ELECTRONIC SUPPLEMENTARY MATERIAL

SUSTAINABLE FOOD PRODUCTION AND CONSUMPTION

Back to the future: dynamic full carbon accounting applied to prospective bioenergy scenarios

Ariane Albers[1,2,3] • Pierre Collet[1] • Anthony Benoist[3,4] • Arnaud Hélias[2,5,6]

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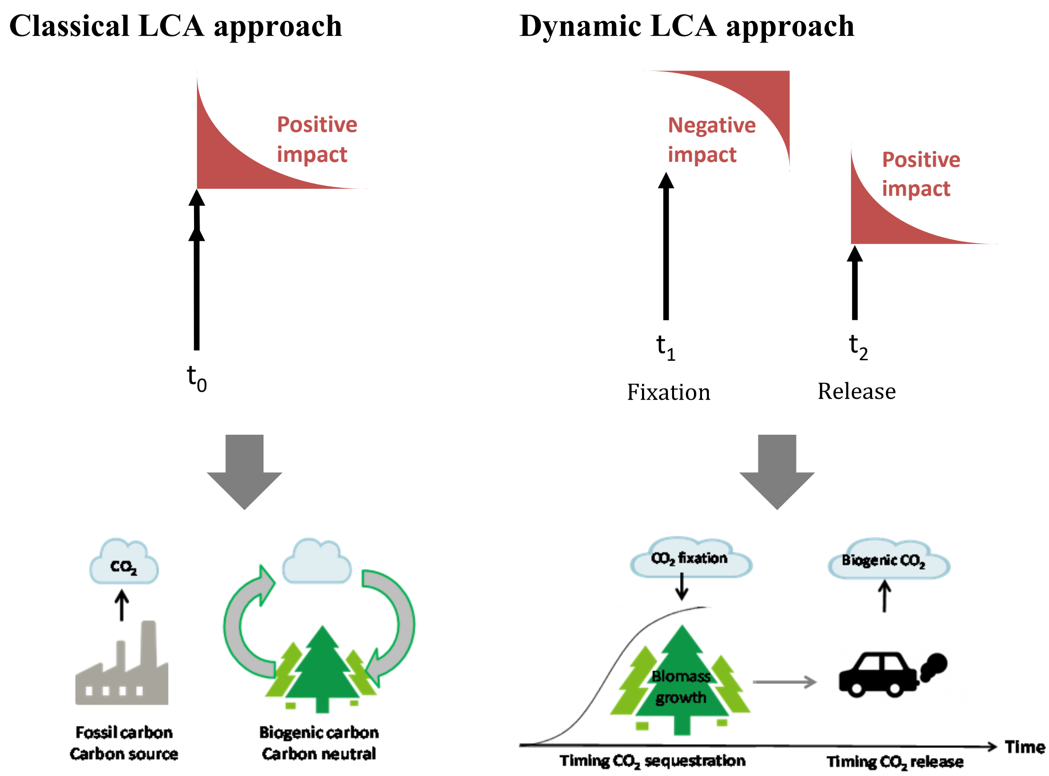
[1]IFP Energies nouvelles, 1 et 4 Avenue de Bois-Préau, 92852 Rueil-Malmaison, France
[2]LBE, Montpellier SupAgro, INRA, UNIV Montpellier, Narbonne, France
[3]Elsa, Research group for Environmental Lifecycle and Sustainability Assessment, Montpellier, France
[4]CIRAD - UPR BioWooEB, Avenue Agropolis, 34398 Montpellier, France
[5]Chair of Sustainable Engineering, Technische Universität Berlin, Berlin, Germany
[6] ITAP, Irstea, Montpellier SupAgro, Univ Montpellier, ELSA Research Group, Montpellier, France

✉ Ariane Albers
ariane.albers@ifpen.fr

1 Static versus dynamic LCA approaches

Comparison between classical and dynamic LCA approaches concerning the time dimension, biogenic carbon and climate change.



