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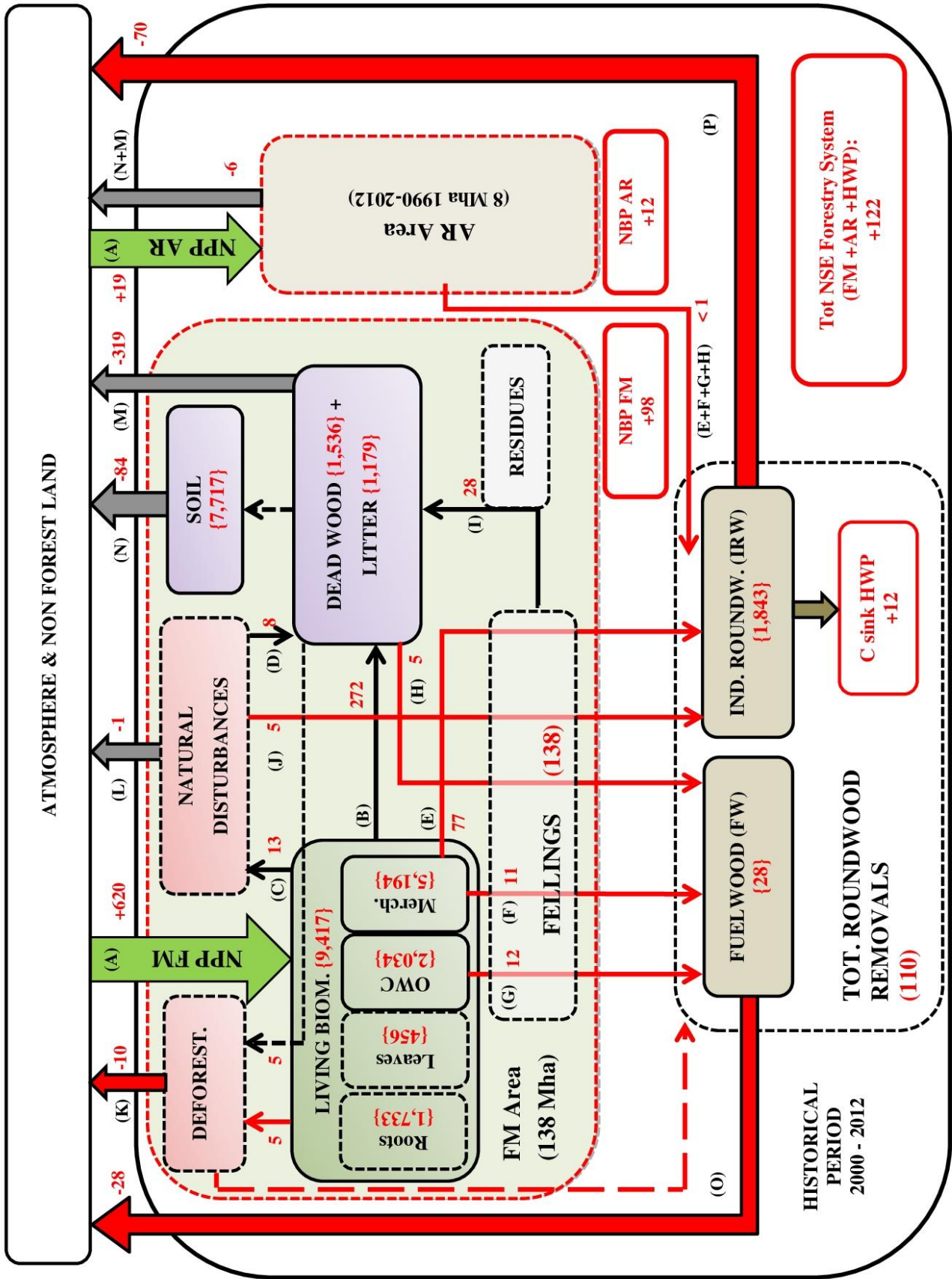
Supplement of

The European forest sector: past and future carbon budget and fluxes under different management scenarios

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Tot NSE Forestry System (FM +AR +HWP): +122

C sink HWP +12

TOT. ROUNDWOOD REMOVALS (110)

