Carbon: Seeing the Forest (and Products) for the Trees

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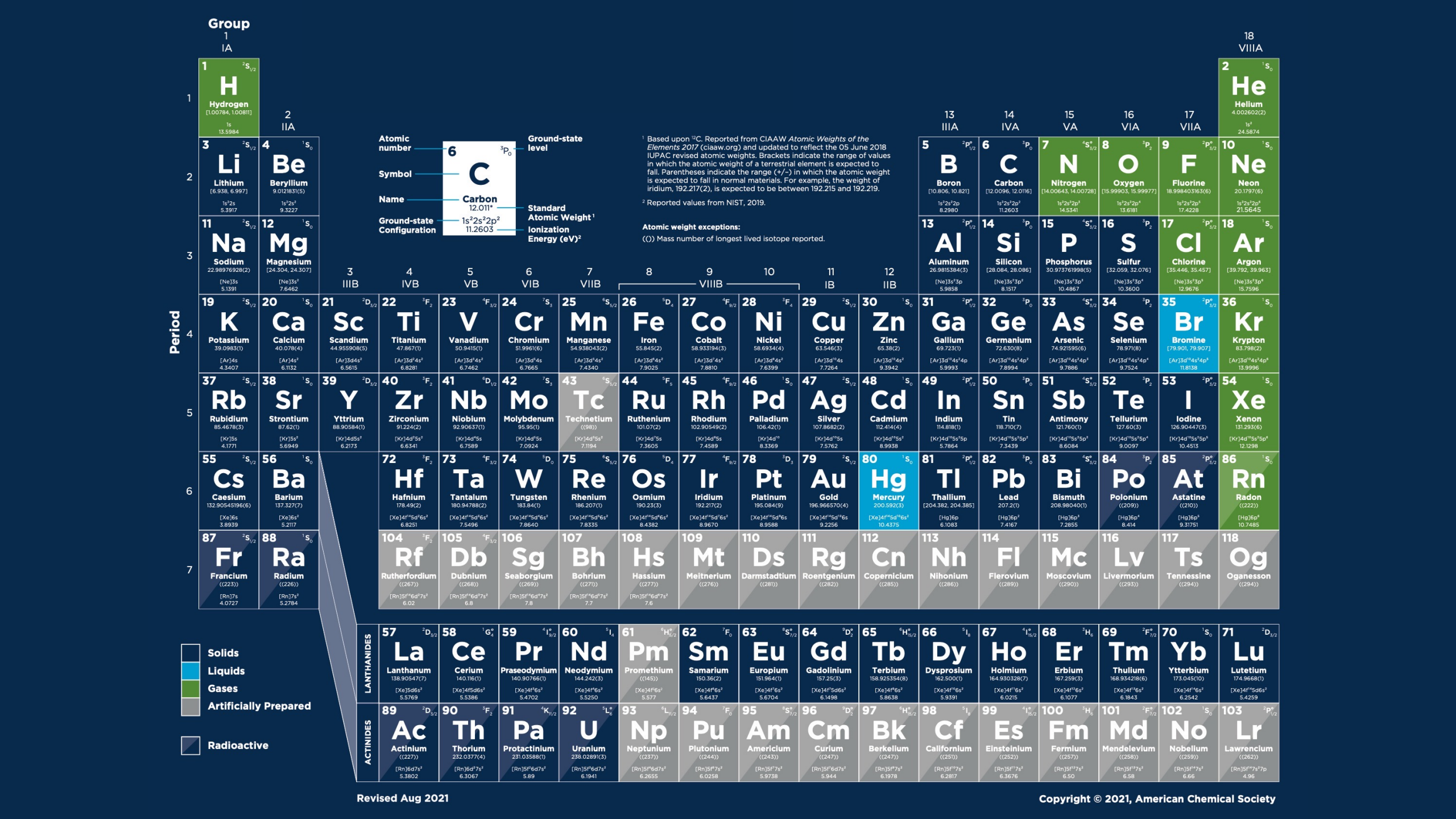
College of Natural Resources and Environment

