Supplementary Figure Legends:

Figure S1 Location of 3 sampling villages selected in this study

Figure S2 Stoves used in this study: a) Heated Kang b) Traditional coal stove c) Semi-gasifier stove

Figure S3 Profiles of VOCs emitted from heating and cooking activities

Table S1 Solid fuel and stoves used in this study

Purpose	Heating					
Fuel type	Wood				Residue	
Stove type	Heated Kang		Semi-gasifier Stove		Heated Kang	
Fuel used	Firewood	Branch	Firewood	Branch	Maize straw	Wheat straw
Abbreviation	Firewood-HK	Branch-HK	Firewood-SG	Branch-SG	Maize-HK	Wheat-HK
Sample No.	2	2	2	2	2	2
Purpose	Heating				Cooking	
Fuel type	Coal				Wood and residue	
Stove type	Traditional coal stove		Semi-gasifier stove		Traditional cooking stove	
Fuel used	Anthracite	Honeycomb	Anthracite	Bitumite	Branch	Corn cob
Abbreviation	Anthracite-CS	Honeycomb-CS	Anthracite-SG	Bitumite-SG	Branch-TS	Corn cob-TS
Sample No.	2	2	2	2	2	2

Table S2 Profiles of VOCs measured in solid fuel burning in this study (ug/kg)

		Wood heating				Residue heating		Coal heating				Cooking	
		Heated Kang		semi-gasifier stove		Heated Kang		Traditional coal stove		semi-gasifier stove		Old fashioned stove	
No.	Species	Firewood	Branch	Firewood	Branch	Maize	Wheat	Anthracite	Honeycomb	Anthracite	Bitumite	Branch	Corncob
1	Ethane	13.6	7.6	0.1	0.0	13.7	40.4	0.0	0.0	0.2	0.0	2.5	24.9
2	Propane	166.9	102.4	106.5	63.6	139.3	64.1	1.4	0.7	10.0	39.0	17.2	24.3
3	Isobutane	32.6	8.9	24.5	18.2	9.6	12.2	1.7	0.6	14.6	52.8	16.4	6.1
4	n-Butane	31.0	21.2	55.3	25.7	22.9	21.6	7.4	3.7	22.0	77.8	42.0	27.2
5	iso-Pentane	359.7	252.7	111.4	177.7	344.3	137.4	5.0	1.1	10.0	25.5	93.6	181.9
6	n-Pentane	12.1	12.5	49.1	27.6	8.4	0.3	1.1	0.8	7.4	21.5	8.4	5.7
7	2,2-Dimethylbutane	0.1	0.1	1.2	0.8	0.0	0.0	0.0	0.0	0.3	0.7	0.4	0.2
8	Cyclopentane	5.5	3.4	2.1	6.5	4.4	1.6	0.0	0.0	0.0	2.2	0.0	0.0
9	2,3-Dimethylbutane	17.6	16.6	21.2	22.7	21.3	6.1	0.5	0.1	2.3	4.5	26.3	12.9
10	2-Methylpentane	17.1	40.8	28.5	34.5	14.4	18.4	1.0	0.5	4.7	13.0	28.0	32.2
11	3-Methylpentane	0.9	0.9	8.6	1.2	0.4	0.3	0.4	0.2	1.7	5.2	3.2	2.3
12	n-Hexane	5.1	5.9	23.3	13.8	9.3	1.4	0.6	0.4	2.8	10.2	4.6	5.5
13	Methylcyclopentane	1.2	1.5	6.2	3.0	0.7	0.3	0.3	0.2	1.0	3.5	2.2	2.8
14	2,4-Dimethylpentane	0.2	0.1	0.3	0.0	0.8	0.2	0.0	0.0	0.2	0.7	0.4	0.7
15	Cyclohexane	1.3	1.1	0.5	1.1	0.7	0.8	0.1	0.0	0.8	2.3	0.8	2.8
16	2-Methylhexane	11.4	16.4	4.7	12.4	1.2	30.4	0.2	0.1	1.0	2.4	4.3	30.0
17	2,3-Dimethylpentane	0.6	0.7	3.5	0.2	0.7	0.2	0.1	0.0	0.4	0.5	0.6	0.3
18	3-Methylhexane	1.8	1.3	6.8	3.4	1.1	1.2	0.1	0.1	1.0	0.7	1.1	3.5
19	2,2,4-Trimethylpentane	0.1	0.1	0.3	1.8	1.3	0.0	0.0	0.0	0.6	0.3	0.5	0.9
20	n-Heptane	6.2	6.8	20.5	11.1	6.5	22.0	0.3	0.2	1.4	9.8	3.6	9.4
21	Methylcyclohexane	0.6	0.9	4.5	3.0	0.2	0.8	0.1	0.1	0.9	2.8	0.6	0.8
22	2,3,4-Trimethylpentane	0.2	0.2	0.2	0.2	0.3	0.2	0.0	0.0	0.2	0.1	0.1	0.5
23	2-Methylheptane	0.3	0.2	0.6	0.3	1.4	0.9	0.1	0.1	0.3	1.2	0.5	2.8
24	3-Methylheptane	0.1	0.2	1.8	0.0	0.1	0.2	0.0	0.0	0.3	0.3	0.4	0.7
25	n-Octane	3.4	3.6	11.9	4.6	9.9	5.9	0.2	0.1	0.8	3.1	1.6	7.1
26	n-Nonane	3.1	2.7	11.5	4.9	4.9	7.9	0.1	0.1	1.1	3.4	1.3	5.6

