Supplementary online material

Nitrogen and phosphorus availability of biologically and thermochemically decomposed human wastes and urine in soils with different texture and pH

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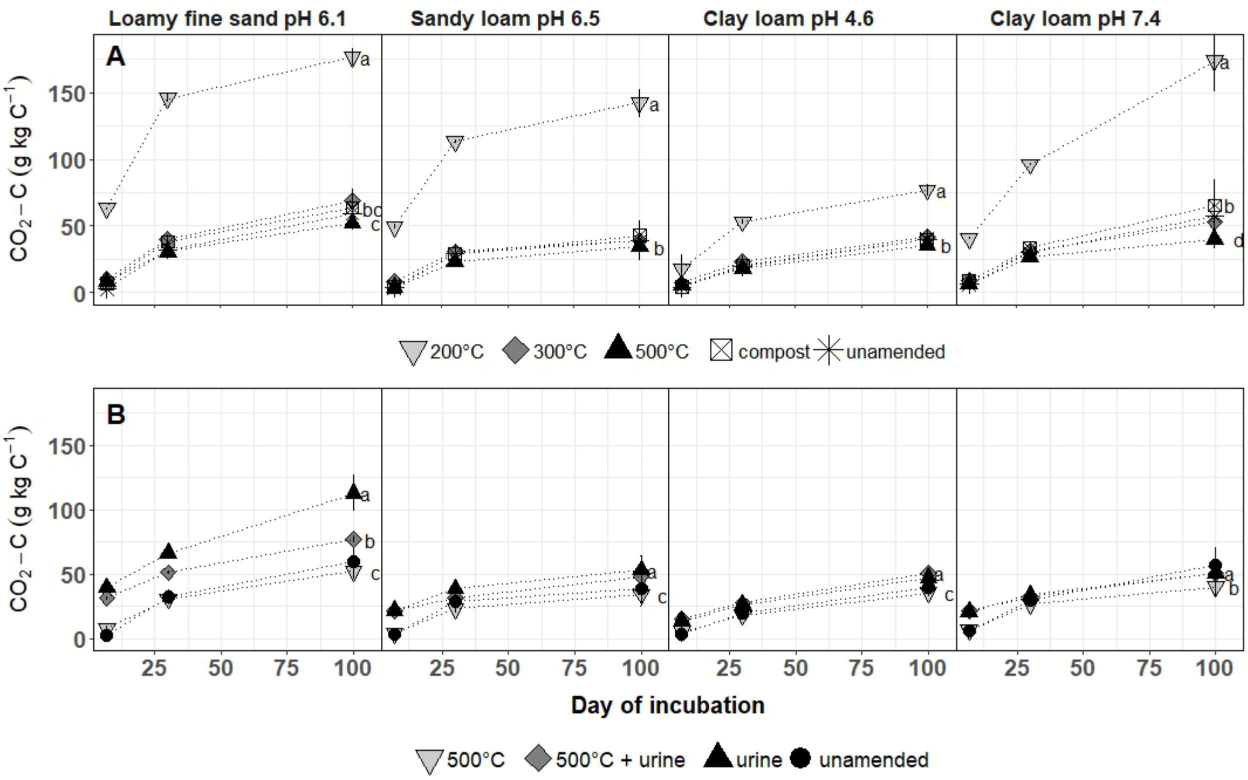
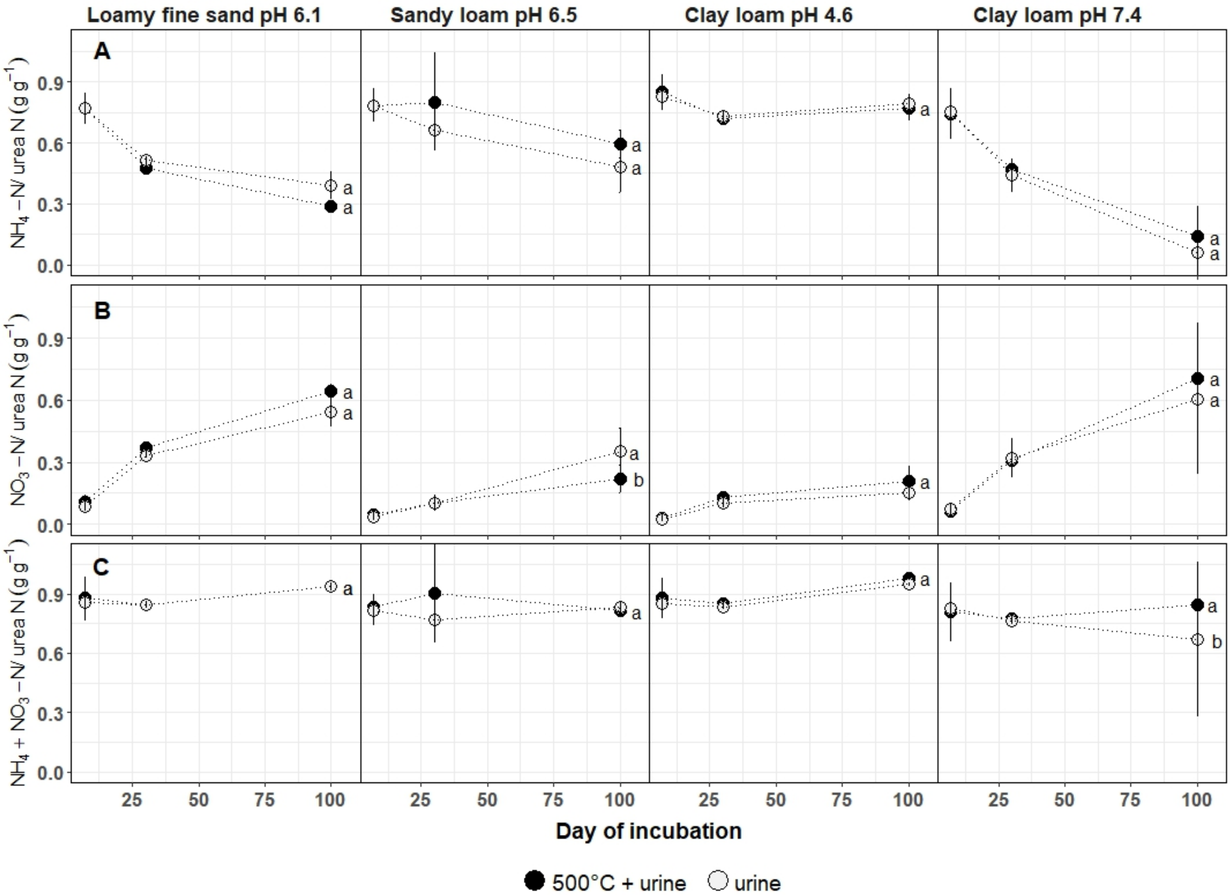
Supplementary Information Appendix I