Virginia Tech


Group
1
IA
2
IIA
3
IIIB
4
IVB
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VB
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VIB
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VIIB
8
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VIIIB
10
11
IB
12
IIB
13
IIIA
14
IVA
15
VA
16
VIA
17
VIIA
18
VIIIA
Period
1 H Hydrogen [1.00784, 1.00811] 1s 13.5984
2 He Helium 4.002602(2) 1s² 24.5874
3 Li Lithium [6.938, 6.997] 1s²2s 5.3917
4 Be Beryllium 9.0121831(5) 1s²2s² 9.3227
5 B Boron [10.806, 10.821] 1s²2s²2p 8.2980
6 C Carbon [12.0096, 12.0116] 1s²2s²2p² 11.2603
7 N Nitrogen [14.00643, 14.00728] 1s²2s²2p³ 14.5341
8 O Oxygen [15.99903, 15.99977] 1s²2s²2p⁴ 13.6181
9 F Fluorine 18.9984032(5) 1s²2s²2p⁵ 17.4228
10 Ne Neon 20.1797(6) 1s²2s²2p⁶ 21.5645
11 Na Sodium 22.98976928(2) [Ne]3s 5.1391
12 Mg Magnesium [24.304, 24.307] [Ne]3s² 7.6462
13 Al Aluminum 26.9815384(3) [Ne]3s²3p 5.9858
14 Si Silicon [28.084, 28.086] [Ne]3s²3p² 8.1517
15 P Phosphorus 30.973761998(5) [Ne]3s²3p³ 10.4867
16 S Sulfur [32.059, 32.076] [Ne]3s²3p⁴ 10.3600
17 Cl Chlorine [35.446, 35.457] [Ne]3s²3p⁵ 12.9676
18 Ar Argon [39.792, 39.963] [Ne]3s²3p⁶ 15.7596
19 K Potassium 39.0983(1) [Ar]4s 4.3407
20 Ca Calcium 40.078(4) [Ar]4s² 6.1132
21 Sc Scandium 44.955908(5) [Ar]3d4s² 6.5615
22 Ti Titanium 47.867(1) [Ar]3d²4s² 6.8281
23 V Vanadium 50.9415(1) [Ar]3d³4s² 6.7462
24 Cr Chromium 51.9961(6) [Ar]3d⁵4s 6.7665
25 Mn Manganese 54.938043(2) [Ar]3d⁵4s² 7.4340
26 Fe Iron 55.845(2) [Ar]3d⁶4s² 7.9025
27 Co Cobalt 58.933194(3) [Ar]3d⁷4s² 7.8810
28 Ni Nickel 58.6934(4) [Ar]3d⁸4s² 7.6399
29 Cu Copper 63.546(3) [Ar]3d¹⁰4s 7.7264
30 Zn Zinc 65.38(2) [Ar]3d¹⁰4s² 9.3942
31 Ga Gallium 69.723(1) [Ar]3d¹⁰4s²4p 5.9993
32 Ge Germanium 72.630(8) [Ar]3d¹⁰4s²4p² 7.8994
33 As Arsenic 74.921595(6) [Ar]3d¹⁰4s²4p³ 9.7886
34 Se Selenium 78.971(8) [Ar]3d¹⁰4s²4p⁴ 9.7524
35 Br Bromine [79.901, 79.907] [Ar]3d¹⁰4s²4p⁵ 11.8138
36 Kr Krypton 83.798(2) [Ar]3d¹⁰4s²4p⁶ 13.9996
37 Rb Rubidium 85.4678(3) [Kr]5s 4.1771
38 Sr Strontium 87.62(1) [Kr]5s² 5.6949
39 Y Yttrium 88.90584(1) [Kr]4d5s² 6.2173
40 Zr Zirconium 91.224(2) [Kr]4d²5s² 6.6341
41 Nb Niobium 92.90637(1) [Kr]4d⁴5s 6.7589
42 Mo Molybdenum 95.95(1) [Kr]4d⁵5s 7.0924
43 Tc Technetium ((98)) [Kr]4d⁵5s² 7.1194
44 Ru Ruthenium 101.07(2) [Kr]4d⁷5s 7.3605
45 Rh Rhodium 102.90549(2) [Kr]4d⁸5s 7.4589
46 Pd Palladium 106.42(1) [Kr]4d¹⁰ 8.3369
47 Ag Silver 107.8682(2) [Kr]4d¹⁰5s 7.5762
48 Cd Cadmium 112.414(4) [Kr]4d¹⁰5s² 8.9938
49 In Indium 114.818(1) [Kr]4d¹⁰5s²5p 5.7864
50 Sn Tin 118.710(7) [Kr]4d¹⁰5s²5p² 7.3439
51 Sb Antimony 121.760(1) [Kr]4d¹⁰5s²5p³ 8.6084
52 Te Tellurium 127.60(3) [Kr]4d¹⁰5s²5p⁴ 9.0097
53 I Iodine 126.90447(3) [Kr]4d¹⁰5s²5p⁵ 10.4513
54 Xe Xenon 131.293(6) [Kr]4d¹⁰5s²5p⁶ 12.1298
55 Cs Caesium 132.90545196(6) [Xe]6s 3.8939
56 Ba Barium 137.327(7) [Xe]6s² 5.2117
72 Hf Hafnium 178.49(2) [Xe]4f¹⁴5d²6s² 6.8251
73 Ta Tantalum 180.94788(2) [Xe]4f¹⁴5d³6s² 7.5496
74 W Tungsten 183.84(1) [Xe]4f¹⁴5d⁴6s² 7.8640
75 Re Rhenium 186.207(1) [Xe]4f¹⁴5d⁵6s² 7.8335
76 Os Osmium 190.23(3) [Xe]4f¹⁴5d⁶6s² 8.4382
77 Ir Iridium 192.217(2) [Xe]4f¹⁴5d⁷6s² 8.9670
78 Pt Platinum 195.084(9) [Xe]4f¹⁴5d⁹6s 8.9588
79 Au Gold 196.966570(4) [Xe]4f¹⁴5d¹⁰6s 9.2256
80 Hg Mercury 200.592(3) [Xe]4f¹⁴5d¹⁰6s² 10.4375
81 Tl Thallium [204.382, 204.385] [Hg]6p 6.1083
82 Pb Lead 207.2(1) [Hg]6p² 7.4167
83 Bi Bismuth 208.98040(1) [Hg]6p³ 7.2855
84 Po Polonium ((209)) [Hg]6p⁴ 8.414
85 At Astatine ((210)) [Hg]6p⁵ 9.31751
86 Rn Radon ((222)) [Hg]6p⁶ 10.7485
87 Fr Francium ((223)) [Rn]7s 4.0727
88 Ra Radium ((226)) [Rn]7s² 5.2784
104 Rf Rutherfordium ((267)) [Rn]5f¹⁴6d²7s² 6.02
105 Db Dubnium ((268)) [Rn]5f¹⁴6d³7s² 6.8
106 Sg Seaborgium ((269)) [Rn]5f¹⁴6d⁴7s² 7.8
107 Bh Bohrium ((271)) [Rn]5f¹⁴6d⁵7s² 7.7
108 Hs Hassium ((277)) [Rn]5f¹⁴6d⁶7s² 7.6
109 Mt Meitnerium ((276))
110 Ds Darmstadtium ((281))
111 Rg Roentgenium ((282))
112 Cn Copernicium ((285))
113 Nh Nihonium ((286))
114 Fl Flerovium ((289))
115 Mc Moscovium ((290))
116 Lv Livermorium ((293))
117 Ts Tennessine ((294))
118 Og Oganesson ((294))
LANTHANIDES
57 La Lanthanum 138.90547(7) [Xe]5d6s² 5.5769
58 Ce Cerium 140.116(1) [Xe]4f5d6s² 5.5386
59 Pr Praseodymium 140.90766(1) [Xe]4f³6s² 5.4702
60 Nd Neodymium 144.242(3) [Xe]4f⁴6s² 5.5250
61 Pm Promethium ((145)) [Xe]4f⁵6s² 5.577
62 Sm Samarium 150.36(2) [Xe]4f⁶6s² 5.6437
63 Eu Europium 151.964(1) [Xe]4f⁷6s² 5.6704
64 Gd Gadolinium 157.25(3) [Xe]4f⁷5d6s² 6.1498
65 Tb Terbium 158.925354(8) [Xe]4f⁹6s² 5.8638
66 Dy Dysprosium 162.500(1) [Xe]4f¹⁰6s² 5.9391
67 Ho Holmium 164.930328(7) [Xe]4f¹¹6s² 6.0215
68 Er Erbium 167.259(3) [Xe]4f¹²6s² 6.1077
69 Tm Thulium 168.934218(6) [Xe]4f¹³6s² 6.1843
70 Yb Ytterbium 173.045(10) [Xe]4f¹⁴6s² 6.2542
71 Lu Lutetium 174.9668(1) [Xe]4f¹⁴5d6s² 5.4259
ACTINIDES
89 Ac Actinium ((227)) [Rn]6d7s² 5.3802
90 Th Thorium 232.0377(4) [Rn]6d²7s² 6.3067
91 Pa Protactinium 231.03588(1) [Rn]5f²6d7s² 5.89
92 U Uranium 238.02891(3) [Rn]5f³6d7s² 6.1941
93 Np Neptunium ((237)) [Rn]5f⁴6d7s² 6.2655
94 Pu Plutonium ((244)) [Rn]5f⁶7s² 6.0258
95 Am Americium ((243)) [Rn]5f⁷7s² 5.9738
96 Cm Curium ((247)) [Rn]5f⁷6d7s² 5.944
97 Bk Berkelium ((247)) [Rn]5f⁹7s² 6.1978
98 Cf Californium ((251)) [Rn]5f¹⁰7s² 6.2817
99 Es Einsteinium ((252)) [Rn]5f¹¹7s² 6.3676
100 Fm Fermium ((257)) [Rn]5f¹²7s² 6.50
101 Md Mendelevium ((258)) [Rn]5f¹³7s² 6.58
102 No Nobelium ((259)) [Rn]5f¹⁴7s² 6.66
103 Lr Lawrencium ((262)) [Rn]5f¹⁴7s²7p 4.96
Atomic number
Symbol
Name
Ground-state Configuration
6 C Carbon 12.011* 1s²2s²2p² 11.2603
Ground-state level
Standard Atomic Weight[1]
Ionization Energy (eV)[2]
[1] Based upon ¹²C. Reported from CIAAW Atomic Weights of the Elements 2017 (ciaaw.org) and updated to reflect the 05 June 2018 IUPAC revised atomic weights. Brackets indicate the range of values in which the atomic weight of a terrestrial element is expected to fall. Parentheses indicate the range (+/-) in which the atomic weight is expected to fall in normal materials. For example, the weight of iridium, 192.217(2), is expected to be between 192.215 and 192.219.
[2] Reported values from NIST, 2019.
Atomic weight exceptions:
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Solids
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Artificially Prepared
Radioactive
Revised Aug 2021
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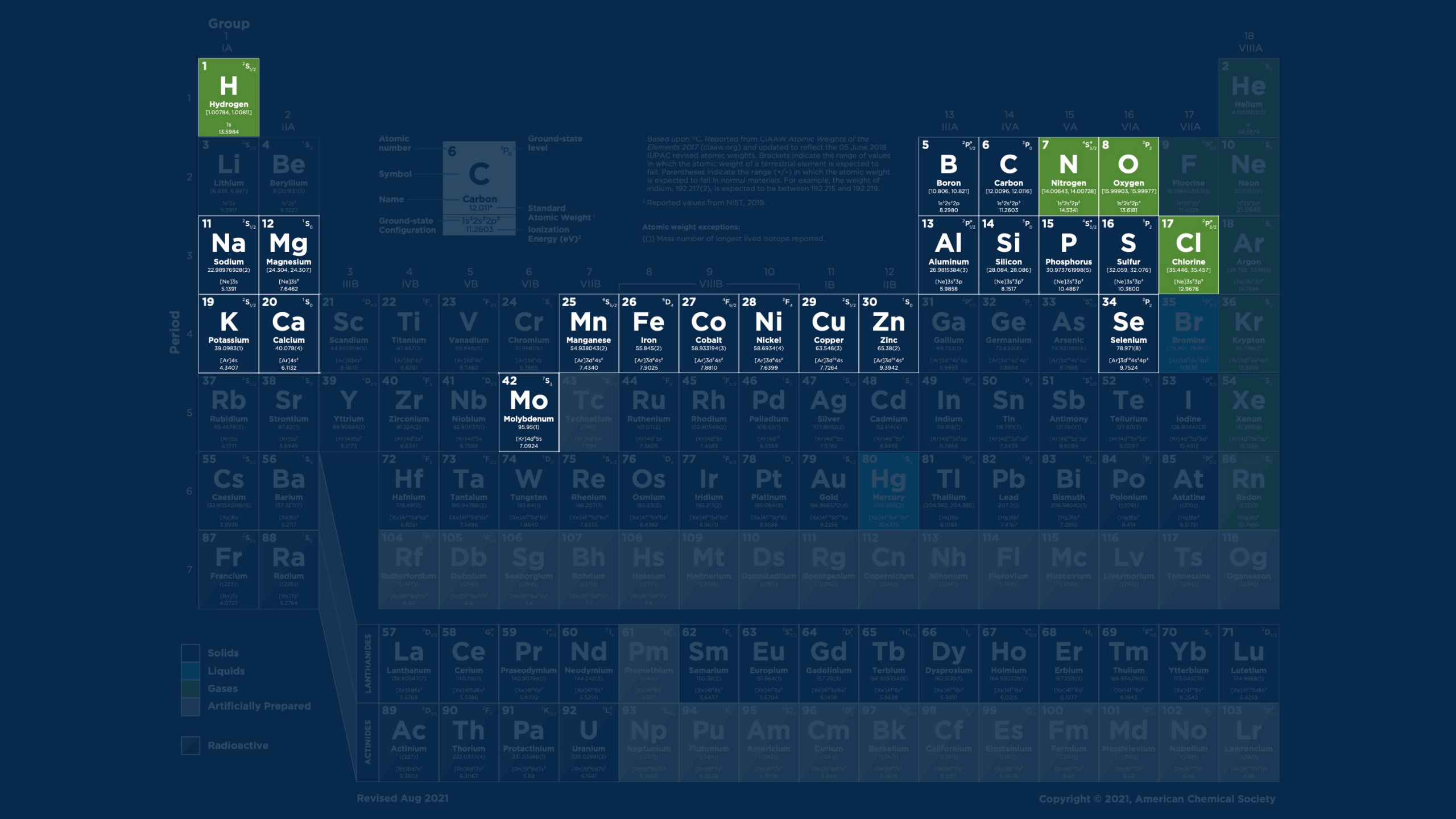
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102 No Nobelium ((259)) [Rn]5f¹⁴7s² 6.66
103 Lr Lawrencium ((262)) [Rn]5f¹⁴7s²7p 4.96
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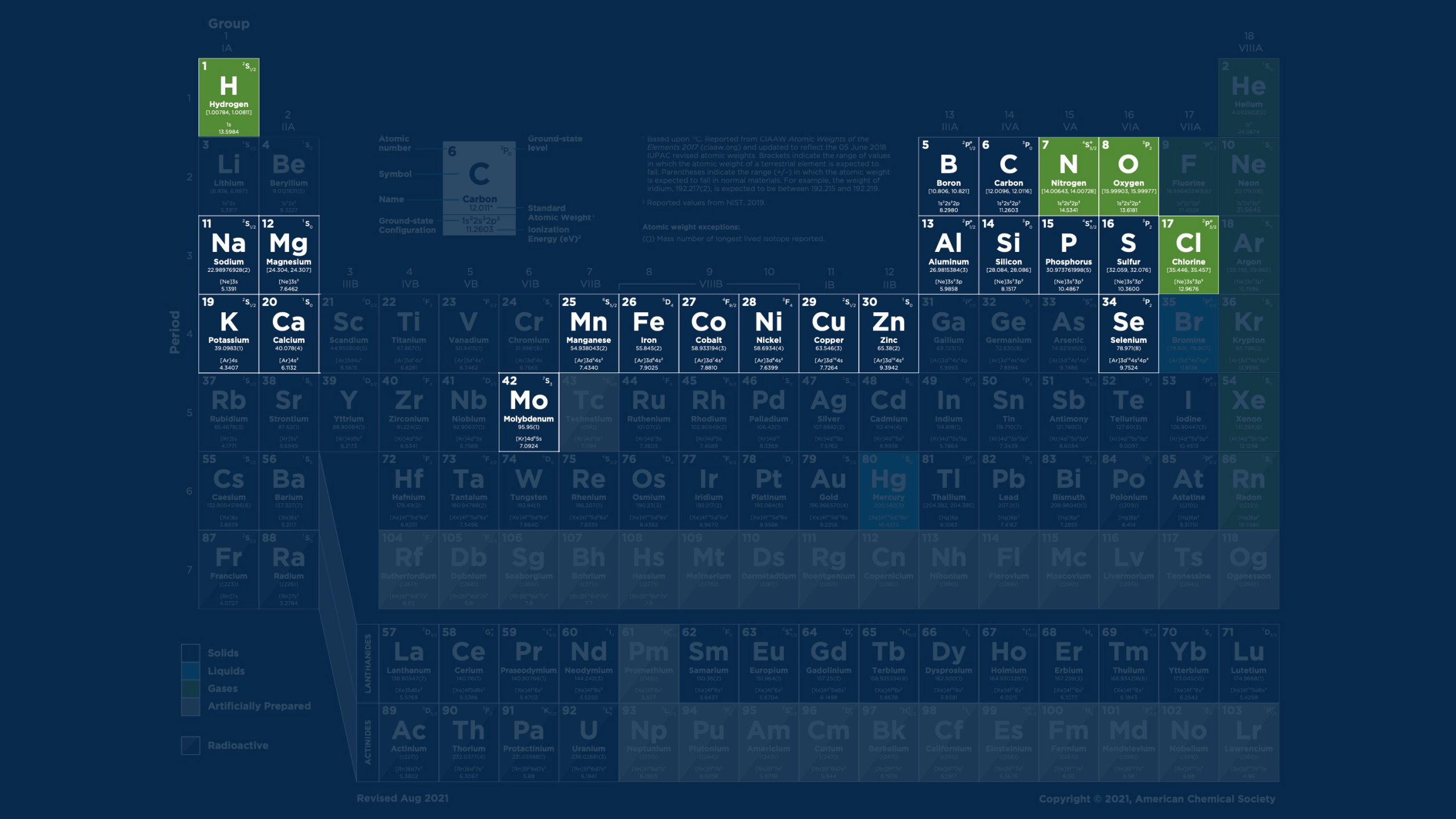
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26 Fe Iron 55.845(2) [Ar]3d⁶4s² 7.9025
27 Co Cobalt 58.933194(3) [Ar]3d⁷4s² 7.8810
28 Ni Nickel 58.6934(4) [Ar]3d⁸4s² 7.6399
29 Cu Copper 63.546(3) [Ar]3d¹⁰4s 7.7264
30 Zn Zinc 65.38(2) [Ar]3d¹⁰4s² 9.3942
31 Ga Gallium 69.723(1) [Ar]3d¹⁰4s²4p 5.9993
32 Ge Germanium 72.630(8) [Ar]3d¹⁰4s²4p² 7.8994
33 As Arsenic 74.921595(6) [Ar]3d¹⁰4s²4p³ 9.7886
34 Se Selenium 78.971(8) [Ar]3d¹⁰4s²4p⁴ 9.7524
35 Br Bromine [79.901, 79.907] [Ar]3d¹⁰4s²4p⁵ 11.8138
36 Kr Krypton 83.798(2) [Ar]3d¹⁰4s²4p⁶ 13.9996
37 Rb Rubidium 85.4678(3) [Kr]5s 4.1771
38 Sr Strontium 87.62(1) [Kr]5s² 5.6949
39 Y Yttrium 88.90584(1) [Kr]4d5s² 6.2173
40 Zr Zirconium 91.224(2) [Kr]4d²5s² 6.6341
41 Nb Niobium 92.90637(1) [Kr]4d⁴5s 6.7589
42 Mo Molybdenum 95.95(1) [Kr]4d⁵5s 7.0924
43 Tc Technetium ((98)) [Kr]4d⁵5s² 7.1944
44 Ru Ruthenium 101.07(2) [Kr]4d⁷5s 7.3605
45 Rh Rhodium 102.90549(2) [Kr]4d⁸5s 7.4589
46 Pd Palladium 106.42(1) [Kr]4d¹⁰ 8.3369
47 Ag Silver 107.8682(2) [Kr]4d¹⁰5s 7.5762
48 Cd Cadmium 112.414(4) [Kr]4d¹⁰5s² 8.9938
49 In Indium 114.818(1) [Kr]4d¹⁰5s²5p 5.7864
50 Sn Tin 118.710(7) [Kr]4d¹⁰5s²5p² 7.3439
51 Sb Antimony 121.760(1) [Kr]4d¹⁰5s²5p³ 8.6084
52 Te Tellurium 127.60(3) [Kr]4d¹⁰5s²5p⁴ 9.0097
53 I Iodine 126.90447(3) [Kr]4d¹⁰5s²5p⁵ 10.4513
54 Xe Xenon 131.293(6) [Kr]4d¹⁰5s²5p⁶ 12.1298
55 Cs Caesium 132.90545196(6) [Xe]6s 3.8939
56 Ba Barium 137.327(7) [Xe]6s² 5.2117
72 Hf Hafnium 178.49(2) [Xe]4f¹⁴5d²6s² 6.8251
73 Ta Tantalum 180.94788(2) [Xe]4f¹⁴5d³6s² 7.5496
74 W Tungsten 183.84(1) [Xe]4f¹⁴5d⁴6s² 7.8640
75 Re Rhenium 186.207(1) [Xe]4f¹⁴5d⁵6s² 7.8335
76 Os Osmium 190.23(3) [Xe]4f¹⁴5d⁶6s² 8.4382
77 Ir Iridium 192.217(2) [Xe]4f¹⁴5d⁷6s² 8.9670
78 Pt Platinum 195.084(9) [Xe]4f¹⁴5d⁹6s 8.9588
79 Au Gold 196.966570(4) [Xe]4f¹⁴5d¹⁰6s 9.2256
80 Hg Mercury 200.592(3) [Xe]4f¹⁴5d¹⁰6s² 10.4375
81 Tl Thallium [204.382, 204.385] [Hg]6p 6.1083
82 Pb Lead 207.2(1) [Hg]6p² 7.4167
83 Bi Bismuth 208.98040(1) [Hg]6p³ 7.2855
84 Po Polonium ((209)) [Hg]6p⁴ 8.414
85 At Astatine ((210)) [Hg]6p⁵ 9.3751
86 Rn Radon ((222)) [Hg]6p⁶ 10.7485
87 Fr Francium ((223)) [Rn]7s 4.0727
88 Ra Radium ((226)) [Rn]7s² 5.2784
104 Rf Rutherfordium ((267)) [Rn]5f¹⁴6d²7s² 6.02
105 Db Dubnium ((268)) [Rn]5f¹⁴6d³7s² 6.8
106 Sg Seaborgium ((269)) [Rn]5f¹⁴6d⁴7s² 7.8
107 Bh Bohrium ((270)) [Rn]5f¹⁴6d⁵7s² 7.7
108 Hs Hassium ((277)) [Rn]5f¹⁴6d⁶7s² 7.6
109 Mt Meitnerium ((276))
110 Ds Darmstadtium ((281))
111 Rg Roentgenium ((282))
112 Cn Copernicium ((285))
113 Nh Nihonium ((286))
114 Fl Flerovium ((289))
115 Mc Moscovium ((290))
116 Lv Livermorium ((293))
117 Ts Tennessine ((294))
118 Og Oganesson ((294))
LANTHANIDES
57 La Lanthanum 138.90547(7) [Xe]5d6s² 5.5769
58 Ce Cerium 140.116(1) [Xe]4f5d6s² 5.5386
59 Pr Praseodymium 140.90766(1) [Xe]4f³6s² 5.4702
60 Nd Neodymium 144.242(3) [Xe]4f⁴6s² 5.5250
61 Pm Promethium ((145)) [Xe]4f⁵6s² 5.577
62 Sm Samarium 150.36(2) [Xe]4f⁶6s² 5.6437
63 Eu Europium 151.964(1) [Xe]4f⁷6s² 5.6704
64 Gd Gadolinium 157.25(3) [Xe]4f⁷5d6s² 6.1498
65 Tb Terbium 158.925354(8) [Xe]4f⁹6s² 5.8638
66 Dy Dysprosium 162.500(1) [Xe]4f¹⁰6s² 5.9391
67 Ho Holmium 164.930328(7) [Xe]4f¹¹6s² 6.0215
68 Er Erbium 167.259(3) [Xe]4f¹²6s² 6.1077
69 Tm Thulium 168.934218(6) [Xe]4f¹³6s² 6.1843
70 Yb Ytterbium 173.045(10) [Xe]4f¹⁴6s² 6.2542
71 Lu Lutetium 174.9668(1) [Xe]4f¹⁴5d6s² 5.4259
ACTINIDES
89 Ac Actinium ((227)) [Rn]6d7s² 5.3802
90 Th Thorium 232.0377(4) [Rn]6d²7s² 6.3067
91 Pa Protactinium 231.03588(1) [Rn]5f²6d7s² 5.89
92 U Uranium 238.02891(3) [Rn]5f³6d7s² 6.1941
93 Np Neptunium ((237)) [Rn]5f⁴6d7s² 6.2655
94 Pu Plutonium ((244)) [Rn]5f⁶7s² 6.0258
95 Am Americium ((243)) [Rn]5f⁷7s² 5.9738
96 Cm Curium ((247)) [Rn]5f⁷6d7s² 5.944
97 Bk Berkelium ((247)) [Rn]5f⁹7s² 6.1978
98 Cf Californium ((251)) [Rn]5f¹⁰7s² 6.2817
99 Es Einsteinium ((252)) [Rn]5f¹¹7s² 6.3676
100 Fm Fermium ((257)) [Rn]5f¹²7s² 6.50
101 Md Mendelevium ((258)) [Rn]5f¹³7s² 6.58
102 No Nobelium ((259)) [Rn]5f¹⁴7s² 6.66
103 Lr Lawrencium ((262)) [Rn]5f¹⁴7s²7p 4.96
Atomic number
Symbol
Name
Ground-state Configuration
6 C Carbon 12.011* 1s²2s²2p² 11.2603
Ground-state level
Standard Atomic Weight [1]
Ionization Energy (eV) [2]
[1] Based upon ¹²C. Reported from CIAAW Atomic Weights of the Elements 2017 (ciaaw.org) and updated to reflect the 05 June 2018 IUPAC revised atomic weights. Brackets indicate the range of values in which the atomic weight of a terrestrial element is expected to fall. Parentheses indicate the range (+/–) in which the atomic weight is expected to fall in normal materials. For example, the weight of iridium, 192.217(2), is expected to be between 192.215 and 192.219.
[2] Reported values from NIST, 2019.
Atomic weight exceptions:
(()) Mass number of longest lived isotope reported.
Solids
Liquids
Gases
Artificially Prepared
Radioactive
Revised Aug 2021
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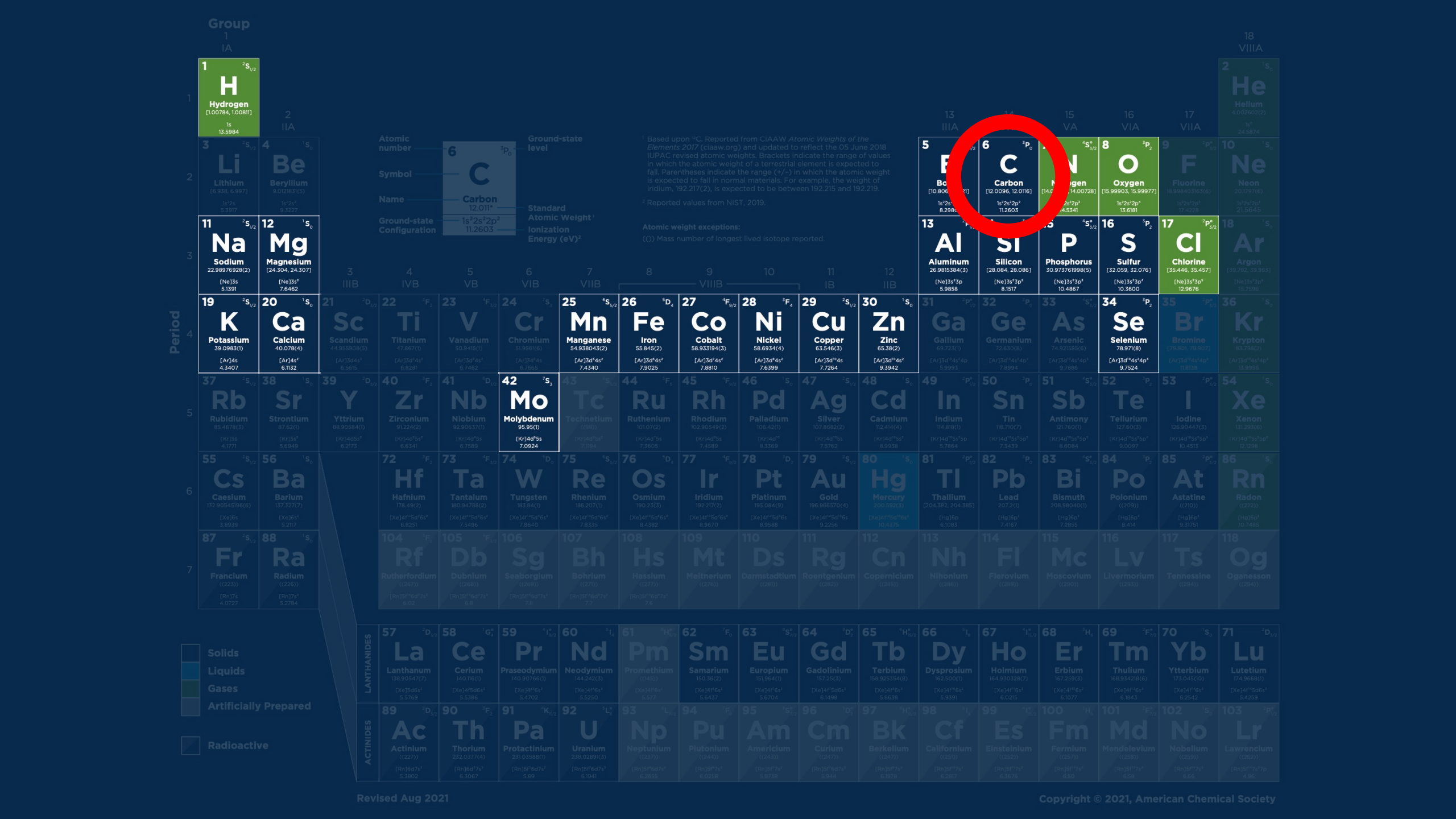
Group
1 IA
2 IIA
3 IIIB
4 IVB
5 VB
6 VIB
7 VIIB
8
9 VIIIB
10
11 IB
12 IIB
13 IIIA
14 IVA
15 VA
16 VIA
17 VIIA
18 VIIIA
Period
Atomic number
Symbol
Name
Ground-state Configuration
Ground-state level
Standard Atomic Weight [1]
Ionization Energy (eV) [2]
6 C Carbon 12.011* 1s²2s²2p² 11.2603
[1] Based upon ¹²C. Reported from CIAAW Atomic Weights of the Elements 2017 (ciaaw.org) and updated to reflect the 05 June 2018 IUPAC revised atomic weights. Brackets indicate the range of values in which the atomic weight of a terrestrial element is expected to fall. Parentheses indicate the range (+/–) in which the atomic weight is expected to fall in normal materials. For example, the weight of iridium, 192.217(2), is expected to be between 192.215 and 192.219.
[2] Reported values from NIST, 2019.
Atomic weight exceptions:
(()) Mass number of longest lived isotope reported.
1 H Hydrogen [1.00784, 1.00811] 1s 13.5984
2 He Helium 4.002602(2) 1s² 24.5874
3 Li Lithium [6.938, 6.997] 1s²2s 5.3917
4 Be Beryllium 9.012183(5) 1s²2s² 9.3227
5 B Boron [10.806, 10.821] 1s²2s²2p 8.298
6 C Carbon [12.0096, 12.0116] 1s²2s²2p² 11.2603
7 N Nitrogen [14.006, 14.00728] 1s²2s²2p³ 14.5341
8 O Oxygen [15.99903, 15.99977] 1s²2s²2p⁴ 13.6181
9 F Fluorine 18.9984032(5) 1s²2s²2p⁵ 17.4228
10 Ne Neon 20.1797(6) 1s²2s²2p⁶ 21.5645
11 Na Sodium 22.98976928(2) [Ne]3s 5.1391
12 Mg Magnesium [24.304, 24.307] [Ne]3s² 7.6462
13 Al Aluminum 26.9815384(3) [Ne]3s²3p 5.9858
14 Si Silicon [28.084, 28.086] [Ne]3s²3p² 8.1517
15 P Phosphorus 30.973761998(5) [Ne]3s²3p³ 10.4867
16 S Sulfur [32.059, 32.076] [Ne]3s²3p⁴ 10.3600
17 Cl Chlorine [35.446, 35.457] [Ne]3s²3p⁵ 12.9676
18 Ar Argon [39.792, 39.963] [Ne]3s²3p⁶ 15.7596
19 K Potassium 39.0983(1) [Ar]4s 4.3407
20 Ca Calcium 40.078(4) [Ar]4s² 6.1132
21 Sc Scandium 44.955908(5) [Ar]3d4s² 6.5615
22 Ti Titanium 47.867(1) [Ar]3d²4s² 6.8281
23 V Vanadium 50.9415(1) [Ar]3d³4s² 6.7462
24 Cr Chromium 51.9961(6) [Ar]3d⁵4s 6.7665
25 Mn Manganese 54.938043(2) [Ar]3d⁵4s² 7.4340
26 Fe Iron 55.845(2) [Ar]3d⁶4s² 7.9025
27 Co Cobalt 58.933194(3) [Ar]3d⁷4s² 7.8810
28 Ni Nickel 58.6934(4) [Ar]3d⁸4s² 7.6399
29 Cu Copper 63.546(3) [Ar]3d¹⁰4s 7.7264
30 Zn Zinc 65.38(2) [Ar]3d¹⁰4s² 9.3942
31 Ga Gallium 69.723(1) [Ar]3d¹⁰4s²4p 5.9993
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40 Zr Zirconium 91.224(2) [Kr]4d²5s² 6.6341
41 Nb Niobium 92.90637(1) [Kr]4d⁴5s 6.7589
42 Mo Molybdenum 95.95(1) [Kr]4d⁵5s 7.0924
43 Tc Technetium (98)) [Kr]4d⁵5s² 7.194
44 Ru Ruthenium 101.07(2) [Kr]4d⁷5s 7.3605
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47 Ag Silver 107.8682(2) [Kr]4d¹⁰5s 7.5762
48 Cd Cadmium 112.414(4) [Kr]4d¹⁰5s² 8.9938
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106 Sg Seaborgium ((269)) [Rn]5f¹⁴6d⁴7s² 7.8
107 Bh Bohrium ((270)) [Rn]5f¹⁴6d⁵7s² 7.7
108 Hs Hassium ((277)) [Rn]5f¹⁴6d⁶7s² 7.6
109 Mt Meitnerium ((276)) 109
110 Ds Darmstadtium ((281)) 110
111 Rg Roentgenium ((282)) 111
112 Cn Copernicium ((285)) 112
113 Nh Nihonium ((286)) 113
114 Fl Flerovium ((289)) 114
115 Mc Moscovium ((290)) 115
116 Lv Livermorium ((293)) 116
117 Ts Tennessine ((294)) 117
118 Og Oganesson ((294)) 118
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58 Ce Cerium 140.116(1) [Xe]4f5d6s² 5.5386
59 Pr Praseodymium 140.90766(1) [Xe]4f³6s² 5.4702
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61 Pm Promethium ((145)) [Xe]4f⁵6s² 5.577
62 Sm Samarium 150.36(2) [Xe]4f⁶6s² 5.6437
63 Eu Europium 151.964(1) [Xe]4f⁷6s² 5.6704
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65 Tb Terbium 158.925354(8) [Xe]4f⁹6s² 5.8638
66 Dy Dysprosium 162.500(1) [Xe]4f¹⁰6s² 5.9391
67 Ho Holmium 164.930328(7) [Xe]4f¹¹6s² 6.0215
68 Er Erbium 167.259(3) [Xe]4f¹²6s² 6.1077
69 Tm Thulium 168.934218(6) [Xe]4f¹³6s² 6.1843
70 Yb Ytterbium 173.045(10) [Xe]4f¹⁴6s² 6.2542
71 Lu Lutetium 174.9668(1) [Xe]4f¹⁴5d6s² 5.4259
ACTINIDES
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90 Th Thorium 232.0377(4) [Rn]6d²7s² 6.3067
91 Pa Protactinium 231.03588(1) [Rn]5f²6d7s² 5.89
92 U Uranium 238.02891(3) [Rn]5f³6d7s² 6.1941
93 Np Neptunium ((237)) [Rn]5f⁴6d7s² 6.2655
94 Pu Plutonium ((244)) [Rn]5f⁶7s² 6.0258
95 Am Americium ((243)) [Rn]5f⁷7s² 5.9738
96 Cm Curium ((247)) [Rn]5f⁷6d7s² 5.944
97 Bk Berkelium ((247)) [Rn]5f⁹7s² 6.1978
98 Cf Californium ((251)) [Rn]5f¹⁰7s² 6.2817
99 Es Einsteinium ((252)) [Rn]5f¹¹7s² 6.3676
100 Fm Fermium ((257)) [Rn]5f¹²7s² 6.50
101 Md Mendelevium ((258)) [Rn]5f¹³7s² 6.58
102 No Nobelium ((259)) [Rn]5f¹⁴7s² 6.65
103 Lr Lawrencium ((262)) [Rn]5f¹⁴7s²7p 4.96
Solids
Liquids
Gases
Artificially Prepared
Radioactive
Revised Aug 2021
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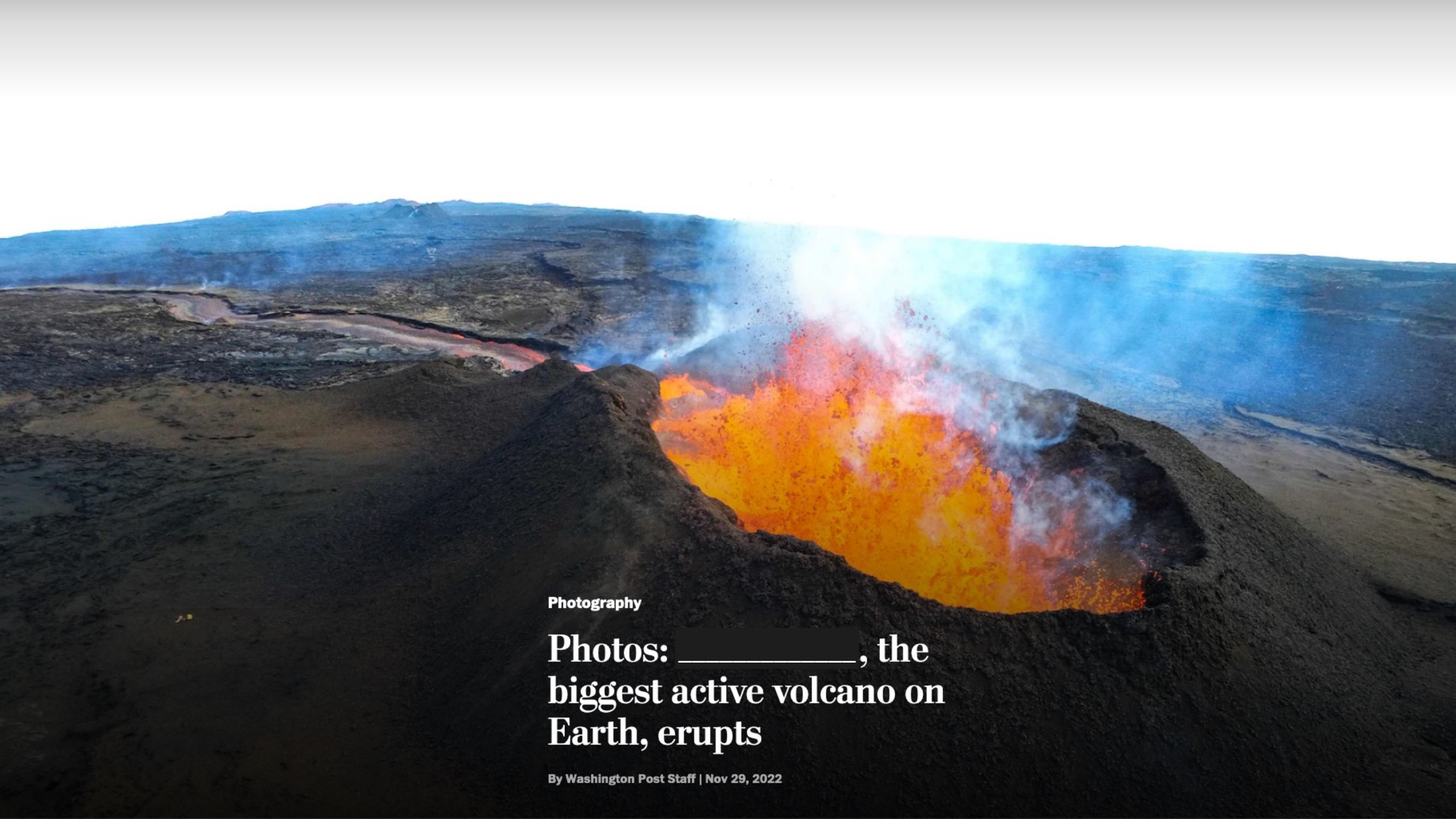