27	n-Decane	3.4	2.3	20.8	12.2	1.6	11.9	0.2	0.2	2.1	8.1	2.0	7.4
28	Undecane	4.6	2.3	32.1	59.0	3.5	2.1	0.8	1.1	12.8	53.0	6.0	39.2
29	Dodecane	11.2	5.3	157.6	119.2	15.0	20.3	13.3	10.1	127.0	105.1	63.5	374.0
30	Ethylene	3.3	0.0	2.3	0.5	4.3	2.3	0.3	0.1	0.7	0.6	2.2	1.0
31	Propylene	294.6	191.5	164.2	57.0	275.7	16.9	0.3	0.1	2.4	19.0	15.8	63.8
32	1-Butene	47.4	34.1	22.7	18.5	44.7	3.5	0.6	0.4	4.0	19.8	14.3	15.7
33	trans-2-Butene	25.6	14.1	7.3	5.3	12.9	1.0	0.3	0.1	1.4	3.5	4.2	9.5
34	cis-2-Butene	20.4	11.4	7.4	5.4	9.4	0.7	0.2	0.1	1.2	2.9	3.3	8.2
35	Isoprene	19.6	20.1	13.0	20.7	14.8	0.5	0.3	0.1	2.1	5.1	6.8	12.1
36	1-Pentene	13.5	15.2	18.4	4.4	5.0	1.1	0.3	0.1	1.1	6.1	2.7	13.2
37	trans-2-Pentene	13.8	11.0	5.2	3.3	8.2	0.5	0.1	0.0	0.5	1.9	2.1	7.5
38	cis-2-Pentene	7.5	6.6	2.4	2.0	4.8	0.3	0.1	0.0	0.3	1.2	1.2	5.5
39	1-Hexene	11.7	17.5	16.5	11.3	25.6	2.9	0.3	0.1	1.3	5.7	6.2	9.4
40	1,3-Butadiene	58.1	44.2	33.7	23.9	29.2	66.2	0.3	0.1	3.2	0.7	13.3	90.4
41	Benzene	166.1	193.3	419.0	408.9	141.5	71.1	3.4	2.8	27.3	121.1	120.2	463.7
42	Toluene	105.3	109.3	280.1	126.0	104.1	86.5	2.4	1.7	21.8	83.7	45.3	143.5
43	Ethylbenzene	17.5	19.1	41.8	35.0	12.5	22.3	0.6	0.6	5.6	19.9	9.5	43.9
44	m-Xylene	16.7	13.9	63.0	29.5	10.9	23.7	0.5	0.5	5.3	19.1	7.1	29.2
45	p-Xylene	16.7	13.9	63.0	29.5	11.5	23.7	0.5	0.5	5.3	19.1	7.1	29.2
46	Styrene	23.4	25.3	33.7	40.7	9.4	36.4	0.5	0.4	5.0	18.2	12.9	61.6
47	o-Xylene	12.5	10.1	35.3	24.8	8.5	19.6	0.4	0.4	4.7	15.0	5.8	23.5
48	Isopropylbenzene	0.8	0.8	1.9	0.7	0.4	0.8	0.0	0.0	0.2	0.8	0.4	2.0
49	n-Propylbenzene	1.8	1.4	2.6	2.0	0.2	1.0	0.0	0.0	0.7	2.7	0.5	1.0
50	m-Ethyltoluene	3.3	1.4	7.2	4.9	0.9	4.7	0.1	0.1	1.0	3.6	0.7	3.5
51	p-Ethyltoluene	3.0	1.4	7.6	4.5	0.6	2.6	0.0	0.0	1.0	2.8	0.8	2.0
52	1,3,5-Trimethylbenzene	2.0	1.2	4.9	3.4	0.8	3.3	0.1	0.1	0.8	2.3	0.7	2.3
53	o-Ethyltoluene	2.3	1.4	8.3	5.4	1.0	5.5	0.1	0.1	1.0	3.1	1.1	3.7
54	1,2,4-Trimethylbenzene	5.0	2.6	20.0	15.4	2.5	12.9	0.2	0.2	3.4	10.6	2.7	9.3
55	1,2,3-Trimethylbenzene	1.4	0.7	10.5	9.6	0.8	2.9	0.2	0.1	2.0	5.7	1.6	5.2
56	m-Diethylbenzene	0.4	0.3	4.5	13.6	0.2	1.3	0.1	0.1	0.8	3.1	2.2	1.9