Supplementary Figure 1. Carbon mineralization (CO_2-C) measured at days 7, 30, and 100 in four soils amended with (A) composted, torrefied (200°C), and pyrolyzed (300°C, 500°C) HSW and (B) 500°C HSW +urine and urine only, compared to an unamended soil. Marker values are means (n = 4) ± standard deviation. Letters indicate significant differences at day 100 between amendments within soil type ($p < 0.05$). Results for LS means and ANOVA and are shown in (A) Supplementary Table 6 and Supplementary Table 7 and (B) Supplementary Table 12 and Supplementary Table 13.



Supplementary Figure 2. Urine-N recovery as available (A) ammonium (NH_4-N), (B) nitrate (NO_3-N), and (C) total mineral N (NH_4+NO_3-N) measured at days 7, 30, and 100 in four soils amended with 500°C +urine and urine only. Marker values are means (n = 4) ± standard deviation. Letters indicate significant differences at day 100 between amendments within soil type ($p < 0.05$).

Soil mineralogy was qualitatively identified using XRD (Ultima IV X-Ray Diffractometer, Rigaku, Tokyo, Japan) following fractionation into sand, silt, and clay particle sizes as per Soukup et al. (2008). Following fractionation, samples were freeze-dried under vacuum and milled to < 50 µm. Clay fractions were suspended in acetone until evaporation to promote random particle orientation (Paterson et al., 1986). Samples were scanned across the 2 theta/theta axis between 3 and 90°, at 2.5° min^{-1}, at a step width of 0.02°. Background peaks from an empty sample holder were subtracted from sample scans prior to mineral identification in the International Center for Diffraction Data (ICDD) database accessed through PDXL2 (Rigaku, Tokyo, Japan). Operation settings were 'calibrated' with known minerals; goethite was used for minerals in the sand and oxide fractions, as well as 1: 1 clays. Ca-montmorillonite was used to identify silicate clays.

Supplementary Table 1

The mineralogy of four Kenyan soils, as analyzed through X-ray diffraction.

Soil type	Phase	Formula	Mineral type	Mineral structure	Description
Clay loam; pH 4.5; clay fraction	Kaolinite-1A	$Al_2\ Si_2\ O_5\ (OH)_4$	Secondary	Phyllosilicate 1:1	
	Cronstedtite-1T	$Fe_3\ ((Si_{1.40}\ Fe_{0.60})O_5)\ (OH)_4$	Secondary	Phyllosilicate 1:1	Kaolinite layers composed of tetrahedral and octahedral sheets
	Lizardite-2H1	$Mg_3\ Si_2\ O_5\ (OH)_4$	Secondary	Phyllosilicate 1:1	Kaolinite layers (with Mg instead of Al) composed of tetrahedral and octahedral
	Muscovite-2M1	$K\ (Al_{1.5}\ Mg_{.5})\ (Si_{3.5}\ Al_{.5})\ O_{10}\ (OH)_2$	Primary	Phyllosilicate 2:1	Mica proper group
	Biotite-2M1	$(K_{1.891}\ Na_{0.062})\ (Fe_{2.427}\ Mg_{3.090}\ Mn_{0.035}\ Ti_{0.448})\ ((Si_{5.568}\ Al_{2.432})\ O_{21.452}\ (OH)_{2.548})$	Primary	Phyllosilicate 2:1	Mica proper group
	Celadonite	$K_{0.83}\ Na_{0.01}\ Ca_{0.03}\ Mg_{0.41}\ Fe_{1.51}\ Al_{0.12}\ Si_{3.94}\ O_{10}\ (OH)_2$	Primary	Phyllosilicate 2:1	Di-octahedral true micas