Photography

Photos: _____, the biggest active volcano on Earth, erupts

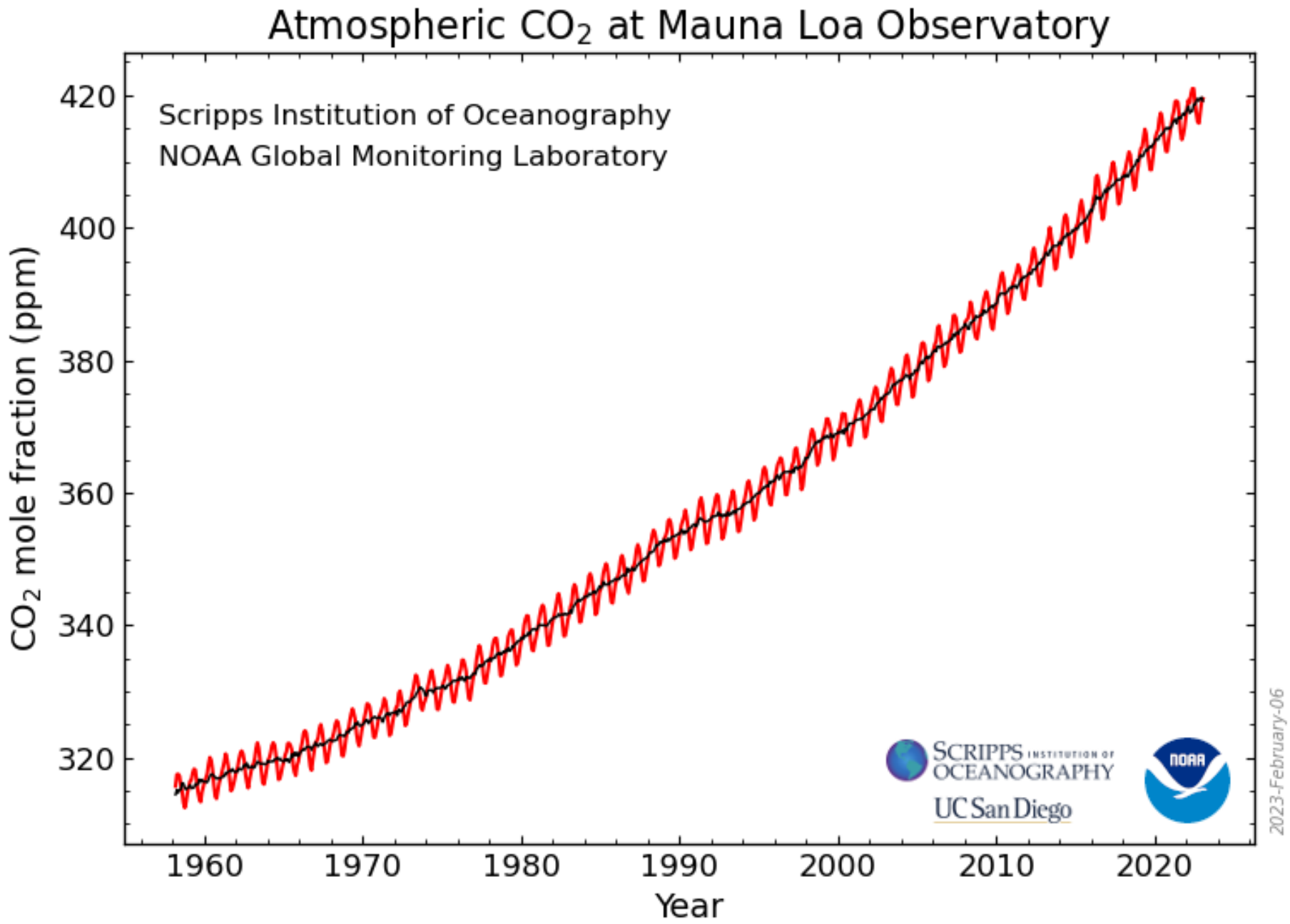
By Washington Post Staff | Nov 29, 2022

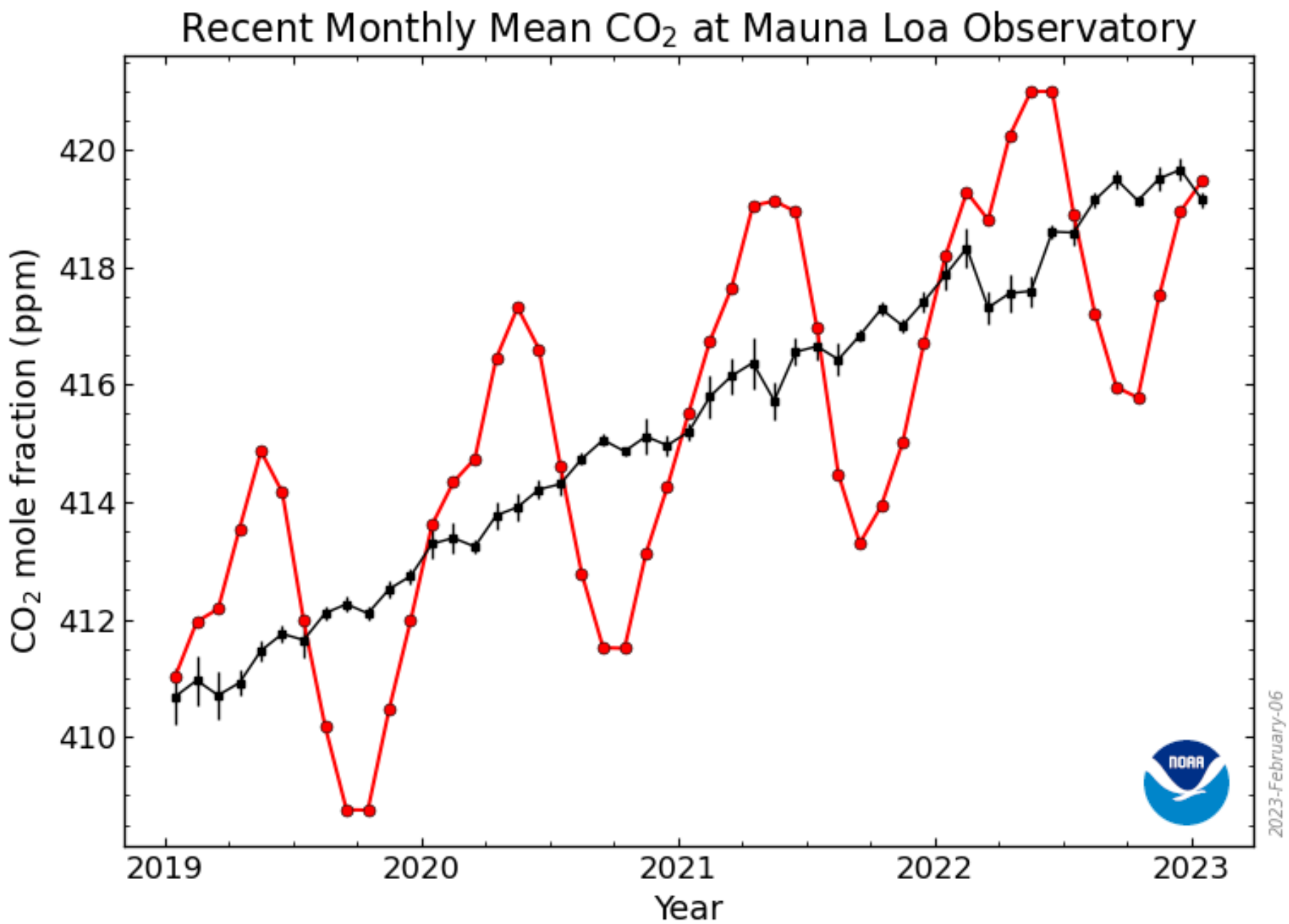
Photography

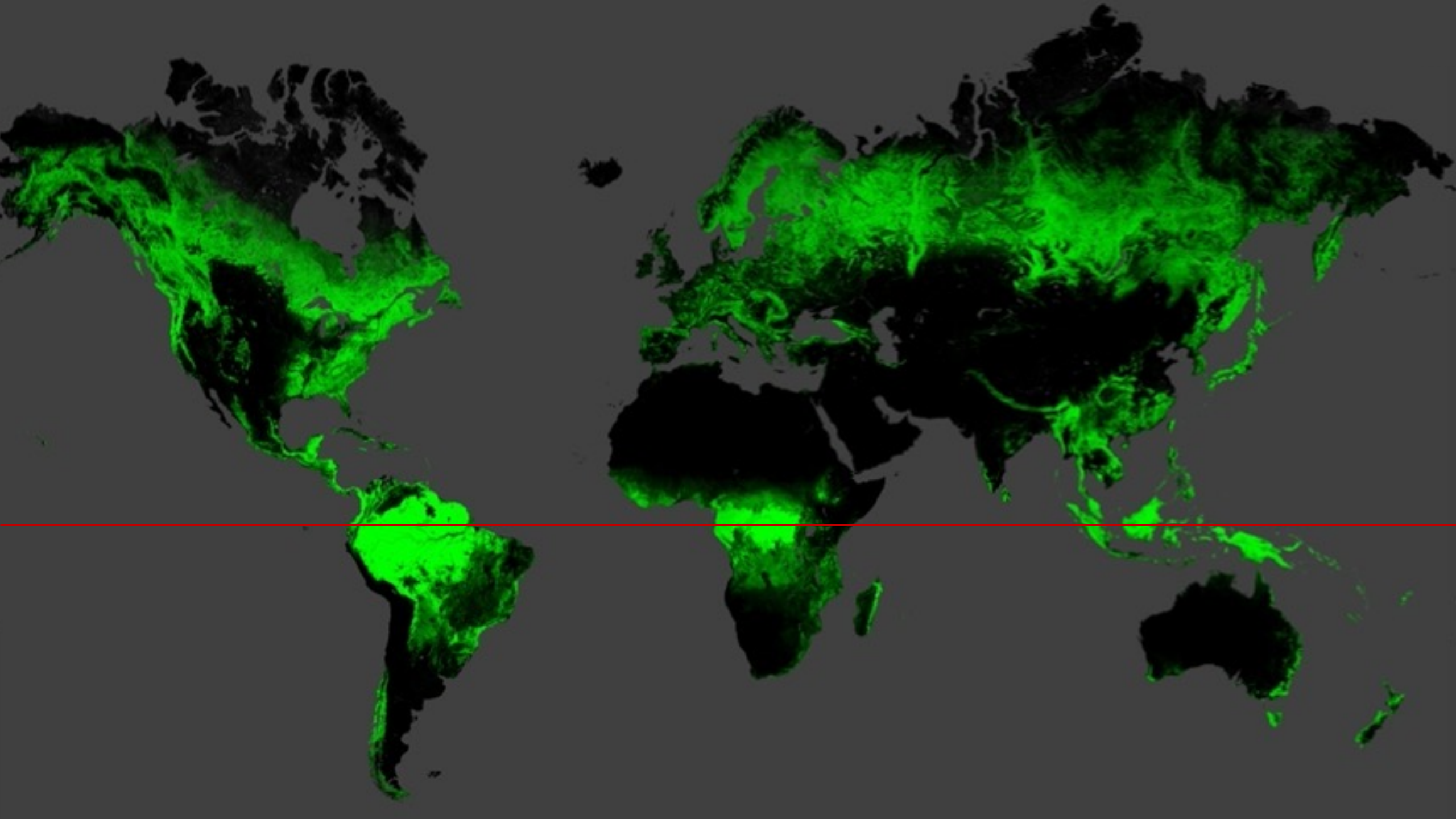
Photos: Mauna Loa, the biggest active volcano on Earth, erupts

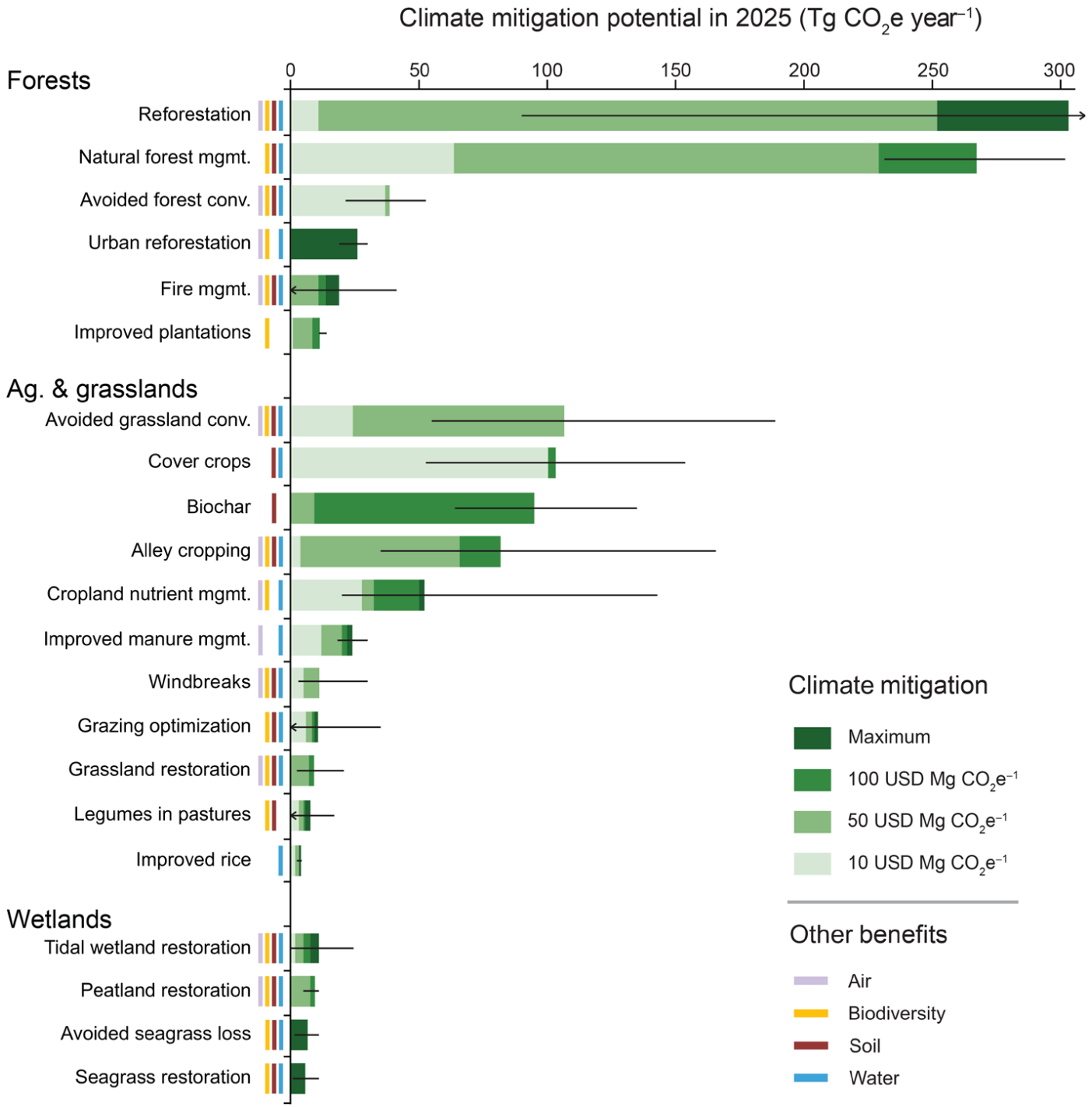
By Washington Post Staff | Nov 29, 2022


NOAA
MAUNA LOA
OBSERVATORY
Earth System Research Laboratories
Global Monitoring Division
Est. June 28, 1956 • Elevation 3,396m (11,141 ft.)


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
CO_2 mole fraction (ppm)
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego
NOAA
2023-February-06


Recent Monthly Mean CO_2 at Mauna Loa Observatory
CO_2 mole fraction (ppm)
420
418
416
414
412
410
2019
2020
2021
2022
2023
Year
NOAA
2023-February-06

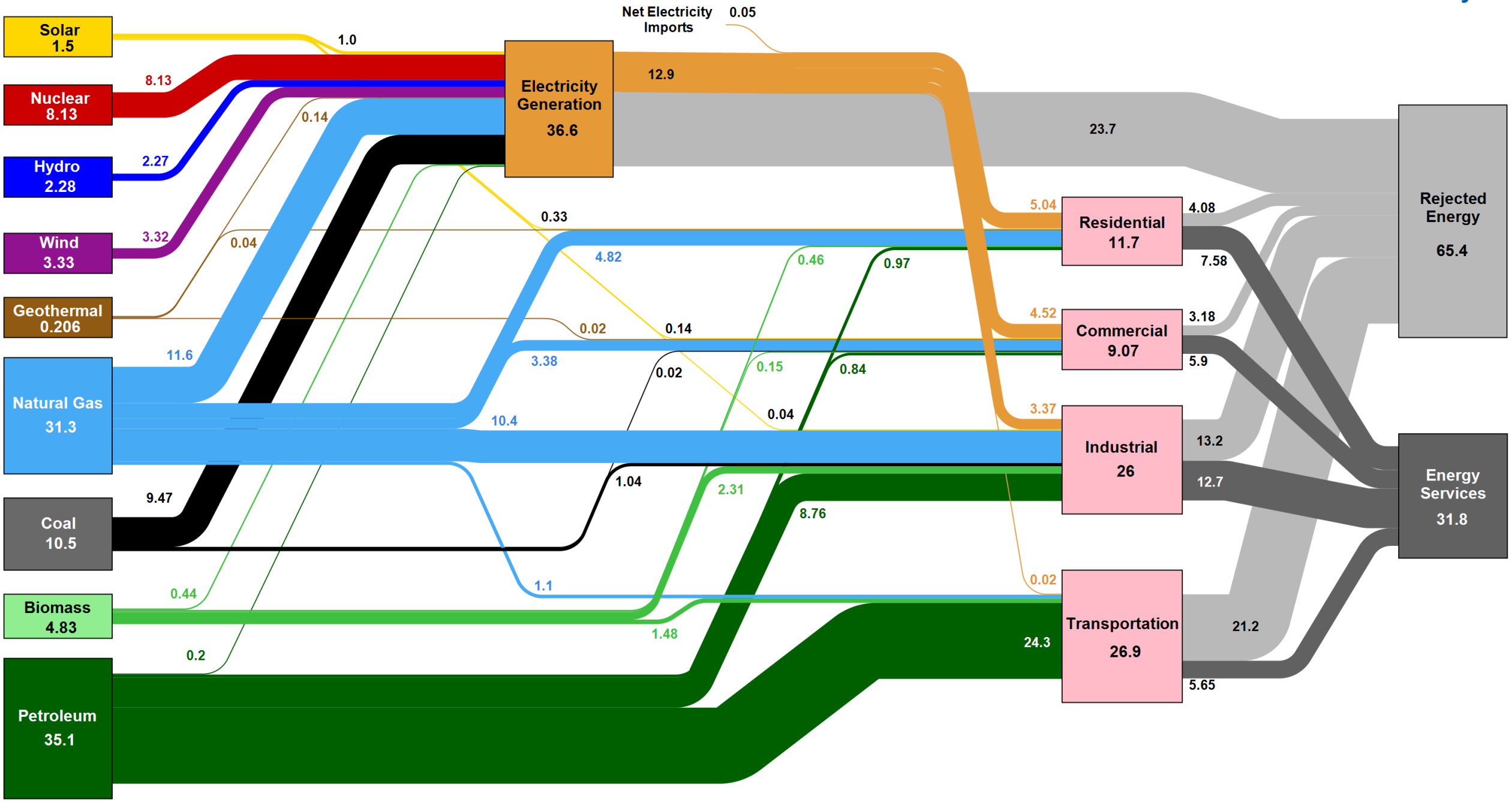




(Fargione et al., 2018)

Estimated U.S. Energy Consumption in 2021: 97.3 Quads

Lawrence Livermore National Laboratory

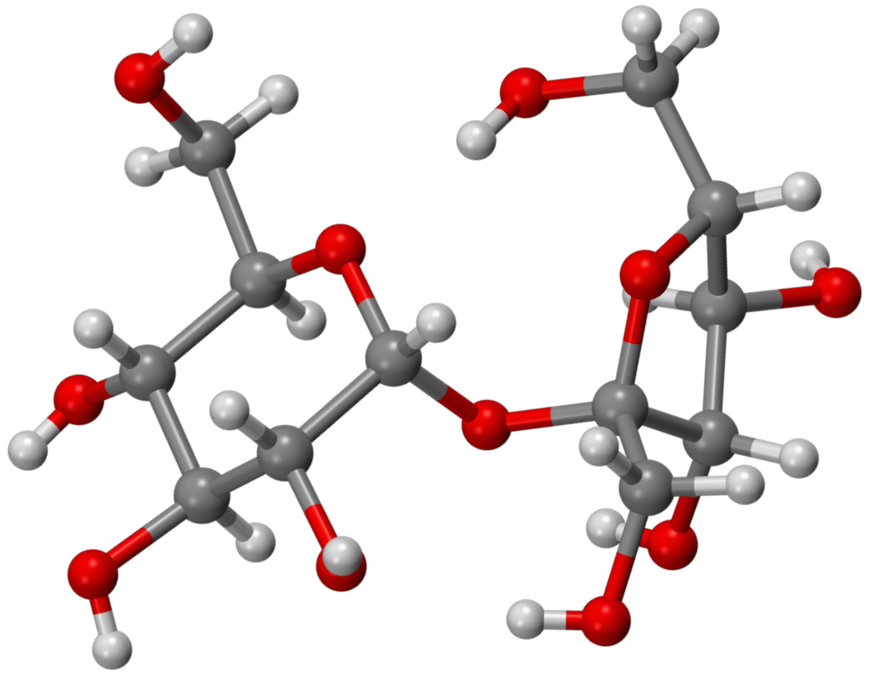


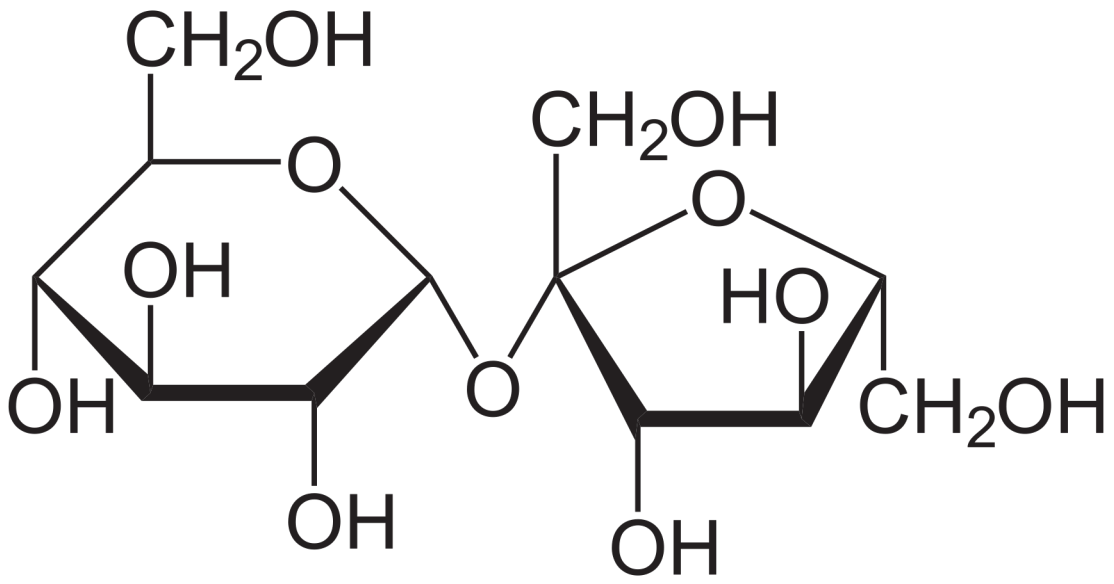
Carbon Accounting

example: sucrose

(a.k.a. table sugar)

