SUPPORTING INFORMATION (SI)

High-Resolution Mapping of Biomass Burning Emissions in Three Tropical Regions

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S1. Fuel loads

Biomass density data for shrub and grass is derived from an estimate for the maximum standing biomass in savannas. The following equation of biomass density versus annual rainfall (P, unit: mm) has been applied,[1] which was demonstrated to be in good agreement with the measured biomass density (kg Dry Matter m^{-2}).[2]

$$Biomass\ density = 4.9 \times 10^{-4} \times P - 0.58 \quad (1)$$

This equation was used in this work to estimate the maximum biomass in herbaceous cover. Monthly variability in the aboveground production of herbaceous biomass was accounted for by using the monthly precipitation data from the Global Precipitation Climatology Project (GPCP) of NASA Goddard Space Flight Center. This data set is available at a resolution of 1° × 1° and was used for monthly rainfall in 2010. We converted them to a 1 km grid resolution using the ordinary kriging interpolation method, assuming the data indicate the value at the central point of each pixel.[3]

The crop residue burning is found to be another significant source of biomass burning emissions in agriculture dominated areas. In this study, the burned crop residues covering broad categories of crop types (maize, sugarcane, rice, wheat, etc.) in each country in 2010 were collected from the Food and Agriculture Organization Statistical Yearbook (FAOSTAT) (http://faostat.fao.org) (SI Table S1). The amount of dry crop residues burned was calculated from harvested area statistics, taken from FAOSTAT (domain Production/crops), and the mean default crop values of mass of fuel available for combustion and combustion factor[4] in IPCC (2006) Guidelines for National Greenhouse Gas

Inventories.[5] The mass is then reduced by the fraction of crop residue burned on-site (assumed to be 10%) following IPCC (2000) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories: Agriculture, Section 4A.2.1.1.[6] And then, the burned crop residues were allocated according to the burned area in cropland for each country.

The tropical peatland burning in Sumatra and Kalimantan of Indonesia (SI Figure S3) is also a contributor to the total emissions because of the extensive burning of soil organic matter in drained peatland.[7,8] Actually, large fires that burn for some time can go deep down to the soil up to a depth of 30 cm,[9] and can burn even deeper during dry condition. Therefore, we also employed the 1 km spatial resolution belowground biomass (BGB) of peatland as fuels for combustion during peat fires. However, since relatively little information currently is available on the depth or thickness of peatland burning in Indonesia. Here, we assumed that a fire consumed almost 50% of the BGB in peatland. This assumption is very similar to the study from Chang and Song,[10] which used the mean peat dry bulk density of 100 kg m^{-3} and average carbon concentration of 60% with an average burn depth of 51 cm in Indonesia.[4]

S2. Combustion factor

For purposes of estimating combustion factors, each burned pixel was assigned a cover type (forest, woodland, or grassland) based on the percent tree cover (Tc) after Ito and Penner.[2]

for forest:

We employed the Vegetation Condition Index (*VCI*) as a surrogate to reflect the fuel moisture

conditions required for calculating the *CF*, which has been demonstrated to be effective in monitoring vegetation condition for various environments.[11] This parameter is derived from the Normalized Difference Vegetation Index (NDVI).[12] The monthly NDVI data were derived from the MODIS Vegetation Indices Monthly L3 Global 1-km product (MOD13A3) for 2010 at a spatial resolution of 1 km:

$$VCI = 100 \times \frac{NDVI_t - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \quad (2)$$

where $NDVI_t$ is the NDVI at time t, and $NDVI_{min}$ and $NDVI_{max}$ are the minimum and maximum of NDVI, respectively, in the corresponding month in 2010. Then, we equally divided the *VCI* values, which range from 0 to 100, into six different categories, representing fuel moisture conditions of very dry, dry, moderate, moist, wet, and very wet, respectively.[11] The monthly variation in moisture conditions is used to associate with fuel moisture category factors (*mcf*), and *CF* is a function of moisture category factor:[13]

$$CF = (1 - e^{-1})^{mcf} \quad \text{Tc} > 60\% \quad (3)$$

The *mcf* value (very dry: 0.33, dry: 0.5, moderate: 1, moist: 2, wet: 4, very wet: 5)[13] is determined using the fuel moisture condition derived from MODIS VCI data, which increases from dry to wet fuel conditions. This equation also applies to the estimation of CFs of duff, grass and shrubs with a separate equation for woody fuels and litter according to Anderson et al.[13] The VCI-based CF estimation presented strong spatial and temporal variations and can reflect the fuel moisture conditions of different fuel types, which were demonstrated to be effective in quantifying the

proportion of actual burned biomass in continental regions.[4,11]

for woodland:

CF was estimated based on the Tc according to Ito and Penner.[2]

$$CF = \exp(-0.013 \times T_c) \quad 40\% < \text{Tc} \leq 60\% \tag{4}$$

For grassland, Ito and Penner[2] developed the relationship between *CF* and the percentage of green grass to total grass (PGREEN) based on measurements in Africa.

for grassland:

$$CF = \frac{1}{100} \times (-213 \times \text{PGREEN} + 138) \quad \text{Tc} \leq 40\% \tag{5}$$

Here, NDVI was used to determine PGREEN by using the following equation:[12,15,16]

$$\text{PGREEN}_t = \frac{NDVI_t - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \tag{6}$$

where *t* denotes the month, and $NDVI_{min}$ and $NDVI_{max}$ are the minimum and maximum of all NDVI values for a given pixel over the preceding growing season. We limited the value of *CF* to the range from 0.44 to 0.98 to avoid any extrapolation beyond the measured values for grassland fires.[14] The spatial distributions and variations of *CFs* are shown in SI Figure S4.

S3. Burned waste

The amount of residential waste burned (W_{Bres}) is calculated as:

$$W_{Bres} = [(MSW_P \times P_{rural}) + (MSW_P \times P_{urban} \times f_{uncollected})] \times B_{frac} \tag{4}$$

where P_{rural} and P_{urban} are the rural and urban population, and $f_{uncollected}$ is the fraction of waste that is not collected. In developing countries, only the urban populations are assumed to have waste

collection.

The amount of waste burned by open burning in dumps (W_{Bdump}) is expressed as:

$$W_{Bdump} = (MSW_P \times P_{urban} \times f_{collected}) \times B_{frac} \quad (5)$$

where $f_{collected}$ is the waste collection efficiency. IPCC recommends a default value of 0.6 for B_{frac}, representing 60% of the total waste available to be burned that is actually burned.[17] In this study, the value of each parameter used for the calculations here is derived from Wiedinmyer et al.[17] and available in SI Table S3.

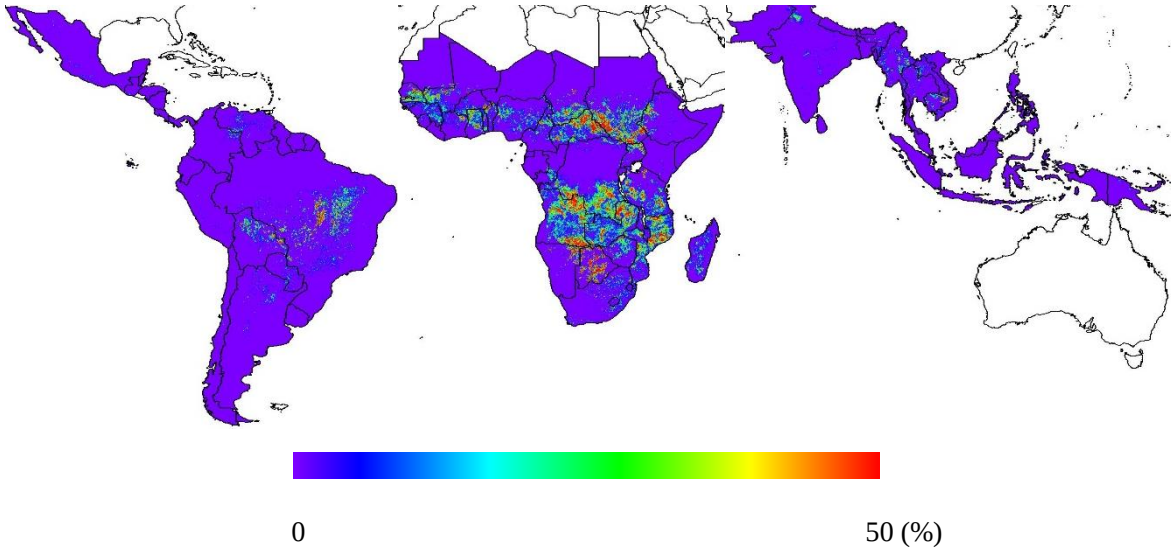
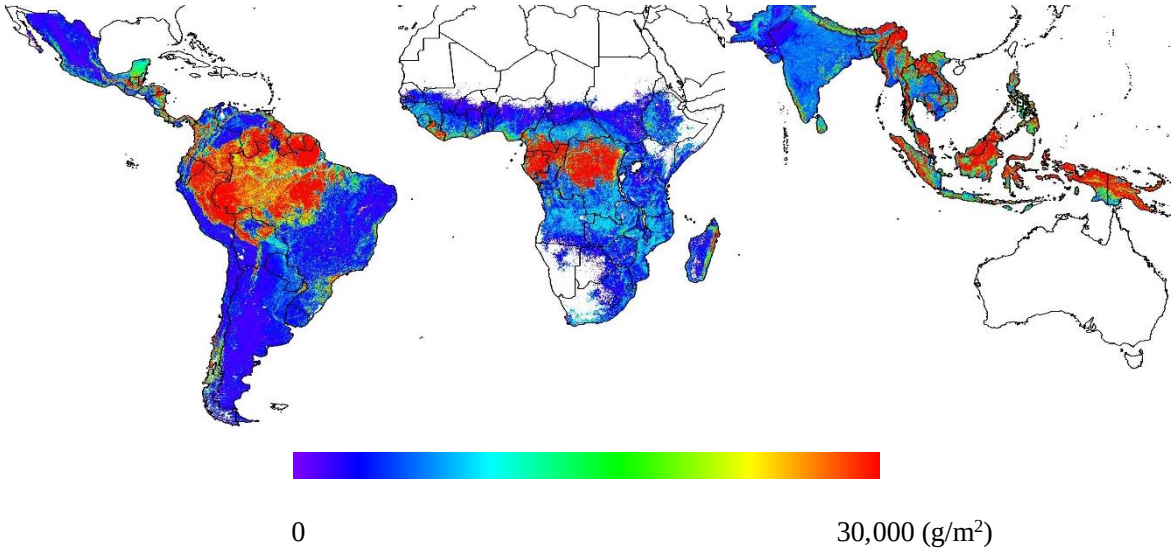