57	p-Diethylbenzene	0.0	0.1	3.3	2.8	0.3	0.9	0.1	0.1	0.7	2.6	0.8	2.8
58	4-Ethyltoluene	6.6	4.2	27.3	13.1	3.4	12.9	0.5	0.4	3.6	2.1	7.1	13.5
59	Naphthalene	19.2	10.5	107.7	145.6	7.5	23.3	2.9	3.1	90.7	47.0	38.1	276.3
60	Acrolein	170.7	109.7	50.5	116.8	95.9	93.8	0.6	0.3	3.3	1.9	47.1	227.5
61	Acetone	351.8	247.2	167.0	254.4	385.4	248.6	2.0	0.9	32.9	8.5	95.7	235.6
62	Methyl ethyl ketone	180.2	152.4	32.0	78.6	193.5	152.3	2.8	1.4	9.1	6.3	45.1	158.3
63	Methyl Isobutyl Ketone	1.2	1.4	0.5	0.3	0.0	4.3	0.1	0.0	0.4	0.3	0.8	2.9
64	Methyl butyl ketone	8.3	5.9	8.8	2.6	4.3	26.2	0.5	0.3	2.1	2.0	7.3	16.0
65	Ethanol	0.0	0.0	7.3	103.0	18.6	91.7	6.0	1.6	29.8	18.8	57.4	28.8
66	Isopropyl Alcohol	0.7	0.5	1.5	1.9	1.7	7.2	0.3	0.1	0.9	0.9	3.9	3.9
67	Methyl tert-butyl ether	1.6	1.1	2.8	4.4	2.6	10.8	0.9	0.4	3.1	2.2	9.7	8.6
68	Ethyl Acetate	3.0	2.5	6.4	9.1	3.9	15.1	1.7	1.1	6.4	4.5	15.4	18.4
69	Methyl Methacrylate	2.2	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
70	Freon-12	1.4	0.8	0.0	0.0	0.3	3.1	0.0	0.0	0.0	0.0	0.0	0.0
71	Chloromethane	6.6	9.8	8.5	11.0	43.9	99.7	0.0	0.0	0.0	0.0	35.2	36.6
72	Freon-114	0.2	0.1	0.5	0.6	0.3	1.3	0.1	0.0	0.4	0.3	0.9	0.8
73	Vinyl chloride	0.5	0.6	0.7	0.9	0.7	2.8	0.1	0.1	0.4	0.4	1.5	2.0
74	Bromomethane	3.5	2.3	5.5	7.2	6.2	25.3	1.0	0.5	3.4	3.2	14.8	14.0
75	Freon-11	2.4	1.7	5.4	6.7	4.3	18.9	0.9	0.6	5.3	3.9	10.8	9.5
76	1,1-Dichloroethene	1.7	1.3	3.2	4.0	3.9	15.5	0.6	0.3	2.0	2.0	8.4	8.4
77	Methylene Chloride	1.1	0.9	3.7	2.4	0.6	4.0	0.0	0.0	1.9	0.0	0.0	0.0
78	Freon-113	0.5	0.4	1.5	1.7	0.4	1.9	0.2	0.1	1.6	1.1	1.9	2.0
79	trans-1,2-Dichloroethene	0.6	0.6	0.8	0.9	0.9	3.6	0.1	0.1	0.5	0.5	2.0	2.0
80	1,1-Dichloroethane	0.0	0.0	0.6	0.6	0.0	0.0	0.3	0.1	1.0	0.5	0.0	0.0
81	cis-1,2-Dichloroethene	2.8	2.2	3.3	4.1	4.5	16.0	0.6	0.5	2.1	2.1	8.7	8.7
82	Chloroform	1.8	1.7	1.6	2.9	0.7	0.6	0.5	0.3	2.1	0.9	3.9	4.8
83	1,2-Dichloroethane	0.3	0.7	2.1	2.6	0.0	0.0	0.4	0.4	4.7	1.6	1.8	3.8
84	1,1,1-Trichloroethane	0.1	0.0	0.1	0.2	0.1	0.6	0.0	0.0	0.1	0.1	0.3	0.3
85	Carbon Tetrachloride	0.5	0.4	1.0	1.6	0.6	2.2	0.2	0.1	1.4	1.0	2.2	2.4
86	1,2-Dichloropropane	0.0	0.0	1.8	2.9	0.0	0.0	0.3	0.3	5.1	2.1	1.2	3.1

