Table 1. Emission factors ($g\,kg^{-1}$) for species emitted from different types of biomass burning[a].

	Tropical Forest	Savanna	Crop Residue	Pasture Maintenance	Boreal Forest	Temperate Forest	Extratropical Forest[b]
Carbon Dioxide (CO_2)	1643 (58)	1686 (38)	1585 (100)	1548 (142)	1489 (121)	1637 (71)	1509 (98)
Carbon Monoxide (CO)	93 (27)	63 (17)	102 (33)	135 (38)	127 (45)	89 (32)	122 (44)
Methane (CH_4)	5.07 (1.98)	1.94 (0.85)	5.82 (3.56)	8.71 (4.97)	5.96 (3.14)	3.92 (2.39)	5.68 (3.24)
Acetylene (C_2H_2)	0.44 (0.35)	0.24 (0.10)	0.27 (0.08)	0.21 (0.29)	0.18 (0.10)	0.29 (0.10)	0.19 (0.090)
Ethylene (C_2H_4)	1.06 (0.37)	0.82 (0.35)	1.46 (0.59)	1.28 (0.71)	1.42 (0.43)	1.12 (0.35)	1.38 (0.42)
Ethane (C_2H_6)	0.71 (0.28)	0.66 (0.41)	0.91 (0.49)	0.95 (0.43)	1.79 (1.14)	1.12 (0.67)	1.70 (1.05)
Propadiene (C_3H_4)	0.016 (0.0066)	0.012 (0.005)	–	0.020 (0.009)	–	–	–
Propylene (C_3H_6)	0.64 (0.43)	0.79 (0.56)	0.68 (0.37)	0.85 (0.66)	1.13 (0.60)	0.95 (0.54)	1.11 (0.61)
Propyne (C_3H_4)	–	–	–	–	0.059	–	0.059
Propane (C_3H_8)	0.126 (0.060)	0.10 (0.067)	0.28 (0.15)	0.22 (0.10)	0.44	0.26 (0.11)	0.42 (0.18)
n-Butane (C_4H_{10})	0.038 (0.023)	0.016 (0.013)	0.072 (0.036)	0.040 (0.018)	0.12	0.083 (0.10)	0.12 (0.14)
i-Butane (C_4H_{10})	0.011 (0.009)	0.0043 (0.0027)	0.025 (0.013)	0.014 (0.0063)	0.042	–	0.042
1-Butene (C_4H_8)	0.079 (0.024)	0.043 (0.022)	0.134 (0.060)	0.17 (0.077)	0.16	–	0.16
i-Butene (C_4H_8)	0.11 (0.051)	0.024 (0.0051)	0.117 (0.060)	0.11 (0.05)	0.11	–	0.11
1,3-Butadiene (C_4H_6)	0.039	0.052 (0.028)	0.151 (0.072)	–	0.14	–	0.14
trans-2-Butene (C_4H_8)	0.029 (0.013)	0.011 (0.0055)	0.057 (0.030)	0.050 (0.023)	0.040	–	0.040
cis-2-Butene (C_4H_8)	0.024 (0.010)	0.0084 (0.0043)	0.043 (0.023)	0.040 (0.018)	0.030	–	0.030
n-Pentane (C_5H_{12})	8.03×10^{-3} (8.03×10^{-3})	0.0032 (0.0032)	0.025 (0.012)	0.0056 (0.0025)	0.085	–	0.085
i-Pentane (C_5H_{12})	0.010 (0.010)	0.0022 (0.0032)	0.020 (0.012)	0.0074 (0.0033)	0.038	–	0.038
trans-2-Pentene (C_5H_{10})	3.30×10^{-3}	0.0045 (0.0028)	–	–	–	–	–
cis-2-Pentene (C_5H_{10})	1.90×10^{-3}	0.0025 (0.0018)	–	–	–	–	–
3-Methyl-1-Butene (C_5H_{10})	3.80×10^{-3}	0.0051 (0.0034)	–	–	–	–	–
2-Methyl-2-Butene (C_5H_{10})	4.00×10^{-3}	0.0048 (0.0035)	–	–	–	–	–
2-Methyl-1-Butene (C_5H_{10})	4.40×10^{-3}	0.0059 (0.0037)	–	–	–	–	–
Isoprene (C_5H_8)	0.13 (0.056)	0.039 (0.027)	0.38 (0.16)	0.12 (0.055)	0.15	–	0.15
Cyclopentane (C_5H_{10})	–	–	0.0019 (0.0012)	–	–	–	–
2+3-Methylpentane (C_6H_{14})	–	–	–	–	0.036	–	0.036
2-Methyl-1-Pentene (C_6H_{12})	2.80×10^{-3}	0.0035 (0.0021)	–	–	–	–	–