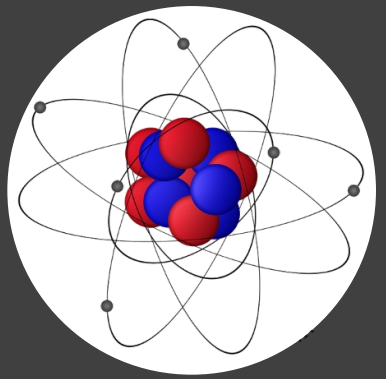
$C_{12}H_{22}O_{11}$

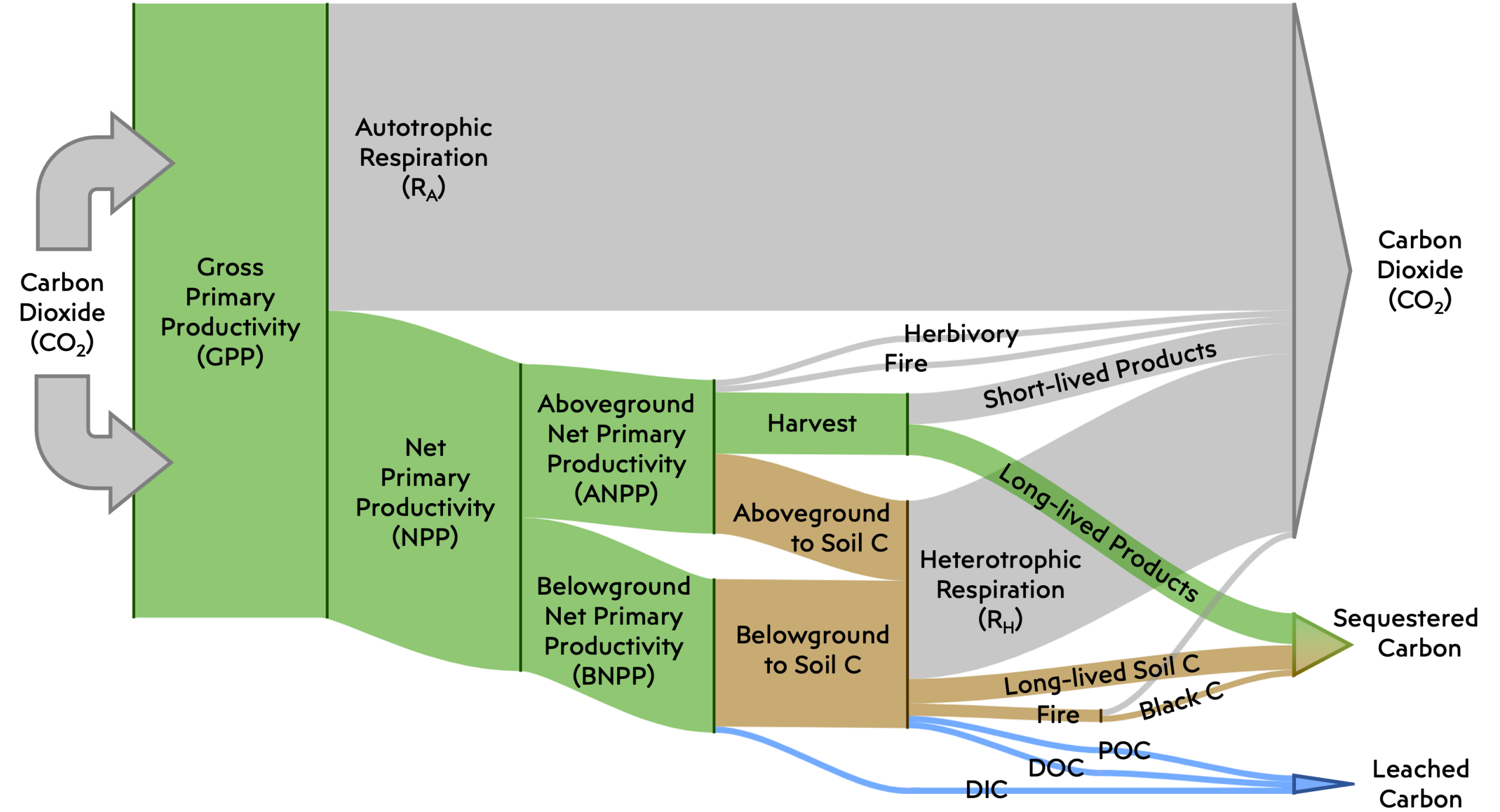


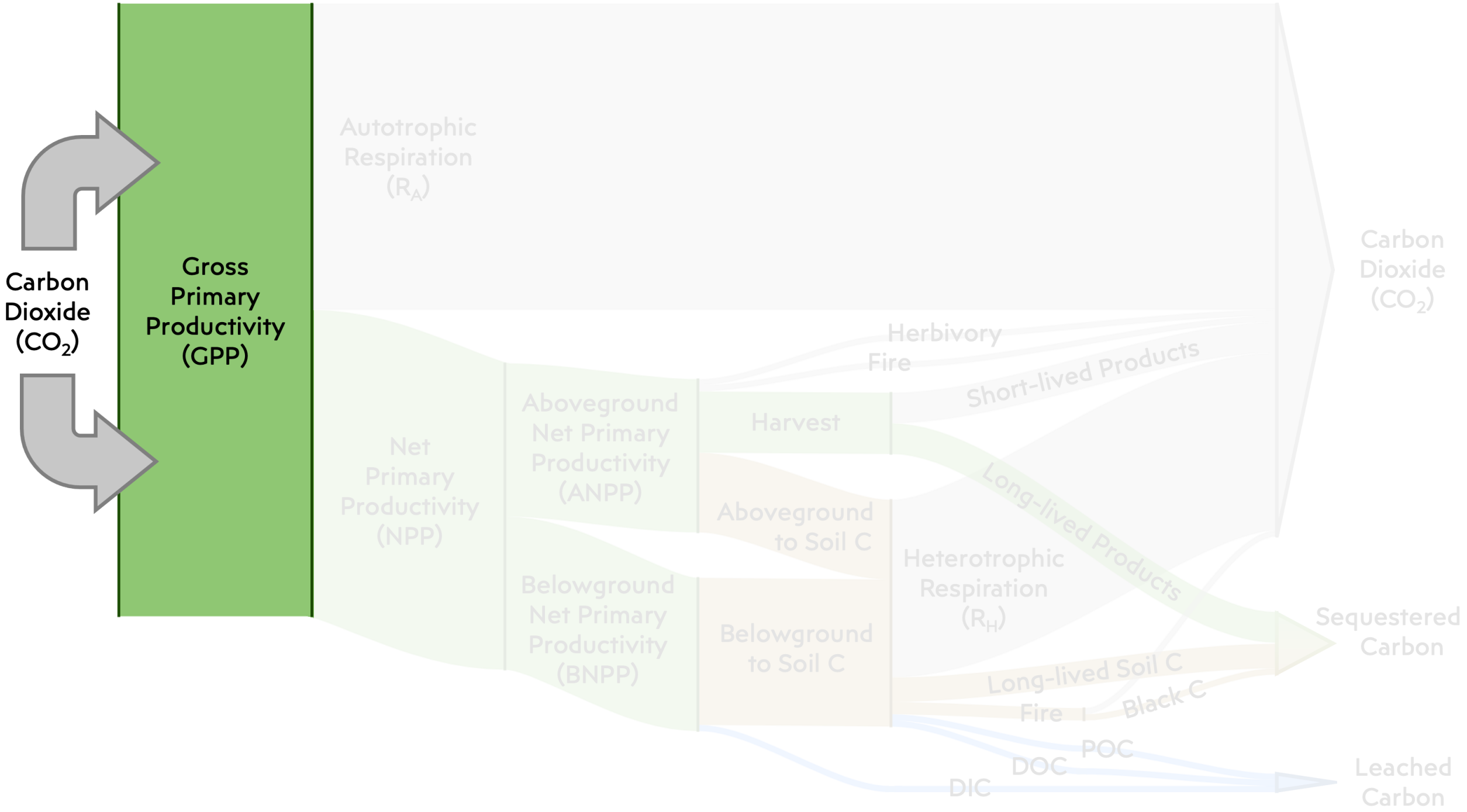


84,000,000,000,000,000,000,000

(or 84 sextillion)




Carbon Dioxide (CO_2)
Gross Primary Productivity (GPP)
Autotrophic Respiration (R_A)
Net Primary Productivity (NPP)
Aboveground Net Primary Productivity (ANPP)
Belowground Net Primary Productivity (BNPP)
Herbivory
Fire
Harvest
Aboveground to Soil C
Belowground to Soil C
Heterotrophic Respiration (R_H)
Short-lived Products
Long-lived Products
Carbon Dioxide (CO_2)
Sequestered Carbon
Long-lived Soil C
Fire
Black C
POC
DOC
DIC
Leached Carbon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Belowground Net Primary Productivity (BNPP)
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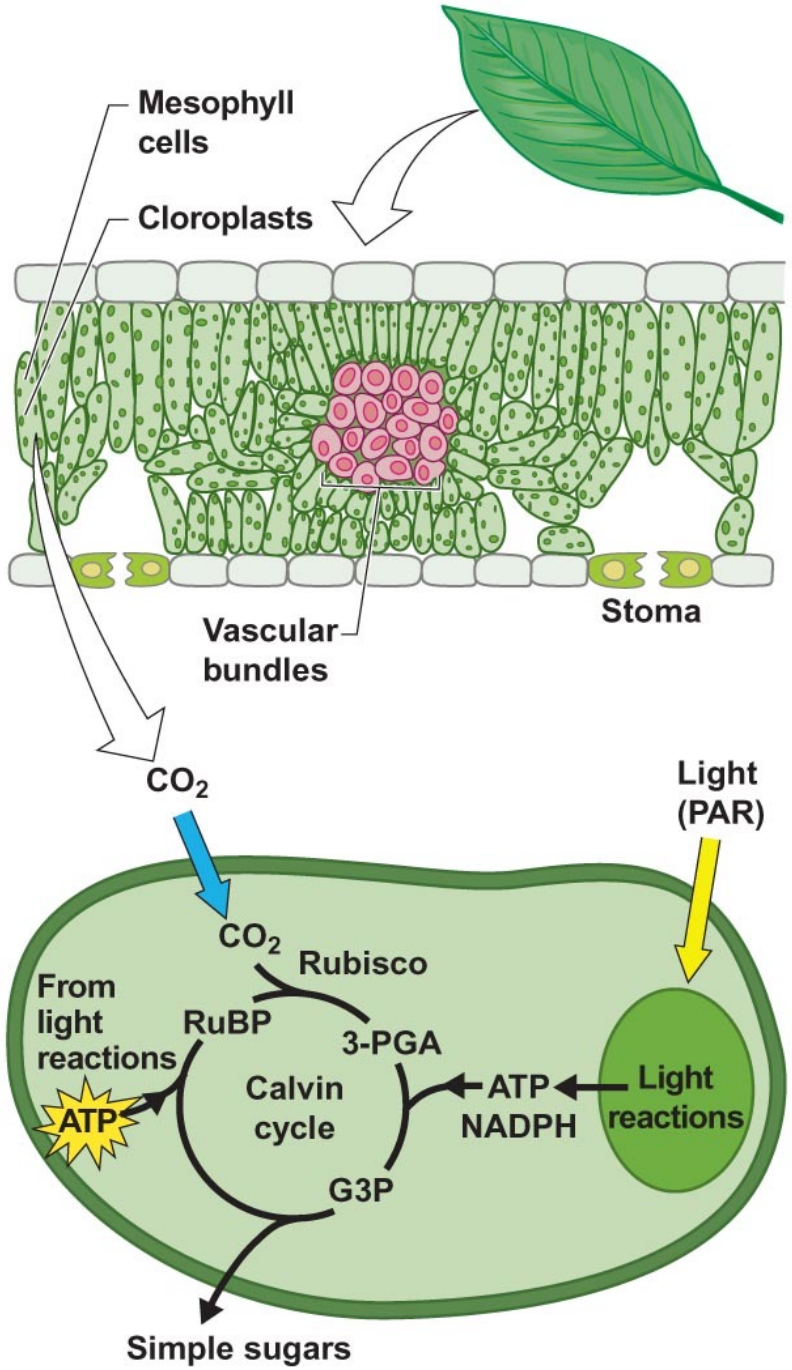
Belowground to Soil C
Herbivory
Fire
Short-lived Products
Long-lived Products
Heterotrophic Respiration (R_H)
Carbon Dioxide (CO_2)
Sequestered Carbon
Long-lived Soil C
Fire
Black C
POC
DOC
DIC
Leached Carbon

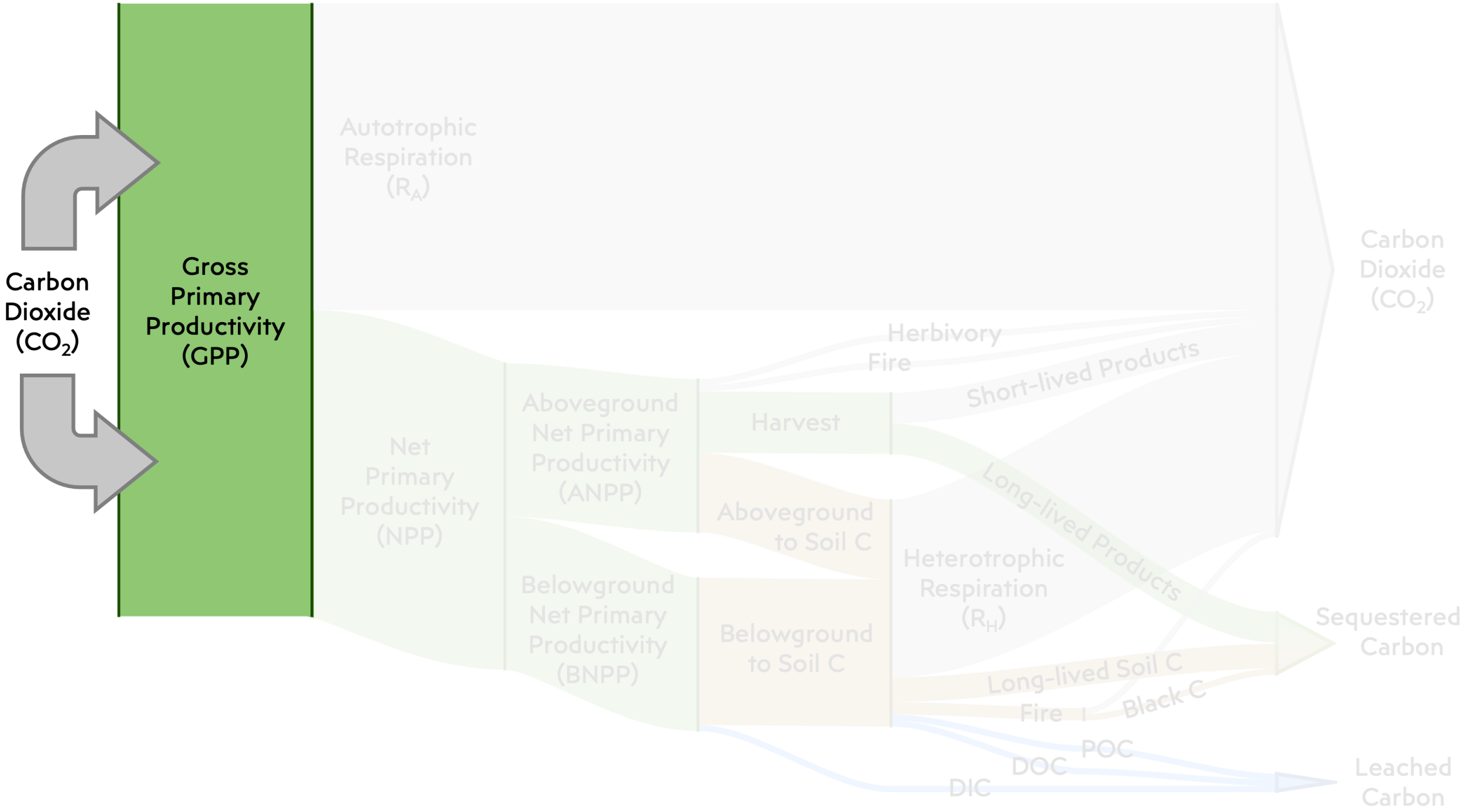
Photosynthesis

$$6\ CO_2 + 6\ H_2O + light \rightleftharpoons C_6H_{12}O_6 + 6\ O_2$$

or...

...in the presence of water, sunlight provides the energy to drive the conversion of carbon dioxide into sugar and produces oxygen as a by-product.

