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CADSES programme



Carbon balance drafting and new
resources management tools according to
Kyoto Protocol

Research report on the
quantity of carbon
immobilized by the various
territorial contexts

WP2 – Activity 2.5

Quantifying the carbon stock changes caused by land cover changes for the federal state of Salzburg, Austria

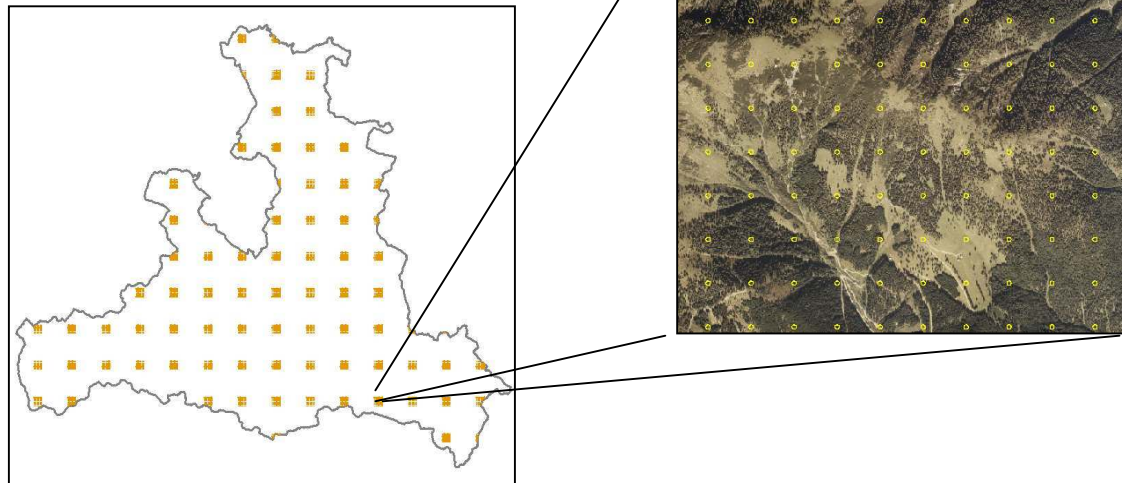
JOANNEUM RESEARCH, Institute of Energy Research

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As part of the agreement with the project partner CERE the task of JOANNEUM RESEARCH was to estimate the C stock change in the federal state of Salzburg for the time period 1990 to 2000. The result of the estimation amounts up to a change of -192199, 31 tC between 1990 and 2000.

Methodological issues

The data are based on systematically distributed land cover attributes by means of 7000 sampling points.



Area Frame Sampling for quantification of land cover changes 1990 to 2000

Source: Power Point Presentation: *CarbonPro contributions, Joanneum Research, Institute of Digital Image Processing*. By Heinz Gallaun.

Land cover was interpreted in the EU project "CarboInvent" on the basis of multi-temporal aerial and satellite remote sensing data. The estimation of C stock change was performed based on the activity data for afforestation and deforestation. Only C stock changes within the living biomass pool have been estimated.



A land cover exchange matrix has been created by the Joanneum Research's Institute of Digital Image Processing. It included the land cover changes of the following categories:

- Forest
- Other wooded land
- Settlement
- Grassland/Cropland
- Wetland
- Other Land.

The following table displays the exchange matrix: the values show the number of samples that were recorded within the categories.

historical	current	Settlement	Grass/Crop.	Forest	Other wood.L.	Wetland	Other Land	# Sample Plots	%
		1	2	3	4	5	6	1990	
Settlement	1	145	1	0	0	1	0	147	2,08
Grass/Crop.	2	19	2589	4	4	14	0	2630	37,29
Forest	3	3	26	2800	0	1	5	2835	40,20
Other wood.L.	4	2	2	1	348	0	0	353	5,01
Wetland	5	0	0	0	1	103	0	104	1,47
Other Land	6	0	2	0	2	0	979	983	13,94
# Sample plots	2000	169	2620	2805	355	119	984	7052	100,00
%		2,40	37,15	39,78	5,03	1,69	13,95	100,00	



The sample plot numbers were converted into hectares by transferring the percentages (also given in the exchange matrix) on the total size (71.5423 ha) of the federal state of Salzburg (see modified exchange matrix below).