n-Hexane (C_6H_{14})	0.010	0.013 (0.0074)	–	–	0.055	–	0.055
Heptane (C_7H_{16})	5.60×10^{-3}	0.0070 (0.0072)	–	–	0.048	–	0.048
Benzene (C_6H_6)	0.39 (0.16)	0.20 (0.084)	0.15 (0.04)	0.70 (0.32)	1.11	–	1.11
Toluene ($C_6H_5CH_3$)	0.26 (0.13)	0.080 (0.058)	0.19 (0.06)	0.34 (0.15)	0.48	–	0.48
Xylenes (C_8H_{10})	0.11 (0.082)	0.014 (0.024)	–	0.11 (0.050)	0.18	–	0.18
Ethylbenzene (C_8H_{10})	0.050 (0.036)	0.006 (0.010)	–	0.067 (0.030)	0.051	–	0.051
n-Propylbenzene (C_9H_{12})	–	–	–	–	0.018	–	0.018
α-Pinene ($C_{10}H_{16}$)	–	–	–	–	1.64	–	1.64
β-Pinene ($C_{10}H_{16}$)	–	–	–	–	1.45	–	1.45
Ethanol (CH_3CH_2OH)	–	–	–	–	0.055	–	0.055
Methanol (CH_3OH)	2.43 (0.80)	1.18 (0.41)	3.29 (1.38)	5.84 (3.42)	2.82 (1.62)	1.93 (1.38)	2.70 (1.75)
Phenol (C_6H_5OH)	0.45 (0.088)	0.52 (0.36)	0.52 (0.14)	1.68 (3.34)	2.96	0.33 (0.38)	2.60 (3.00)
Formaldehyde (HCHO)	1.73 (1.22)	0.73 (0.62)	2.08 (0.84)	1.90 (1.11)	1.86 (1.26)	2.27 (1.13)	1.92 (1.14)
Glycolaldehyde ($C_2H_4O_2$)	2.84	0.81 (0.38)	2.01 (0.38)	–	0.77	0.25 (0.45)	0.70 (1.26)
Acetaldehyde (CH_3CHO)	1.55 (0.75)	0.57 (0.30)	1.24 (0.28)	2.40 (1.08)	–	–	–
Acrolein (C_3H_4O)	0.65 (0.23)	–	–	–	–	–	–
Furaldehydes	0.29 (0.0010)	–	–	–	–	–	–
Propanal (C_3H_6O)	0.10 (0.026)	–	–	0.16 (0.074)	–	–	–
Methyl Propanal (C_4H_8O)	0.18 (0.075)	–	–	0.33 (0.15)	–	–	–
Hexanal ($C_6H_{12}O$)	0.01 (0.005)	–	–	0.034 (0.015)	–	–	–
Acetone (C_3H_6O)	0.63 (0.17)	0.16 (0.13)	0.45 (0.07)	1.05 (0.47)	0.75	–	0.75
Methyl Vinyl Ether (C_3H_6O)	–	0.16 (0.045)	0.08 (0.01)	–	–	–	–
Methacrolein (C_4H_6O)	0.15 (0.045)	–	–	0.40 (0.18)	0.087	–	0.087
Crotonaldehyde (C_4H_6O)	0.24 (0.068)	–	–	0.60 (0.27)	–	–	–
2,3-Butanedione ($C_4H_6O_2$)	0.73 (0.22)	–	–	1.58 (0.71)	–	–	–
Methyl Vinyl Ketone (C_4H_6O)	0.39 (0.11)	–	–	1.00 (0.45)	0.20	–	0.20
Methyl Ethyl Ketone (C_4H_8O)	0.50 (0.21)	–	–	0.94 (0.42)	0.22	–	0.22
2-Pentanone ($C_5H_{10}O$)	0.08 (0.024)	–	–	0.17 (0.077)	–	–	–
3-Pentanone ($C_5H_{10}O$)	0.03 (0.011)	–	–	0.08 (0.034)	–	–	–
Furan (C_4H_4O)	0.41 (0.10)	0.17 (0.058)	0.11 (0.04)	1.02 (0.43)	0.80 (0.50)	0.20 (0.21)	0.72 (0.62)
3-Methylfuran (C_5H_6O)	0.59 (0.20)	–	–	1.41 (0.64)	–	–	–
2-Methylfuran (C_5H_6O)	0.08 (0.028)	–	–	0.20 (0.091)	–	–	–
Other substituted furans	1.21 (0.016)	–	–	–	–	–	–
C_6 Carbonyls	0.24 (0.11)	–	–	0.61 (0.28)	–	–	–
Acetol ($C_3H_6O_2$)	1.13 (0.12)	0.45 (0.24)	3.77 (0.91)	6.18 (5.60)	–	–	–
Acetonitrile (CH_3CN)	0.41 (0.10)	0.11 (0.058)	0.21 (0.06)	0.55 (0.25)	0.61	–	0.61
Propenenitrile (C_3H_3N)	0.04 (0.01)	0.051 (0.022)	0.03 (0.002)	–	–	–	–
Propanenitrile (C_3H_5N)	0.090	0.031 (0.014)	0.06 (0.002)	–	–	–	–

Table 1. Continued.