Figure S1. Mean annual area burned with 1 km grid, expressed as the fraction of each grid cell that burns in the year of 2010, derived from the January-December 2010 monthly MCD64A1 burned area time series with 500 m spatial resolution.

(a)



(b)

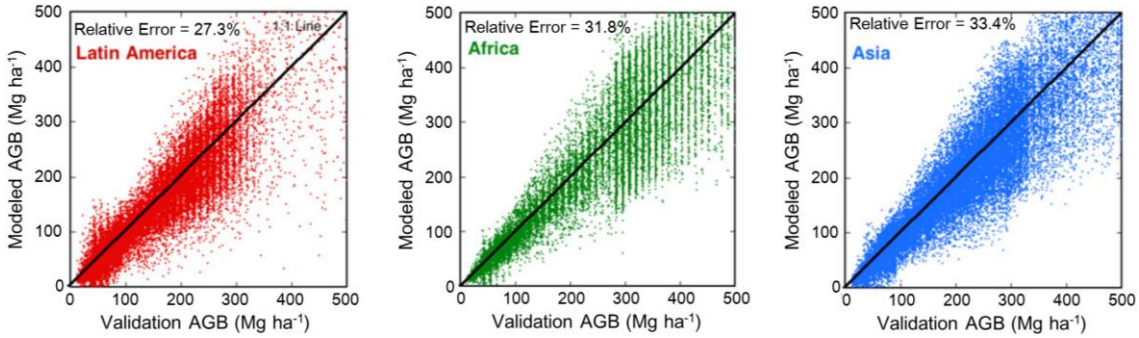


Figure S2. (a) Spatial distribution of above ground biomass density at 1 km spatial resolution and (b) their validation of modeled AGB by a mixture of ground and Lidar observation estimated AGB in three tropical regions.[18]

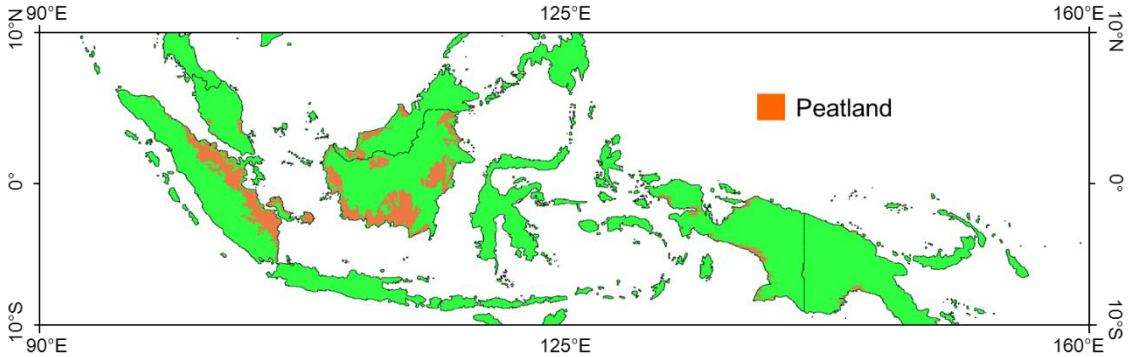


Figure S3. The spatial distribution of peat forest (orange area) in Southeast Asia, extracted from World Wildlife Fund terrestrial ecoregions map (1999-2000).

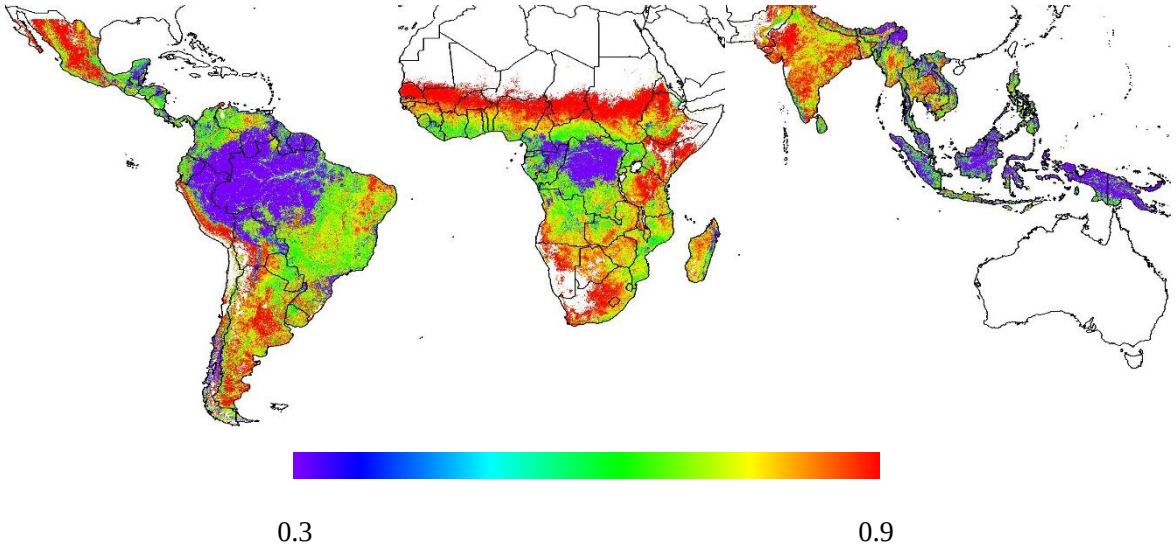


Figure S4. Spatial distribution of average monthly combustion factors in 2010.

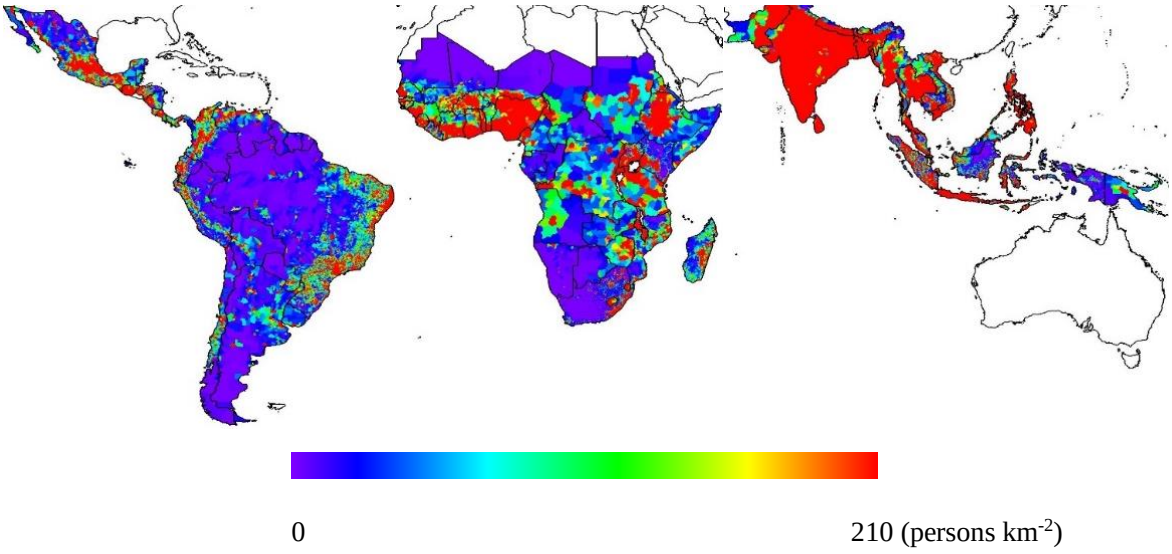
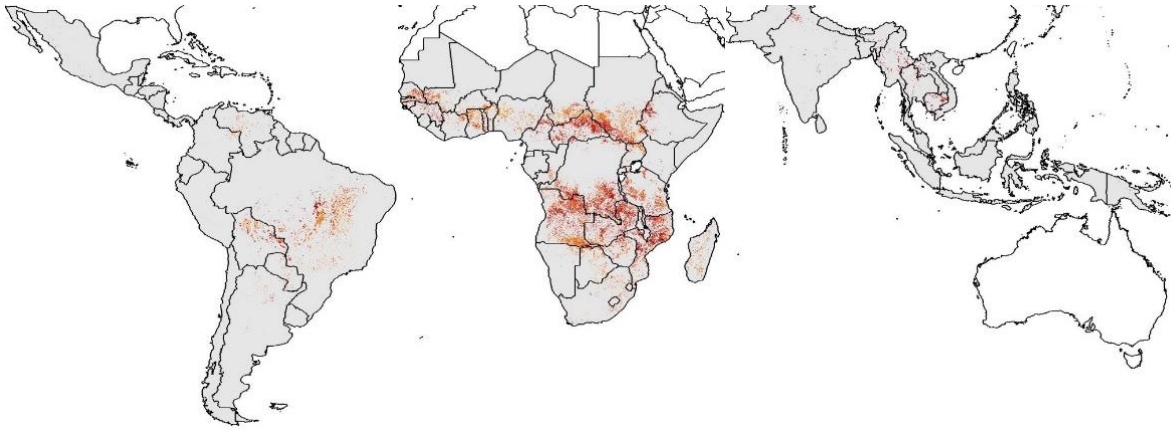