	Chlorite IIb-4	$(Mg_{11.06}\ Fe_{0.94})\ ((Si_{5.22}\ Al_{2.78})\ O_{20}\ (OH)_{16})$	Secondary	Phyllosilicate 2:1:1	Brittle Mica
Clay loam; pH 4.5; sand fraction	Quartz	$Si\ O_2$	Primary	Tectosilicates	
	Actinolite	$Na_{0.1}\ Ca_{1.68}\ Mg_{4.59}\ Fe_{0.52}\ Al_{0.19}\ Si_{7.92}\ O_{22}\ (OH)_2$	Primary	Inosilicate	Amphibole silicate mineral, possibly fibrous
	Sanidine	$K\ (Al\ Si_3\ O_8)$	Primary	Tectosilicates	High temp form of alkali feldspar (orthoclase)
Loamy fine sand; pH 6.1; clay fraction	Yoderite	$Mg\ Fe_{0.16}\ Al_{2.84}\ (Si\ O_4)_2\ O(OH)$	Secondary	Nesosilicate	Subgroup of Andalusite, Al,Si nesosilicate mineral
	Staurolite	$Al_{17.57}\ Fe_{3.53}\ Mg_{0.78}\ Li_{0.09}\ Si_{7.67}\ Al_{0.33}\ O_{45.32}\ (OH)_{2.81}$	Secondary	Nesosilicate	Subgroup of Andalusite, Al,Si nesosilicate mineral
	Clinohumite	$(Mg_{7.69}\ Fe_{0.87}\ Ti_{0.454})\ (SiO_4)_4\ (O_{1.06}\ (OH)_{0.94})$	Secondary	Nesosilicate	Magnesium silicate, four olivine, one brucite; hydrated olivine, occurs in
	Kaolinite-1A	$Al_2\ Si_2\ O_5\ (OH)_4$	Secondary	Phyllosilicate 1:1	
	Clintonite-1M	$Ca\ Mg_2\ Al_4\ Si\ O_{10}\ (OH)_2$	Secondary	Phyllosilicate 1:1	Ca, Mg, Al phyllosilicate, brittle micas= less Si than other micas, low alkalis
	Celadonite	$K_{0.9}\ Na_{0.1}\ Mg_{0.73}\ Fe_{1.22}\ Al_{0.1}\ Si_{3.96}\ O_{10}\ (OH)_2$	Primary	Phyllosilicate 2:1	Di-octahedral true micas
	Illite-2M2 (NR)	$K\ Al_2\ (Si_3\ Al)\ O_{10}\ (OH)_2$	Secondary	Phyllosilicate 2:1	
Loamy fine sand; pH 6.1; sand fraction	Quartz	$Si\ O_2$	Primary	Tectosilicates	
	Albite	$Na\ Al\ Si_3\ O_8$	Primary	Tectosilicate	Feldspar (plagioclase)
	Orthoclase	$(K_{0.94}\ Na_{0.06})\ (Al\ Si_3\ O_8)$	Primary	Tectosilicate	Alkali feldspar
Clay loam; pH 7.4; clay fraction	Chloritoid-2A	$Mg_{0.64}\ Mn_{0.07}\ Fe_{1.52}\ Al_{3.87}\ Si_2\ O_{10}\ (OH)_4$	Secondary	Nesosilicate	
	Clintonite-1M	$Ca\ Mg_{2.08}\ Fe_{0.18}\ Al_{3.64}\ Si_{1.10}\ O_{10}\ (OH)_2$	Secondary	Phyllosilicate 1:1	Ca, Mg, Al, brittle micas= less Si than other micas, low alkalis
	Kaolinite-1A	$Al_2\ Si_2\ O_5\ (OH)_4$	Secondary	Phyllosilicate 1:1	
	Lizardite-1T	$Mg_3\ (Si_2\ O_5\ (OH)_4)$	Secondary	Phyllosilicate 1:1	Kaolinite layers (with Mg instead of Al) composed of tetrahedral and octahedral
	Muscovite-2M1	$K(Al,V)_2\ (S{+}B_{31i},\ Al)_4\ O_{10}\ (OH)_2$	Primary	Phyllosilicate 2:1	
	Bentonite	$(Ca_{0.06}\ Na_{0.21}\ K_{0.27})\ (Al_{1.64}\ Fe_{0.06}\ Mg_{0.31})\ (Al_{0.29}\ S_{i3.71}\ O_{10}\ (OH)_2)$	Secondary	Phyllosilicate 2:1	Swelling

	Montmorillonite	$Na_{0.3} (Al, Mg)_2 Si_4 O_{10} (OH)_2 \cdot xH_2O$	Secondary	Phyllosilicate 2:1	Swelling
	Palygorskite	$(Mg_{0.669} Al_{0.331})_4 (Si_4 O_{10})_2 (OH)_2 (H_2O)_8$	Secondary	Phyllosilicate 2:1	Mg, Al
	Illite-2M2	$(K, H_{30}) Al_2 (Si_3 Al) O_{10} (OH)_2 \cdot xH_2O$	Secondary	Phyllosilicate 2:1	
	Gibbsite	$Al (OH)_3$	Oxide		
	Birnessite	$Na_{0.55} Mn_2 O_4 \cdot 1.5H_2O$	Oxide		
Clay loam; pH 7.4; sand fraction	Quartz	$Si O_2$	Primary	Tectosilicate	
	Sanidine	$K_{0.41} Na_{0.56} Ca_{0.03} (Al_{1.03} Si_{2.97}) O_8$	Primary	Tectosilicate	High temp form of orthoclase
	Orthoclase	$K Si_3 Al O_8$	Primary	Tectosilicate	Alkali feldspar
	Albite	$Na (Al Si_3 O_8)$	Primary	Tectosilicate	Feldspar (plagioclase)
Sandy loam; pH 6.5; clay fraction	Forsterite, ferroan	$Mg_{1.784} Fe_{0.216} Si O_4$	Primary	Nesosilicates	Olivine group
	Sodium Manganese Silicate	$Na_2 Mn Si O_4$		Inosilicates	Pyroxene family
	Sursassite	$Mn_2 Al_3 (Si O_4) (Si_2 O_7) (OH)_3$		Sorosilicates	Isolated double tetrahedral groups with $(Si_2O_7)^{6-}$ or a ratio of 2:7.
	Lizardite	$Mg_{2.79} Fe_{0.14} Al_{0.24} Si_{1.83} O_5 (OH)_4$	Secondary	Phyllosilicate 1:1	Kaolinite layers (with Mg instead of Al) composed of tetrahedral and octahedral
	Kaolinite-1A	$Al_2 Si_2 O_5 (OH)_4$	Secondary	Phyllosilicate 1:1	
	Halloysite-14 anstrom	$Al_2 Si_2 O_5 (OH)_4$	Secondary	Phyllosilicates 1:1	Mica group; possible neoformation
	Montmorillonite-22A	$Na_{0.3} (Al, Mg)_2 Si_4 O_{10} (OH)_2 \cdot 8H_2O$	Secondary	Phyllosilicates 2:1	Swelling
	Sodium phlogopite hydrate	$Na Mg_3 Al Si_3 O_{10} (OH)_2 \cdot 2H_2O$	Primary	Phyllosilicates 2:1	Mica 'proper' group
Sandy loam; pH 6.5, sand fraction	Sanidine, disordered	$K (Si_3 Al) O_8$	Primary	Tectosilicate	High temp form of orthoclase
	Anorthite, ordered	$Ca Al_2 Si_2 O_8$	Primary	Tectosilicate	Feldspar (plagioclase)
	Phillipsite-K	$(K, Na)_2 (Si, Al)_8 O_{16} \cdot 4H_2O$	Secondary	Tectosilicate	Zeolite family

	Albite (heat-treated)	N (Al Si_3 O_8)	Primary	Tectosilicate	Feldspar (plagioclase)
	Microcline	K (Al Si_3 O_8)	Primary	Tectosilicate	Alkali feldspar

Analysis is qualitative, and only one sample per soil type and clay or sand fraction was analyzed.