In order to estimate the C stock change according to the 2006 IPCC Guidelines for National GHG Inventories, the categories had to be adapted to the categories used in the 2006 Guidelines. According to Austria's forest definition chosen in the National Inventory Report (NIR) 2007 to the UNFCCC "other wooded land" had to be included in "forest land". Further, the category Grassland/Cropland (GL/CL) had to be separated for proper C stock change estimation. After the changes the categories are the following:

Forest
Settlement
Grassland
Cropland
Wetland
Other Land.

The separation of GL/CL has been accomplished by using additional data of Statistic Austria (Land- und forstwirtschaftlichen Betriebszählung 1990) for 1990 and for the year 2000 data of the "Grüne Bericht 2000" (data acquired by information via phone from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management). The information provided on the surface areas by the external data sources allowed to calculate a ratio for GL and CL, which than was used to calculate the absolute area for CL for the years 1990 and 2000 out of the area GL/CL provided by the exchange matrix.

Splitting Grassland and Cropland into two separate areas:

	1990	2000	
	in ha		
CL	7660	6869	Source: Statistik Austria
GL	299919	294000	Source: Grüner Bericht
calculation of the ratio CL/ GL, that is applied to the exchange matrix			
	1990	2000	
	0,025	0,023	



The ratios (0,025 and 0,023) were multiplied with the GL/CL area of 1990 and 2000 and the result was the area of Cropland in 1990 (6645 ha) and in 2000 (6068 ha), which can be seen in the exchange matrix below.

historical	Current Land use	Settlement	Grassland	Cropland	Forest	Wetland	Other Land	Area (ha)	%
		1	2		3	5	6	1990	
Settlement	1	14710,20	101,45		0,00	101,45	0,00	14913,10	2,08
Grassland	2	1927,54	256584,86		811,60	1420,30	0,00	260167,86	37,29
Cropland					???			6644,75	
Forest	3	507,25	2840,59		319464,98	101,45	507,25	323421,52	45,21
Wetland	5	0,00	0,00		101,45	10449,31	0,00	10550,76	1,47
Other Land	6	0,00	202,90	???	202,90	0,00	99319,22	99725,02	13,94
Area (ha)	2000	17144,99	259729,80	6068,31	320580,92	12072,51	99826,47	715423,00	
%		2,40	37,15		39,78	1,69	13,95		100,00

The determination on the land cover changes of GL and CL into Forest Land or vice versa was accomplished by using data from the NIR (marked orange in the table below) of Austria 2007 (Chp. 7.2.2). The data has been extrapolated to the Salzburg data (marked green) and to the year 1990. The NIR data presents land cover changes in ha from 2000-2002. With that the percentage of change between the land cover categories was determined and was used to complete the exchange matrix regarding changes from and to forest land of GL and CL .