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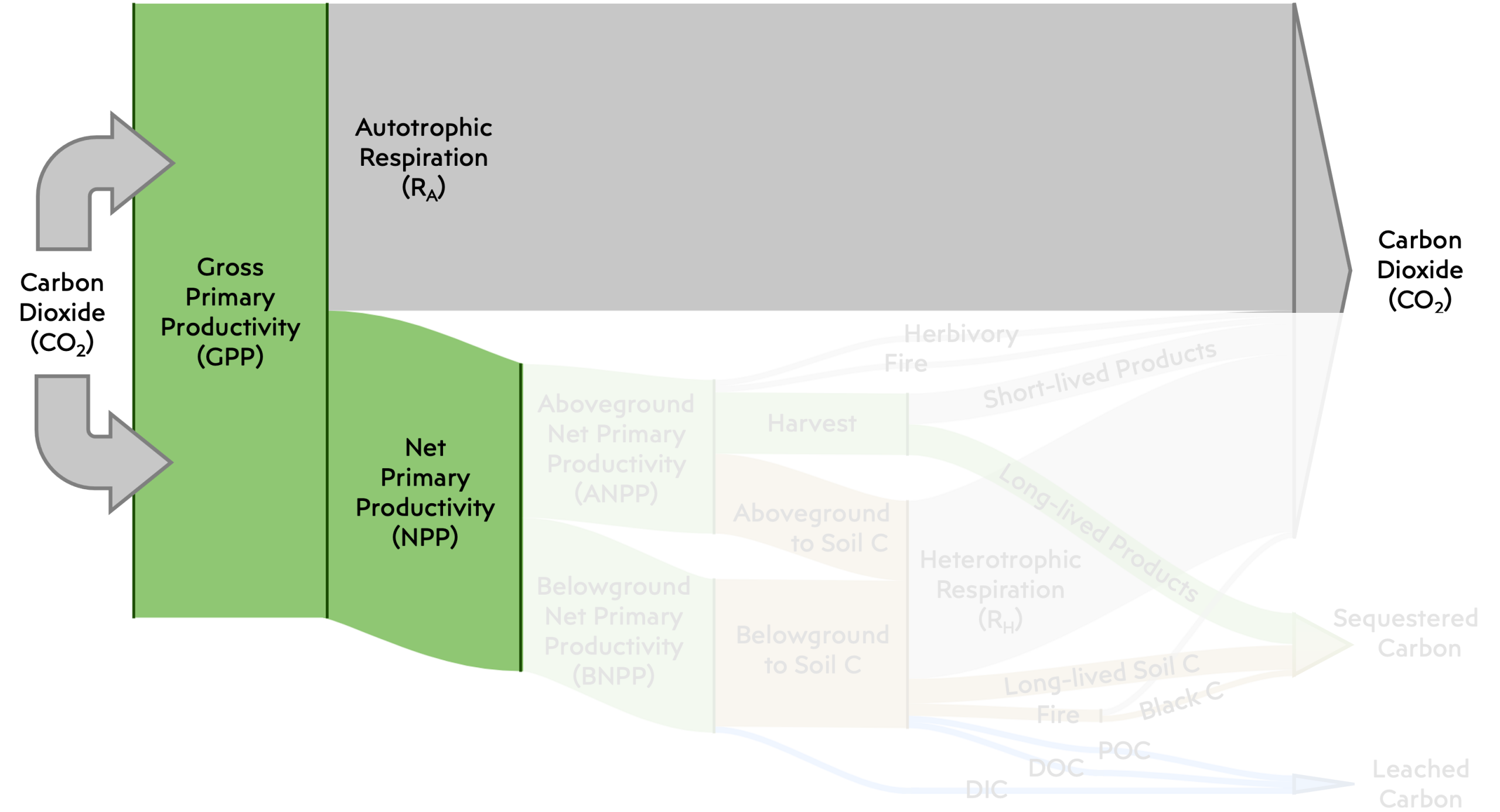
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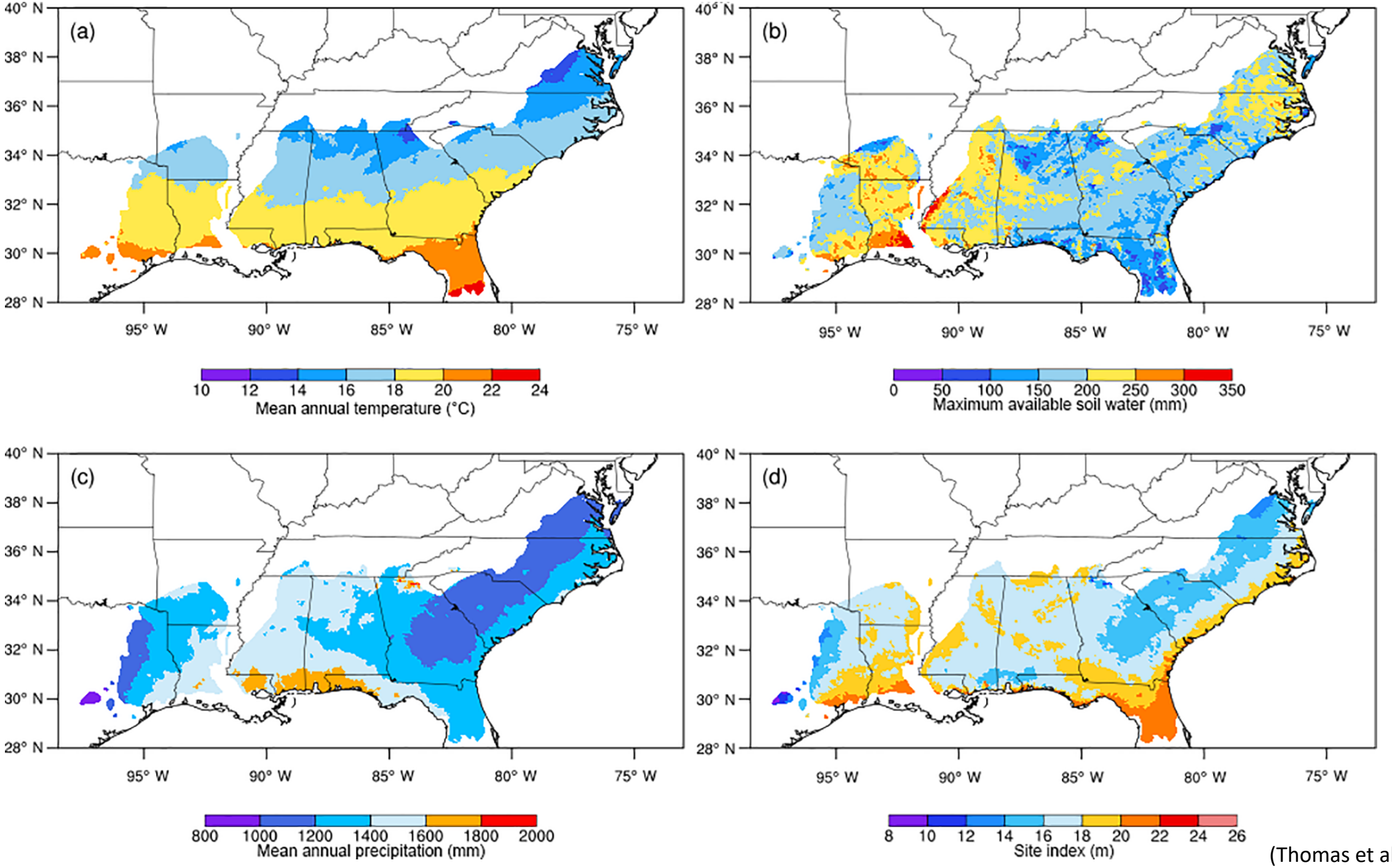
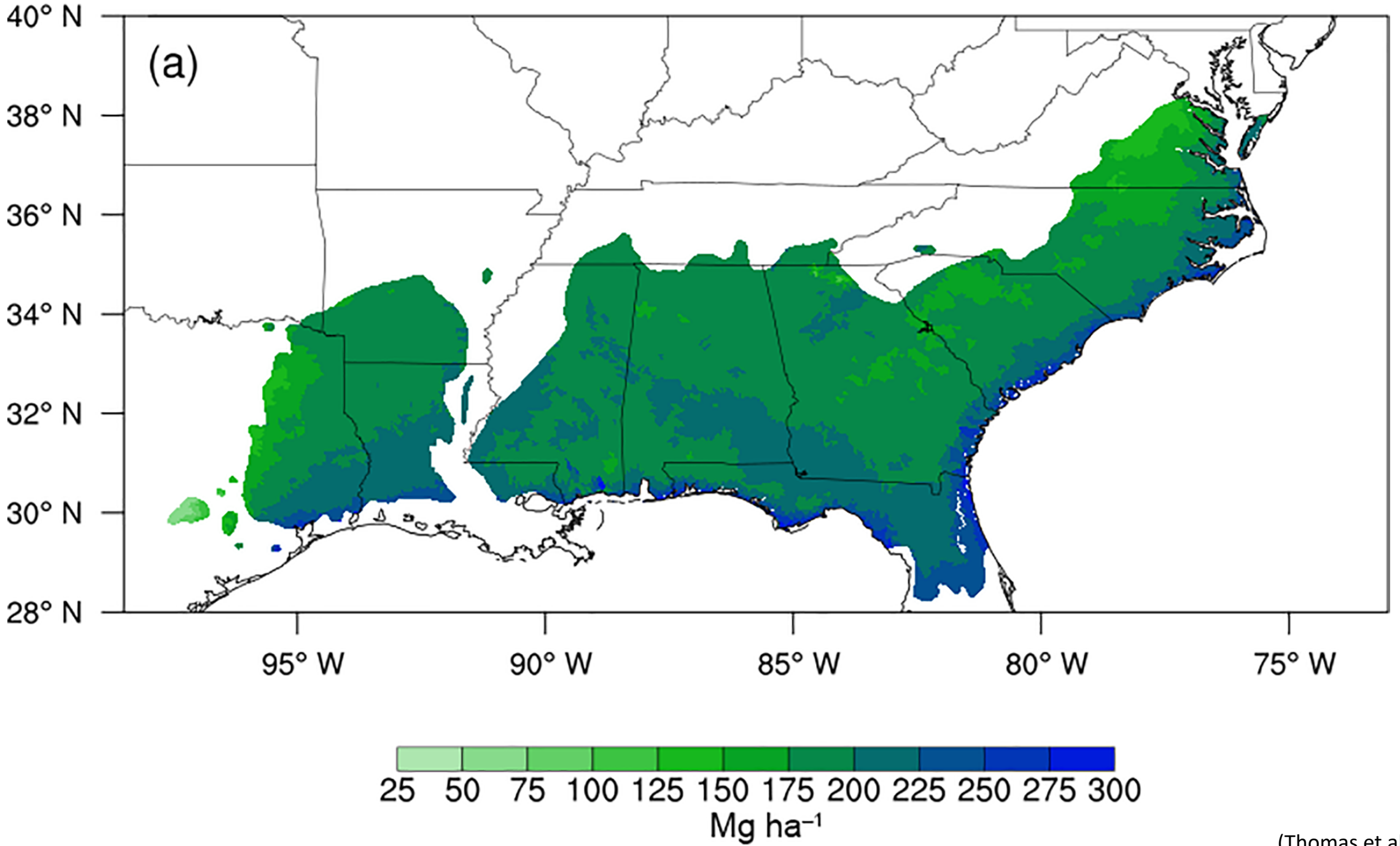


(Thomas et al., 2017)



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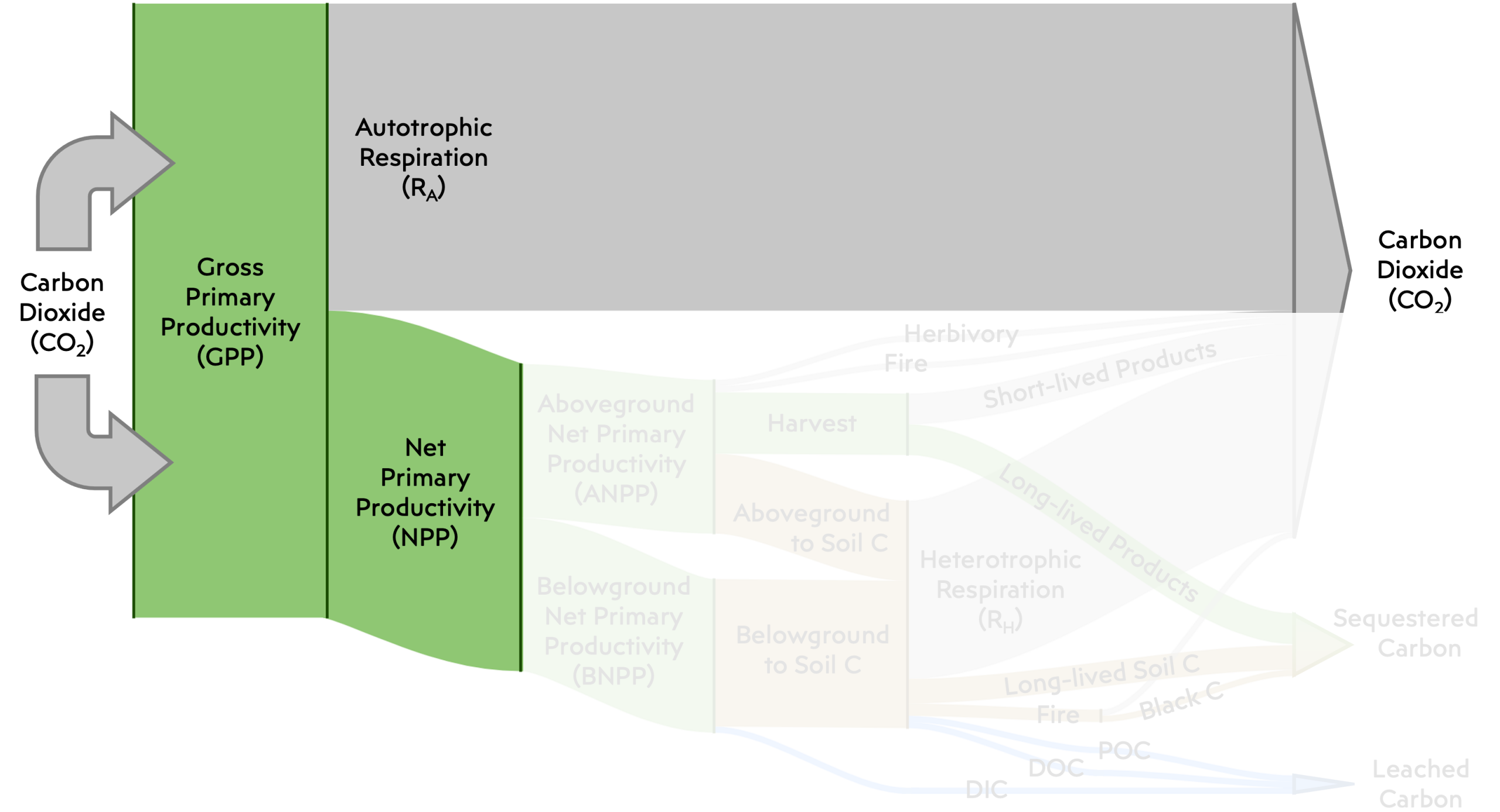
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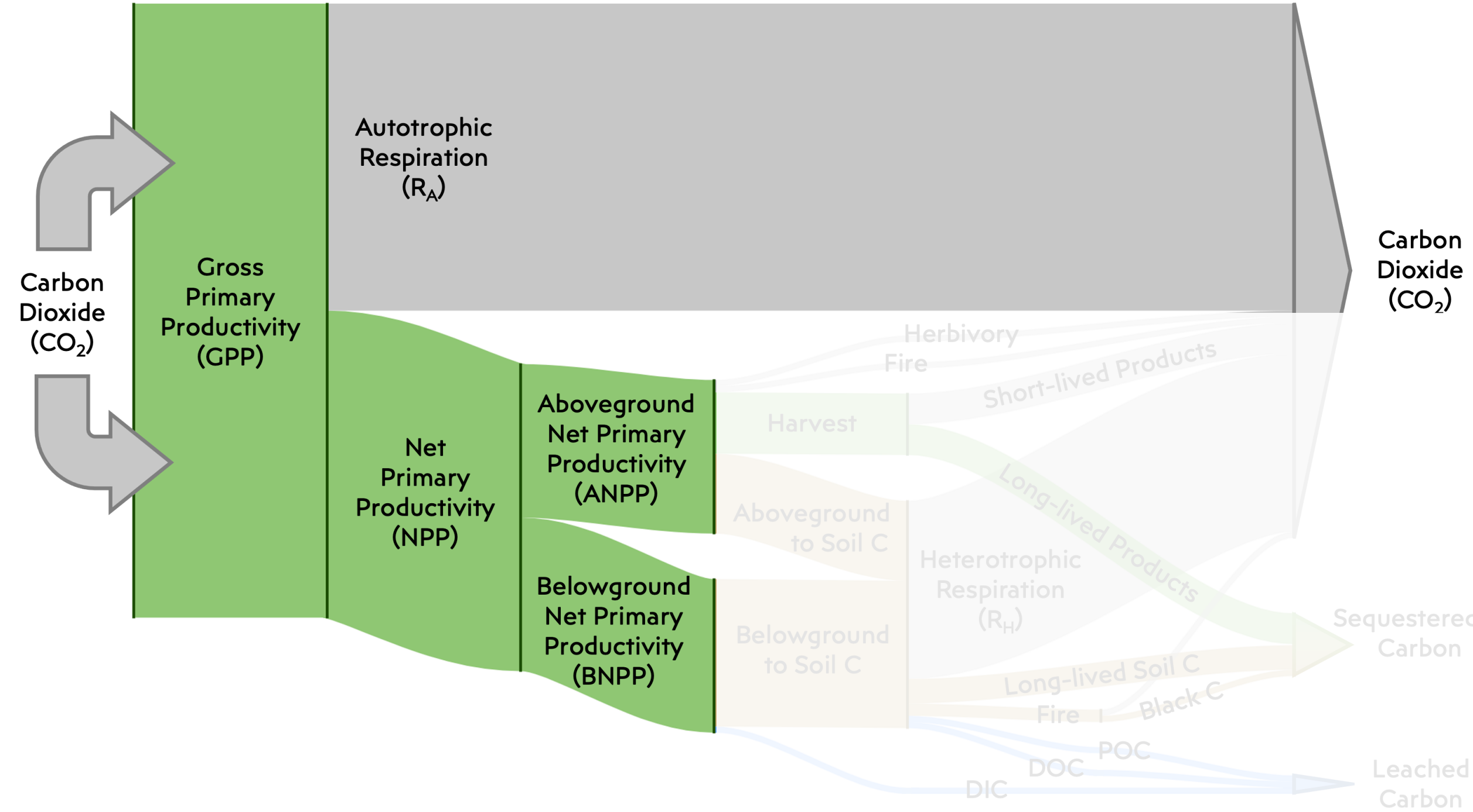
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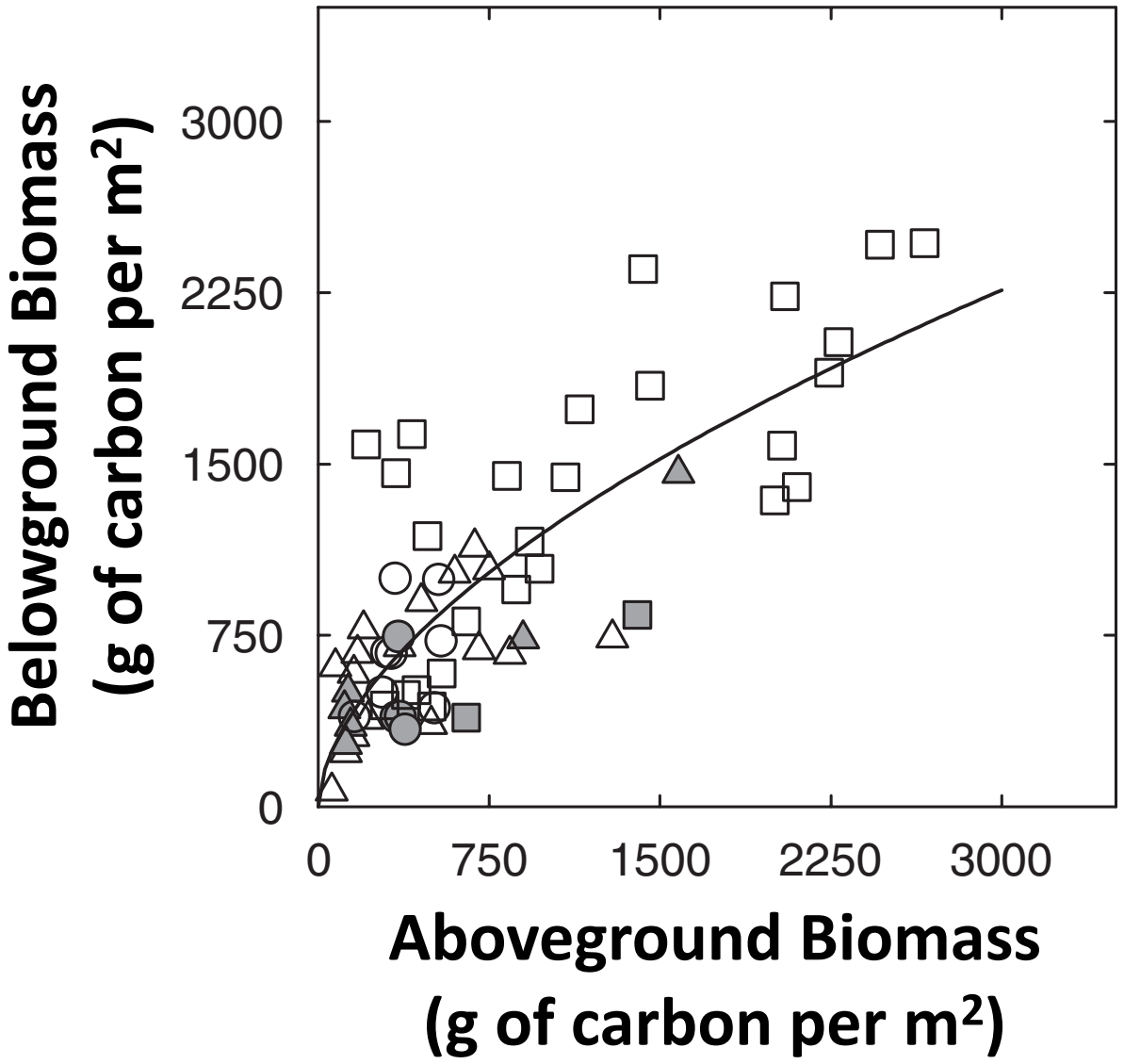
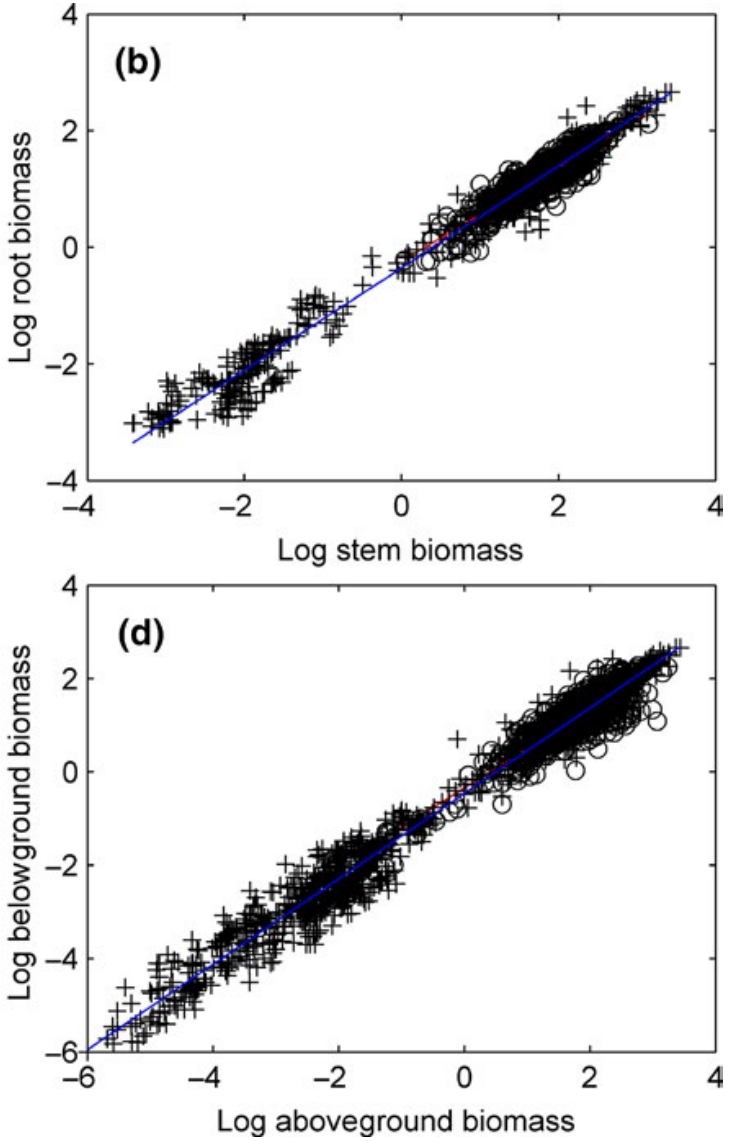
“The taproot of this longleaf pine stump in Mississippi has a diameter of 14 inches at a depth of 10 feet below the surface.”