Supplementary Table 2

Plant-available nutrients extractable with Mehlich-III solution and acid-digestible, total nutrients in composted, torrefied, and pyrolyzed HSW, with and without urine. Values are means (n = 4) ± standard deviation.

Analysis	Units	200°C	300°C	500°C	compost (60°C)	500°C + urine	urine
Mehlich-III extractable nutrients							
Ca	g kg^{-1}	3.7 ± 0.2	2.9 ± 0.2	3.5 ± 0.1	5.1 ± 0.3		
K	g kg^{-1}	14.2 ± 0.5	15.1 ± 0.6	19.9 ± 0.6	2.9 ± 0.1		
Mg	g kg^{-1}	4.2 ± 0.3	4.0 ± 0.2	5.7 ± 0.4	1.4 ± 0.08		
P	g kg^{-1}	7.7 ± 0.5	6.7 ± 0.3	8.1 ± 0.4	1.4 ± 0.09		
S	g kg^{-1}	0.52 ± 0.03	0.18 ± 0.01	0.26 ± 0.02	0.17 ± 0.01		
B	mg kg^{-1}	1.3 ± 2.3	0.96 ± 1.7	0.3 ± 0.5	0.6 ± 1.1		
Cu	mg kg^{-1}	7.2 ± 0.6	4.3 ± 0.5	9.4 ± 0.2	1.3 ± 0.2		
Zn	mg kg^{-1}	169.3 ± 11.2	46.2 ± 2.5	69.0 ± 3.2	79.0 ± 3.1		
Na	g kg^{-1}	1.7 ± 0.07	2.0 ± 0.1	3.2 ± 0.2	0.40 ± 0.02		
Al	mg kg^{-1}	15.8 ± 2.1	6.1 ± 2.5	14.8 ± 5.6	494.7 ± 24.4		
Mn	mg kg^{-1}	119.1 ± 7.7	86.2 ± 4.4	128.1 ± 9.8	274.0 ± 17.3		
$HClO_4 + HNO_3$ extractable nutrients							
Ca	g kg^{-1}	9.3 ± 1.2	17.9 ± 0.1	22.1 ± 0.6	15.0 ± 0.8		
K	g kg^{-1} [g L^{-1}]	10.5 ± 1.9	10.7 ± 0.8	26.4 ± 0.6	4.9 ± 0.8	32.9 ± 0.6	[1.0 ± 0.0]
Mg	g kg^{-1}	5.0 ± 0.5	8.8 ± 0.2	11.5 ± 0.3	2.6 ± 0.08		
P	g kg^{-1} [g L^{-1}]	11.2 ± 1.3	20.1 ± 0.4	24.7 ± 0.5	7.8 ± 1.5	54.1 ± 0.5	[4.5 ± 0.0]
S	g kg^{-1}	2.9 ± 0.3	1.9 ± 0.02	1.9 ± 0.04	1.7 ± 0.1		
B	mg kg^{-1}	9.1 ± 4.6	6.6 ± 4.0	5.3 ± 4.0	11.1 ± 6.7		
Cu	mg kg^{-1}	29.1 ± 3.4	82.9 ± 12.8	110.8 ± 6.0	42.2 ± 1.1		
Zn	g kg^{-1}	0.22 ± 0.03	0.38 ± 0.02	0.46 ± 0.04	0.28 ± 0.02		
Na	g kg^{-1} [g L^{-1}]	1.9 ± 0.4	4.3 ± 0.09	8.1 ± 0.3	1.1 ± 0.02	23.8 ± 0.3	[2.4 ± 0.0]
Al	g kg^{-1}	1.7 ± 0.17	0.93 ± 0.0	3.0 ± 0.4	44.1 ± 2.4		
Mn	g kg^{-1}	0.18 ± 0.03	0.31 ± 0.0	0.54 ± 0.06	4.3 ± 1.3		

Supplementary Table 3

Plant-available nutrients extractable with Mehlich-III solution and acid-digestible, total nutrients in four soils collected in Western Kenya.

Analysis	Units	Clay loam pH 4.6	Loamy fine sand pH 6.1	Clay loam pH 7.4	Sandy loam pH 6.5
Mehlich-III extractable nutrients					
Ca	mg kg^{-1}	121.5 ± 8.2	348.0 ± 9.0	3012.5 ± 56.5	920.1 ± 11.9
K	mg kg^{-1}	78.2 ± 10.2	78.2 ± 2.9	745.5 ± 12.2	289.8 ± 3.7
Mg	mg kg^{-1}	29.0 ± 0.5	80.9 ± 3.0	319.0 ± 6.2	218.9 ± 0.1
P	mg kg^{-1}	6.1 ± 0.6	3.3 ± 0.5	2.90 ± 0.3	0.49 ± 0.2
Cu	mg kg^{-1}	2.7 ± 0.0	0.21 ± 0.3	0.00 ± 0.0	0.00 ± 0.0
Zn	mg kg^{-1}	0.35 ± 0.1	0.61 ± 0.1	0.27 ± 0.1	1.74 ± 0.0
Na	mg kg^{-1}	26.5 ± 3.8	28.1 ± 2.3	458.7 ± 13.2	29.7 ± 2.6
$HClO_4$ + HNO_3 extractable nutrients					
Ca	g kg^{-1}	0.21 ± 0.1	0.35 ± 0.1	3.7 ± 0.2	1.2 ± 0.04
K	g kg^{-1}	0.68 ± 0.2	0.56 ± 0.3	5.9 ± 0.3	1.9 ± 0.1
Mg	mg kg^{-1}	354.2 ± 39.8	391.4 ± 8.9	2548.7 ± 150.3	820.3 ± 28.8
P	mg kg^{-1}	376.1 ± 99.1	276.1 ± 105.8	186.1 ± 10.6	359.1 ± 27.6
Cu	mg kg^{-1}	20.2 ± 10.3	10.4 ± 11.2	5.8 ± 0.3	9.0 ± 0.6
Zn	mg kg^{-1}	19.7 ± 5.2	15.2 ± 6.3	95.3 ± 5.5	72.4 ± 4.0
Na	mg kg^{-1}	15.5 ± 2.5	15.3 ± 5.0	755.7 ± 45.6	33.0 ± 3.8

Supplementary Table 4

Least square means of soil and HSW amendment type combinations for available phosphorus (P) at day 100, the change in available phosphorus (ΔP) between days 100 and 0, pH at day 100, and the change in pH (ΔpH) between days 100 and 0. Letters indicates significant differences ($p < 0.05$) for means of n = 4 observations.