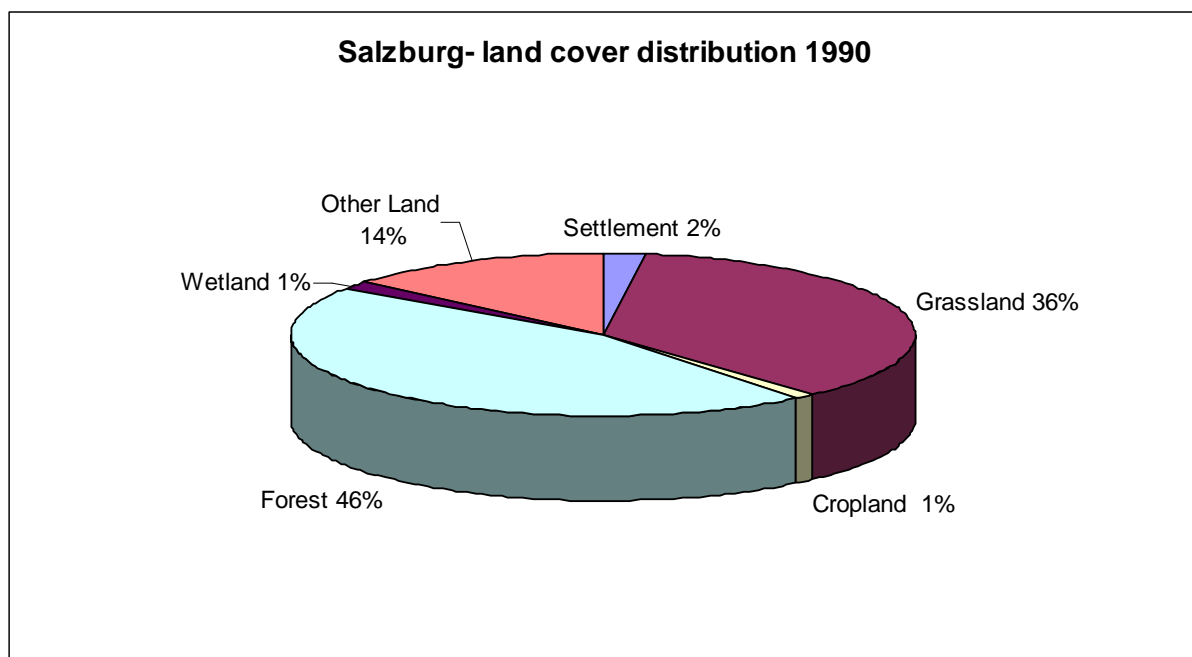
Afforestation			%	
Area GL/CL to Forest (ha)				811,6
Cropland to Forest (ha)	10900		21,29	172,78
Grassland to Forest (ha)	40.300		78,71	638,82
sum	51200			
Deforestation				
Area Forest to GL/CL (ha)				2840,59
Forest to Cropland	1600		8,70	247,01
Forest to Grassland	16800		91,30	2.593,58
sum	18400			



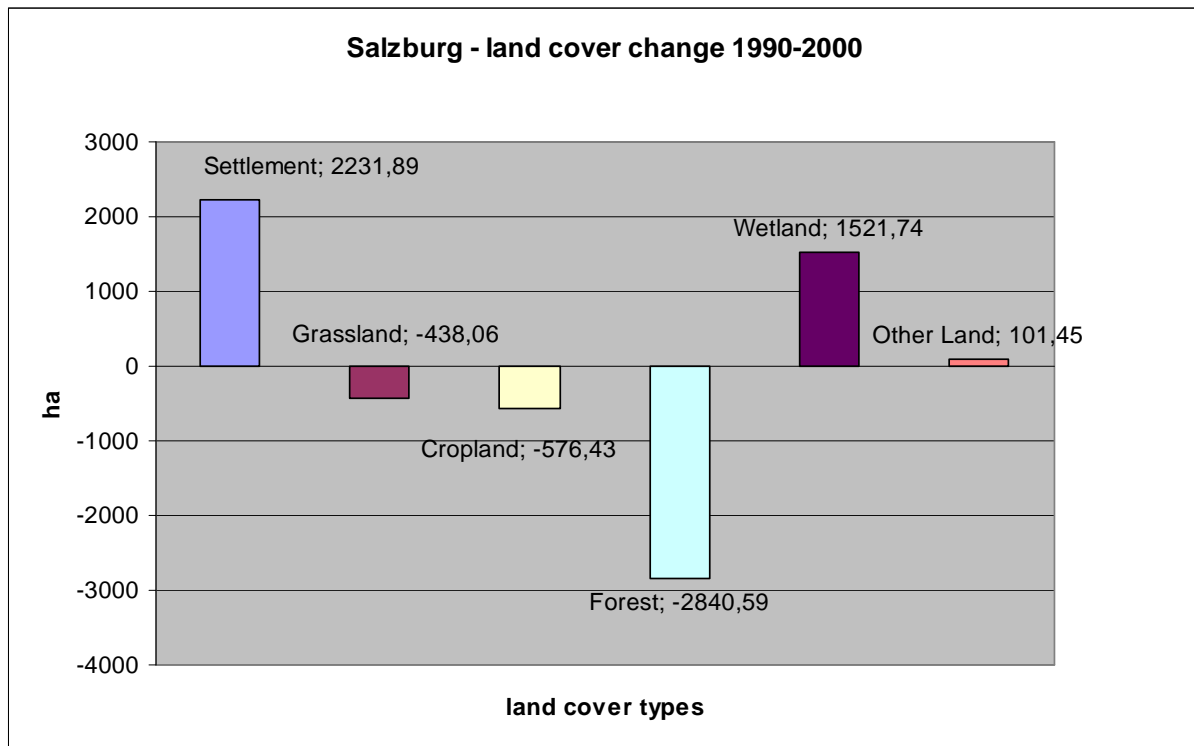
The estimation of changes from/to forest land can be seen in the matrix below, marked red:

	current Land Use	Settlement	Grassland	Cropland	Forest	Wetland	Other Land	Area (ha)	%
historical		1	2	3	4	5	6	1990	
Settlement	1	14710	101		0	101	0	14913	2
Grassland	2	1928	256585		639	1420	0	260168	36
Cropland	3				173			6645	1
Forest	4	507	2594	247	319465	101	507	323422	45
Wetland	5	0	0		101	10449	0	10551	1
Other Land	6	0	203		203	0	99319	99725	14
Area (ha)	2000	17145	259730	6068	320581	12073	99826	715423	
%		2	36	1	45	2	14		100

The exchange matrix already provides information on the land use – cover distribution, which can be seen in the following diagram:



Changes within the land cover categories between 1990 and 2000 can be seen in the following graph:



The graph shows clearly that forest lost the most hectares while the categories settlement and wetland expanded.

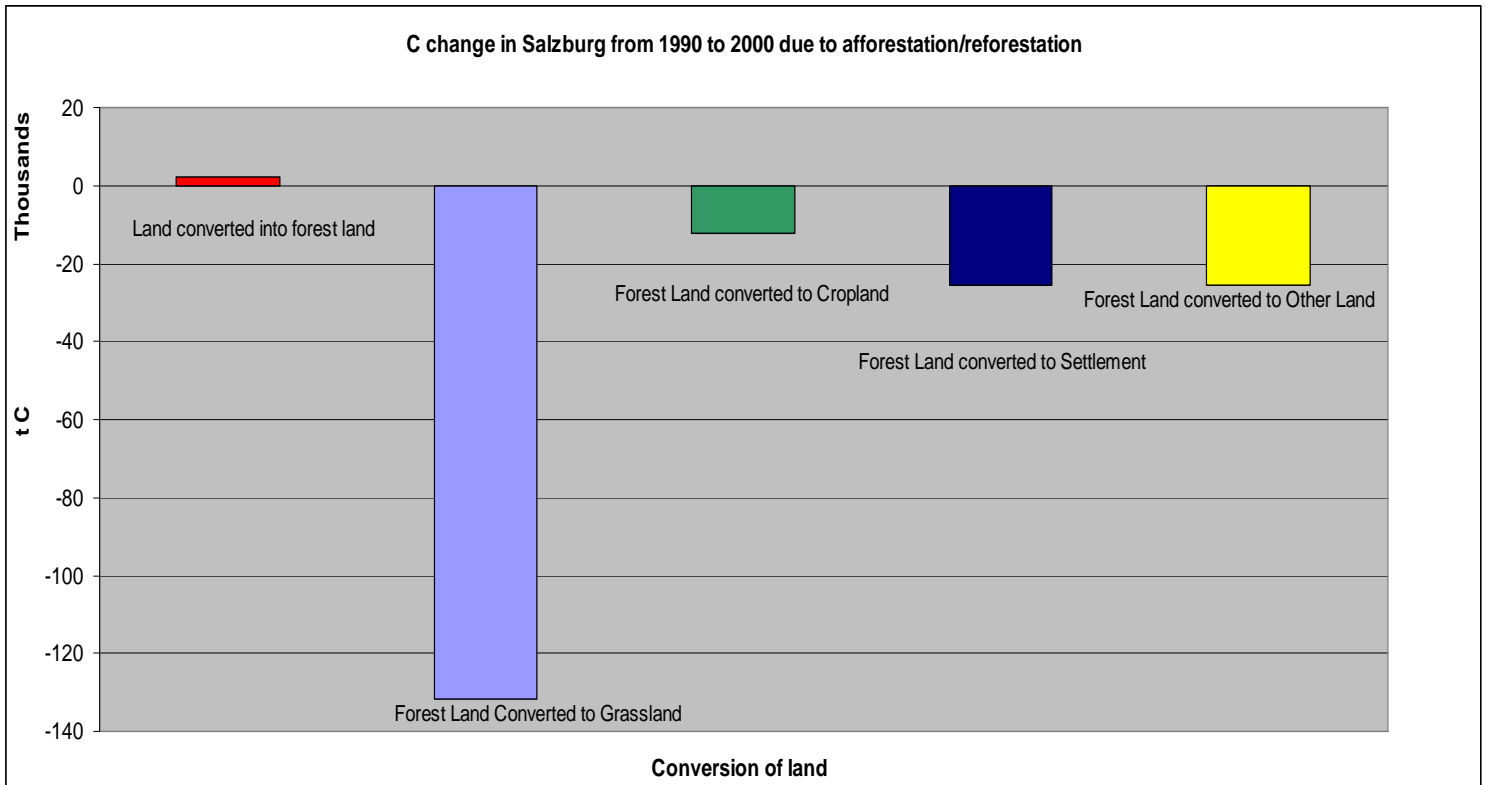
The actual C stock change estimation was done according to the worksheets in the 2006 IPCC Guidelines for National GHG Inventories using default values provided by the 2006 IPCC Guidelines for National GHG Inventories (look at the end of the document for the worksheets).