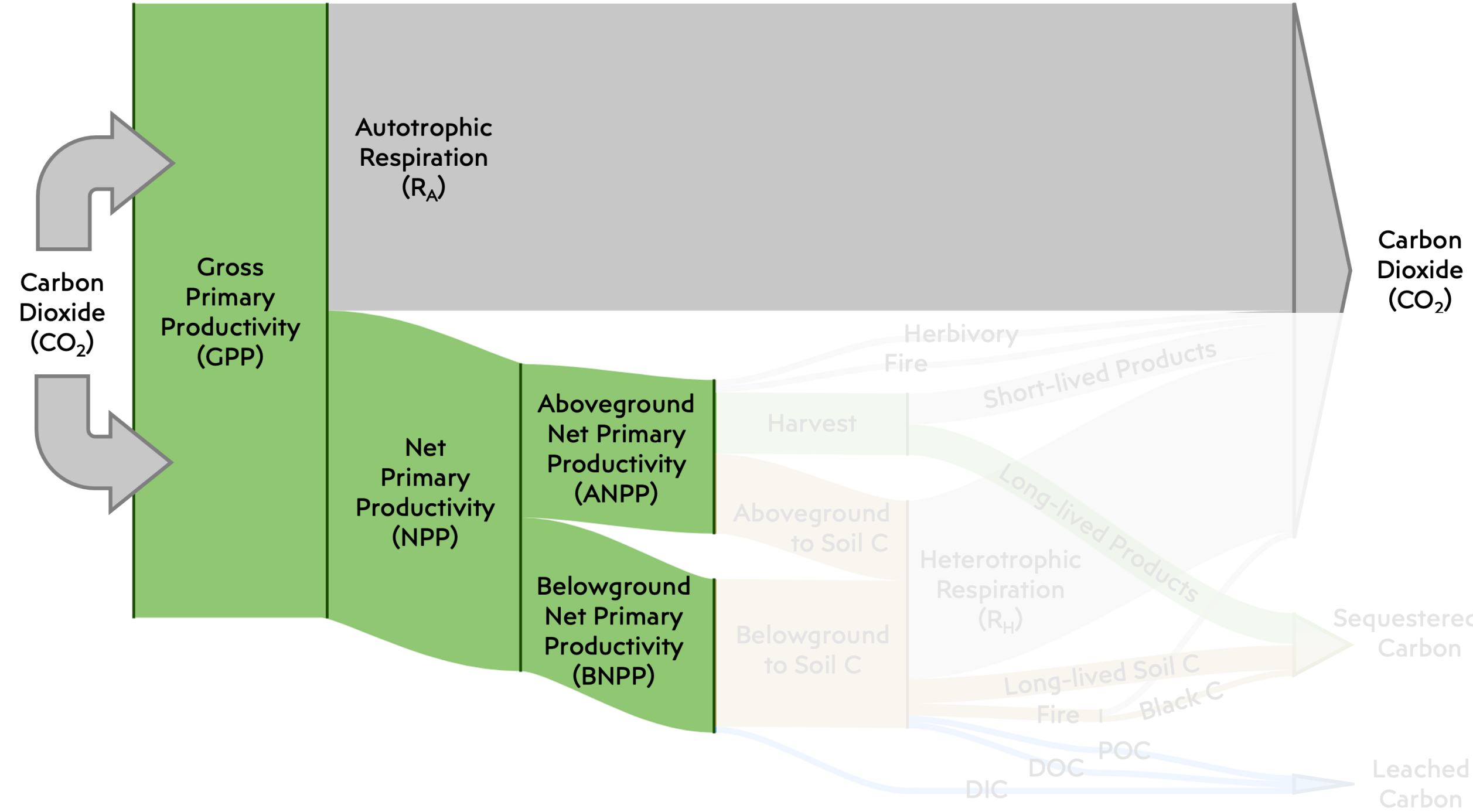

216805



(adapted from Litton et al., 2007)



(Jiang and Wang, 2017)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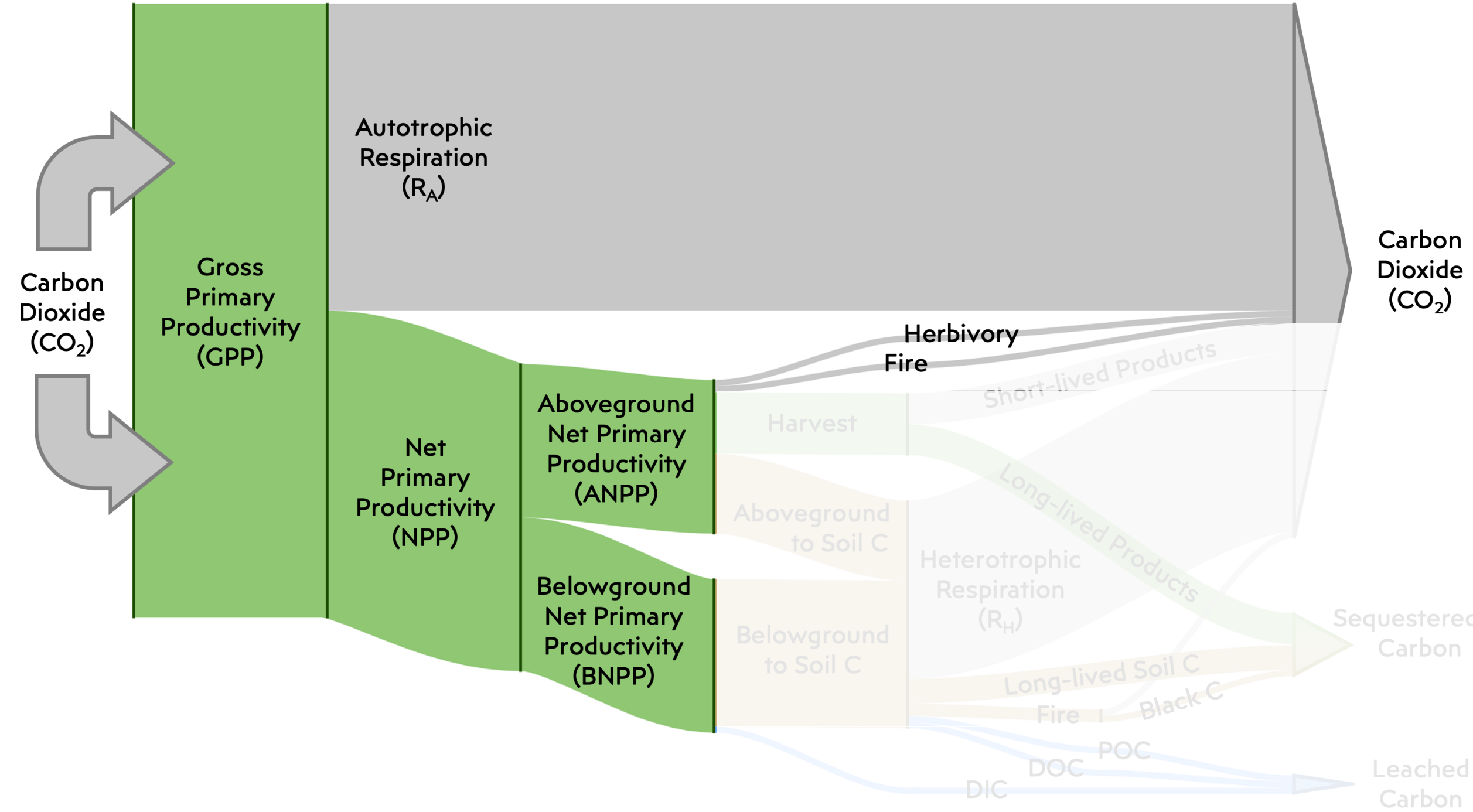
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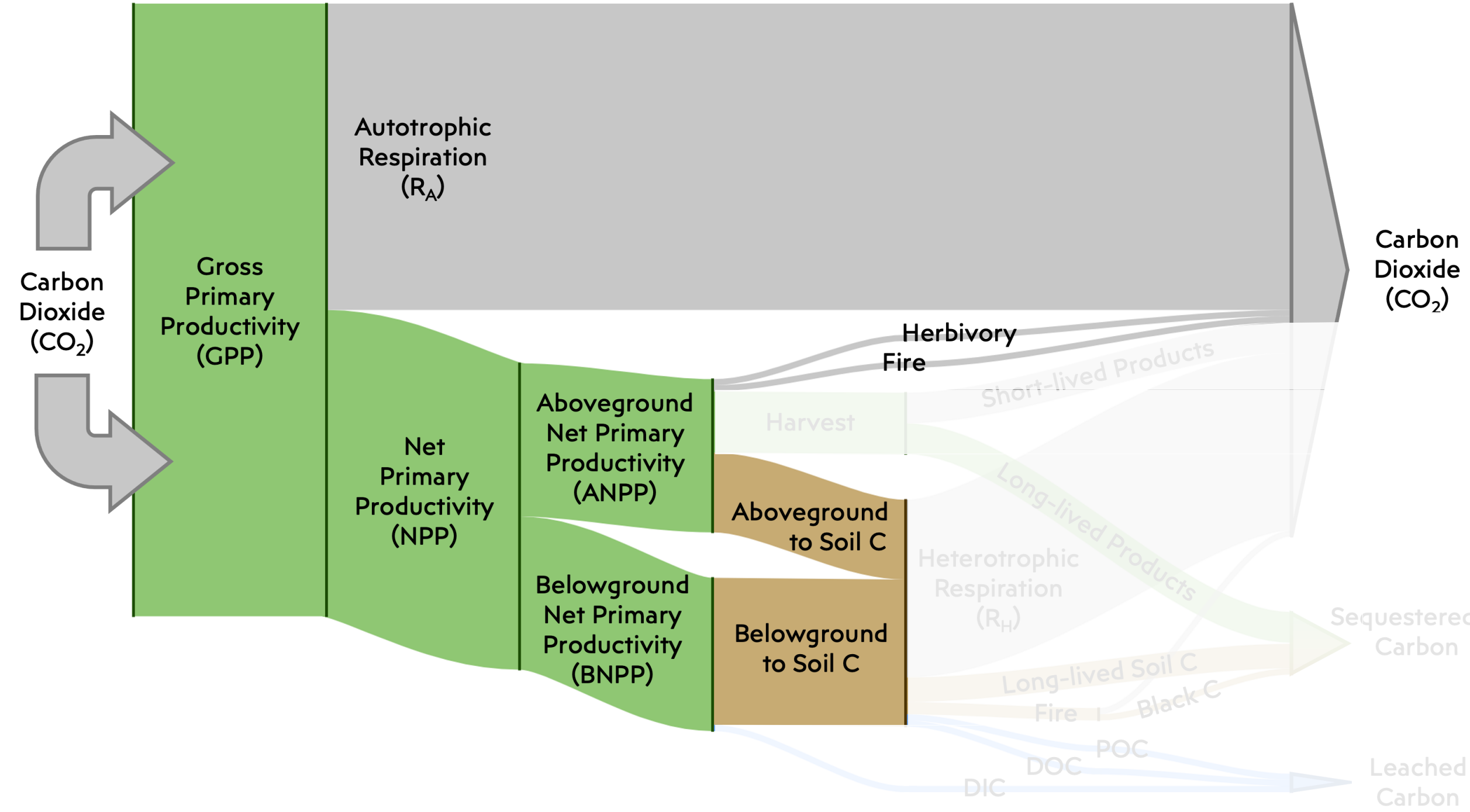
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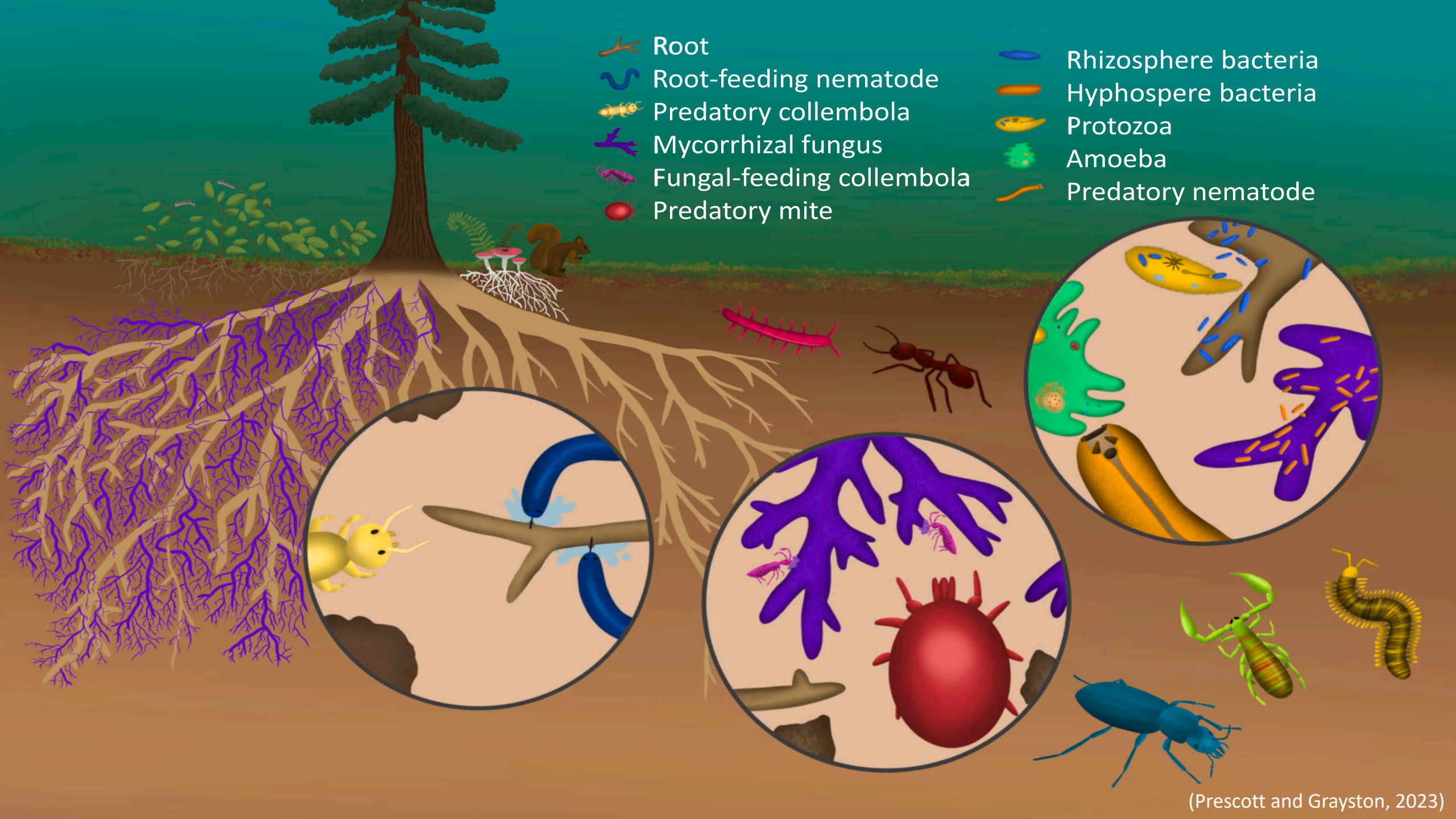
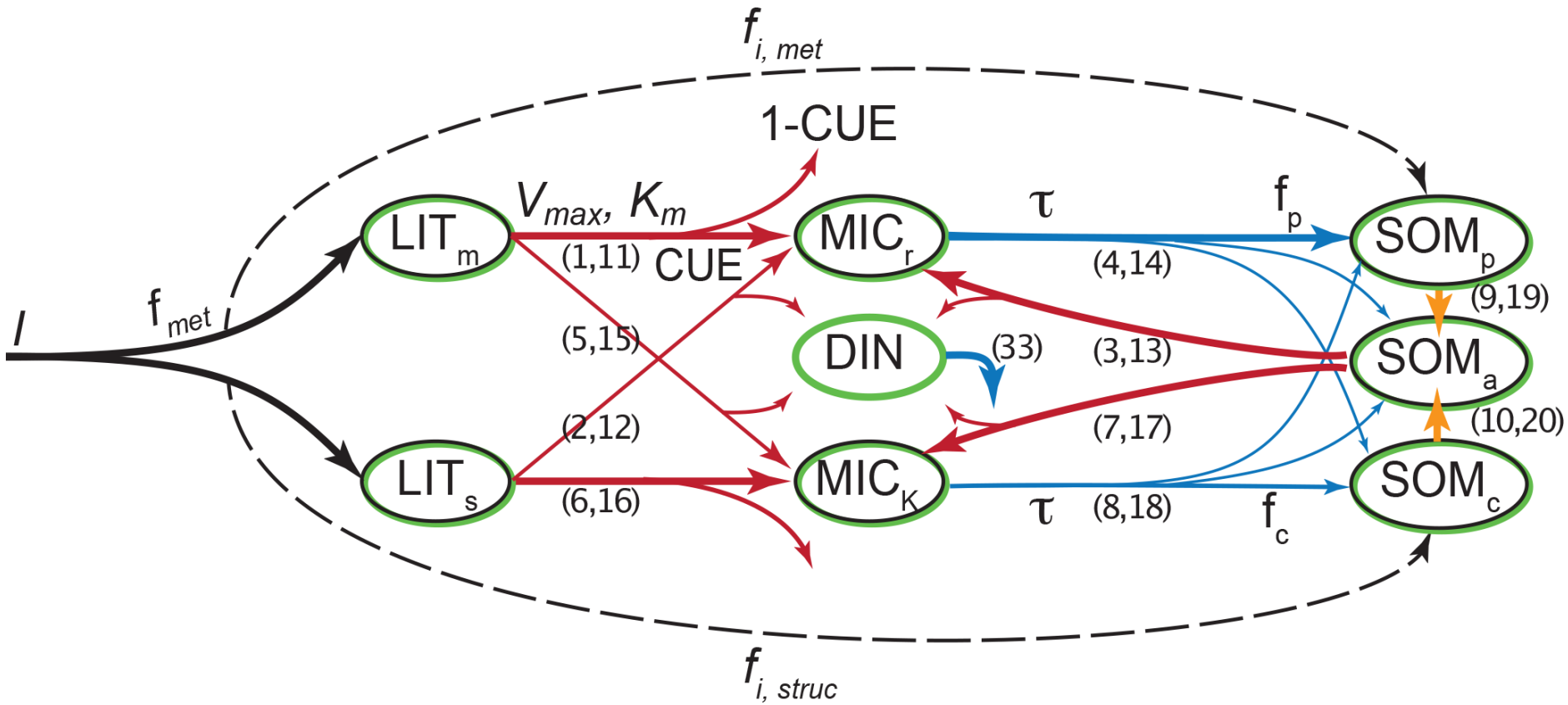
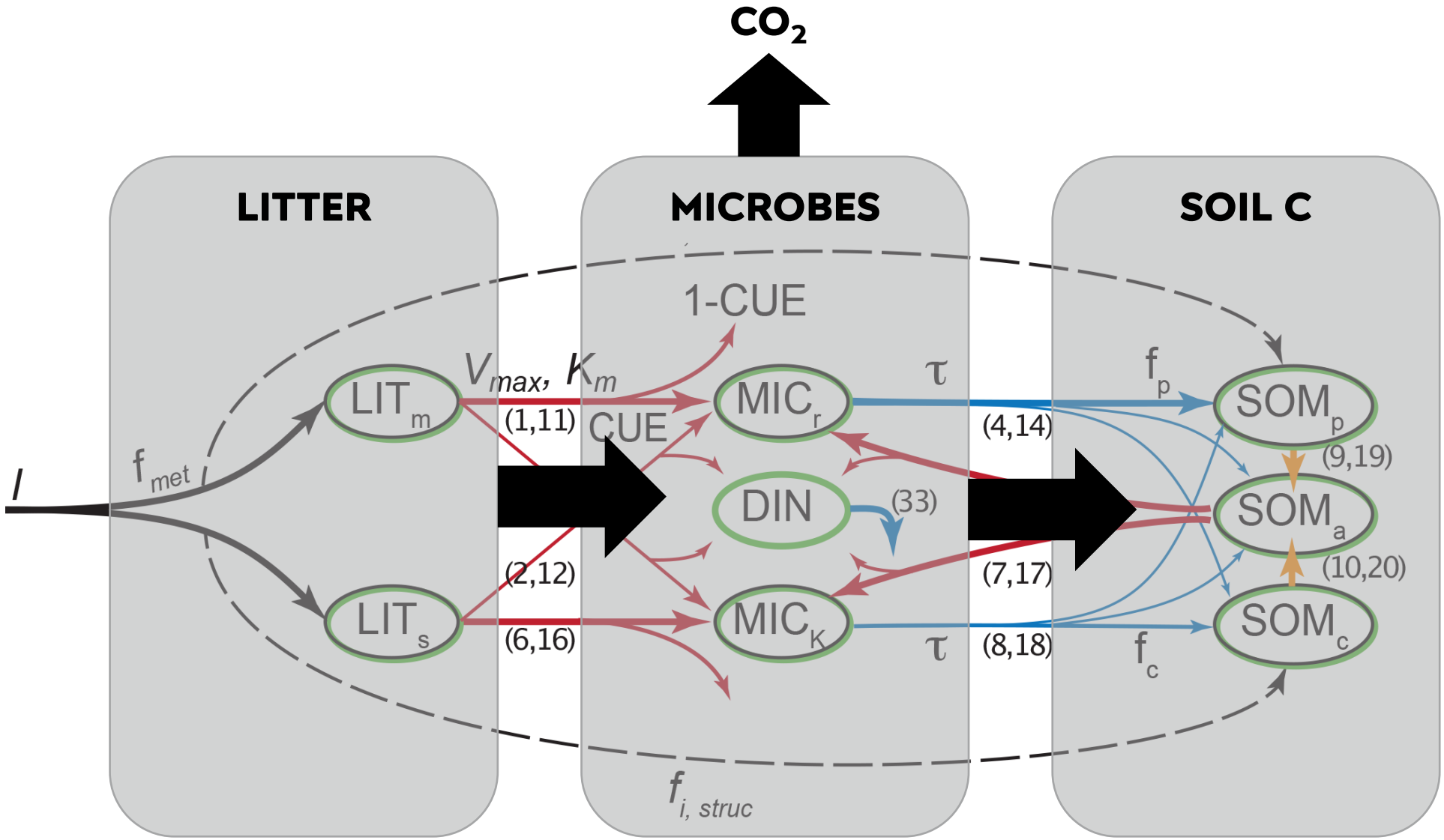


(Prescott and Grayston, 2023)



(Kyker-Snowman et al., 2020)