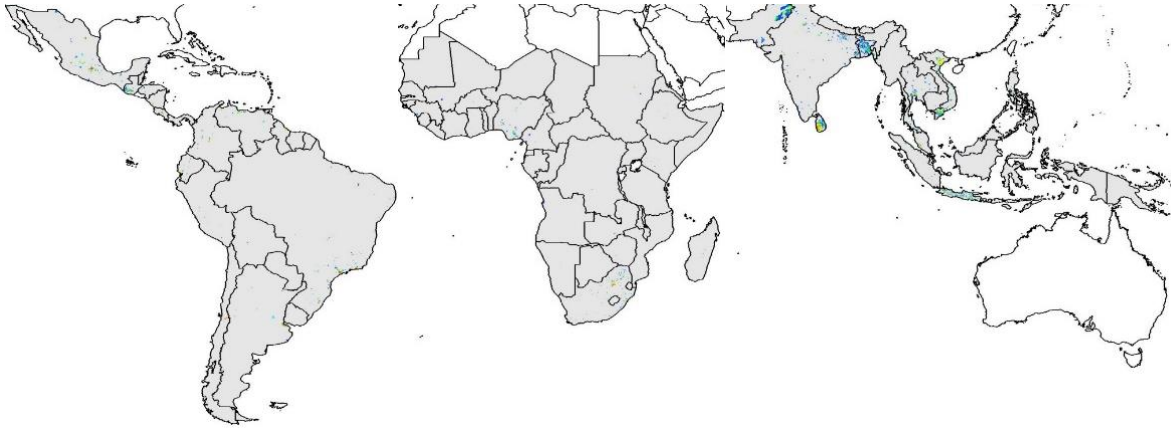
Figure S5. Gridded maps of population density for 2010 from GPW3.[19]

Americas: Argentina, Belize, Bolivia, Brazil, Chile, Costa Rica, Colombia, Ecuador, French Guiana, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, Venezuela; Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Guinea, Cameroon, Central African Republic, Chad, Congo, Cote d'Ivoire, Demo. Rep. Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea-Bissau, Kenya, Lesotho, Liberia, Malawi, Madagascar, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra, Somalia, South Africa, Sudan, Swaziland, Togo, Mali, Uganda, Tanzania, Zambia, Zimbabwe; Asia: Bangladesh, Bhutan, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Sri Lanka, Thailand, Vietnam.

(a) Burned vegetation



(b) Burned waste



(c) Burned fuelwood

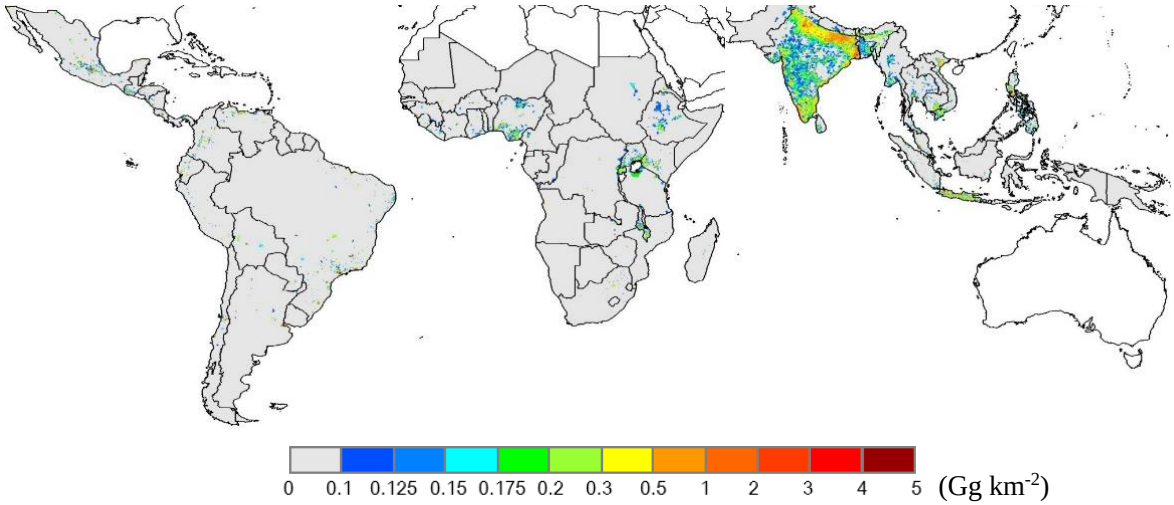
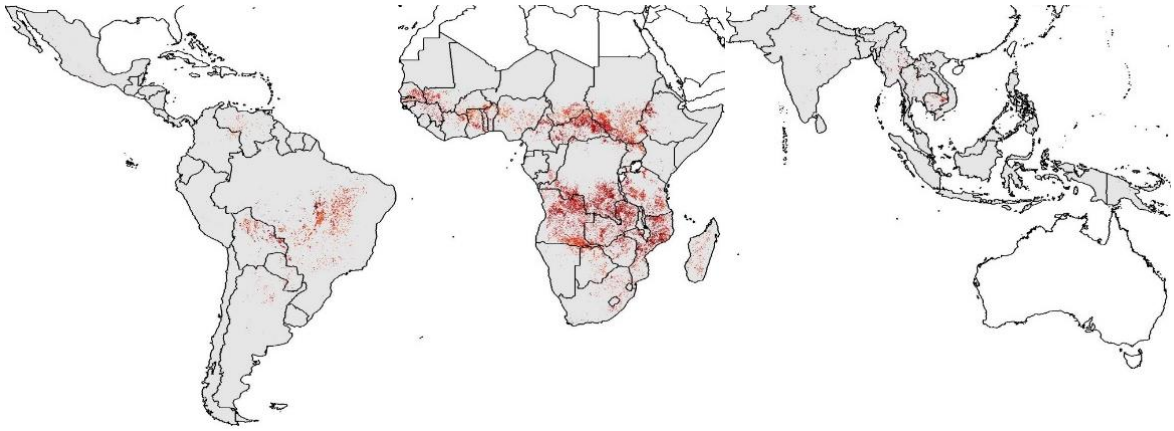


Figure S6. Spatial distribution of the estimated annual burned biomass from burning of (a) vegetation, (b) human waste and (c) fuelwood with 1 km spatial resolution.