87	Trichloroethene	1.9	1.4	4.0	4.9	4.1	17.1	0.7	0.4	2.7	2.4	9.7	10.5
88	cis-1,3-Dichloropropene	0.0	0.0	0.1	0.1	0.1	0.4	0.0	0.0	0.1	0.1	0.2	0.2
89	1,1,2-Trichloroethane	8.3	5.9	8.8	7.9	4.3	26.2	0.5	0.3	2.1	2.0	7.3	16.0
90	1,1,2,2-Tetrachloroethane	0.5	1.9	1.3	1.1	0.5	2.5	0.1	0.0	0.6	0.4	1.0	0.9
91	Benzyl Chloride	0.3	0.2	0.5	0.5	0.5	2.1	0.0	0.0	0.0	0.0	1.0	1.0
92	1,3-Dichlorobenzene	3.3	2.4	19.3	18.0	7.5	31.3	1.9	1.3	9.8	7.9	24.2	45.9
93	1,4-Dichlorobenzene	5.3	3.5	23.7	28.1	4.8	19.5	2.5	2.0	15.9	15.0	27.1	136.4
94	1,2-Dichlorobenzene	1.9	1.3	4.3	5.4	4.0	16.9	0.7	0.4	2.7	2.8	9.2	11.9
95	Acetylene	6.8	3.3	0.0	0.3	5.8	48.6	0.0	0.0	0.0	0.0	0.4	11.4
96	Carbon disulfide	0.5	0.4	3.0	2.7	0.7	1.6	0.2	0.0	3.6	0.3	6.1	1.1
97	Tetrahydrofuran	21.4	12.1	2.5	1.5	8.3	1.8	0.3	0.0	3.2	1.7	2.7	4.9
98	1,4-Dioxane	0.5	0.4	1.3	1.3	0.9	3.9	0.1	0.1	10.6	0.8	2.1	2.6

Table S3 Coefficient of divergence among VOCs profiles emitted from solid fuel burning*