	Tropical Forest	Savanna	Crop Residue	Pasture Maintenance	Boreal Forest	Temperate Forest	Extratropical Forest[b]
Pyrrole (C_4H_5N)	0.12 (0.038)	–	–	–	–	–	–
Formic Acid (HCOOH)	0.79 (0.66)	0.21 (0.096)	1.00 (0.49)	0.20 (0.64)	0.57 (0.46)	0.35 (0.33)	0.54 (0.47)
Acetic Acid (CH_3COOH)	3.05 (0.90)	3.55 (1.47)	5.59 (2.55)	10.4 (6.8)	4.41 (2.66)	1.97 (1.66)	4.08 (2.99)
Hydrogen Cyanide (HCN)	0.42 (0.26)	0.41 (0.15)	0.29 (0.38)	0.46 (0.45)	1.52 (0.82)	0.73 (0.19)	1.41 (0.60)
Dimethyl Sulfide (C_2H_6S)	1.35×10^{-3} (1.71×10^{-3})	0.0013 (0.0011)	–	–	4.65×10^{-3}	–	4.65×10^{-3}
Carbonyl Sulfide (OCS)	0.025	–	–	–	0.46 (0.47)	–	0.46 (0.47)
Chloromethane(CH_3Cl)	0.053 (0.038)	0.055 (0.036)	–	0.29 (0.13)	0.059	–	0.059
Dibromomethane (CH_2Br_2)	–	–	–	–	8.28×10^{-5}	–	8.28×10^{-5}
1,2-Dichloroethane ($C_2H_4Cl_2$)	–	–	–	–	1.29×10^{-3}	–	1.29×10^{-3}
Methyl Bromide (CH_3Br)	2.83×10^{-3} (2.38×10^{-3})	8.53×10^{-4} (8.62×10^{-4})	–	5.71×10^{-3} (2.57×10^{-3})	3.64×10^{-3}	–	3.64×10^{-3}
Methyl Iodide (CH_3I)	2.50×10^{-3} (3.45×10^{-3})	5.06×10^{-4} (3.88×10^{-4})	–	3.48×10^{-3} (1.56×10^{-3})	7.88×10^{-4}	–	7.88×10^{-4}
Trichloromethane ($CHCl_3$)	2.94×10^{-4} (6.75×10^{-3})	0.012 (0.020)	–	6.32×10^{-4} (2.84×10^{-4})	–	–	–
Dichlorodifluoromethane (CCl_2F_2)	2.80×10^{-3}	–	–	–	–	–	–
Ethylchloride (C_2H_5Cl)	–	–	–	–	7.47×10^{-4}	–	7.47×10^{-4}
Ammonia (NH_3)	1.33 (1.21)	0.52 (0.35)	2.17 (1.27)	1.47 (1.29)	2.72 (2.32)	0.78 (0.82)	2.46 (2.35)
Methyl Nitrate (CH_3ONO_2)	8.29×10^{-3} (1.60×10^{-2})	5.1×10^{-4} (3.7×10^{-4})	–	–	2.83×10^{-3}	–	2.83×10^{-3}
Ethyl Nitrate ($C_2H_5NO_3$)	5.70×10^{-3}	–	–	–	1.78×10^{-3}	–	1.78×10^{-3}
n-Propyl Nitrate ($C_3H_7NO_3$)	0.0003	–	–	–	3.23×10^{-4}	–	3.23×10^{-4}
i-Propyl Nitrate ($C_3H_7NO_3$)	0.001	–	–	–	3.23×10^{-3}	–	3.23×10^{-3}
2-Butyl Nitrate ($C_4H_9NO_3$)	0.0006	–	–	–	3.84×10^{-3}	–	3.84×10^{-3}
3-Pentyl Nitrate ($C_5H_{11}NO_3$)	–	–	–	–	7.27×10^{-4}	–	7.27×10^{-4}
2-Pentyl Nitrate ($C_5H_{11}NO_3$)	–	–	–	–	9.70×10^{-4}	–	9.70×10^{-4}
3-Methyl-2-Butyl Nitrate ($C_5H_{11}NO_3$)	–	–	–	–	1.15×10^{-3}	–	1.15×10^{-3}
3-Ethyltoluene (C_9H_{12})	–	–	–	–	0.024	–	0.024
2-Ethyltoluene (C_9H_{12})	–	–	–	–	0.011	–	0.011
4-Ethyltoluene (C_9H_{12})	–	–	–	–	0.015	–	0.015
1,2,3-Trimethylbenzene (C_9H_{12})	–	–	–	–	0.051	–	0.051
1,2,4-Trimethylbenzene (C_9H_{12})	–	–	–	–	0.030	–	0.030
1,3,5-Trimethylbenzene (C_9H_{12})	–	–	–	–	5.86×10^{-3}	–	5.86×10^{-3}
Hydrogen (H_2)	3.36 (1.30)	1.70 (0.64)	2.59 (1.78)	–	–	2.03 (1.79)	2.03 (1.79)
Sulfur Dioxide (SO_2)	0.40 (0.19)	0.48 (0.27)	–	0.32 (0.14)	–	–	–