(a) Vegetation CO



(b) Waste CO

(c) Fuelwood CO

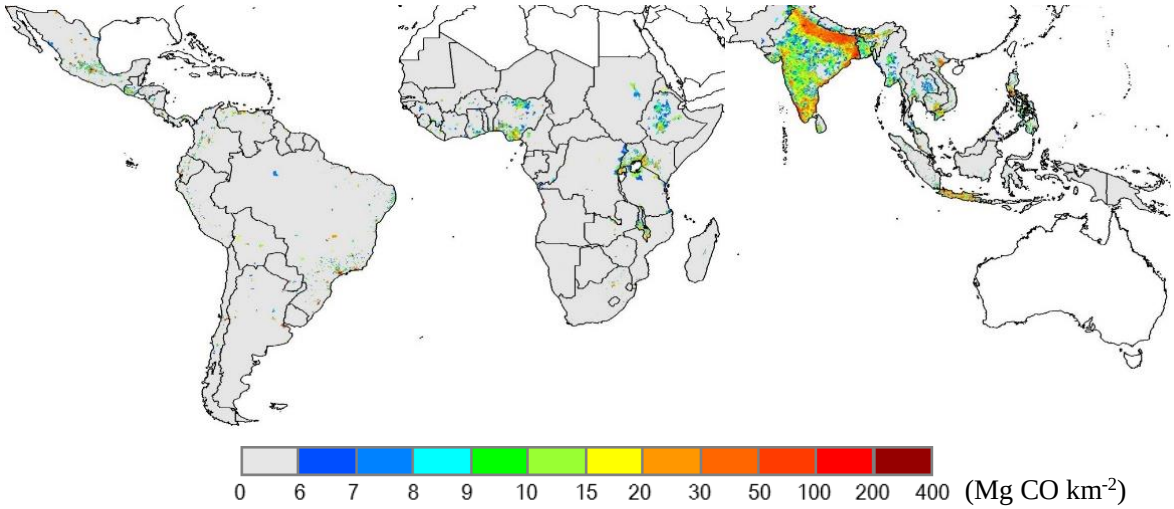
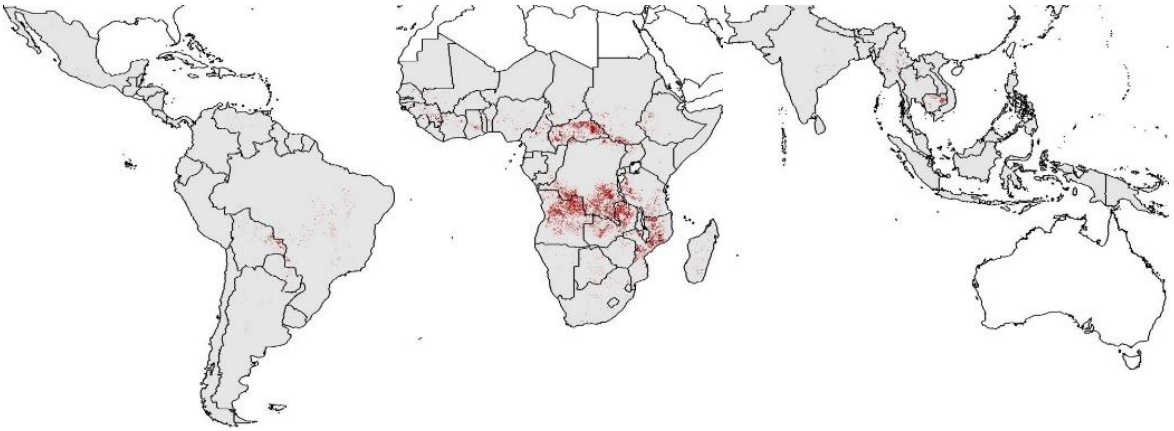
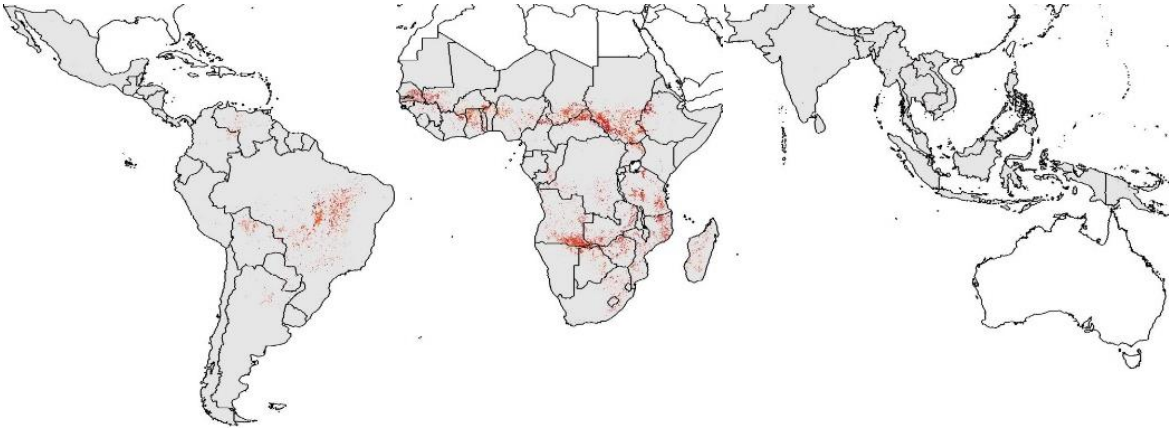


Figure S7. Spatial distribution of the estimated CO emissions from burning of (a) vegetation, (b) human waste and (c) fuelwood with 1 km spatial grid.

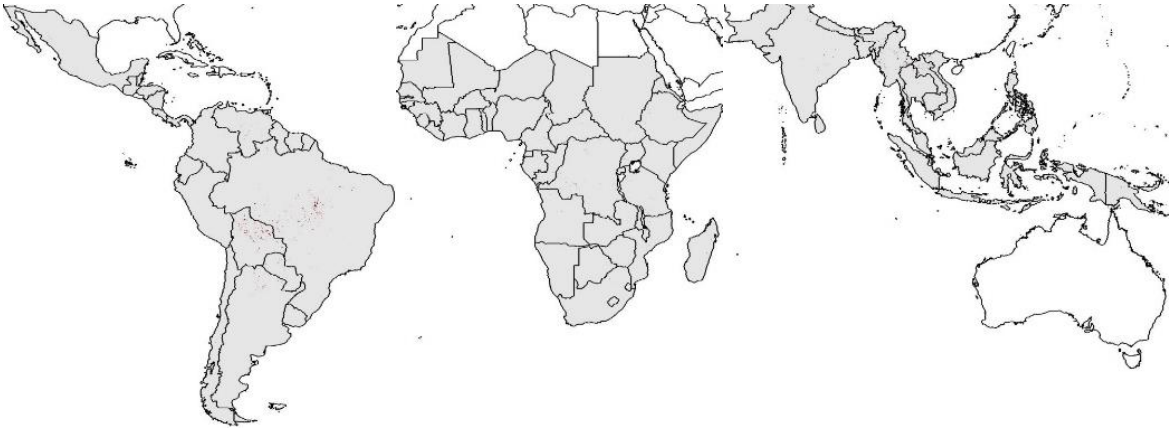
(a) Woody Savanna/Shrubland



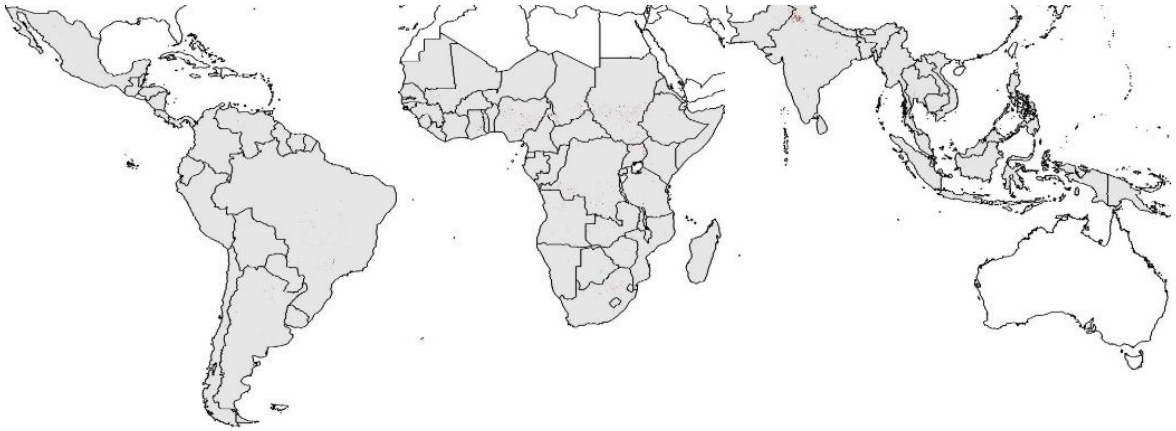
(b) Savanna/Grassland



(c) Forest



(d) Cropland



(e) Peatland

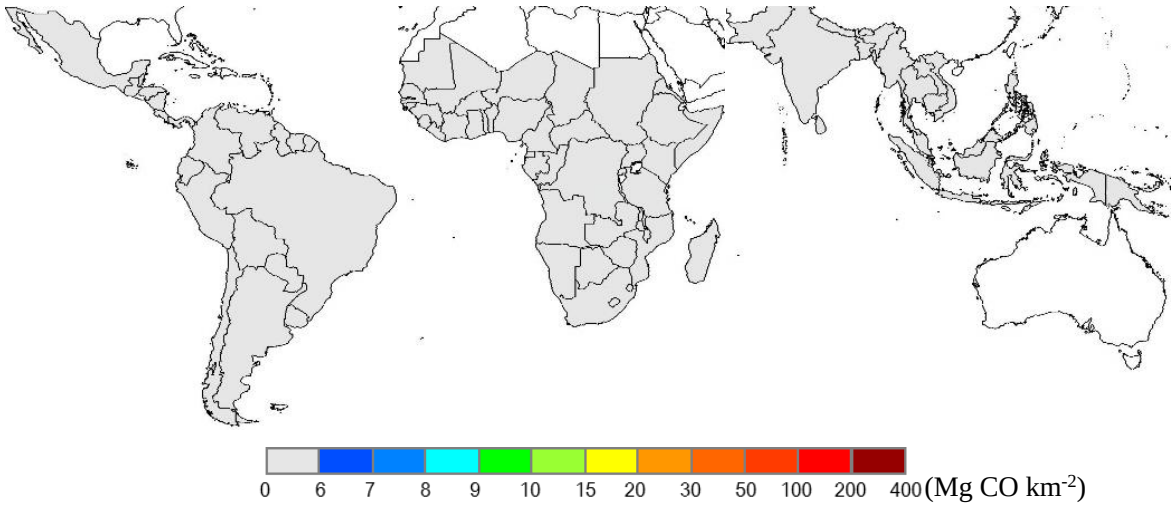


Figure S8. Spatial patterns of the CO emissions from vegetation burning of (a) Woody Savanna/Shrubland, (b) Savanna/Grassland, (c) Forest, (d) Cropland and (e) Peatland.