	Firewood -HK	Branch -HK	Firewood -SG	Branch -SG	Corn straw -HK	Wheat straw-HK	Anthracite -CS	Honeycomb -CS	Anthracite -SG	Bitumite -SG	Branch - -TS	Corn hub -TS
Firewood-HK	0											
Branch-HK	0.23	0										
Firewood-SG	0.55	0.58	0									
Branch-SG	0.53	0.55	0.35	0								
Corn straw-HK	0.70	0.66	0.78	0.76	0							
Wheat straw-HK	0.71	0.68	0.81	0.80	0.52	0						
Anthracite-CS	0.81	0.79	0.86	0.86	0.61	0.61	0					
Honeycomb-CS	0.85	0.83	0.90	0.90	0.66	0.65	0.32	0				
Anthracite-SG	0.63	0.63	0.61	0.58	0.67	0.67	0.72	0.80	0			
Bitumite-SG	0.57	0.59	0.47	0.46	0.72	0.75	0.77	0.84	0.46	0		
Branch-TS	0.57	0.57	0.53	0.48	0.71	0.75	0.84	0.88	0.47	0.52	0	
Corn hub-TS	0.54	0.57	0.49	0.44	0.81	0.84	0.89	0.92	0.63	0.56	0.45	0

$$\mathrm{CD}_{jk} = \sqrt{\frac{1}{p}\sum_{i=1}^{p}\left(\frac{x_{ij} - x_{ik}}{x_{ij} + x_{ik}}\right)^2}$$

where, x_{ij} represents the average concentration for a chemical component i at site j, j and k represent two sampling sites, and p is the number of chemical components

Table S4 Industrial analysis results of solid fuel used in this study

Fuel type	Moisture, %	Ash, %	Volatile Matters, VM%	Fixed Carbon， %	Calorific value, $MJ\cdot kg^{-1}$
Firewood	4.39	2.15	82.96	10.51	19.03
Branch	4.37	2.72	79.66	13.25	17.92
Wheat straw	4.39	8.90	67.36	19.32	18.52
Maize straw	6.10	4.70	76.00	13.20	17.73
Corncob	4.87	5.93	71.95	17.25	17.72
Anthracite	0.88	9.72	6.12	83.28	29.68
Honeycomb briquette	3.00	32.34	4.99	59.67	20.37
Bitumite	7.98	7.98	33.20	50.84	22.02

***Proximate Analysis Was Conducted by the Analytical Center of Chinese Academy of Guangzhou Institute of Energy Conversion**

Table S5 Parameters in evaluation of O_3 contribution from solid fuel burning in Guanzhong Plain

Box model – Atmospheric capacity parameters				Emission rate of OFP			
Dimensions	300km in length [a]	100 km in width [a]	516.2m in height [b]	Biomass fuels consumed	1.59E9 kg [f]	Coal used	2.50E9 kg [f]
Atmospheric volume of Guanzhong Plain	1.55E13 m^3 [c]			EFs of OFP	4.51 $g·kg^{-1}$ [g]	EFs of OFP	0.62 $g·kg^{-1}$ [h]
				Heating periods	100 days [i]		
O_3 concentration	28.8 $\mu g·m^{-3}$ [d]			OFP emission rate	7.17E4 $kg·day^{-1}$ [j]	OFP emission rate	1.55E4 $kg·day^{-1}$ [j]
O_3 atmospheric capacity	4.46E5 kg [e]			Total OFP emission rate	8.72E4 $kg·day^{-1}$ [k]		

a Sun, Shen et al. (2017)
b http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/ boundary layer
c Expressed as volume = length * width * height
d http://www.zhb.gov.cn/hjzl/dqhj/cskqzlzkyb/, average O_3 concentration in winter of 2013
e Expressed as Atmospheric capacity = [O_3] * Atmospheric volume
f Shaanxi Province Statistical Yearbook 2013
g Average OFP value of biomass fuels heating burning in this study
h Account as bitumite only, use OFP of bitumite-SG in this study
i Sun, Shen et al. (2017)
j Expressed as OFP emission rate = Total fuels consumed * EFs of OFP / Heating period (unit: $kg·day^{-1}$)
k Expressed as Total OFP emission rate = OFP emission rate (biomass) + OFP emission rate (coal)

Table S6 Parameters in evaluation of SOA contribution from solid fuel burning in Guanzhong Plain