Nitrous Acid (HONO)	1.18	0.20	–	0.16 (0.07)	–	0.52 (0.15)	0.52 (0.15)
Nitrogen Oxides (NO_x as NO)	2.55 (1.40)	3.9 (0.80)	3.11 (1.57)	0.75 (0.59)	0.90 (0.69)	2.51 (1.02)	1.12 (0.69)
Nitrous Oxide (N_2O)	–	–	–	–	0.41	0.16 (0.21)	0.38 (0.35)
NMOC (identified)	26.0 (8.8)	12.4 (6.2)	25.7 (9.8)	44.8 (30.1)	29.3 (10.1)	11.9 (7.6)	27.0 (13.8)
NMOC (identified + unidentified)[c]	51.9	24.7	51.4	89.6	58.7	23.7	54.0
Total Particulate Carbon	5.24 (2.91)	3.00 (1.43)	–	10.6 (4.8)	–	–	–
Total Suspended Particulate (TSP)	13	–	–	–	–	–	–
CN (particles 0.003–3 μm diameter)[d]	5.90×10^{16}	–	–	–	–	–	–
$PM^e_{2.5}$	9.1 (3.5)	7.17 (3.42)	6.26 (2.36)	14.8 (6.7)	15.3 (5.9)	12.7 (7.5)	15.0 (7.5)
PM_{10}	18.5 (4.1)	–	–	28.9 (13.0)	–	–	–
Black Carbon (BC)	0.52 (0.28)	0.37 (0.20)	0.75	0.91 (0.41)	–	–	0.56 (0.19)[f]
Organic Carbon (OC)	4.71 (2.73)	2.62 (1.24)	2.30	9.64 (4.34)	–	–	8.6–9.7[f]
Oxylate (C_2O_4)	0.04 (0.034)	0.0055 (0.0055)	–	0.040 (0.018)	–	–	–
Nitrate (NO_3)	0.11 (0.050)	0.016 (0.013)	–	0.14 (0.063)	–	–	–
Phosphate (PO_4)	5.56×10^{-3} (8.99×10^{-3})	0.0045 (0.0060)	–	1.07×10^{-3} (4.80×10^{-4})	–	–	–
Sulfate (SO_4)	0.13 (0.088)	0.018 (0.009)	–	0.19 (0.086)	–	–	–
Ammonium (NH_4)	5.64×10^{-3} (1.72×10^{-2})	0.0035 (0.0035)	–	3.97×10^{-3} (1.79×10^{-3})	–	–	–
Cl	0.15 (0.16)	0.23 (0.055)	–	0.24 (0.11)	–	–	–
Ca	0.085 (0.089)	0.021 (0.018)	–	0.020 (0.009)	–	–	–
Mg	0.040 (0.034)	0.016 (0.007)	–	0.030 (0.014)	–	–	–
Na	6.37×10^{-3} (5.46×10^{-3})	0.0055 (0.0045)	–	0.030 (0.014)	–	–	–
K	0.29 (0.28)	0.23 (0.053)	–	0.34 (0.15)	–	–	–

[a] See Sect. 2.3 for guidance in use. Emission factors are shown with an estimate of the natural variation in parenthesis, when available.
[b] EF calculated from a weighted average of boreal and temperate forest EF based on GFED3 biomass consumption estimates.
[c] Estimated (see Sect. 3.4).
[d] Number of particles per kg of fuel burned.
[e] PM_1–PM_5 categorized as $PM_{2.5}$.
[f] Source is Andreae and Merlet (2001).

categories at the user's discretion. As an example, we also derive values for an "extratropical forest" category (shown in Table 1) by merging the boreal and temperate forest EF with the formula described in Sect. 2.2.1. Some users may instead desire EF in more detail than is provided by our 14 categories in Tables 1–2 and this can often be retrieved by consulting the Supplement Tables. For instance, the EF for smoldering combustion of hand-piled crop residue (common in much of Asia) are very different from the EF for flaming combustion of crop residue produced by mechanized agriculture and they can be found separately in Table S13.