HISTORICAL PERIOD 2000 - 2012

Figure S1: Forest carbon (C) flow modelled for EU 26 by CBM for the historical period 2000 – 2012, for the forest area (further distinguished between forest management area, FM and afforestation, AR) and main links with the HWP pools, further distinguished between industrial roundwood (IRW) and fuelwood (FW). The main forest pools and fluxes in our analysis are: living biomass (LB), which includes roots, leaves, merchantable tree portion and other wood components (OWCs, branches and tops), dead wood and litter pools (DOM) and soil. C moves from the atmosphere to LB through photosynthesis (*A*) and from there to DOM (black arrows, only highlighted for the FM area) because of litterfall and natural mortality (*B*) and natural disturbance events (fires and storms, arrows *C* and *D*). Red arrows highlight the main C fluxes due to direct human activities: harvest, moves a fraction of the merchantable portion to IRW (*E*) and to FW (*F*), part of the OWCs moves to FW (*G*) and a fraction of the standing dead trees may be collected as FW (*H*). A fraction of the living biomass is left as residues that move from LB to DOM (*I*). Salvage logging (*J*) following natural disturbances moves C from the LB to IRW or FW. Deforestation releases LB and DOM C to the atmosphere (or transfers the C to non-forest land, *K*) of which the LB fraction (about 50% of the total C removed by deforestation), could in the future be used as FW or IRW. Due to the lack of detailed information, this amount, highlighted by a red dotted arrow and equal as maximum to about 5 Tg C yr⁻¹, was not included in the sum of the total roundwood removals but reported in total emissions due to deforestation. Further releases are related to natural disturbances, i.e., fires (*L*), and the decay rate of DOM (*M*) and soil (*N*) pools. The C used for energy (FW) is directly released to the atmosphere (i.e, immediate oxidation, *O*) while the C stocked as IRW has a carbon retention time before being emitted to the atmosphere (*P*).

The arrows reported by the figure, such as the C stock of the main forest pools and the total amount of C moved to the IRW and FW pools (further distinguished between broadleaved and coniferous species) were quantified by our analysis (see Results section). The figure reports (inside the main boxes) the average total C stock (red numbers between parenthesis, in Tg C) estimated for EU 26, for the main FM pools (i.e., living biomass and its sub-pools); the total amount of fellings, further distinguished between roundwood removals and harvest residues; the roundwood removals used as fuelwood and industrial roundwood. The fluxes (in Tg C yr⁻¹), reported near the main arrows, are further distinguished between: (1) inputs, i.e., the Net Primary Production (NPP, highlighted by green arrows) distinguished between FM and AR area; (2) outputs (red arrows), including (i) direct C emissions from the forest to the atmosphere; (ii) harvest removals from living biomass and dead wood to the HWP pool (further distinguished between the removals used as FW and IRW) and due to the salvage logging after natural disturbances and provided by AR; (3) internal fluxes (black arrows), from the living biomass to the DOM pool, due to natural processes, to natural disturbances, and to harvest activities (i.e., residues). The total C sink referred to the FM activities (including the effect of deforestation) is equal to the sum of inputs and outputs to/from the FM area. From the total roundwood removals, further releases of C to the atmosphere are due to the direct oxidation of the wood used as FW. The indirect C emissions from the wood used as IRW were estimated as the difference between the total C stock removed as IRW and the average (2000-2012) amount of C stocked as IRW as estimated by Pilli et al., 2015.

Adding to the total C sink of FM, the IRW removals minus the releases from prior years (i.e., C sink HWP) and the C sink of the afforested area, we estimated the Net Sector Exchange (NSE) of the forest sector.

Carbon pools	Sub pools	Historical	Constant	+20%	-20%	Fluxes	Historical	Constant	+20%	-20%
	Tg C	Av 2000-12	2030	2030	2030	Tg C yr ⁻¹	Av 2000-12	2030	2030	2030
Living B.		9,417	11,596	11,154	11,758	NPP FM (A)	620	661	653	669
						To DOM (<i>B</i>)	272	306	302	310
	Tot ABG	7,684	9,527	9,191	9,693	To IRW (<i>E</i>)	77	83	98	67
	Merchantable	5,194	6,594	6,402	6,762	To FW (<i>F</i>)	11	11	12	9
	OWCs	2,034	2,401	2,286	2,403	To FW (<i>G</i>)	12	12	14	9
	Leaves	456	532	503	529	To HWP (<i>E+F+G</i>)	99	105	124	85
	Roots	1,733	2,069	1,963	2,065					
DOM		2,715	2,852	2,827	2,765	To FW (<i>H</i>)	5	3	3	2
		0	0	0	0	To atm. (<i>M</i>)	319	359	361	357
	Dead wood	1,536	1,531	1,522	1,476	IRW to Atm (<i>P</i>)	70	75	85	65
	Litter	1,179	1,321	1,305	1,289		0	0	0	0
Soil		7,717	7,714	7,556	7,557	To atm. (<i>N</i>)	84	89	88	89
Harvest	Tot Removals	109	108	128	88	Tot HWP (<i>E+F+G+H+J</i>)	109	108	128	88
	from LB to FW	22	22	26	18	HWP C sink	12	8	13	2
	from LB to IRW	77	83	98	67		0	0	0	0
	from Nat.Disturb.	5	1	0	0		0	0	0	0
	from DOM	5	3	3	2		0	0	0	0
	to DOM (residues)	28	23	26	17	To DOM (<i>I</i>)	28	23	26	17
Nat Dist.						Tot Losses (<i>C</i>)	13	10	7	3
						To DOM (<i>D</i>)	8	2	2	2
						To HWP (<i>J</i>)	5	1	0	0
						To Atm. (<i>L</i>)	1	1	1	1
Deforest		10	11	11	11	To atm. (<i>K</i>)	10	11	11	11
Total Area (ha)		136,700,054	134,385,853	134,385,853	134,385,853	C sink FM	98	92	61	123
						C sink FM+HWP	110	100	74	126
Afforest.						NPP AR	19	57	58	56
						AR to Atm.	6	24	24	24
	From to	1990-2012	1990-2030	1990-2030	1990-2030	Harvest AR	1	6	6	6
Total Area (ha)		8,558,909	11,771,101	12,204,450	11,337,160	C sink AR	12	26	27	25
Total Area (ha)		145,258,964	148,471,155	148,904,504	148,037,214	Tot. C sink (NSE)	122	126	101	151