Box model – Atmospheric capacity parameters				Emission rate of OFP			
Dimensions	300km in length [a]	100 km in width [a]	516.2m in height [b]	Biomass fuels consumed	1.59E9 kg [g]	Coal used	2.50E9 kg [g]
Atmospheric volume of Guanzhong Plain	1.55E13 m^3 [c]			EFs of SOAP	24.33 $mg \cdot kg^{-1}$ [h]	EFs of SOAP	16.40 $mg \cdot kg^{-1}$ [i]
				Heating periods	100 days [j]		
$PM_{2.5}$ concentration	142.6 $\mu g \cdot m^{-3}$ [d]	SOA fraction	15.5% [e]	SOAP emission rate	386.85 $kg \cdot day^{-1}$ [k]	OFP emission rate	410.00 $kg \cdot day^{-1}$ [k]
SOA atmospheric capacity	3.42E5 kg [f]			Total OFP emission rate	796.85 $kg \cdot day^{-1}$ [m]		

a Sun et al., 2017
b http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/ boundary layer
c Expressed as volume = length * width * height
d http://www.zhb.gov.cn/hjzl/dqhj/cskqzlzkyb/, average O_3 concentration in winter of 2013
e Huang et al. (2014)
f Expressed as Atmospheric capacity = [$PM_{2.5}$] * Atmospheric volume
g Shaanxi Province Statistical Yearbook 2013
h Average SOAP value of biomass fuels heating burning in this study
i Account as bitumite only, use SOAP of bitumite-SG in this study
j Sun et al., 2017
k Expressed as SOAP emission rate = Total fuels consumed * EFs of SOAP / Heating period (unit: $kg \cdot day^{-1}$)
m Expressed as Total SOAP emission rate = SOAP emission rate (biomass) + SOAP emission rate (coal)