Soil	Amendment	P (mg kg soil^{-1})	ΔP (mg kg soil^{-1})	pH	ΔpH
	200°C	18.3 c	-0.59 d	5.9 ab	-0.15 a
	300°C	28.2 b	9.3 b	6.0 a	-0.22 a
Loamy fine sand pH 6.1	500°C	39.5 a	16.6 a	6.2 a	-0.32 a
	compost	16.9 c	5.9 bc	5.6 bc	-0.5 a
	unamended	7.0 d	3.6 cd	5.5 c	-0.44 a
	200°C	7.3 bc	-18.5 b	6.0 a	-0.26 a
	300°C	11.1 b	-17.4 b	6.1 a	-0.11 a
Sandy loam pH 6.5	500°C	17.9 a	-17.9 b	6.3 a	-0.24 a
	compost	7.3 bc	-1.3 a	6.0 a	-0.5 a
	unamended	3.3 c	-4.6 a	5.9 a	-0.54 a
	200°C	16.9 b	1.4 c	4.6 a	-0.12 a
	300°C	25.8 a	9.7 a	4.2 ab	-0.50 a
Clay loam pH 4.6	500°C	30.3 a	8.8 ab	4.4 ab	-0.44 a
	compost	15.5 b	5.2 abc	4.1 b	-0.51 a
	unamended	8.9 c	3.7 bc	4.1 b	-0.53 a
	200°C	15.7 c	-12.2 d	7.3 a	0.06 a
	300°C	26.3 b	15.3 a	7.0 ab	-0.33 ab
Clay loam pH 7.4	500°C	34.9 a	18.9 a	7.1 a	-0.36 ab
	compost	13.4 c	-1.1 c	6.9 ab	-0.4 ab
	unamended	7.8 d	4.9 b	6.7 b	-0.68 b

Supplementary Table 5

Results of ANOVA F test evaluating the significance of HSW amendment and soil type on available phosphorus (P) at day 100, the change in available phosphorus (ΔP) between days 100 and 0, pH at day 100, and the change in pH (ΔpH) between days 100 and 0. Stars indicates significant differences ($p < 0.05$) for means of n = 4 observations.

Order	Variable	P (mg kg soil^{-1})	ΔP (mg kg soil^{-1})	pH	ΔpH
			p value		
1	Amendment[a]	4.5E-33 *	1.1E-20 *	2.1E-09 *	3.2 E-04 *
2	Soil	1.5E-21 *	3.1E-32 *	1.6E-47 *	0.67
3	Amendment:Soil	3.9E-06 *	6.4E-21 *	0.05	0.67

[a]Amendments include torrefied HSW (200°C), pyrolyzed HSW (300°C, 500°C), and composted HSW, and the unamended soil. Variables are nested, with antecedent variables included in each successive analysis.

Supplementary Table 6

Least square means of soil and HSW amendment type combinations for ammonium-N (NH_4-N), nitrate-N (NO_3-N), total mineral nitrogen (NH_4-N, NO_3-N, and NH_4+NO_3-N), and carbon mineralization (CO_2-C) measured on three days. Letters indicates significant differences ($p< 0.05$) for means of n = 4 observations.

Soil	Amendment	Day	NH_4-N (g N kg N^{-1})	NO_3-N (mg N kg N^{-1})	NH_4+NO_3-N (g N kg N^{-1})	CO_2-C (g C kg C^{-1})
Loamy fine sand pH 6.1	200°C	7	-7.1 b	9.1 b	2.0 b	63.0 a
	300°C	7	-2.0 ab	16.4 ab	14.5 a	9.9 b
	500°C	7	-1.8 ab	18.3 a	16.5 a	8.0 b
	compost	7	1.2 a	17.9 a	19.0 a	6.8 b
	unamended	7	0.07 a	20.2 a	20.2 a	2.5 b
Sandy loam pH 6.5	200°C	7	-4.4 a	3.7 a	-0.80	49.4 a
	300°C	7	-5.2 a	10.5 a	5.4 ab	8.2 b
	500°C	7	-3.4 a	8.3 a	5.0 ab	4.0 b
	compost	7	-2.9 a	11.1 a	8.3 a	4.3 b
	unamended	7	-5.4 a	12.1 a	6.7 ab	3.2 b
Clay loam pH 4.6	200°C	7	-2.6 a	3.7 a	1.1 a	17.9 a
	300°C	7	0.87 a	5.6 a	6.5 a	6.8 ab
	500°C	7	-1.4 a	4.7 a	3.3 a	5.5 ab
	compost	7	2.9 a	3.1 a	6.0 a	4.2 b
	unamended	7	2.3 a	3.6 a	5.9 a	3.9 b
Clay loam pH 7.4	200°C	7	-9.9 b	10.0 a	0.11 b	40.3 a
	300°C	7	-4.4 ab	11.7 a	7.4 ab	8.7 b
	500°C	7	-4.3 a	13.0 a	8.7 a	6.4 b
	compost	7	-5.6 ab	9.4 a	3.8 ab	8.2 b