The results show that between 1990 and 2000 Salzburg C stock has been reduced by 192.199,31 t C.

Final Result C stock change 1990-2000 due to ARD	
Afforestation	t C
Land converted to Forest Land	2343,49
Deforestation	
Forest Land converted to GL	-131517,58
Forest Land converted to CL	-12350,39
Forest Land converted to Settlement	-25312,41
Forest Land converted to Other Land	-25362,41
SUM	-192199,31



The following graph shows this better:





Worksheets of the 2006 IPCC Guidelines on national GHG monitoring

In the following table C increase due to afforestation is calculated. Therefore, the areas (ha) that changed into forest land according to the exchange matrix were used. The table estimates an annual C increase; consequently the data from the exchange matrix had to be divided by 10 since it covers a time period of 10 years. The other values used are default values deriving from the IPCC Guidelines and can be looked up in the corresponding tables as indicated.



Sector		Agriculture, Forestry and Other Land Use						
Category		Land Converted to Forest Land: Annual increase in carbon stocks in biomass (includes above- and below-ground biomass)						
Category code		3B1b						
Sheet		1 of 4						
Equation		Equation 2.2	Equation 2.9	Equation 2.10		Equation 2.9		
Land-use category		Subcategories for reporting year	Area of land Converted to Forest Land	Average annual above-ground biomass growth	Ratio of below-ground biomass to above-ground biomass	Average annual biomass growth above and below-ground	Carbon fraction of dry matter	Annual increase in biomass carbon stocks due to biomass growth
Initial land use ¹	Land use during reporting year		(ha)	(tonnes dm ha ⁻¹ yr ⁻¹)	[tonnes bg dm (tonne ag dm) ⁻¹]	(tonnes dm ha ⁻¹ yr ⁻¹)	[tonnes C (tonne dm) ⁻¹]	(tonnes C yr ⁻¹)
			National statistics or international data sources	Tables	zero (0) or	G _{TOTAL} = G _W * (1+R)	0.5 or	ΔC _G = A * G _{TOTAL} * CF
			A	G _W	R	G _{TOTAL}	CF	□C _G
CL	FL	(a)	17,28	3,00	0,4	4,2	0,5	36,28
		(b)						
Sub-total								
GL	FL	(a)	63,88	3,00	0,4	4,2	0,5	134,15
		(b)						
Sub-total								
WL	FL	(a)	10,14	3,00	0,4	4,2	0,5	21,30
		(b)						
Sub-total								
SL	FL	(a)						
		(b)						
Sub-total								
OL	FL	(a)	20,29	3,00	0,4	4,2	0,5	42,61
		(b)						
Sub-total								
Total								234,35