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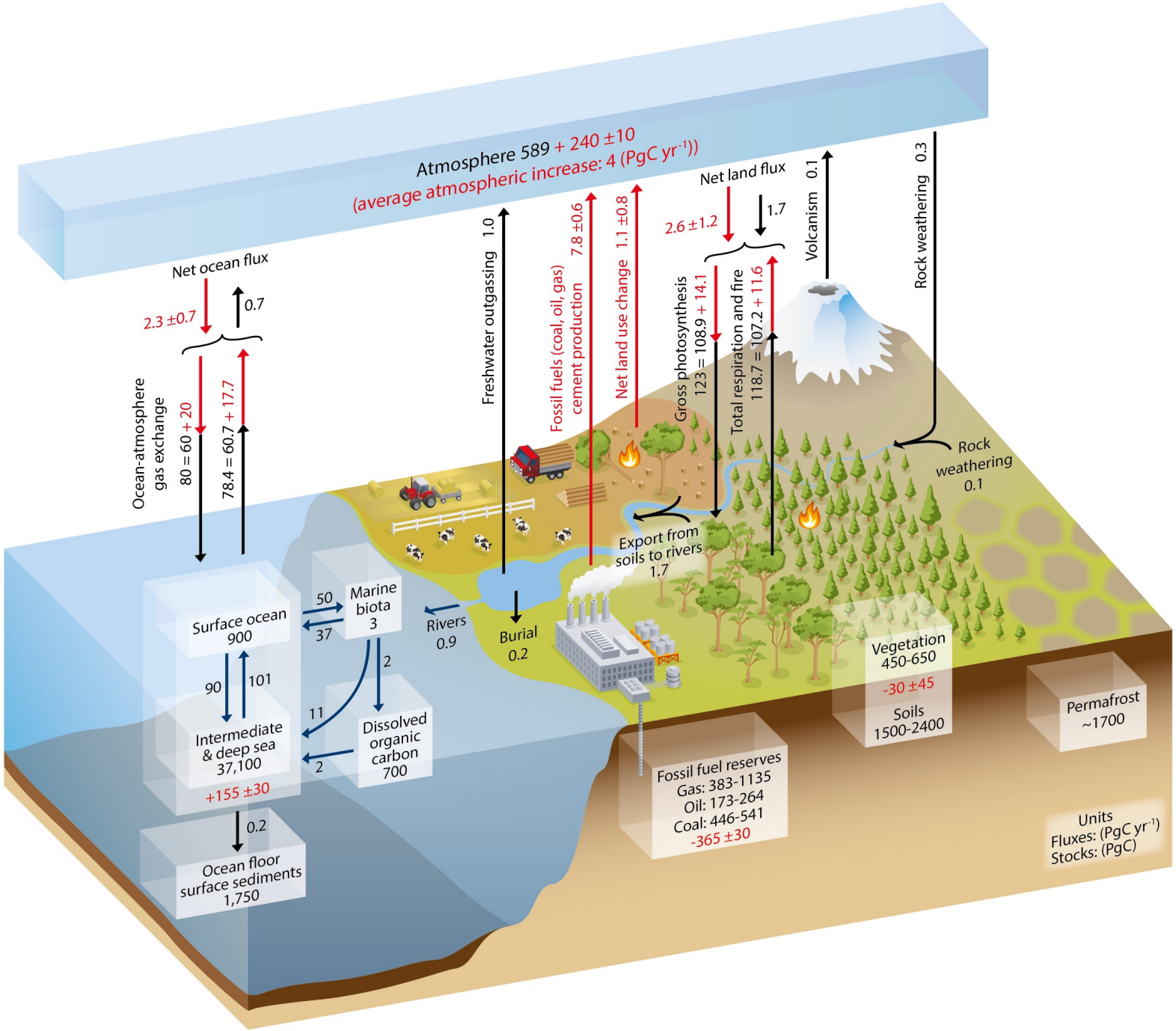
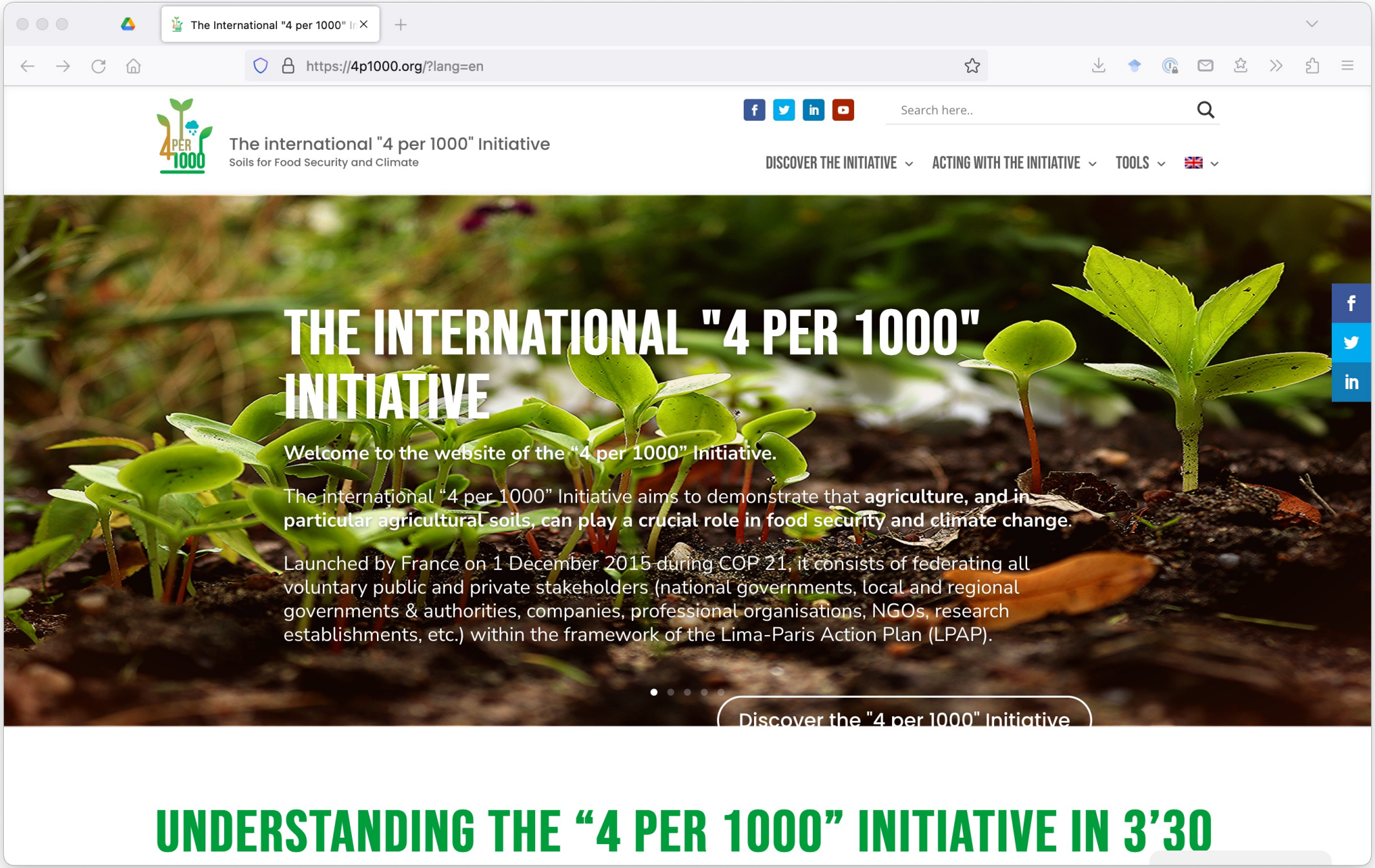

Atmosphere 589 + 240 ±10
(average atmospheric increase: 4 (PgC yr⁻¹))
Net ocean flux
2.3 ±0.7
0.7
Ocean-atmosphere gas exchange
80 = 60 + 20
78.4 = 60.7 + 17.7
Freshwater outgassing 1.0
Fossil fuels (coal, oil, gas) cement production 7.8 ±0.6
Net land use change 1.1 ±0.8
Net land flux
2.6 ±1.2
1.7
Gross photosynthesis 123 = 108.9 + 14.1
Total respiration and fire 118.7 = 107.2 + 11.6
Volcanism 0.1
Rock weathering 0.3
Rock weathering 0.1
Export from soils to rivers 1.7
Surface ocean 900
50
37
Marine biota 3
Rivers 0.9
Burial 0.2
90
101
2
11
2
Intermediate & deep sea 37,100
+155 ±30
Dissolved organic carbon 700
0.2
Ocean floor surface sediments 1,750
Vegetation 450-650
-30 ±45
Soils 1500-2400
Permafrost ~1700
Fossil fuel reserves
Gas: 383-1135
Oil: 173-264
Coal: 446-541
-365 ±30
Units
Fluxes: (PgC yr⁻¹)
Stocks: (PgC)

(USGRP, 2018)


The International "4 per 1000" In
https://4p1000.org/?lang=en
The international "4 per 1000" Initiative
Soils for Food Security and Climate
Search here..
DISCOVER THE INITIATIVE
ACTING WITH THE INITIATIVE
TOOLS
THE INTERNATIONAL "4 PER 1000" INITIATIVE
Welcome to the website of the "4 per 1000" Initiative.
The international "4 per 1000" Initiative aims to demonstrate that agriculture, and in particular agricultural soils, can play a crucial role in food security and climate change.
Launched by France on 1 December 2015 during COP 21, it consists of federating all voluntary public and private stakeholders (national governments, local and regional governments & authorities, companies, professional organisations, NGOs, research establishments, etc.) within the framework of the Lima-Paris Action Plan (LPAP).
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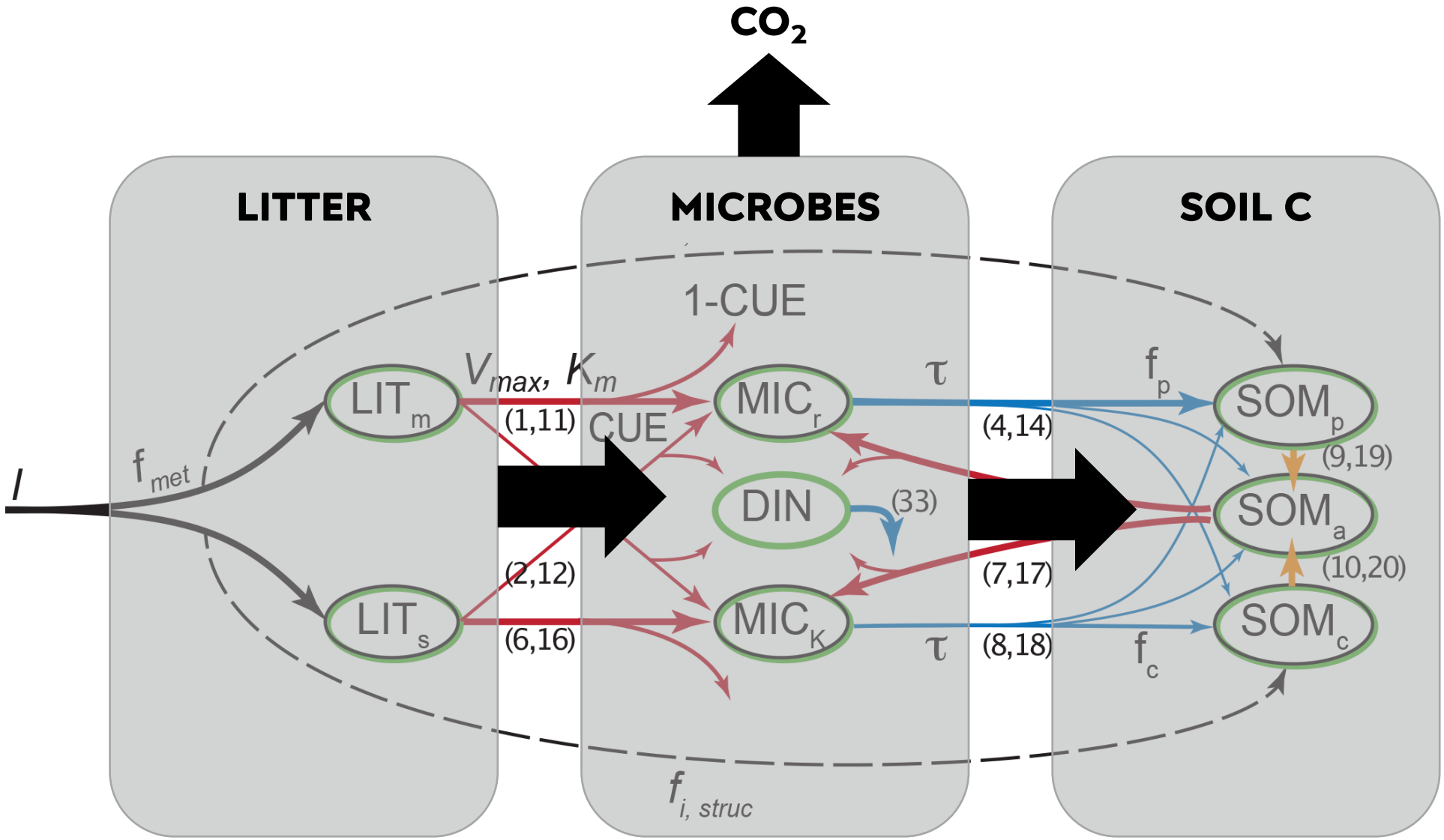
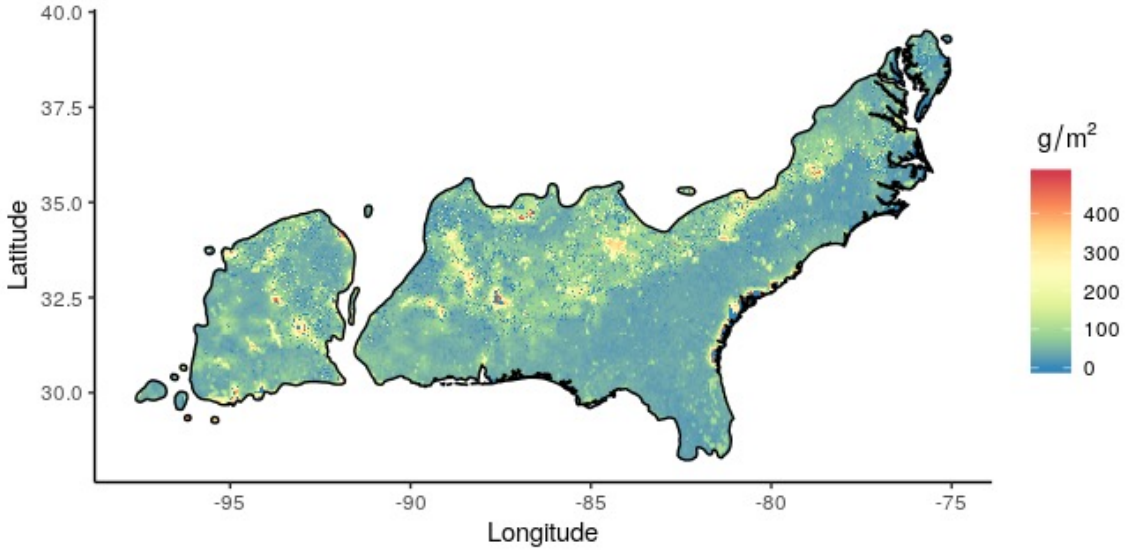
UNDERSTANDING THE "4 PER 1000" INITIATIVE IN 3'30

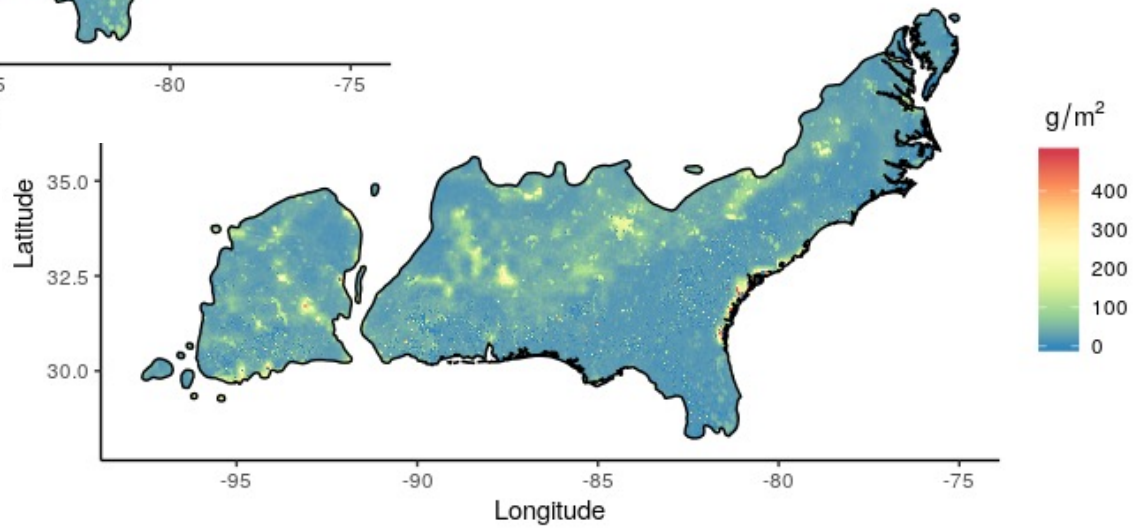


(Kyker-Snowman et al., 2020)