	unamended	7	-5.4 ab	15.5 a	10.1 a	6.0 b
Loamy fine sand pH 6.1	200°C	30	-13.5 b	61.4 a	47.9 a	145.8 a
	300°C	30	-4.6 a	33.3 bc	28.7 b	39.9 b
	500°C	30	-6.1 a	27.6 c	21.5 b	30.7 b
	compost	30	-8.6 ab	38.3 b	29.7 b	38.0 b
	unamended	30	-7.6 a	33.8 bc	26.1 b	32.2 b
Sandy loam pH 6.5	200°C	30	-17.1 b	36.6 a	19.5 a	113.5 a
	300°C	30	-9.4 a	23.3 b	13.9 a	30.6 b
	500°C	30	-7.7 a	24.9 b	17.2 a	22.9 b
	compost	30	-11.5 a	30.9 ab	19.4 a	28.9 b
	unamended	30	-8.3 a	29.5 ab	21.3 a	28.9 b
Clay loam pH 4.6	200°C	30	-5.6 a	15.0 a	9.4 a	53.0 a
	300°C	30	-3.6 a	15.6 a	12.0 a	23.4 b
	500°C	30	-6.0 a	16.9 a	10.9 a	18.1 b
	compost	30	-2.8 a	15.9 a	13.1 a	20.3 b
	unamended	30	-1.4 a	13.1 a	11.8 a	19.6 b
Clay loam pH 7.4	200°C	30	-10.7 b	31.4 a	20.7 a	96.2 a
	300°C	30	-4.4 a	19.9 b	15.5 a	30.9 b
	500°C	30	-4.5 a	21.2 b	16.6 a	26.7 b
	compost	30	-6.0 ab	25.0 ab	19.0 a	33.2 b
	unamended	30	-4.4 a	23.4 ab	19.0 a	30.1 b
Loamy fine sand pH 6.1	200°C	100	-14.2 b	107.0 a	92.7 a	176.9 a
	300°C	100	-5.6 a	55.2 c	49.6 bc	68.8 b
	500°C	100	-6.2 a	54.0 c	47.8 c	52.1 c
	compost	100	-8.0 a	64.2 b	56.2 b	63.5 bc

	unamended	100	-7.1 a	54.9 c	47.8 c	59.5 bc
Sandy loam pH 6.5	200°C	100	-17.0 b	76.7 a	59.7 a	142.4 a
	300°C	100	-9.3 a	36.6 c	27.3 b	39.3 b
	500°C	100	-7.8 a	36.4 c	28.6 b	34.3 b
	compost	100	-11.9 ab	46.2 b	34.3 b	42.7 b
	unamended	100	-10.8 a	42.0 bc	31.3 b	38.7 b
Clay loam pH 4.6	200°C	100	4.1 a	32.2 a	36.3 a	76.9 a
	300°C	100	1.9 a	24.8 ab	26.7 b	41.3 b
	500°C	100	0.54 a	21.1 b	21.7 b	35.6 b
	compost	100	2.5 a	25.5 ab	27.9 b	39.5 b
	unamended	100	5.4 a	17.8 b	23.2 b	40.0 b
Clay loam pH 7.4	200°C	100	-10.7 b	76.4 a	65.7 a	174.0 a
	300°C	100	-4.5 a	36.5 bc	32.0 bc	52.6 cd
	500°C	100	-4.7 a	32.7 c	28.0 c	40.2 d
	compost	100	-6.1 ab	43.4 b	37.3 b	65.3 b
	unamended	100	-5.5 ab	37.7 bc	32.1 bc	57.1 bc

Supplementary Table 7

Results of ANOVA F test evaluating the significance of HSW amendment and soil type on ammonium-N (NH_4-N), nitrate-N (NO_3-N), total mineral nitrogen (NH_4-N, NO_3-N, and NH_4+NO_3-N), and carbon mineralization (CO_2-C). Stars indicates significant differences ($p < 0.05$) for means of n = 4 observations.

	NH_4 (g N kg N^{-1})	NO_3 (mg N kg N^{-1})	NH_4 + NO_3 (g N kg N^{-1})	CO_2 (g C kg C^{-1})
		p value		
Amendment[a]	2.7E-17 *	1.1E-43 *	6.9E-27 *	6.3E-125 *
Soil	2.9E-37 *	4.5E-75 *	2.7E-63 *	4.1E-53 *
Day	8.4E-17 *	7.7E-108 *	5.3E-105 *	1.9E-110 *
Amendment:Soil	2.1E-04 *	7.2E-15 *	4.8E-08 *	1.1E-49 *
Amendment:Day	0.20	9.3E-49 *	4.0E-49 *	1.4E-50 *
Soil:Day	8.6E-16 *	1.5E-32 *	6.8E-20 *	3.6E-22 *
Amendment:Soil:Day	0.38	1.0E-11 *	1.3E-10 *	1.3E-10 *

[a]Amendments include torrefied HSW (200°C), pyrolyzed HSW (300°C, 500°C), and composted HSW, and the unamended soil. Variables are nested, with antecedent variables included in each successive analysis.

Supplementary Table 8

Least square means of soil and HSW amendment type combinations for the ratio of cumulative extractable mineral nitrogen (NH_4+NO_3-N; N_{min}) per unit carbon mineralization (CO_2-C; C_{min}) at day 100. Letters indicates significant differences ($p < 0.05$) for means of n = 4 observations.

Soil	Amendment	N_{min}/C_{min} (g N kg N^{-1}/g C kg C^{-1})
Loamy fine sand pH 6.1	200°C	0.53 b
	300°C	0.73 ab
	500°C	0.92 a
	compost	0.89 a
	unamended	0.83 a
Sandy loam pH 6.5	200°C	0.42 b
	300°C	0.70 a
	500°C	0.85 a
	compost	0.85 a
	unamended	0.86 a
Clay loam pH 4.6	200°C	0.47 a
	300°C	0.65 a
	500°C	0.61 a
	compost	0.71 a
	unamended	0.58 a
Clay loam pH 7.4	200°C	0.38 b
	300°C	0.63 ab
	500°C	0.72 a
	compost	0.61 ab
	unamended	0.60 ab

Supplementary Table 9

Results of ANOVA F test evaluating the significance of HSW amendment and soil type on the ratio of cumulative extractable mineral nitrogen (N_{min}) per unit carbon mineralization (C_{min}) at day 100. Stars indicates significant differences ($p < 0.05$) for means of n = 4 observations.