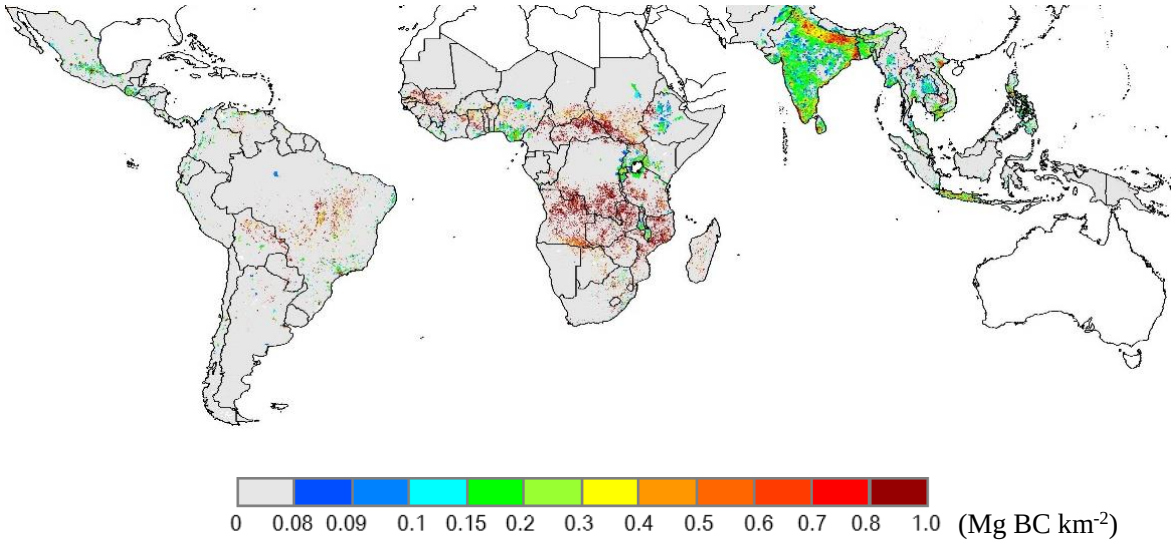
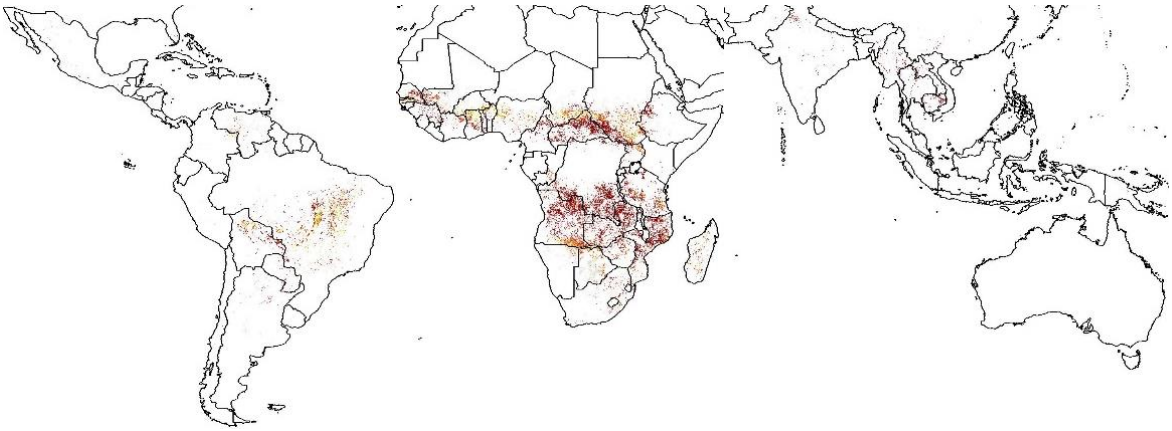
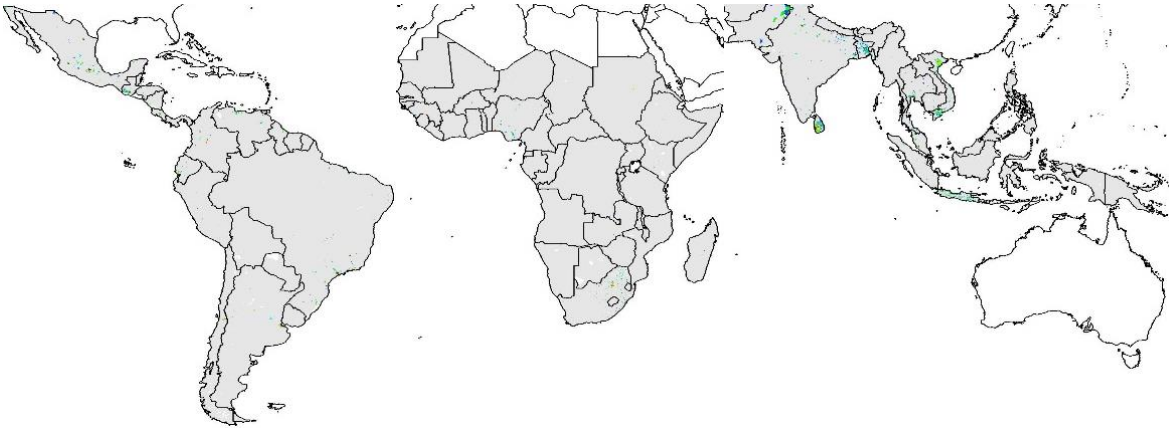


Figure S9. Spatial distribution of the total BC emissions from burning vegetation, human waste and fuelwood in 2010 (1 km grid).

(a) Vegetation BC



(b) Waste BC



(c) Fuelwood BC

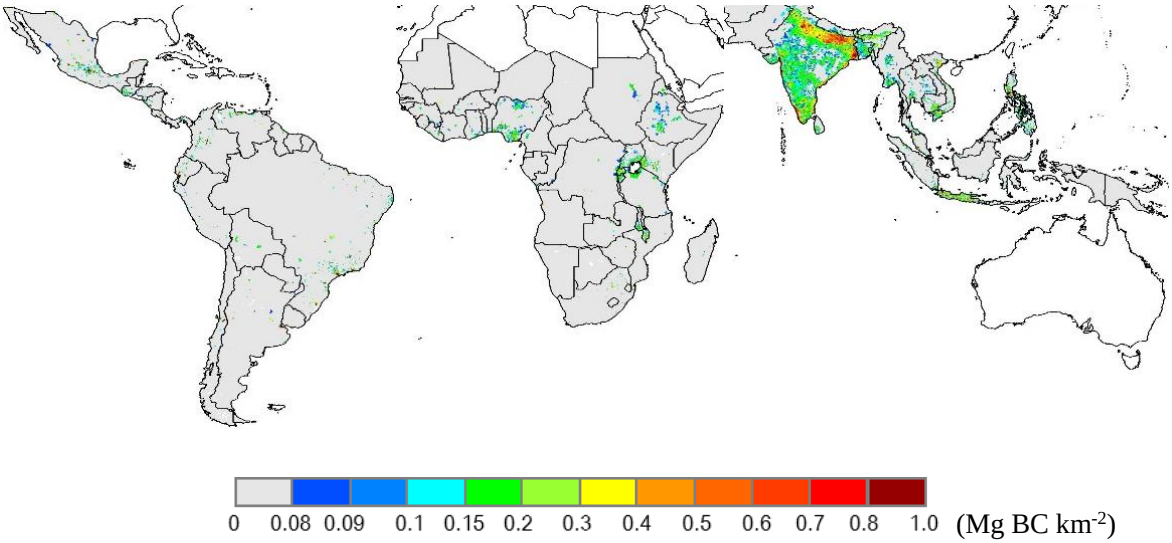


Figure S10. Spatial distribution of the estimated BC emissions from (a) vegetation, (b) human waste and (c) fuelwood with 1 km spatial grid.