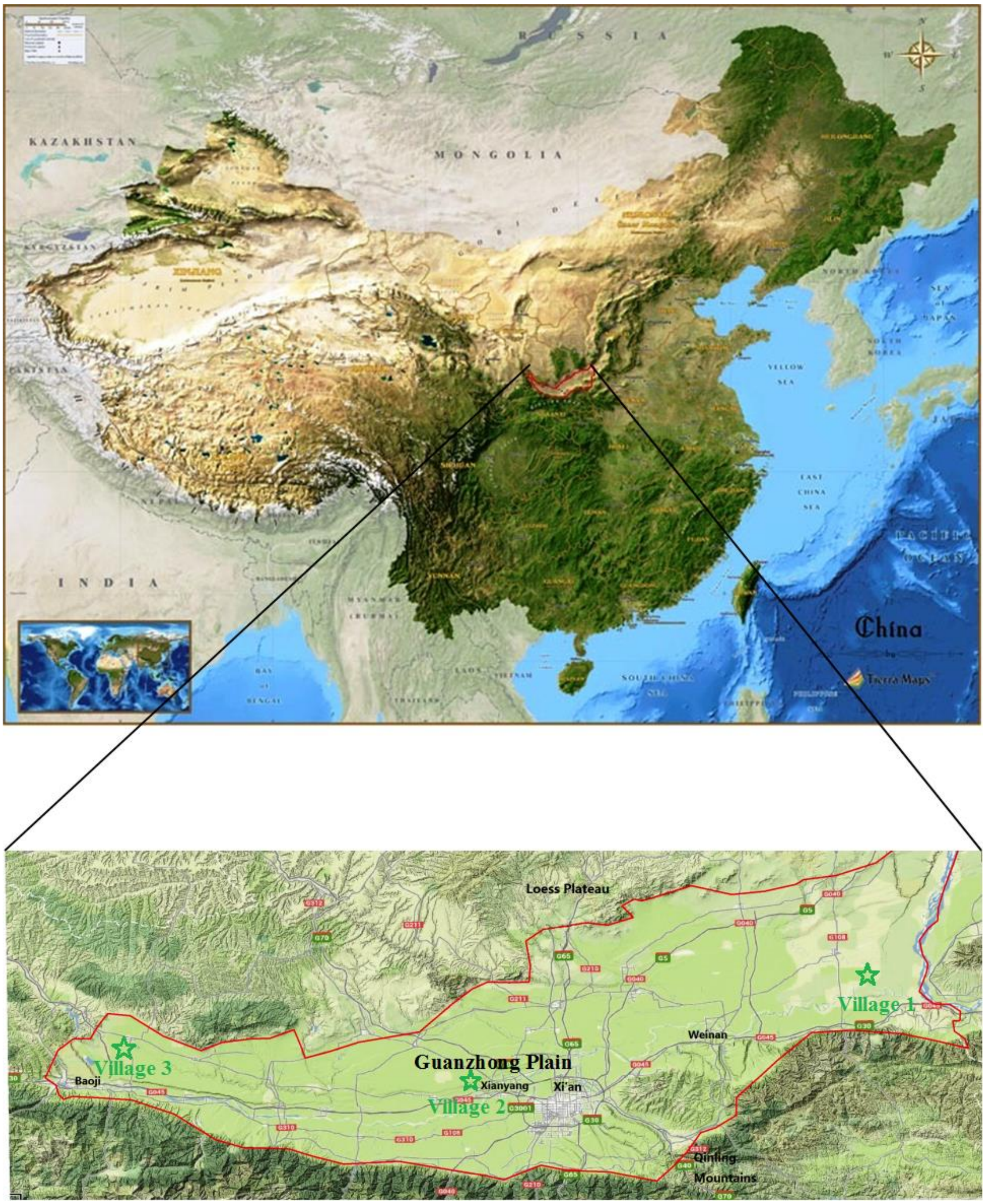
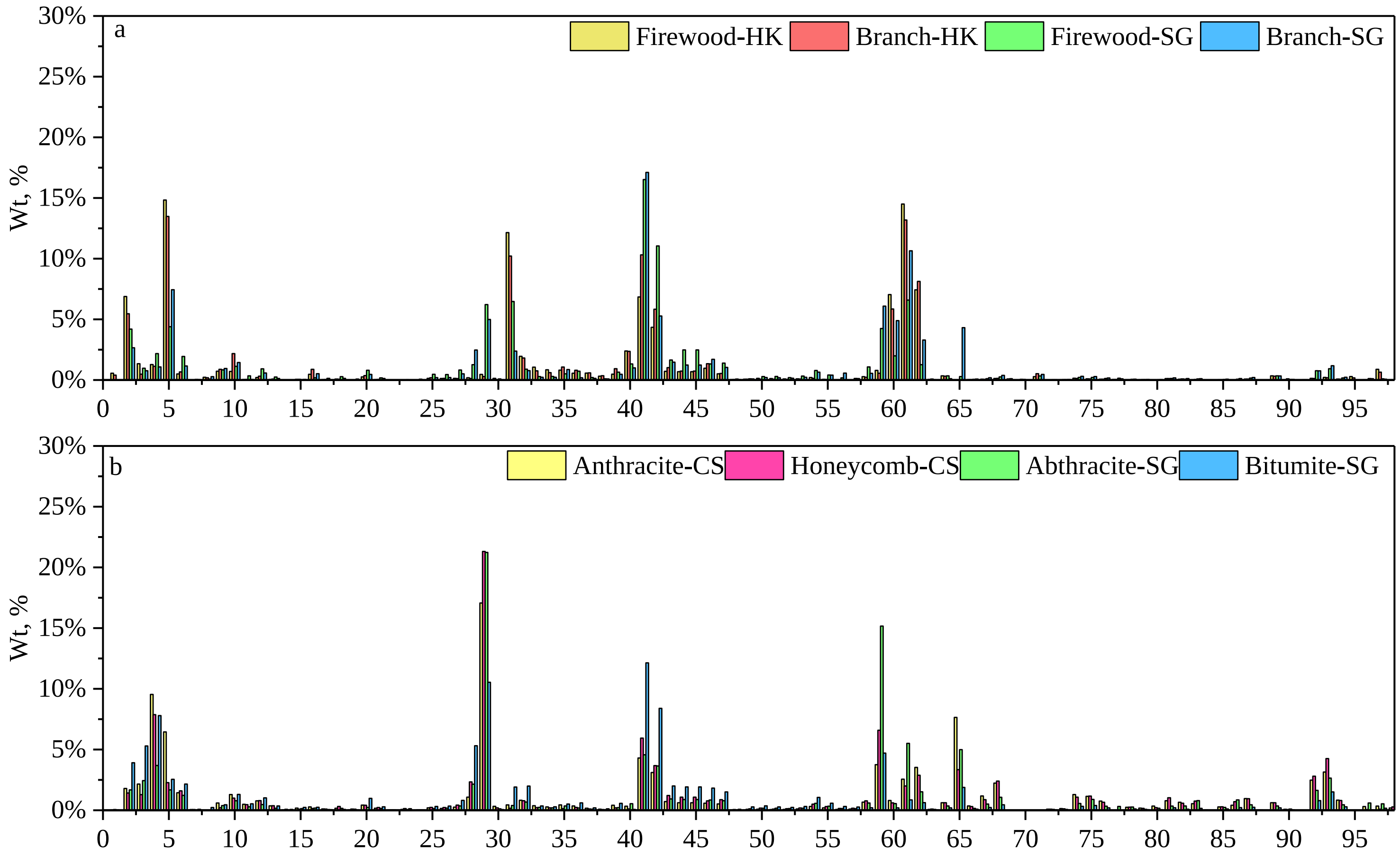
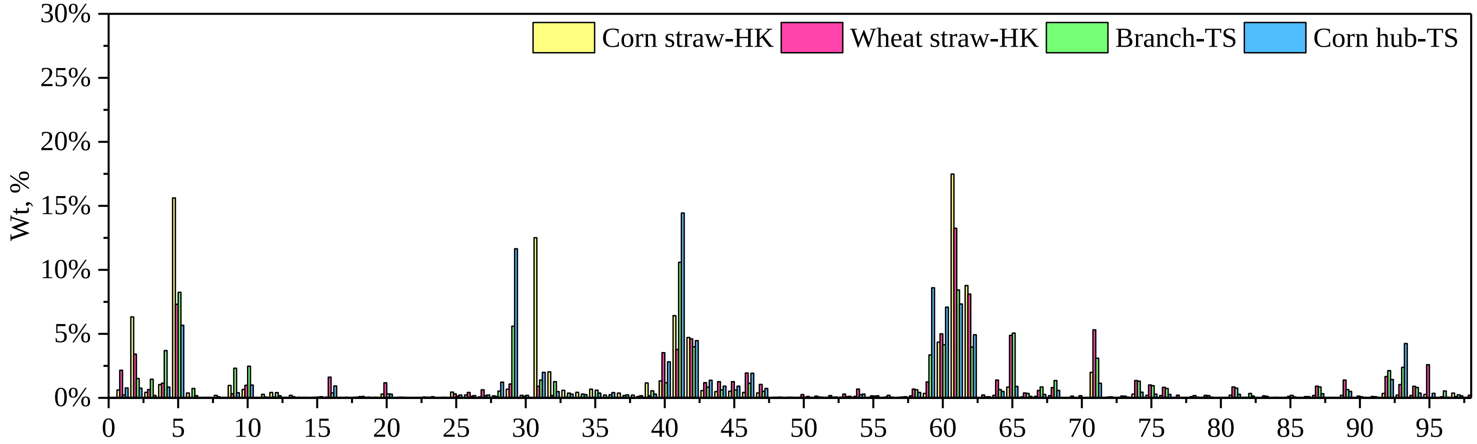

R U S S I A
KAZAKHSTAN
M O N G O L I A
I N D I A
YELLOW SEA
EAST CHINA SEA
China
Tierra Maps
Loess Plateau
Village 1
Weinan
Guanzhong Plain
Village 3
Baoji
Xianyang
Xi'an
Village 2
Qinling
Mountains

Figure S1

Figure S2


a
Firewood-HK
Branch-HK
Firewood-SG
Branch-SG
Wt, %
30%
25%
20%
15%
10%
5%
0%
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
b
Anthracite-CS
Honeycomb-CS
Abthracite-SG
Bitumite-SG
Wt, %
30%
25%
20%
15%
10%
5%
0%
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95



30%
25%
20%
15%
10%
5%
0%
Wt, %
Corn straw-HK
Wheat straw-HK
Branch-TS
Corn hub-TS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95

Figure S3