¹ If data by initial land use are not available, use only "non-FL" in this column.

Increase in t C biomass stock due to afforestation 1990-2000 **2343,49**

The subsequent tables estimate the C loss due to deforestation.



Sector		Agriculture, Forestry and Other Land Use								
Category		Land Converted to Grassland: Annual change in carbon stocks in biomass								
Category code		3B3b								
Sheet		1 of 1								
Equation		Equation 2.2		Equation 2.16			Equation 2.15, 2.16			
Land-use category		Subcategories for reporting year	Type of vegetation ²	Annual area of Land Converted to Grassland	Biomass stocks after the conversion	Biomass stocks before the conversion	Carbon fraction of dry matter	Annual biomass carbon growth	Annual loss of biomass carbon	Annual change in carbon stocks in biomass
Initial land use ¹	Land use during reporting year			(ha)	(tonnes dm ha ⁻¹)	(tonnes dm ha ⁻¹)	[tonnes C (tonne dm) ⁻¹]	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C yr ⁻¹)
				0 or Table 6.4	(see section 6.3.1.2)	0,47 (for herbaceous vegetation); 0,5 or Table 4.3 (for woody vegetation)	Table 5.9	National estimates, or Table 5.1	$HC_B = ?C_G + ((B_{AFTER} - B_{BEFORE}) * \Delta A_{TO_OTHER}) * CF - ?C_L$	
				ΔA_{TO_OTHER}	B_{AFTER}	B_{BEFORE}	CF	ΔC_G	ΔC_L	HC_B
[non-GL]	GL	(a)	Herbaceous							
			Woody	259,36	2,4	100	0,5	0	0	-12656,68
		Sub-total								
		(b)	Herbaceous converted to Wetland*	10,14	2,4	100	0,5	0	0	-495,07
Sub-total										
Total										-13151,76

¹ If data by initial land use are not available, use only "non-GL" in this column. Otherwise use separate blocks by initial land use.

² Within each subcategory (a), (b) etc., calculations are to be made separately for herbaceous and wood vegetation.

* this category has been included in here because there is no worksheet in the 2006 IPCC guidelines, that allows me to estimate C stock change from conversion of land into wetland. But in order to include the C-change from forest land to wetland, it was decided to estimate it within land converted to grassland

Change in C stocks in biomass t C due to deforestation 1990-2000 -131517,58

The 2006 IPCC Guidelines for National GHG Inventories (chp.4) provide no worksheet that allows calculating C stock change from forest land into wetland; therefore wetland was considered as GL.



Sector		Agriculture, Forestry and Other Land Use						
Category		Land Converted to Cropland: Annual change in carbon stocks in biomass						
Category code		3B2b						
Sheet		1 of 1						
Equation		Equation 2.2			Equation 2.16		Equation 2.15, 2.16	
Land-use category		Annual area of Land Converted to Cropland	Biomass stocks before the conversion	Carbon fraction of dry matter	Annual biomass carbon growth	Annual loss of biomass carbon	Annual change in carbon stocks in biomass	
Initial land use ¹	Land use during reporting year	(ha)	(tonnes dm ha ⁻¹)	[tonnes C (tonne dm) ⁻¹]	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C yr ⁻¹)	
			Table 5.8	0,5	Table 5.9	National estimates, or Table 5.1	$\square C_B = ?C_G + ((0 - B_{BEFORE}) * \Delta A_{TO_OTHER}) * CF - ?C_L$	
		ΔA_{TO_OTHER}	B_{BEFORE}	CF	ΔC_G	ΔC_L	$\square C_B$	
FL	CL	(a)	24,70	100	0,5	0	0	-1235,04
		(b)			0,5			
Sub-total								
GL	CL	(a)			0,5			
		(b)			0,5			
Sub-total								
WL	CL	(a)			0,5			
		(b)			0,5			
Sub-total								
SL	CL	(a)			0,5			
		(b)			0,5			
Sub-total								
OL	CL	(a)			0,5			
		(b)			0,5			
Sub-total								
Total								-1235,04