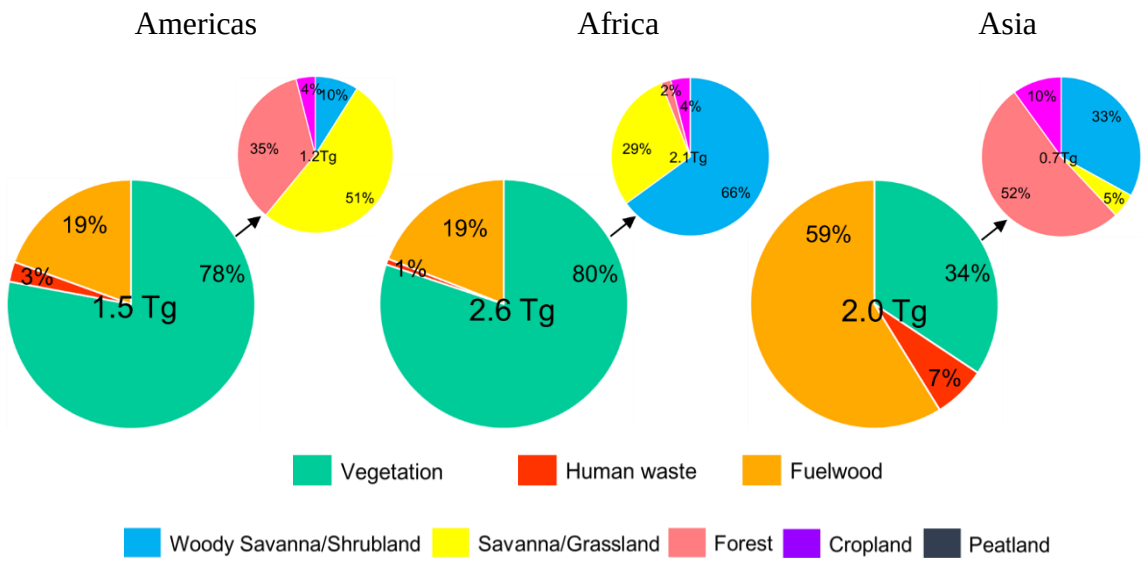
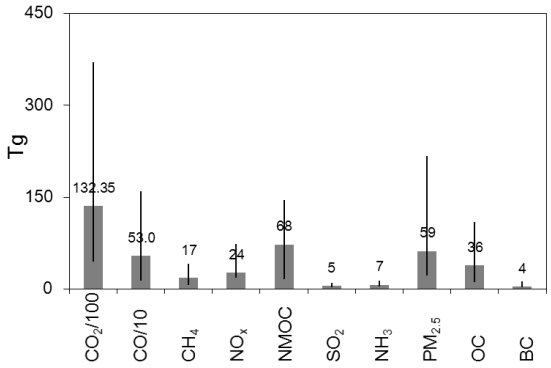
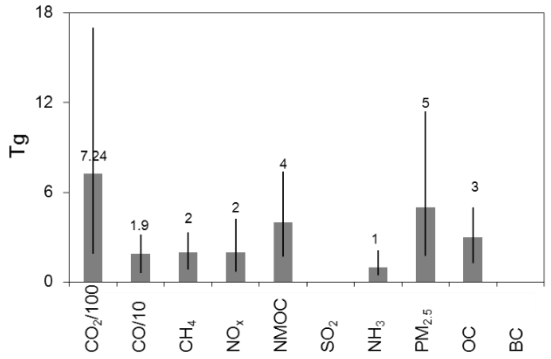


Figure S11. Contributions of the vegetation, human waste and fuelwood burnings to the total BC emissions and the four major fire types to the BC emissions of vegetation burning in the three tropical regions.

(a) Vegetation



(b) Human waste



(c) Fuelwood

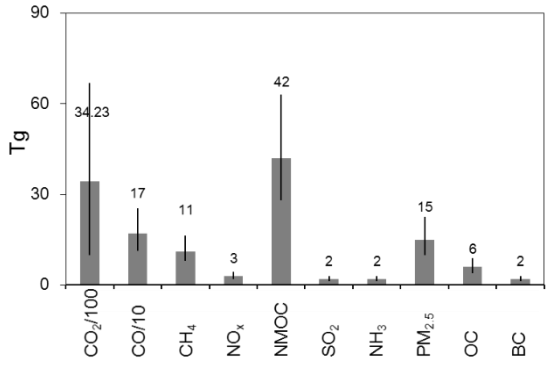


Figure S12. Uncertainty estimates for different species emitted from (a) vegetation burning, (b) human waste burning and (c) fuelwood combustion.

Table S1. The amount of burned crop residues for all crops in each country in 2010 (Unit: kg of dry matter).

Area Name	Element Name	Item Name	Value
Angola	Biomass burned (dry matter)	All Crops	1512932.75
Argentina	Biomass burned (dry matter)	All Crops	4998245.5
Bangladesh	Biomass burned (dry matter)	All Crops	6719836.4
Bhutan	Biomass burned (dry matter)	All Crops	38600.9
Bolivia	Biomass burned (dry matter)	All Crops	630211.1
Botswana	Biomass burned (dry matter)	All Crops	65388
Brazil	Biomass burned (dry matter)	All Crops	20948713.15
Belize	Biomass burned (dry matter)	All Crops	41224.95
Myanmar	Biomass burned (dry matter)	All Crops	4933541.9
Burundi	Biomass burned (dry matter)	All Crops	145451
Cameroon	Biomass burned (dry matter)	All Crops	1017626.8
Central African Republic	Biomass burned (dry matter)	All Crops	110656
Sri Lanka	Biomass burned (dry matter)	All Crops	650470.5
Chad	Biomass burned (dry matter)	All Crops	285955
Chile	Biomass burned (dry matter)	All Crops	241758.45
Colombia	Biomass burned (dry matter)	All Crops	1014046.44
Congo	Biomass burned (dry matter)	All Crops	25225
Costa Rica	Biomass burned (dry matter)	All Crops	82350.75
Benin	Biomass burned (dry matter)	All Crops	945131.9
Ecuador	Biomass burned (dry matter)	All Crops	729487.75
French Guiana	Biomass burned (dry matter)	All Crops	2077.55
Gabon	Biomass burned (dry matter)	All Crops	27932.3
Ghana	Biomass burned (dry matter)	All Crops	1095049.4
Guatemala	Biomass burned (dry matter)	All Crops	979455.4
Guinea	Biomass burned (dry matter)	All Crops	933395
Guyana	Biomass burned (dry matter)	All Crops	102631.2
Honduras	Biomass burned (dry matter)	All Crops	386657.15
India	Biomass burned (dry matter)	All Crops	46223970
Indonesia	Biomass burned (dry matter)	All Crops	11704863.5
Côte d'Ivoire	Biomass burned (dry matter)	All Crops	557455.5
Kenya	Biomass burned (dry matter)	All Crops	2128142.45
Cambodia	Biomass burned (dry matter)	All Crops	1752175.65
Lao People's Democratic Republic	Biomass burned (dry matter)	All Crops	693038.45

Lesotho	Biomass burned (dry matter)	All Crops	146817.2
Liberia	Biomass burned (dry matter)	All Crops	155076.5
Madagascar	Biomass burned (dry matter)	All Crops	1244215.4
Malawi	Biomass burned (dry matter)	All Crops	1744343.1
Malaysia	Biomass burned (dry matter)	All Crops	389886.2
Mali	Biomass burned (dry matter)	All Crops	770778
Mauritania	Biomass burned (dry matter)	All Crops	37773.7
Mexico	Biomass burned (dry matter)	All Crops	7899989.35
Mozambique	Biomass burned (dry matter)	All Crops	1893028.4
Namibia	Biomass burned (dry matter)	All Crops	32760
Nepal	Biomass burned (dry matter)	All Crops	2022471.35
Nicaragua	Biomass burned (dry matter)	All Crops	425144.33
Niger	Biomass burned (dry matter)	All Crops	28653.25
Nigeria	Biomass burned (dry matter)	All Crops	5561145.5
Pakistan	Biomass burned (dry matter)	All Crops	6540555
Panama	Biomass burned (dry matter)	All Crops	140070.4
Papua New Guinea	Biomass burned (dry matter)	All Crops	7989.1
Paraguay	Biomass burned (dry matter)	All Crops	1116065.8
Peru	Biomass burned (dry matter)	All Crops	822691.4
Philippines	Biomass burned (dry matter)	All Crops	5124499.25
Guinea-Bissau	Biomass burned (dry matter)	All Crops	73273
Eritrea	Biomass burned (dry matter)	All Crops	31280
Zimbabwe	Biomass burned (dry matter)	All Crops	1391152.35
Rwanda	Biomass burned (dry matter)	All Crops	213888.65
Senegal	Biomass burned (dry matter)	All Crops	207009.4
Sierra Leone	Biomass burned (dry matter)	All Crops	338117.1
Somalia	Biomass burned (dry matter)	All Crops	93951.3
South Africa	Biomass burned (dry matter)	All Crops	3139407.65
Sudan (former)	Biomass burned (dry matter)	All Crops	163540
Suriname	Biomass burned (dry matter)	All Crops	31419.15
Swaziland	Biomass burned (dry matter)	All Crops	88939.25
United Republic of Tanzania	Biomass burned (dry matter)	All Crops	3712447.5
Thailand	Biomass burned (dry matter)	All Crops	8361809.4
Togo	Biomass burned (dry matter)	All Crops	560643.65
Uganda	Biomass burned (dry matter)	All Crops	1118450
Burkina Faso	Biomass burned (dry matter)	All Crops	866833.85
Uruguay	Biomass burned (dry matter)	All Crops	350870
Venezuela (Bolivarian Republic of)	Biomass burned (dry matter)	All Crops	765984.3