Approach	Aggregation of all carbon flows	Temporal differentiation of carbon flows
LCI	Carbon neutral (sequestration and release sum up to zero)	Biogenic carbon accounting (timing all sequestration and release flows)
LCIA	Static, with fixed time horizon (GWP 20 or 100 years)	Time-dependent, with flexible/variable time horizon

2 Partial-equilibrium model outputs

1.1 Biomass commodity

Figure S1 shows all biomass commodity outputs of TIMES-MIRET partial-equilibrium model of the LTECV scenario simulation. This study was concerned with modelling the dynamic biogenic carbon flows of the commodity forest wood residue. The annual mean FoWooR supply, described in the LTECV scenario, is estimated at 34 Mt from 2019 to 2050. The mean share to the final energy consumption (energy and transport fuels) amounted to 65%, with higher shares up to 76% during the first decade and subsequent drops to 54% in the year 2050. The decreasing FoWooR share was traced back to the increasing biomass shares from other 2G feedstocks, involving agro-industrial residues and dedicated lignocellulosic material in response to the new set of policy targets. A significant portion of the FoWooR share is mobilised to the transport sub-sector, amounting between 40-50% from the year 2030 to 2050). The FoWooR commodity was linked to Fisher-Tropsch processes for transport fuels (biodiesel and biojet fuels), as well as methanisation and cogeneration for the energy mix.

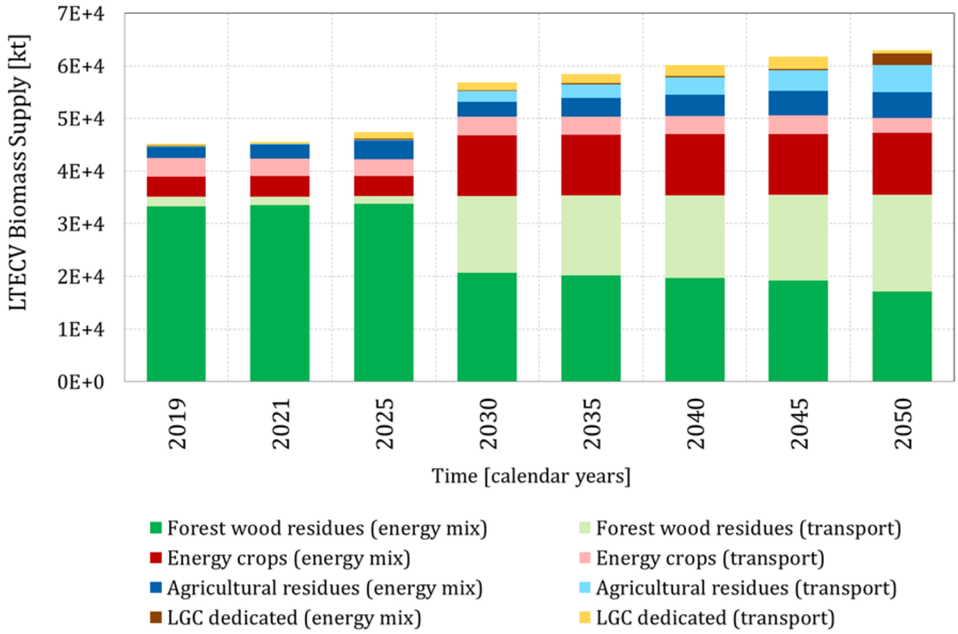


Fig. S1. Biomass supply outputs [per kt] from the partial-equilibrium model in response LTECV scenario

1.2 Greenhouse gas emissions

Figure S2 shows the greenhouse gas emission outputs of the entire energy-transport sector of France (electricity, heat and transport fuels), based on the fossil-sourced CO_2 and N_2O elementary flows, assessed in the partial-equilibrium model with the LTECV scenario simulation. Biogenic flows are excluded in this representation, as it represents a static assessment, providing carbon neutral results, without timing the emissions, based on the static IPCC GWP metric 100 years.

