afforestation of agricultural land in the IPCC sense to be around 500 ha annually. Basing on forest inventories, we estimate land-use change to be around 149 ha and reforestation in the FAO sense around 4,000 ha annually. **Table 6** gives afforestation (A), deforestation (D) and reforestation (R) impacts on changes in C-sequestration according to the IPCC special report on land use, land-use change and forestry (Watson *et al.*, 2000).

4. CONCLUSIONS

An estimate of 1,823 kt eq. CO_2 change in forest and other woody biomass stocks, limited to the Walloon Region, should be compared to the 2 ,057 kt eq. CO_2 as reported for the whole territory in the NCs. ARD activities, as calculated here, induce a very small change in the C stocks in the Walloon forests. Referring to the 1990 base year, ARD increase the C-sequestration potential by a maximum of 2,009 kt over the commitment period 2008–2012, say 1.6% of the 1997 emissions.

Acknowledgement

This study was carried out in the framework of the project "Carbon sequestration potential in the Walloon forest" (1999–2000). We are greatly indebted to Ir Hugues Lecomte and Ir Christian Laurent, Directorate-General for Natural Resources and Environment (DGRNE) for having provided us with the most recent data on the forest inventory in the Walloon region.

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Table 6. Impacts of afforestation (A), deforestation (D) and reforestation (R) on changes in C-sequestration Article 3.3 of the Kyoto protocol.

Art. 3 3	**Def**	**Accounting Framework**	**Type**	**a1** (ha)	**VarC1** (kt C)	**a2** (ha)	**VarC2** (kt C)	**acp** (ha)	**VarCcp** (kt C)
A	IPCC	Activity based	Min	2,500	8	4,500	23	11,000	127
R			Max	2,500	15	4,500	45	11,000	253
A	FAO	Activity based	Min	2,500	8	4,500	23	11,000	127
			Max	2,500	15	4,500	45	11,000	253
R	FAO	Activity based	Min	20,000	60	36,000	180	88,000	1,012
			Max	20,000	120	36,000	360	88,000	2,024
D	IPCC/FAO	Activity based	Min	-746	-58	-1,343	-106	-3,284	-253
			Max	-746	-65	-1,343	-120	-3,284	-268
Total	IPCC		Min	1,754	-50	3,157	-84	7,716	-127
			Max	1,754	-50	3,157	-75	7,716	-15
	FAO		Min	21,754	10	39,157	96	95,716	886
			Max	21,754	70	39,157	285	95,716	2,009

a1 = area (ha) afforested and reforested, or deforested since 1990 up to 1995 (i.e. , over a 6-year period). VarC1 = carbon stock change [ktC] since 1990 up to 1995 on land afforested, reforested, and deforested. a2 = area (ha) afforested and reforested, or deforested since 1990 up to 1999 (i.e., over a 10-year period). VarC2 = carbon stock change (kt C) since 1990 up to 1999 on land afforested, reforested, and deforested. acp = projected area (ha) afforested and reforested, or deforested since 1990 up to 2012 (i.e., over a 23-year period). VarCcp = projected carbon stock change (kt C) over the first commitment period (2008–2012) on land afforested, reforested, and deforested.

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