Viet Nam	Biomass burned (dry matter)	All Crops	5420475.82
Ethiopia	Biomass burned (dry matter)	All Crops	2616074.6
Democratic Republic of the Congo	Biomass burned (dry matter)	All Crops	1747871.9
Zambia	Biomass burned (dry matter)	All Crops	1129855.8

All datasets were obtained from the Food and Agriculture Organization Statistical Yearbook (FAOSTAT) (http://faostat3.fao.org/download/G1/GB/E) in 2010. The data set excludes Equatorial Guinea.

Table S2. Land use/land cover classifications as assigned by the MODIS Land Cover Type (LCT), assigned generic land cover class, and emission factors (g kg^{-1} Dry Matter).

LCT classes	Vegetation type	CO_2	CO	CH_4	NO_x	NMOC	SO_2	NH_3	$PM_{2.5}$	OC	BC
Evergreen Needleleaf Forest	FORE	1514(121)	118(45)	6(3.1)	1.8(0.7)	28(8.7)	1(0.3)	3.5(2.3)	13(5.9)	7.8[a](4.8)	0.2[a](0.2)
Evergreen Broadleaf Forest	FORE	1643(58)	92(27)	5.1(2.0)	2.6(1.4)	24(-)	0.5(0.2)	0.8(1.2)	9.7(3.5)	4.7(2.7)	0.5(0.3)
Deciduous Needleleaf Forest	FORE	1514(121)	118(45)	6(3.1)	3(0.7)	28(8.7)	1(0.3)	3.5(2.3)	136(5.9)	7.8[a](4.8)	0.2[a](0.2)
Deciduous Broadleaf Forest	FORE	1630(37)	102(19)	5(0.9)	1.3(0.6)	11(8.7)	1(0.3)	1.5(0.4)	13(5.6)	9.2(4.8)	0.6(0.2)
Mixed Forests	FORE	1630(37)	102(19)	5(0.9)	1.3(0.6)	14(8.7)	1(0.3)	1.5(0.4)	13(5.6)	9.2(4.8)	0.6(0.2)
Closed Shrublands	WS	1716(38)	68(17)	2.6(0.9)	3.9(0.8)	4.8(2.3)	0.7(0.3)	1.2(0.4)	9.3(3.4)	6.6[a](1.2)	0.5[a](0.2)
Open Shrublands	WS	1716(38)	68(17)	2.6(0.9)	3.9(0.8)	4.8(2.3)	0.7(0.3)	1.2(0.4)	9.3(3.4)	6.6[a](1.2)	0.5[a](0.2)
Woody Savannas	WS	1716(38)	68(17)	2.6(0.9)	3.9(0.8)	4.8(2.3)	0.7(0.3)	1.2(0.4)	9.3(3.4)	6.6[a](1.2)	0.5[a](0.2)
Savannas	SG	1692(38)	59(17)	1.5(0.9)	2.8(0.8)	9.3(2.3)	0.5(0.3)	0.5(0.4)	5.4[b](3.4)	2.6(1.2)	0.4(0.2)
Grasslands	SG	1692(38)	59(17)	1.5(0.9)	2.8(0.8)	9.3(2.3)	0.5(0.3)	0.5(0.4)	5.4[b](3.4)	2.6(1.2)	0.4(0.2)
Permanent Wetlands	SG	1692(58)	59(68)	1.5(11.4)	2.8(-)	9.3(-)	0.5(-)	0.5(-)	5.4[b](-)	2.6(-)	0.4(-)
Croplands	CROP	1537(100)	111(33)	6(3.6)	3.5(1.6)	57(7.7)	0.4[b](-)	2.3(1.3)	5.8(2.4)	3.3[b](-)	0.7[b](-)
Cropland/Natural Vegetation Mosaic	SG	1692(38)	59(17)	1.5(0.9)	2.8(0.8)	9.3(2.3)	0.5(0.3)	0.5(0.4)	5.4[b](3.4)	2.6(1.2)	0.4(0.2)
Barren or Sparsely Vegetated	SG	1692(38)	59(17)	1.5(0.9)	2.8(0.8)	9.3(2.3)	0.5(0.3)	0.5(0.4)	5.4[b](3.4)	2.6(1.2)	0.4(0.2)

FORE=Boreal, tropical, temperate forest; WS=Woody Savannah/Shrubland; SG=Savannah/Grassland; CROP=Croplands.

[a]From McMeeking,[20] [b]from Andreae and Merlet,[21] others were from Akagi et al.[22] and Wiedinmyer et al.[23] An estimate of the uncertainties were shown in parenthesis when available based on the compilation of Akagi et al.[22] and GFED4 (http://www.falw.vu/~gwerf/GFED/GFED4/emission_factors/).

Table S3. Country-level population, waste generation and waste collection data used for the calculations and the estimated burned waste at residential and dumps.

Country	2010 Population	2010 Urban population	Waste Generation (Tonne/Capita/year)	Collection Efficiency	Fraction Not Collected	Residential Waste Burned (Tonne/year)	Waste burned at Dumps (Tonne/year)	Total Burned (Tonne/year)
Angola	19549124	11412583	0.1752	0.69	0.31	1227217	827787	2055004
Argentina	40374224	37285192	0.4453	0.59	0.41	4909689	5877496	10787185
Bangladesh	151125475	42154940	0.15695	0.95	0.05	10460242	3771244	14231486
Belize	308595	138754	1.04755	0.50	0.50	150356	43605	193961
Benin	9509798	4208846	0.1971	0.23	0.77	1010149	114480	1124629
Bhutan	716939	249445	0.5329	0.74	0.21	166226	59020	225246
Bolivia	10156601	6743881	0.12045	0.70	0.30	392851	341166	734018
Botswana	1969341	1200845	0.37595	0.69	0.31	257321	186903	444224
Brazil	195210154	164630483	0.37595	0.83	0.17	13210925	30822629	44033554
Burkina Faso	15540284	3988725	0.18615	0.40	0.60	1557494	178200	1735694
Burundi	9232753	982550	0.20075	0.41	0.59	1063562	48523	1112085
Cambodia	14364931	2846267	0.27	0.75	0.25	1981297	345821	2327119
Cameroon	20624343	10624012	0.27	0.52	0.48	2446177	894967	3341144
Central African Republic	4349921	1689901	0.18	0.69	0.31	343860	125931	469791
Chad	11720781	2547981	0.18	0.69	0.31	1075969	189876	1265844
Chile	17150760	15254229	0.39	0.40	0.60	2585482	1427796	4013278
Colombia	46444798	34842887	0.35	0.98	0.02	2582741	7170666	9753408
Congo	4111715	2599550	0.19	0.00	0.31	264255	204481	468736
Costa Rica	4669685	2997284	0.50	0.74	0.26	735508	665397	1400906

Cote d'Ivoire	18976588	9593994	0.18	0.70	0.30	1324166	725306	2049472
Demo. Rep. Congo	62191161	20975213	0.18	0.72	0.28	5085613	1631033	6716645
Ecuador	15001072	10030167	0.41	0.81	0.19	1691653	1998611	3690264
Equatorial Guinea	696167	273851	0.29	0.69	0.31	88254	32879	121133
Eritrea	5741159	1199902	0.18	0.69	0.31	530628	89417	620045
Ethiopia	87095281	14594556	0.11	0.69	0.31	5083652	664636	5748289
French Guiana	243000	0	0.26	0.54	0.46	37908	0	37908
Gabon	1556222	1335830	0.16	0.69	0.31	60912	88485	149397
Ghana	24262901	12426245	0.03	0.60	0.40	302529	134203	436732
Guatemala	14341576	7074413	0.73	0.72	0.28	4050624	2230987	6281610
Guinea	10876033	3803131	0.26	0.50	0.50	1400017	296644	1696661
Guinea-Bissau	1586624	685739	0.29	0.69	0.31	193743	82330	276073
Guyana	786126	222560	1.95	0.89	0.11	688016	231752	919767
Honduras	7621204	3930788	0.53	0.68	0.32	1573549	849994	2423543
India	1205624648	372899704	0.12	0.70	0.10	62641074	18794145	81435219
Indonesia	240676485	120155328	0.19	0.80	0.20	16478953	10958166	27437119
Kenya	40909194	9642706	0.11	0.69	0.31	2260878	439129	2700007
Laos	6395713	2118324	0.26	0.40	0.60	865548	132183	997731
Lesotho	2008921	539335	0.18	0.69	0.31	176772	40191	216963
Liberia	3957990	1891959	0.29	0.69	0.31	461542	227149	688690
Madagascar	21079532	6730695	0.29	0.18	0.82	3457033	210805	3667839
Malawi	15013694	2333578	0.18	0.69	0.31	1447581	173898	1621479
Malaysia	28275835	20360298	0.55	0.70	0.15	3619962	4703229	8323191
Mali	13985961	4793968	0.24	0.40	0.60	1737846	276133	2013978
Mauritania	3609420	1488164	0.18	0.33	0.67	336779	53038	389817
Mexico	117886404	91745094	0.45	0.91	0.09	9287560	22541770	31829329