	N_{min}/C_{min} (g N kg N^{-1}/g C kg C^{-1}) p value
Amendment[a]	7.99E-09 *
Soil	1.75E-05 *
Amendment:Soil	0.45

[a]Amendments are torrefied HSW (200°C), pyrolyzed HSW (300°C, 500°C), HSW compost, pyrolyzed HSW (500°C), and an unamended soil. Variables are nested, with antecedent variables included in each successive analysis.

Supplementary Table 10

Least square means of soil and HSW amendment type combinations for available phosphorus (P) at day 100, the change in available phosphorus (ΔP) between days 100 and 0, pH at day 100, and the change in pH (ΔpH) between days 100 and 0. Letters indicates significant differences ($p < 0.05$) for means of n = 4 observations.

Soil	Amendment	P (mg kg soil^{-1})	ΔP (mg kg soil^{-1})	pH	ΔpH
Loamy fine sand pH 6.1	500°C	39.5 b	16.6 b	6.2 a	-0.3 a
	500°C + urine	49.1 a	24.7 a	5.2 b	-1.2 b
	urine	14.2 c	10.0 c	5.2 b	-0.99 b
	unamended	7.0 d	3.6 d	5.5 b	-0.4 a
Sandy loam pH 6.5	500°C	17.9 a	-17.9 c	6.3 a	-0.2 a
	500°C + urine	19.9 a	-19.1 c	5.5 c	-1.1 b
	urine	6.5 b	2.0 a	5.4 c	-1.1 b
	unamended	3.4 b	-4.6 b	5.9 b	-0.54 a
Clay loam pH 4.6	500°C	30.3 b	8.8 bc	4.4 a	-0.44 a
	500°C + urine	41.1 a	16.5 a	4.4 ab	-0.55 a
	urine	17.7 c	11.5 ab	4.4 a	-0.16 a
	unamended	8.9 d	3.7 c	4.1 b	-0.53 a
Clay loam pH 7.4	500°C	34.9 b	18.9 b	7.1 a	-0.36 a
	500°C + urine	49.0 a	29.5 a	6.2 c	-1.2 b
	urine	16.4 c	13.2 c	6.0 c	-1.4 b
	unamended	7.8 d	4.9 d	6.7 b	-0.68 a

Supplementary Table 11

Results of ANOVA F test evaluating the significance of HSW amendment and soil type on available phosphorus (P) at day 100, the change in available phosphorus (ΔP) between days 100 and 0, pH at day 100, and change in pH (ΔpH) between days 100 and 0. Stars indicates significant differences ($p < 0.05$) for means of n = 4 observations.

Model variable	P (mg kg soil^{-1})	ΔP (mg kg soil^{-1})	pH	ΔpH
			p value	
Amendment[a]	2.7E-34 *	8.5E-13 *	3.2E-16 *	7.8E-10 *
Soil	2.4E-20 *	1.2E-29 *	7.0E-35 *	2.5E-05 *
Amendment:Soil	1.3E-10 *	2.9E-18 *	4.2E-08 *	2.0E-04 *

[a]Amendments are pyrolyzed HSW (500°C), pyrolyzed HSW (500°C)+urine, and urine only, alongside an unamended soil. Variables are nested, with antecedent variables included in each successive analysis.

Supplementary Table 12

Least square means of soil and HSW amendment type combinations for ammonium-N (NH_4-N), nitrate-N (NO_3-N), total mineral nitrogen (NH_4-N, NO_3-N, and NH_4+NO_3-N), and carbon mineralization (CO_2-C) measured on three days. Letters indicates significant differences ($p < 0.05$) for means of n = 4 observations.

Soil	Amendment	Day	NH_4-N (g N kg soil^{-1})	NO_3-N (mg N kg soil^{-1})	NH_4+NO_3-N (g N kg soil^{-1})	CO_2-C (g C kg C^{-1})
Loamy fine sand pH 6.1	500°C	7	-1.3 b	13.0 a	11.7 b	8.0 b
	500°C + urine	7	232.6 a	32.6 a	265.2 a	31.6 a
	urine	7	231.5 a	26.4 a	257.8 a	39.7 a
	unamended	7	0.035 b	11.0 a	11.0 b	2.5 b
Sandy loam pH 6.5	500°C	7	-2.5 b	6.2 a	3.7 b	4.0 b
	500°C + urine	7	235.9 a	14.4 a	250.3 a	21.6 a
	urine	7	234.5 a	10.2 a	244.7 a	21.9 a
	unamended	7	-3.1 b	6.9 a	3.8 b	3.2 b
Clay loam pH 4.6	500°C	7	-2.3 b	7.7 a	5.4 b	5.5 ab
	500°C + urine	7	256.0 a	8.4 a	264.4 a	15.0 a
	urine	7	249.0 a	7.8 a	256.7 a	13.6 ab
	unamended	7	3.4 b	5.3 a	8.7 b	3.8 b
Clay loam pH 7.4	500°C	7	-4.2 b	12.5 a	8.4 b	6.4 b
	500°C + urine	7	223.8 a	19.0 a	242.7 a	21.4 a
	urine	7	227.5 a	21.9 a	249.3 a	21.0 a
	unamended	7	-4.3 b	12.4 a	8.1 b	6.0 b
Loamy fine sand pH 6.1	500°C	30	-4.3 b	19.7 b	15.3 b	30.7 c
	500°C + urine	30	143.9 a	110.7 a	254.6 a	51.2 b
	urine	30	154.9 a	99.7 a	254.6 a	66.4 a
	unamended	30	-4.1 b	18.3 b	14.2 b	32.2 c
Sandy loam pH 6.5	500°C	30	-5.7 c	18.4 a	12.7 b	22.9 b
	500°C + urine	30	240.7 a	31.2 a	271.9 a	31.9 ab