¹ If data by initial land use are not available, use only "non-CL" in this column.

Change in C stocks in biomass t C due to deforestation 1990-2000 -12350,39



Sector		Agriculture, Forestry and Other Land Use						
Category		Land Converted to Settlements: Annual change in carbon stocks in biomass						
Category code		3B5b						
Sheet		1 of 1						
Equation		Eq. 2.2	Equation 2.16			Equation 2.15, 2.16		
Land-use category		Subcategories for reporting year	Annual area of Land Converted to Settlements	Biomass stocks before the conversion	Carbon fraction of dry matter	Annual biomass carbon growth	Annual loss of biomass carbon	Annual change in carbon stocks in biomass
Initial land use ¹	Land use during reporting year		(ha)	(tonnes dm ha ⁻¹)	[tonnes C (tonne dm) ⁻¹]	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C yr ⁻¹)
				Table 5.8	0,5	Table 5.9	National estimates, or Table 5.1	$\square C_B = ?C_G + ((0 - B_{BEFORE}) * \Delta A_{TO_OTHERS} * CF) - ?C_L$
		ΔA_{TO_OTHERS}	B_{BEFORE}	CF	ΔC_G	ΔC_L	$\square C_B$	
FL	SL	(a)	50,72	100	0,5	5	0	-2531,24
		(b)						
Sub-total								
CL	SL	(a)						
		(b)						
Sub-total								
GL	SL	(a)						
		(b)						
Sub-total								
WL	SL	(a)						
		(b)						
Sub-total								
OL	SL	(a)						
		(b)						
Sub-total								
Total								-2531,24

¹ If data by initial land use are not available, use only "non-SL" in this column.

Change in C stocks in biomass t C due to deforestation 1990-2000 -25312,41



Sector		Agriculture, Forestry and Other Land Use						
Category		Land Converted to Other Land: Annual change in carbon stocks in biomass						
Category code		3B6b						
Sheet		1 of 1						
Equation		Eq. 2.2	Equation 2.16			Equation 2.15, 2.16		
Land-use category		Subcategories for reporting year	Annual area of Land Converted to Other Land	Biomass stocks before the conversion	Carbon fraction of dry matter	Annual biomass carbon growth	Annual loss of biomass carbon	Annual change in carbon stocks in biomass
Initial land use ¹	Land use during reporting year		(ha)	(tonnes dm ha ⁻¹)	[tonnes C (tonne dm) ⁻¹]	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C ha ⁻¹ yr ⁻¹)	(tonnes C yr ⁻¹)
				Table 5.8	0,5	Table 5.9	National estimates, or Table 5.1	$\square C_B = ?C_G + ((0 - B_{BEFORE}) * \Delta A_{TO_OTHERS}) * CF$ $?C_L$
			ΔA_{TO_OTHERS}	B_{BEFORE}	CF	ΔC_G	ΔC_L	$\square C_B$
FL	OL	(a)	50,72	100	0,5	0	0	-2536,24
		(b)						
Sub-total								
CL	OL	(a)						
		(b)						
Sub-total								
GL	OL	(a)						
		(b)						
Sub-total								
WL	OL	(a)						
		(b)						
Sub-total								
SL	OL	(a)						
		(b)						
Sub-total								
Total								-2536,24

¹ If data by initial land use are not available, use only "non-OL" in this column.

Change in C stocks in biomass t C due to deforestation 1990-2000 -25362,41