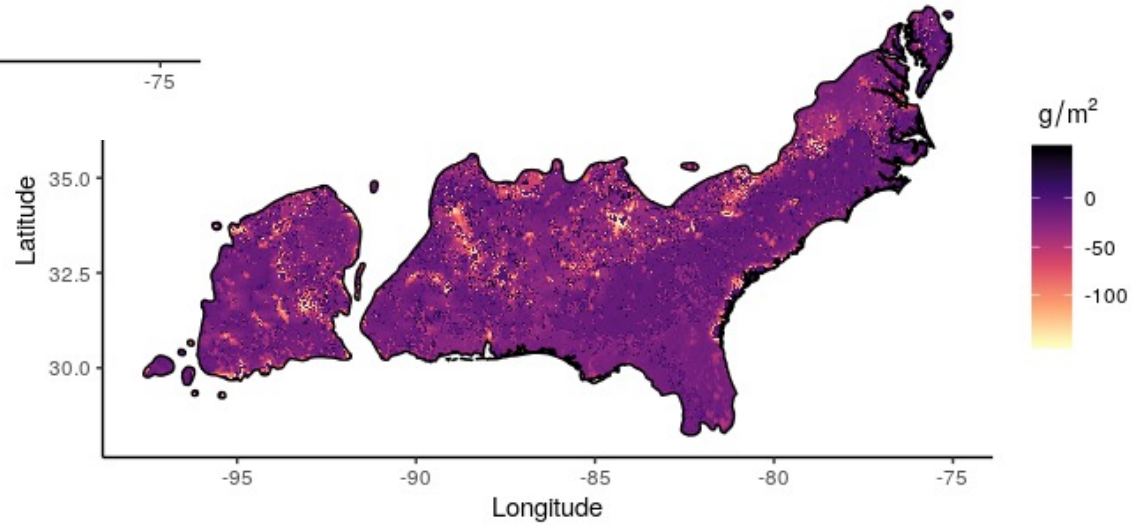
Current climate

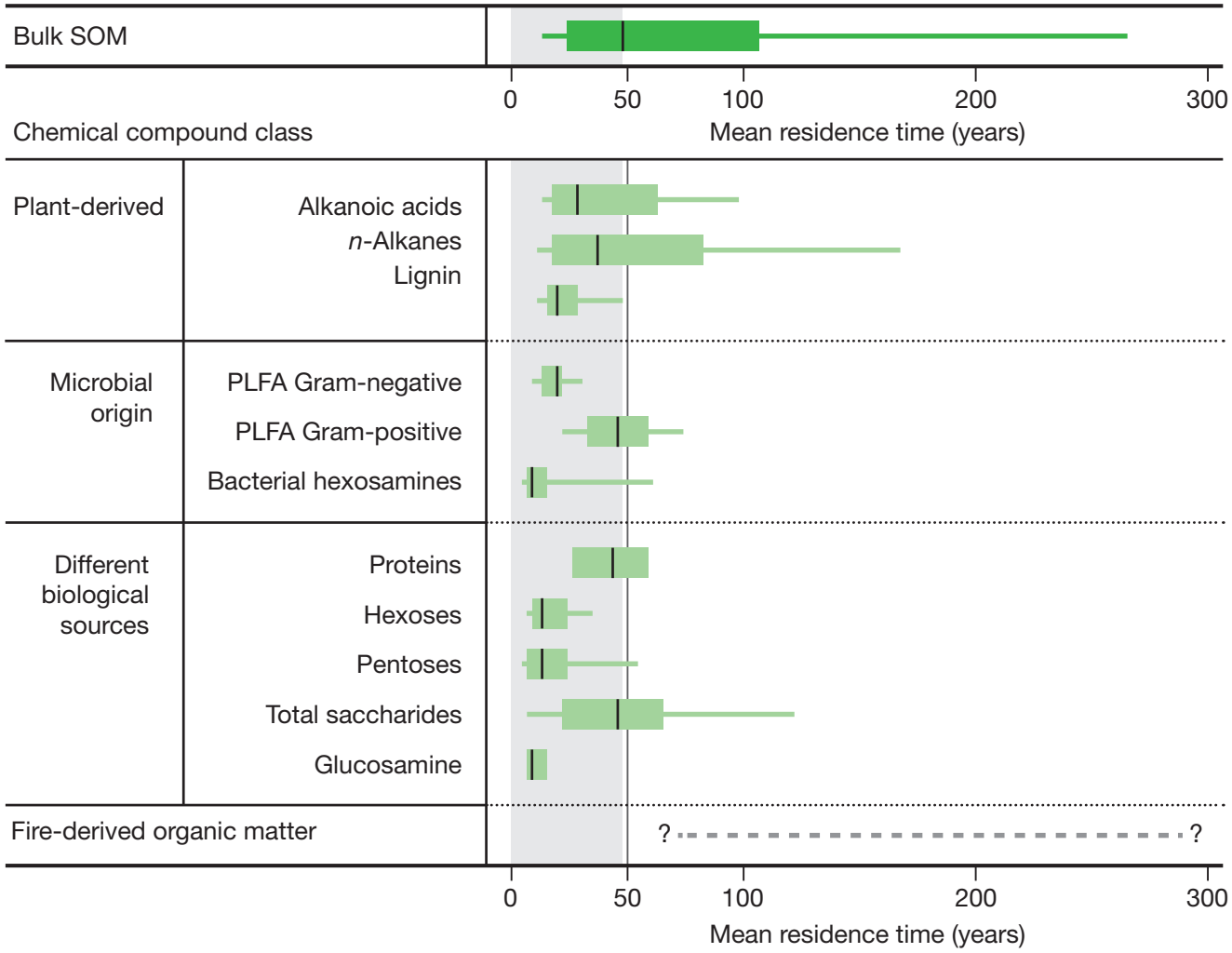


Future climate

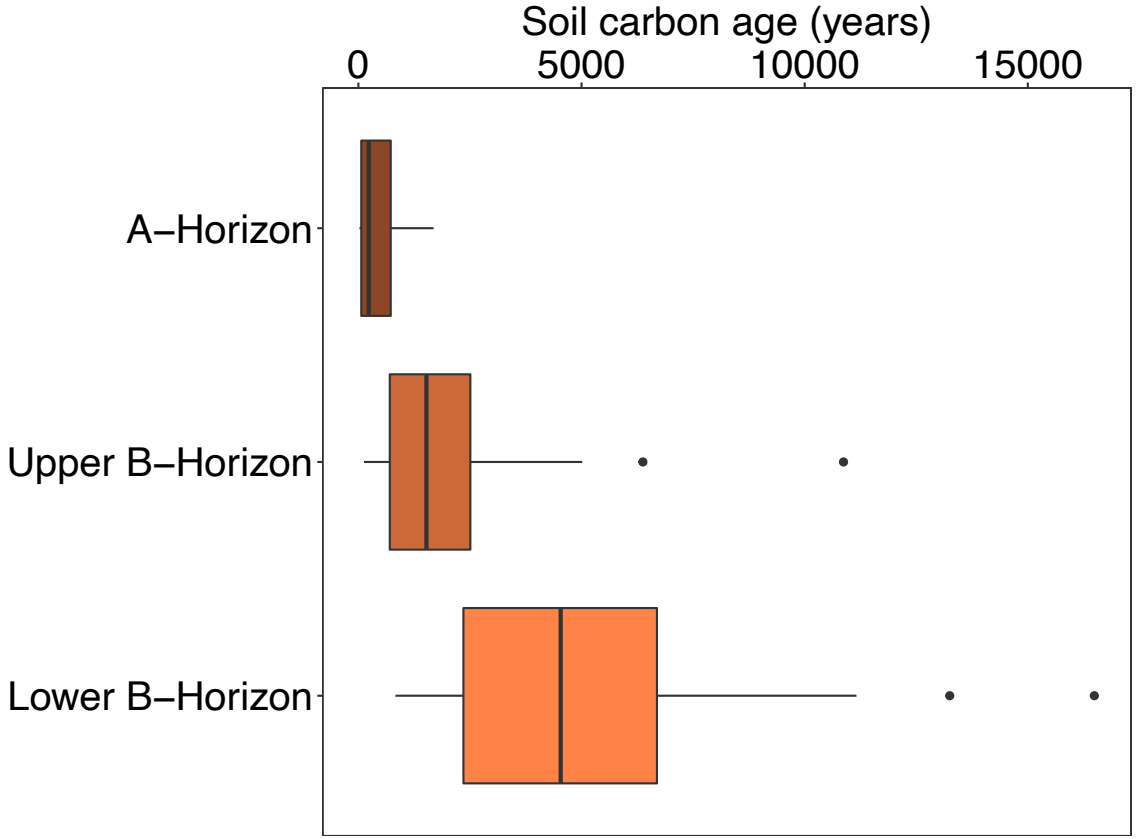


Soil C change

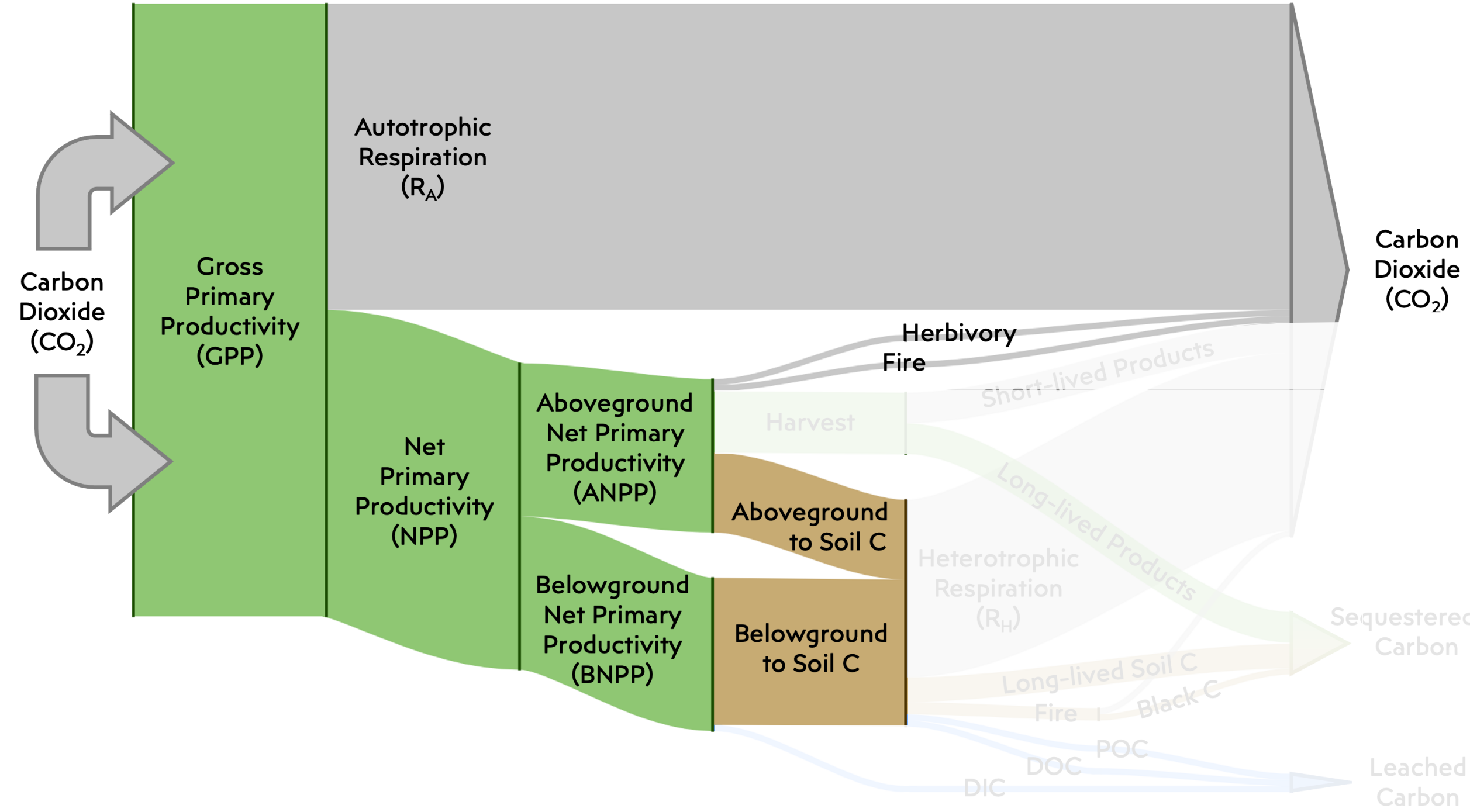




(Schmidt et al., 2011)



(National Ecological Observatory Data from Strahm et al., 2023)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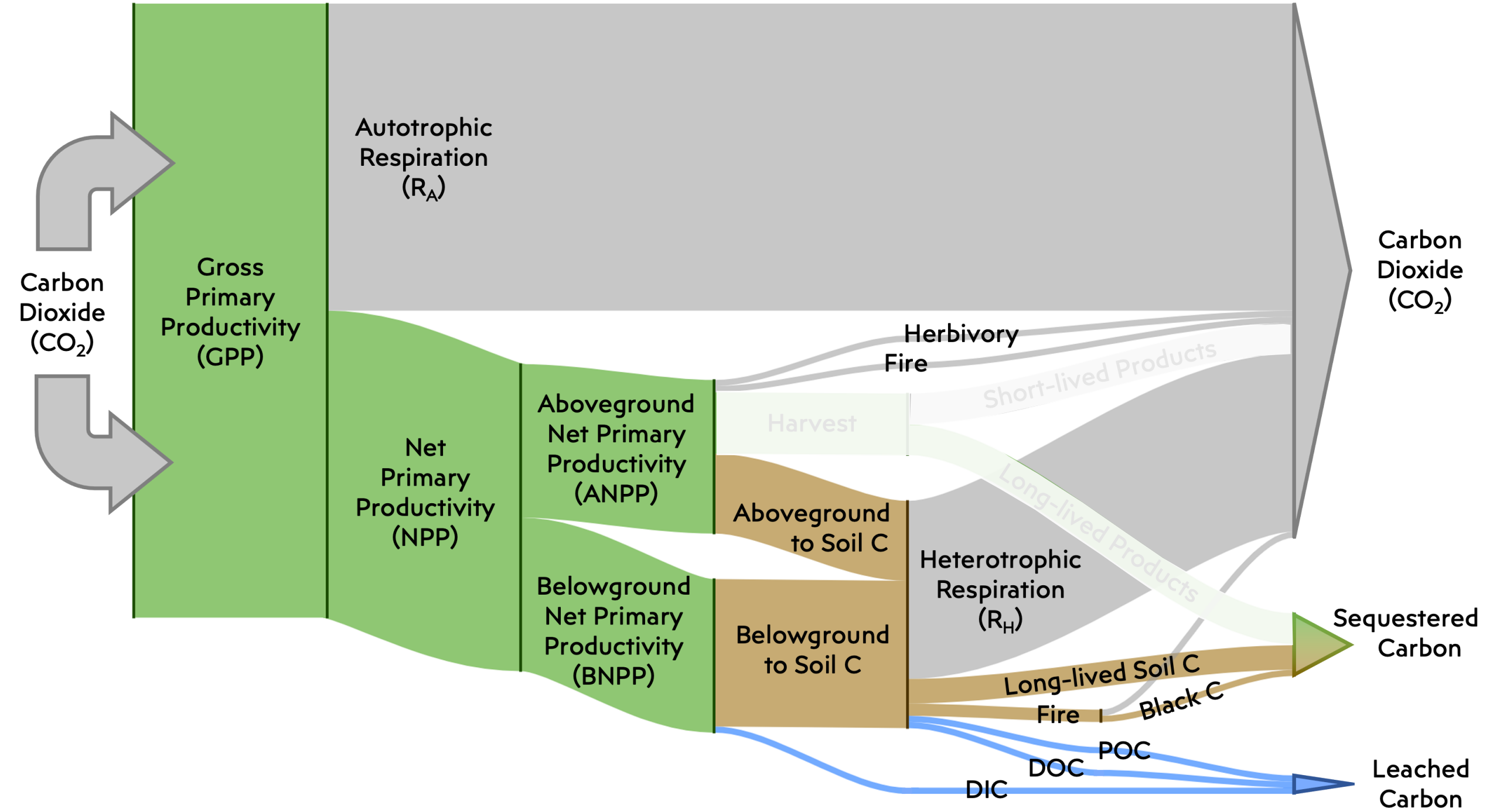
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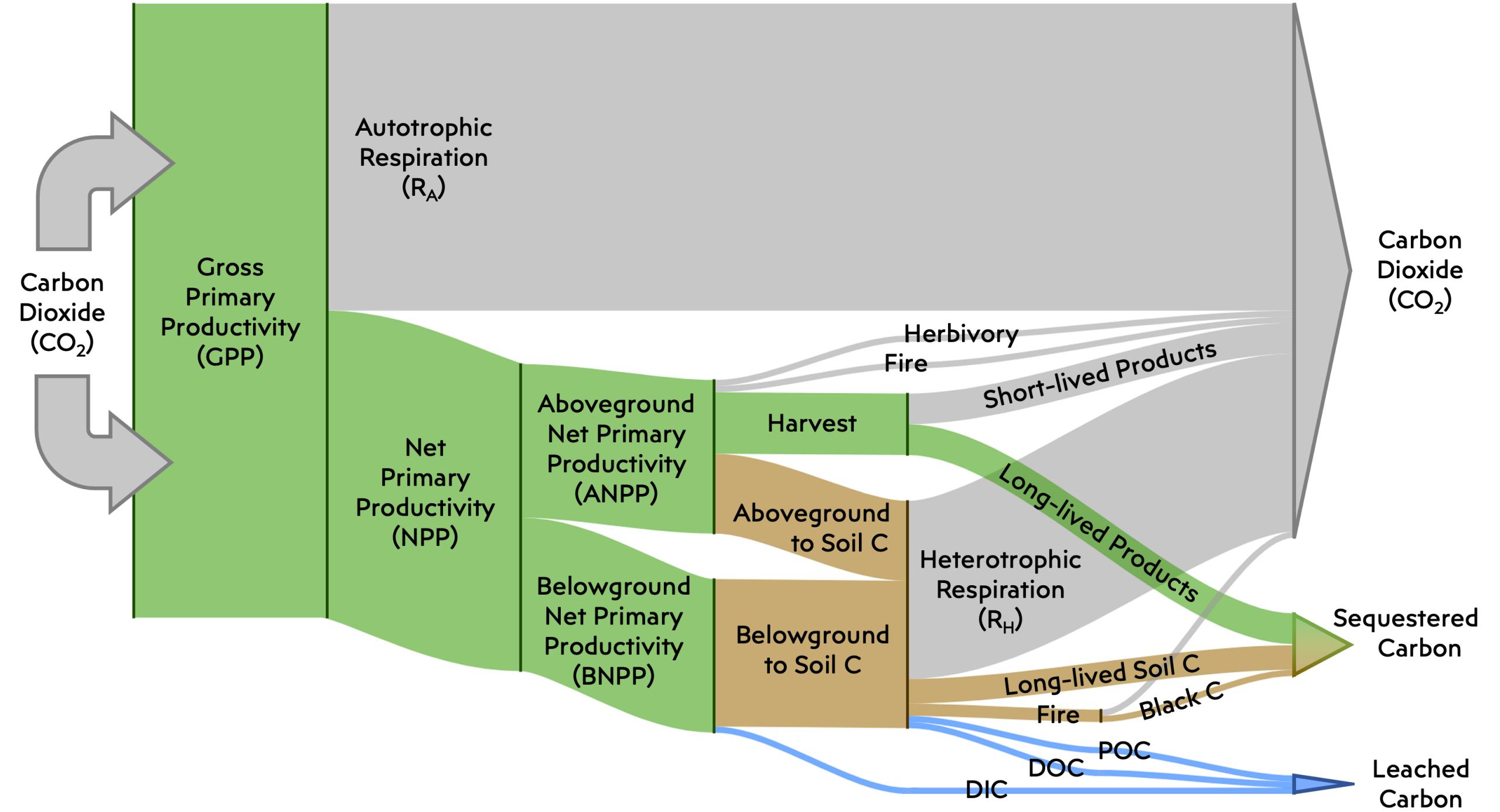
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Dr. Jennifer Russell
Dept. of Sustainable Biomaterials
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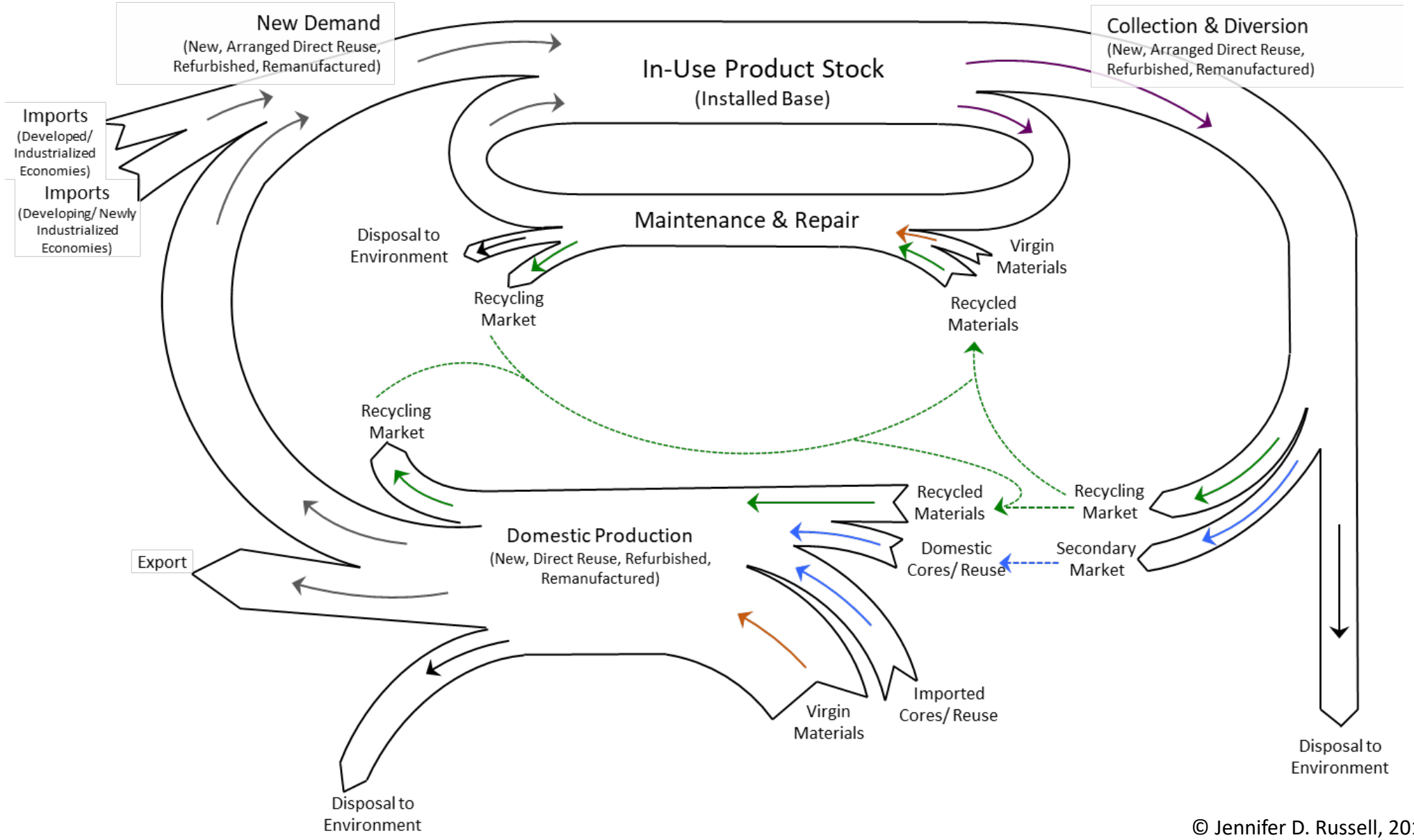


Eur J Forest Res (2009) 128:399–413
DOI 10.1007/s10342-009-0283-5

ORIGINAL PAPER

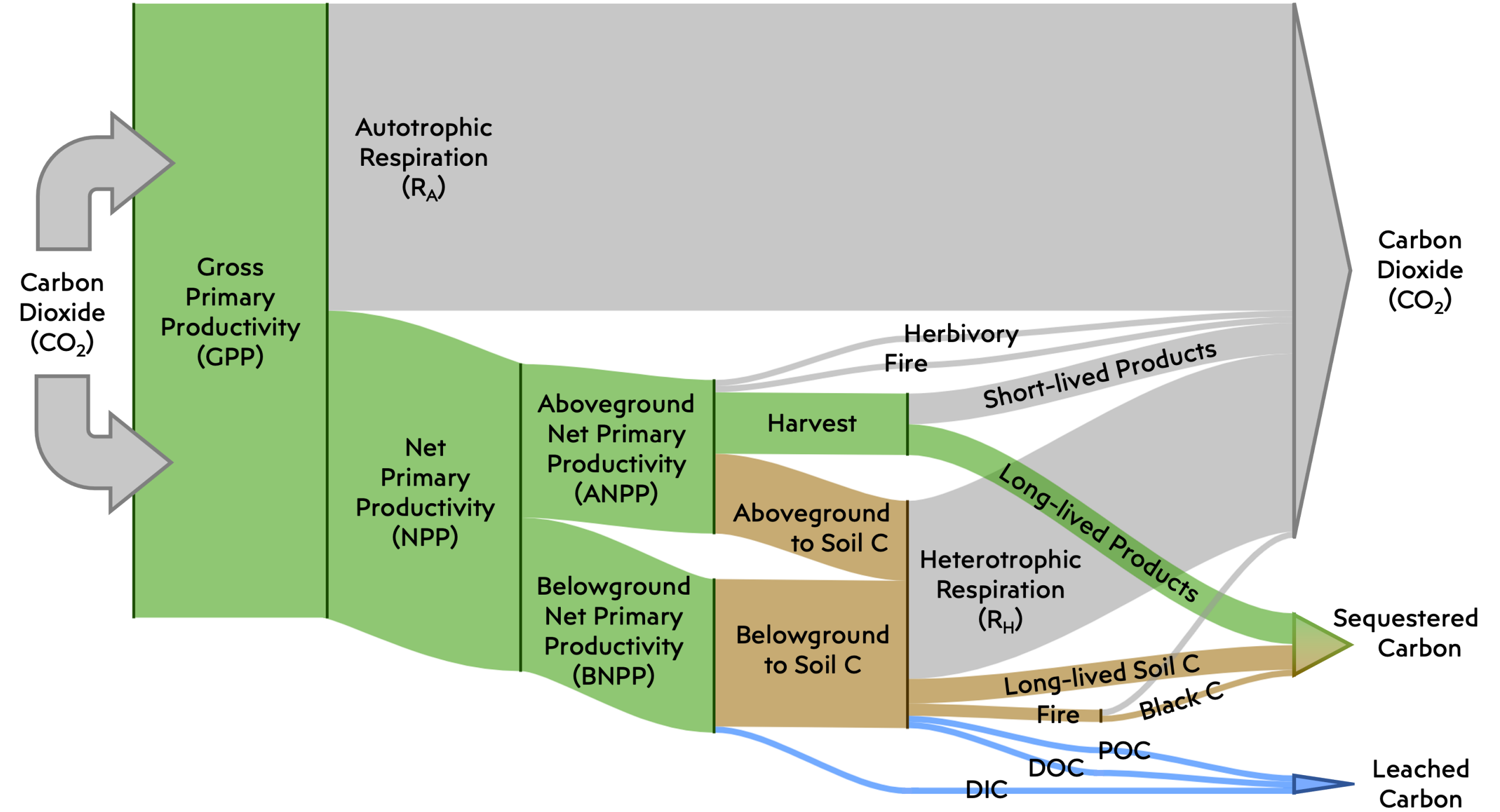
Forest management and carbon sequestration in wood products

Ingolf Profft · Martina Mund · Georg-Ernst Weber · Eberhard Weller · Ernst-Detlef Schulze

Table 7 Average mean residence time (MRT), and average total residence time of wood products from timber harvested in Thuringian state forests (this study) and of dead wood in temperate forest ecosystems (Wirth et al. 2004)

Species group	MRT (total residence time) (years)	
	Wood products	Dead wood
Beech	19 (56)	Deciduous trees, 14 (41)
Oak	20 (59)	
Spruce	21 (62)	Coniferous trees, 34 (103)
Pine	24 (73)	
Mean Thuringia[a]	20 (62)	28 (84)

[a] Weighted by area. MRT = t63 = 63% of the initial amount of a wood product is decomposed or burned, total residence time = t95 = 95% of the initial amount of a wood product is decomposed or burned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Carbon: Seeing the Forest (and Products) for the Trees

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Department of Forest Resources and Environmental Conservation

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Virginia Tech