Table S1: the table summarizes the total (i.e., referred to the total forest area) C stock (in Tg C) and the C fluxes (in Tg C yr⁻¹) estimated by CBM at the EU level for the historical period 2000 – 2012 and for 2030, under different scenarios. The letters in Italics between parentheses near the fluxes refer to the arrows reported in Figure S1. The values reported for deforestation are the average of the period 2013 – 2030, to avoid possible differences due to the random distribution of the deforested area during the model run.

Carbon pools FM area	Sub pools	Historical	Constant	+20%	-20%	Fluxes	Historical	Constant	+20%	-20%
	Mg C ha ⁻¹	Av 2000-12	2030	2030	2030	Mg C ha ⁻¹ yr ⁻¹	Av 2000-12	2030	2030	2030
Living B.		69.87	85.56	81.10	85.48	NPP(A)	4.54	4.84	4.77	4.90
						To DOM (<i>B</i>)	1.99	2.24	2.21	2.27
	Tot ABG	56.21	69.69	67.23	70.91	To IRW (<i>E</i>)	0.56	0.60	0.72	0.49
	Merchantable	37.99	48.23	46.83	49.46	To FW (<i>F</i>)	0.08	0.08	0.09	0.06
	OWCs	14.88	17.56	16.72	17.58	To FW (<i>G</i>)	0.09	0.09	0.10	0.07
	Leaves	3.33	3.89	3.68	3.87					
	Roots	12.68	15.14	14.36	15.11					
DOM		19.86	20.87	20.68	20.23	To FW (<i>H</i>)	0.03	0.02	0.03	0.02
						To atm. (<i>M</i>)	2.33	2.63	2.64	2.61
	Dead wood	11.24	11.20	11.13	10.80					
	Litter	8.62	9.66	9.55	9.43					
Soil		56.45	56.43	55.28	55.28	To atm. (<i>N</i>)	0.61	0.65	0.65	0.65
Harvest	Tot Removals	0.80	0.79	0.93	0.64					
	from LB to FW	0.16	0.16	0.19	0.13					
	from LB to IRW	0.56	0.60	0.72	0.49					
	from Nat.Disturb.	0.04	0.00	0.00	0.00					
	from DOM	0.03	0.02	0.03	0.02					
	to DOM (residues)	0.20	0.16	0.19	0.13	To DOM (<i>I</i>)	0.20	0.16	0.19	0.13
Nat Dist.						Tot Losses (<i>C</i>)	0.10	0.07	0.05	0.02
						To DOM (<i>D</i>)	0.06	0.02	0.02	0.01
						To HWP (<i>J</i>)	0.04	0.00	0.00	0.00
						To Atm. (<i>L</i>)	0.01	0.01	0.01	0.01
Deforest.		0.07	0.08	0.08	0.08	To atm. (<i>K</i>)	0.07	0.08	0.08	0.08
						C sink per ha	0.71	0.67	0.45	0.90

Table S2: the table summarizes the C stock (in Mg C ha⁻¹) and the C fluxes (in Mg C ha⁻¹ yr⁻¹) estimated by CBM at the EU level for the FM area. The letters in Italics between parentheses near the fluxes refer to the arrows reported in Figure S1. The values reported for deforestation are the average of the period 2013 – 2030, to avoid possible differences due to the random distribution of the deforested area during the model run.

Country	EFISCEN	BIOME-BGC	ORCHIDEE	JULES	CBM
AT	921	578	612	391	658
BE	834	672	866	529	511
BG	610	431	579	432	401
CZ	858	638	734	451	623
DK	650	600	677	467	470
EE	583	559	667	383	465
FI	373	456	578	198	273
FR	567	538	535	504	469
DE	812	621	638	485	751
HU	617	556	802	460	508
IE	691	563	577	464	917
IT	510	401	333	437	487
LV	549	602	708	417	467
LT	556	609	719	435	378
LU	972	661	928	515	582
NL	720	622	577	497	577
PL	540	810	716	467	523
PT	344	327	192	438	426
RO	721	616	769	420	596
SK	592	649	859	433	546
SI	598	552	297	477	650
ES	210	353	296	203	314
SE	422	424	507	214	389
UK	642	518	517	447	621
Avg. ± st dev	621±178	557±109	612±185	424±90	515±142

Table S3: the table compared the values reported by Tupek et al. (2010, Table 2), based on the Net Primary Production (NPP, in g C m² yr⁻¹) estimated by four different models (EFISCEN, BIOME-BGC, ORCHIDEE and JULES) with the estimates provided by our study (CBM).