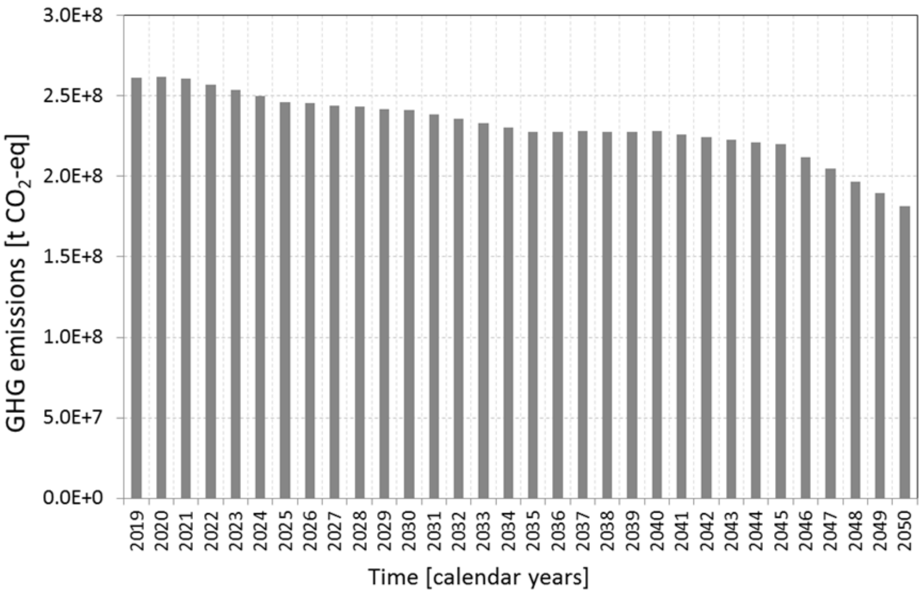
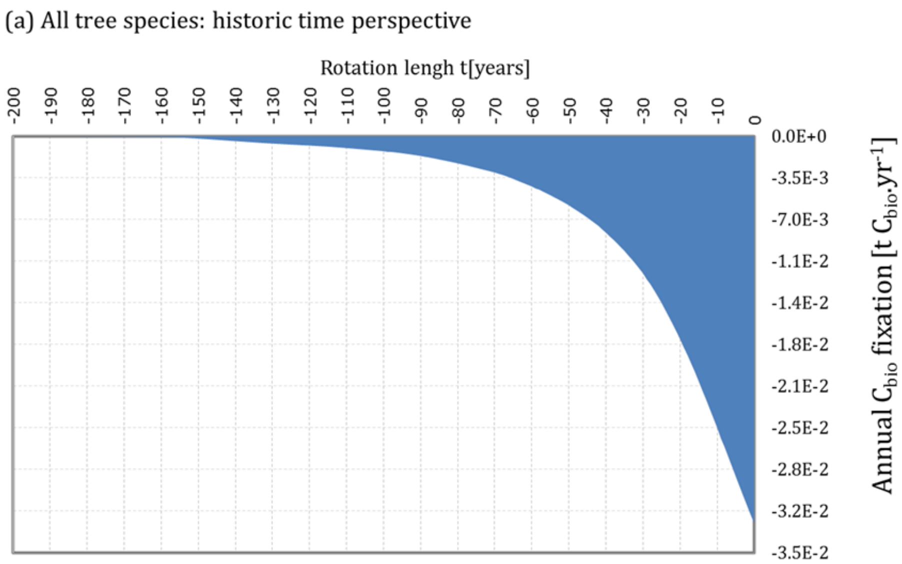


Fig. S2. Greenhouse gas emissions (excluding biogenic flows) of the partial-equilibrium model in response LTECV scenario,

3 Forest carbon modelling outputs

Figure S3 shows the dynamic outputs from biogenic carbon sequestration modelling for a) historic and b) future time perspectives.