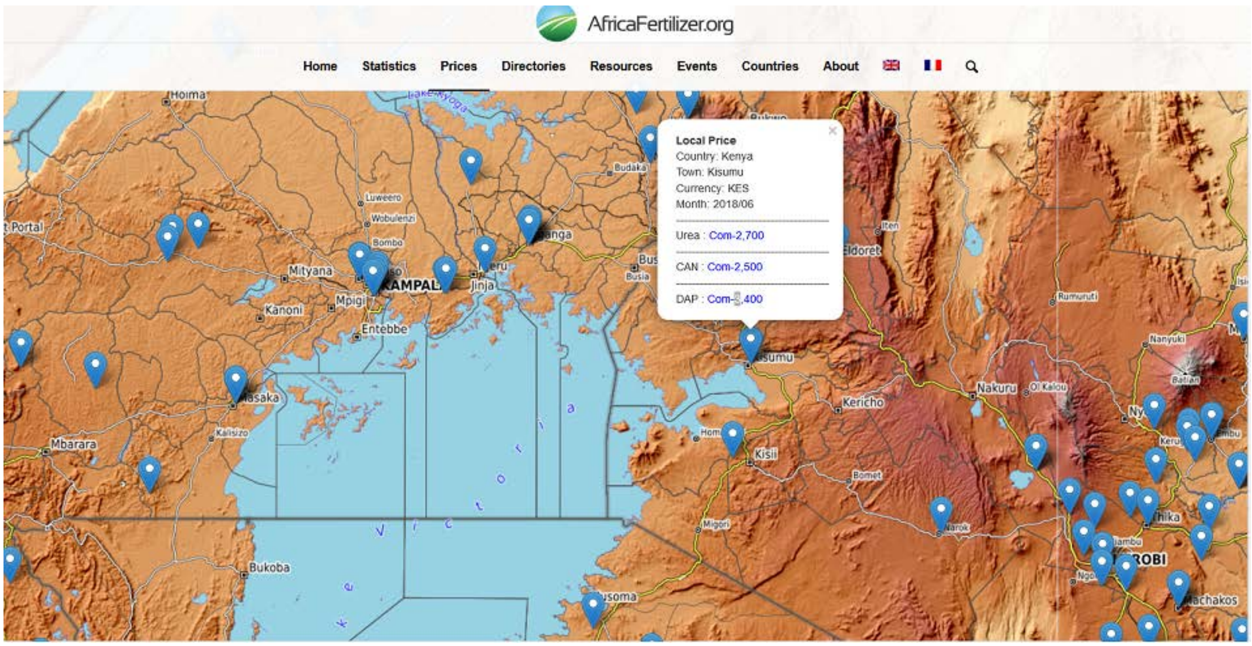
	urine	30	199.1 b	31.4 a	230.5 a	38.8 a
	unamended	30	-4.7 c	16.9 a	12.1 b	28.9 ab
Clay loam pH 4.6	500°C	30	-9.8 b	27.6 a	17.8 b	18.1 a
	500°C + urine	30	216.8 a	38.8 a	255.7 a	27.5 a
	urine	30	219.3 a	30.9 a	250.3 a	26.4 a
	unamended	30	-2.0 b	19.3 a	17.3 b	19.6 a
Clay loam pH 7.4	500°C	30	-4.4 b	20.5 b	16.1 b	26.7 a
	500°C + urine	30	141.6 a	92.2 a	233.7 a	32.8 a
	urine	30	132.5 a	97.0 a	229.5 a	33.9 a
	unamended	30	-3.5 b	18.7 b	15.2 b	30.1 a
Loamy fine sand pH 6.1	500°C	100	-4.4 b	38.5 b	34.1 b	52.1 c
	500°C + urine	100	87.3 a	194.1 a	281.4 a	76.9 b
	urine	100	117.4 a	164.2 a	281.6 a	112.9 a
	unamended	100	-3.9 b	29.8 b	26.0 b	59.5 c
Sandy loam pH 6.5	500°C	100	-5.7 b	26.9 c	21.2 b	34.3 c
	500°C + urine	100	178.9 a	66.1 b	245.0 a	47.7 ab
	urine	100	145.3 a	106.0 a	251.3 a	53.3 a
	unamended	100	-6.2 b	24.0 c	17.8 b	38.7 bc
Clay loam pH 4.6	500°C	100	0.9 b	34.5 a	35.4 b	35.6 c
	500°C + urine	100	231.9 a	62.7 a	294.7 a	50.9 a
	urine	100	239.0 a	46.1 a	285.1 a	47.5 ab
	unamended	100	8.0 b	26.1 a	34.1 b	40.0 bc
Clay loam pH 7.4	500°C	100	-4.5 b	31.7 b	27.1 c	40.2 b
	500°C + urine	100	42.2 a	212.5 a	254.7 a	50.9 a
	urine	100	18.7 ab	182.3 a	201.b	50.4 ab
	unamended	100	-4.4 b	30.1 b	25.7 c	57.1 a

Supplementary Table 13

Results of ANOVA F test evaluating the significance of HSW amendment and soil type on ammonium-N (NH_4-N), nitrate-N (NO_3-N), total mineral nitrogen (NH_4-N, NO_3-N, and NH_4+NO_3-N), and carbon mineralization (CO_2-C). Stars indicates significant differences ($p < 0.05$) for means of n = 4 observations.

	NH_4-N (g N kg soil^{-1})	NO_3-N (mg N kg	NH_4+NO_3-N (g N kg soil^{-1})	CO_2-C (g C kg C^{-1})
			p value	
Amendment[a]	1.6E-107 *	3.3E-36 *	3.0E-110 *	5.0E-41 *
Soil	2.9E-28 *	9.4E-22 *	3.6E-04 *	2.3E-41 *
Day	1.4E-30 *	2.2E-39 *	0.0012 *	1.9E-76 *
Amendment:Soil	9.1E-24 *	1.7E-16 *	0.155	5.3E-23 *
Amendment:Day	5.3E-27 *	6.7E-22 *	0.64	1.4E-04 *
Soil:Day	1.2E-15 *	6.8E-09 *	0.164	1.1E-13 *
Amendment:Soil:Day	2.4E-10 *	8.4E-07 *	0.624	0.003 *

[a]Amendments are pyrolyzed HSW (500°C), pyrolyzed HSW (500°C)+urine, and urine only, alongside an unamended soil. Variables are nested, with antecedent variables included in each successive analysis.



Supplementary Figure 3. Screen-shot showing fertilizer prices in Kisumu, Kenya for June 2018, reported in Kenyan Shillings (KES) per 50 kg bag (http://africafertilizer.org/local-prices/#tab-id-1).