Mozambique	23967265	7419786	0.05	0.69	0.31	565428	153590	719018
Myanmar	51931231	16661097	0.16	0.60	0.40	4025719	959679	4985398
Namibia	2178967	824042	0.18	0.93	0.07	152562	82767	235328
Nepal	26846016	4471472	0.04	0.94	0.06	543428	100876	644304
Nicaragua	5822209	3333331	0.40	0.73	0.27	813331	584000	1397330
Niger	15893746	2799842	0.18	0.25	0.75	1640929	75596	1716525
Nigeria	159707780	78258409	0.20	0.24	0.76	16911091	2253842	19164934
Pakistan	173149306	62129434	0.31	0.74	0.21	23076472	8551495	31627967
Panama	3678128	2744288	0.44	0.77	0.23	413167	557859	971026
Papua New Guinea	6858945	852704	0.69	0.85	0.15	2539537	300067	2839603
Paraguay	6459721	3964589	0.08	0.51	0.49	213013	97053	310067
Peru	29262830	22506335	0.37	0.74	0.26	2799008	3697341	6496348
Philippines	93444322	45458794	0.18	0.62	0.28	6557111	3043921	9601032
Rwanda	10836732	2038389	0.19	0.69	0.31	1075048	160340	1235387
Senegal	12950564	5471872	0.19	0.21	0.79	1345368	130997	1476364
Sierra Leone	5751976	2236138	0.16	0.44	0.56	457735	94454	552190
Somalia	9636173	3593233	0.29	0.69	0.31	1245291	431403	1676694
South Africa	49991300	30767645	0.73	0.90	0.10	9767584	12128606	21896189
Sri Lanka	20653000	3106418	1.86	0.25	0.75	22182057	866691	23048748
Sudan	45592931	13570359	0.29	0.82	0.18	5996951	1936219	7933170
Suriname	524960	363934	0.50	0.80	0.20	70144	87344	157488
Swaziland	1193148	254331	0.19	0.69	0.31	116013	20006	136019
Thailand	66402316	22397501	0.64	0.80	0.05	17327881	6880512	24208393
Togo	6306014	2366836	0.19	0.27	0.73	646034	72851	718886
Uganda	33987213	5151782	0.12	0.20	0.80	2372894	74186	2447079
Tanzania	44973330	11818541	0.09	0.48	0.52	2122223	306337	2428560

Uruguay	3371982	3117499	0.04	0.72	0.28	27057	53870	80928
Venezuela	29043283	27101449	0.42	0.50	0.50	3904125	3414783	7318907
Vietnam	86932500	26421395	0.53	0.60	0.40	22603333	5041202	27644535
Zambia	13216985	5118277	0.08	0.20	0.80	585280	49135	634415
Zimbabwe	13076978	4986252	0.19	0.69	0.31	1098557	392219	1490775

All datasets were derived from Wiedinmyer et al.[17]

Table S4. Emission factors (g kg^{-1} Dry Matter) for species emitted from the burning of waste and fuelwood.

Sources	CO_2	CO	CH_4	NO_x	NMOC	SO_2	NH_3	$PM_{2.5}$	OC	BC
Waste	1453	38	3.7	3.74	7.5	0.5	1.12	9.8	5.27	0.65
burning	(69)	(19)	(4.4)	(1.48)	(-)	(-)	(1.21)	(5.7)	(4.89)	(0.27)
Fuelwood	1548	77	4.86	1.42	19.2	0.7[a]	0.87	6.64	2.89	0.83
burning	(125)	(26)	(2.73)	(0.72)	(7.6)	(0.6)	(0.40)	(1.66)	(1.23)	(0.45)

Waste burning are from Akagi et al.[22] and Wiedinmyer et al.[17] Fuelwood burning are from Yevich and Logan,[24] [a]from Gadi et al.[25] An estimate of the natural variation were shown in parenthesis when available.

Table S5. Fuelwood use per capita in each country across the three tropical regions.

	Country	Per Capita, kg/cap/day	Country	Per Capita, kg/cap/day
Africa				
N. Drylands	Mauritania	1.02		
Sahel	Chad	0.30	Mali	1.49
	Niger	1.17	Senegal	0.48
	Sudan	2.28		
West Coast	Benin	1.30	Burkina Faso	1.70
	Ghana	1.71	Guinea	3.22
	Guinea-Bissau	1.22	Cote d'Ivoire	1.57
	Liberia	2.24	Nigeria	1.50
	Sierra Leone	1.58	Togo	1.40
Central Africa	Angola	1.98	Cameroon	1.59
	Cen. Af. Rep.	1.99	Congo	1.61
	Eq. Guinea	2.54	Gabon	1.61
E. Highlands	Kenya	1.89	Malawi	3.07
	Tanzania	3.21	Uganda	2.18
	Zambia	3.24		
E. and S. Drylands	Botswana	2.04	Burundi	1.25
	Ethiopia	1.84	Lesotho	0.05
	Mozambique	1.66	Namibia	0.50
	Rwanda	1.73	Somalia	0.98
	South Africa	0.79	Swaziland	1.28
	Zimbabwe	1.55		
Islands	Madagascar	0.94		
Asia				
Middle East	Afghanistan	0.57	Pakistan	0.42
Far East	Bangladesh	0.40	Bhutan	4.43
	Cambodia	2.83	India	0.78
	Indonesia	1.00	Lao	3.26
	Malaysia	1.48	Myanmar	1.81
	Nepal	1.57	Philippines	1.52
	Sri Lanka	1.06	Thailand	1.50
	Vietnam	1.18		
Americas				
	Mexico	2.00	Paraguay	2.90

From Yevich and Logan.[24]

Table S6. The ratio of agricultural residue use in biofuel to burn in the fields (%).

Region/Country	Biofuel/Burn in field (%)
Africa	
N. Drylands	0.01
Sahel	0.90
West Coast	0.90
Central Africa	0.43
E. Highlands	2.16
E. and S. Drylands	0.75
Asia	
Afghanistan	3.38
Bangladesh	2.73
Indonesia	0.19
Philippines	0.22
Vietnam	1.00
Pakistan	0.79
India	1.09
Myanmar	0.27
Thailand	0.26
Americas	
Latin America	1.00

From Yevich and Logan.[24]

Table S7. Biomass burning emissions (Tg) from the burning of vegetation, human waste and fuelwood in each region and their total amount in 2010.

Regions	Sources	CO_2	CO	CH_4	NO_x	NMOC	SO_2	NH_3	$PM_{2.5}$	OC	BC
Americas	Vegetation	1763	75	2	3	15	1	1	8	4	1
	Human waste	193	5	1	1	1	0	0	1	1	0
	Fuelwood	623	33	2	1	11	0	0	3	1	0
	Sub-total	2579	113	5	5	27	1	1	12	6	1
Africa	Vegetation	10338	396	12	19	43	4	5	45	28	3
	Human waste	153	4	0	0	1	0	1	1	1	0
	Fuelwood	855	40	3	1	11	1	1	4	2	0
	Sub-total	11346	440	15	20	55	5	7	50	31	3
Asia	Vegetation	1135	59	3	2	10	0	1	6	4	0
	Human waste	377	10	1	1	2	0	0	3	1	0
	Fuelwood	1945	97	6	1	20	1	1	8	3	2
	Sub-total	3457	166	10	4	32	1	2	17	8	2
Total		17382	719	30	29	114	7	10	79	45	6

Table S8. Uncertainties/variability assigned to model inputs and parameters.

	Model component	Uncertainty assigned
Vegetation	Fuel loads (biomass density)	0-50%[a]
	Emission factors	See Table S1
Human waste	National Population	20%[b]
	National Urban Population Fraction	20%[b]
	National Waste Generation Rate	50%[b]
	National Waste Collection Efficiency	50%[b]
	Emission Factor	See Table S3
	Fraction waste available to be burned that is actually burned (B_{frac})	0.25-0.8[b]
Fuelwood	National Population	20%[b]
	Fuelwood Use Per Capita	50%[b]
	Emission Factor	See Table S3

[a]From Saatchi et al.[18] [b]From Wiedinmyer et al.[17]

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