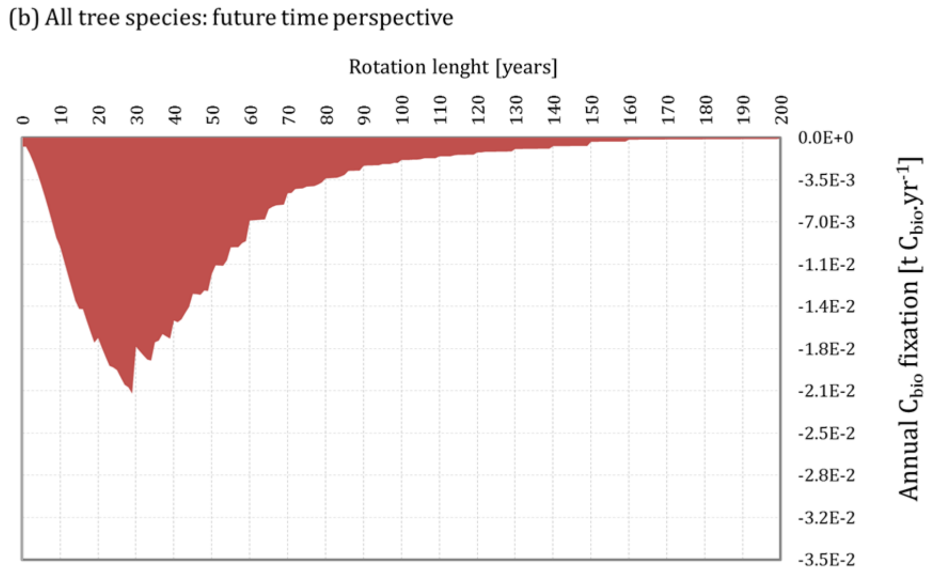


Fig. S3. Means annual biogenic carbon stocking factors of biogenic carbon (C_{bio}) fixation of the French wood supply main species [t·C_{bio}·yr^{-1}]

Table S1 and Table S2 show the dynamic stocking/fixation factors for biogenic carbon sequestration of forestry wood residues per modelling approach (historic or future); as means value from all tree species of the French wood supply chain. Values are retrieved from the study (Albers et al. 2019)

Table S1. Historic biogenic carbon fixation factors [t Cbio yr^{-1}] over a maximum rotation length of 200 years

yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$
-200	0.0000E+0	-155	-1.1959E-4	-110	-1.0002E-3	-65	-3.5930E-3	-20	-1.7049E-2
-199	-4.1275E-8	-154	-1.3411E-4	-109	-1.0256E-3	-64	-3.7246E-3	-19	-1.7752E-2
-198	-2.3716E-7	-153	-1.4987E-4	-108	-1.0513E-3	-63	-3.8478E-3	-18	-1.8396E-2
-197	-5.8325E-7	-152	-1.6662E-4	-107	-1.0774E-3	-62	-3.9743E-3	-17	-1.9097E-2
-196	-1.0666E-6	-151	-1.8413E-4	-106	-1.1036E-3	-61	-4.1015E-3	-16	-1.9810E-2
-195	-1.6776E-6	-150	-2.0225E-4	-105	-1.1300E-3	-60	-4.2270E-3	-15	-2.0575E-2
-194	-2.4075E-6	-149	-2.2239E-4	-104	-1.1565E-3	-59	-4.3936E-3	-14	-2.1364E-2
-193	-3.2485E-6	-148	-2.4265E-4	-103	-1.1830E-3	-58	-4.4943E-3	-13	-2.2108E-2
-192	-4.1927E-6	-147	-2.6363E-4	-102	-1.2094E-3	-57	-4.6534E-3	-12	-2.2903E-2
-191	-5.2330E-6	-146	-2.8507E-4	-101	-1.2384E-3	-56	-4.8055E-3	-11	-2.3699E-2
-190	-6.3624E-6	-145	-3.0682E-4	-100	-1.2656E-3	-55	-4.9620E-3	-10	-2.4490E-2
-189	-7.5769E-6	-144	-3.2875E-4	-99	-1.3118E-3	-54	-5.1295E-3	-9	-2.5381E-2
-188	-8.8773E-6	-143	-3.5072E-4	-98	-1.3234E-3	-53	-5.2895E-3	-8	-2.6111E-2
-187	-1.0257E-5	-142	-3.7264E-4	-97	-1.3574E-3	-52	-5.4567E-3	-7	-2.6931E-2
-186	-1.1710E-5	-141	-3.9440E-4	-96	-1.3948E-3	-51	-5.6276E-3	-6	-2.7752E-2
-185	-1.3230E-5	-140	-4.1592E-4	-95	-1.4350E-3	-50	-5.8072E-3	-5	-2.8572E-2
-184	-1.4811E-5	-139	-4.3716E-4	-94	-1.4783E-3	-49	-6.0256E-3	-4	-2.9386E-2
-183	-1.6448E-5	-138	-4.5823E-4	-93	-1.5223E-3	-48	-6.2159E-3	-3	-3.0192E-2
-182	-1.8134E-5	-137	-4.8052E-4	-92	-1.5682E-3	-47	-6.4213E-3	-2	-3.0988E-2
-181	-1.9867E-5	-136	-5.0178E-4	-91	-1.6152E-3	-46	-6.6318E-3	-1	-3.1771E-2
-180	-2.1640E-5	-135	-5.2256E-4	-90	-1.6627E-3	-45	-6.8501E-3	0	-3.2540E-2
-179	-2.3453E-5	-134	-5.4289E-4	-89	-1.7252E-3	-44	-7.0819E-3		
-178	-2.5315E-5	-133	-5.6275E-4	-88	-1.7756E-3	-43	-7.3097E-3		
-177	-2.7219E-5	-132	-5.8214E-4	-87	-1.8328E-3	-42	-7.5451E-3		
-176	-2.9162E-5	-131	-6.0105E-4	-86	-1.8915E-3	-41	-7.8381E-3		

yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}
-175	-3.1138E-5	-130	-6.1945E-4	-85	-1.9579E-3	-40	-8.1133E-3		
-174	-3.3144E-5	-129	-6.3738E-4	-84	-2.0186E-3	-39	-8.4205E-3		
-173	-3.5175E-5	-128	-6.5494E-4	-83	-2.0824E-3	-38	-8.6982E-3		
-172	-3.7227E-5	-127	-6.7212E-4	-82	-2.1489E-3	-37	-9.0030E-3		
-171	-3.9297E-5	-126	-6.8899E-4	-81	-2.2168E-3	-36	-9.3261E-3		
-170	-4.1382E-5	-125	-7.0721E-4	-80	-2.2855E-3	-35	-9.6454E-3		
-169	-4.3481E-5	-124	-7.2421E-4	-79	-2.3575E-3	-34	-1.0014E-2		
-168	-4.5603E-5	-123	-7.4065E-4	-78	-2.4293E-3	-33	-1.0361E-2		
-167	-4.7745E-5	-122	-7.5662E-4	-77	-2.5069E-3	-32	-1.0734E-2		
-166	-4.9902E-5	-121	-7.7215E-4	-76	-2.5839E-3	-31	-1.1126E-2		
-165	-5.2071E-5	-120	-7.8734E-4	-75	-2.6612E-3	-30	-1.1528E-2		
-164	-5.4250E-5	-119	-8.0548E-4	-74	-2.7400E-3	-29	-1.2035E-2		
-163	-5.6434E-5	-118	-8.2250E-4	-73	-2.8166E-3	-28	-1.2445E-2		
-162	-5.8882E-5	-117	-8.4118E-4	-72	-2.8941E-3	-27	-1.2949E-2		
-161	-6.7272E-5	-116	-8.6075E-4	-71	-2.9738E-3	-26	-1.3468E-2		
-160	-7.2937E-5	-115	-8.8115E-4	-70	-3.0501E-3	-25	-1.4015E-2		
-159	-7.8597E-5	-114	-9.0252E-4	-69	-3.1574E-3	-24	-1.4599E-2		
-158	-8.5887E-5	-113	-9.2678E-4	-68	-3.2456E-3	-23	-1.5191E-2		
-157	-9.5252E-5	-112	-9.5079E-4	-67	-3.3528E-3	-22	-1.5793E-2		
-156	-1.0656E-4	-111	-9.7528E-4	-66	-3.4663E-3	-21	-1.6418E-2		

Table S2. Future biogenic carbon fixation factors [t Cbio yr^{-1}] over a maximum rotation length of 200 years

yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}	yr	t C_{bio}·yr^{-1}
0	-7.5020E-4	45	-1.2957E-2	90	-2.3455E-3	135	-9.3193E-4	180	-1.3466E-4
1	-7.5679E-4	46	-1.2974E-2	91	-2.3155E-3	136	-9.2938E-4	181	-1.3442E-4
2	-1.3531E-3	47	-1.3033E-2	92	-2.3086E-3	137	-9.2680E-4	182	-1.3418E-4
3	-2.0956E-3	48	-1.2674E-2	93	-2.3016E-3	138	-9.2419E-4	183	-1.3394E-4
4	-2.9539E-3	49	-1.2711E-2	94	-2.2946E-3	139	-9.1815E-4	184	-1.3370E-4
5	-3.9067E-3	50	-1.1308E-2	95	-2.1995E-3	140	-7.1356E-4	185	-1.3345E-4
6	-4.9356E-3	51	-1.0587E-2	96	-2.1943E-3	141	-7.1130E-4	186	-1.3319E-4
7	-6.0243E-3	52	-1.0607E-2	97	-2.1891E-3	142	-7.0902E-4	187	-1.3294E-4
8	-7.1579E-3	53	-1.0622E-2	98	-2.1034E-3	143	-7.0673E-4	188	-1.3268E-4
9	-8.3228E-3	54	-1.0162E-2	99	-2.0981E-3	144	-7.0443E-4	189	-1.3242E-4
10	-9.0555E-3	55	-9.0962E-3	100	-1.8611E-3	145	-6.9905E-4	190	-1.2433E-4
11	-1.0183E-2	56	-9.0878E-3	101	-1.8573E-3	146	-6.9676E-4	191	-1.2408E-4
12	-1.1309E-2	57	-9.0767E-3	102	-1.8535E-3	147	-6.9446E-4	192	-1.2382E-4
13	-1.2424E-2	58	-8.7384E-3	103	-1.8361E-3	148	-6.9214E-4	193	-1.2357E-4
14	-1.3522E-2	59	-8.5835E-3	104	-1.8325E-3	149	-6.8982E-4	194	-1.2331E-4
15	-1.4199E-2	60	-6.8758E-3	105	-1.7964E-3	150	-3.4721E-4	195	-1.2305E-4
16	-1.4211E-2	61	-6.8554E-3	106	-1.7164E-3	151	-3.4443E-4	196	-1.2279E-4
17	-1.5168E-2	62	-6.8281E-3	107	-1.7133E-3	152	-3.4385E-4	197	-1.2252E-4
18	-1.6095E-2	63	-6.8057E-3	108	-1.7102E-3	153	-3.4325E-4	198	-1.2226E-4
19	-1.6991E-2	64	-6.7822E-3	109	-1.7070E-3	154	-3.4265E-4	199	-1.2199E-4
20	-1.6613E-2	65	-5.9234E-3	110	-1.5543E-3	155	-3.4203E-4	200	0.0000E+0
21	-1.7414E-2	66	-5.7354E-3	111	-1.5508E-3	156	-3.4141E-4		
22	-1.8183E-2	67	-5.6130E-3	112	-1.5473E-3	157	-3.4078E-4		
23	-1.8919E-2	68	-5.5856E-3	113	-1.5437E-3	158	-3.4013E-4		
24	-1.9048E-2	69	-5.5578E-3	114	-1.4637E-3	159	-3.3948E-4		
25	-1.9275E-2	70	-4.6162E-3	115	-1.4287E-3	160	-1.7288E-4		
26	-1.9897E-2	71	-4.5883E-3	116	-1.4258E-3	161	-1.7251E-4		
27	-2.0486E-2	72	-4.2611E-3	117	-1.4229E-3	162	-1.7215E-4		
28	-2.0696E-2	73	-4.2346E-3	118	-1.4199E-3	163	-1.6366E-4		
29	-2.1229E-2	74	-4.2079E-3	119	-1.4169E-3	164	-1.6347E-4		
30	-1.7333E-2	75	-4.0691E-3	120	-1.2375E-3	165	-1.6326E-4		
31	-1.7711E-2	76	-4.0446E-3	121	-1.2349E-3	166	-1.6305E-4		
32	-1.8066E-2	77	-4.0201E-3	122	-1.1819E-3	167	-1.6284E-4		
33	-1.8400E-2	78	-3.8910E-3	123	-1.1793E-3	168	-1.6262E-4		
34	-1.8480E-2	79	-3.7195E-3	124	-1.1767E-3	169	-1.6239E-4		

yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$	yr	t $C_{bio}\cdot yr^{-1}$
35	-1.6965E-2	80	-3.3894E-3	125	-1.1693E-3	170	-1.5000E-4		
36	-1.6828E-2	81	-3.3698E-3	126	-1.1666E-3	171	-1.4978E-4		
37	-1.6287E-2	82	-3.3503E-3	127	-1.1587E-3	172	-1.4956E-4		
38	-1.6481E-2	83	-3.3309E-3	128	-1.1561E-3	173	-1.4933E-4		
39	-1.6661E-2	84	-3.2260E-3	129	-1.1534E-3	174	-1.4910E-4		
40	-1.5169E-2	85	-3.0888E-3	130	-9.4843E-4	175	-1.4887E-4		
41	-1.5303E-2	86	-2.7642E-3	131	-9.4595E-4	176	-1.4863E-4		
42	-1.5064E-2	87	-2.7536E-3	132	-9.4345E-4	177	-1.4838E-4		
43	-1.4534E-2	88	-2.7430E-3	133	-9.4092E-4	178	-1.4813E-4		
44	-1.4034E-2	89	-2.7325E-3	134	-9.3837E-4	179	-1.4788E-4		