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Designing a suite of measurements to understand the critical zone

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Table S1. Summary of Measurements Planned for Shavers Creek Watershed.

Installation	**Field Site**	**Measurement**
GroundHOG	Shale Hills	Soil Moisture
		Soil Temperature
		Soil Dielectric
		Soil CO_2
		Soil O_2
		Sap Flux
		Groundwater Level
	Garner Run	Soil Moisture
		Soil Temperature
		Soil Dielectric
		Soil CO_2
		Soil O_2
		Sap Flux
		Groundwater Level
TowerHOG	Shale Hills	CO_2 Concentration
		H_2O Concentration
		3-D Wind Velocity
		Air Temperature
		Virtual Temperature
		Relative Humidity
		Precipitation Amount
		Precipitation Type
		Snow Depth

Table S1 (continued).

TowerHOG	Shale Hills	4-Component Radiation (Upwelling & Downwelling; Shortwave & Longwave)
		Digital Imagery (PhenoCam)
	Garner Run	CO_2 Concentration
		H_2O Concentration
		3-D Wind Velocity
		Air Temperature
		Virtual Temperature
		Relative Humidity
		Precipitation Amount
		Precipitation Type
		Snow Depth
		4-Component Radiation (Upwelling & Downwelling; Shortwave & Longwave)
		Digital Imagery
Stream	Shale Hills	Stage/Level
		Discharge
		Water Chemistry (DOC, TOC, DO, NO_3, NH_4, K, F, Cl, pH, EC, ORP, Major Cations, Fe, Mn, Al, Si)
		Suspended Sediment Chemistry (Major Cations, Fe, Mn, Al, Si)
		Hyporheic Zone Exchange (Streambed Water Temperature)
		Turbidity
	Garner Run	Stage/Level
		Discharge
		Chemistry (DOC, TOC, DO, NO_3, NH_4, K, F, Cl, pH, EC, ORP)
		Turbidity
	Shavers Creek - Above Lake	Stage/Level

Table S1 (continued).

Stream	Shavers Creek - Above Lake	Discharge
		Chemistry (DOC, TOC, DO, NO_3, NH_4, K, F, Cl, pH, EC, ORP)
		Turbidity
	Shavers Creek - Below Lake	Stage/Level
		Discharge
		Chemistry (DOC, TOC, DO, NO_3, NH_4, K, F, Cl, pH, EC, ORP)
		Turbidity
	Shavers Creek Outlet	Stage/Level
		Discharge
	Shavers Creek Outlet	Chemistry (DOC, TOC, DO, NO_3, NH_4, K, F, Cl, pH, EC, ORP)
		Turbidity
Groundwater	Shale Hills	Chemistry (Major Cations, Fe, Mn, Al, Si)
		Groundwater Level
		Groundwater Temperature
		Suspended Sediment Chemistry (major cations, Fe, Mn, Al, Si)
COSMOS	Shale Hills	Soil Moisture
	Garner Run	Soil Moisture
Cosmogenics	Shale Hills	Meteoric ^{10}Be Concentrations in Hillslope Regolith
	Garner Run	In Situ ^{10}Be Concentrations in Surface Boulders
Forest Ecology	Shale Hills	Tree Survey (Height, Diameter, Species Distribution)
		Leaf Area Index
		Dendrometer-Basal Growth
		Leaf Litter

Table S1 (continued).

Forest Ecology	Garner Run	Tree Survey (Height, Diameter, Species Distribution)
		Leaf Area Index
		Dendrometer-Basal Growth
		Leaf Litter

Table S2. Soil Descriptions.

Tussey Mountain Midslope Soil Pit (TMMS) (lat/long 40.69965°N, 77.92445°W, dug 6/13/14)

The Tussey Mountain Midslope Soil Pit (TMMS) was observed to be developed on sandstone colluvium parent material. Rock fragments and roots were observed throughout the profile. Large rock fragments were observed mostly below 40 cm. Numerous rock fragments prevented further excavation of the pit. Unaltered parent material was not observed. The hillside was characterized by a 27% slope in the convex-upward part of the hillslope. Pit was dug by hand to 1 m and sampled to 70 cm.

+6 – 0 cm	Oi/a	Organic horizon; largely leaves and some decomposed material.
0 – 6 cm	A	Extremely gravely loamy sand (~12% clay, ~65% rock fragments). 7.5YR 2.5/2 (very dark brown) color. Weak granular structure, very friable moist consistency. Clear wavy boundary. Abundant fine roots.
6 – 21 cm	AE	Extremely gravely loamy sand (~8% clay, ~68% rock fragments), 7.5YR 4/6 (strong brown) color. Clear straight boundary. Weak granular structure, very friable moist consistency. Moderate fine roots.
21 – 37 cm	Bw_1	Extremely gravely sandy loam (~14% clay, ~65% rock fragments), 10YR 5/6 (yellowish brown) color. Clear straight horizon boundary. Weak sub-angular blocky structure, very friable moist consistency. Moderate medium to large roots. Large rock fragments.
37 – 75 cm	Bw_2	Extremely gravely sandy loam (~16% clay, ~70% rock fragments), 10YR 5/6 (yellowish brown) color. Diffuse straight boundary. Weak sub-angular blocky structure, very friable moist consistency. Abundant fine roots, some large roots. Moderately large rock fragments.
75 – 95+ cm	Bw_3	Extremely gravely sandy loam (~19% clay, ~70% rock fragments), 10YR 5/6 (yellowish brown) color. Weak to moderate sub-angular blocky structure, very friable moist consistency. Few moderate iron concentrations present but no depletions. Horizon is saturated after storms. Large rock fragment blocks.

Table S2 (continued).

Leading Ridge Ridgetop Soil Pit (LRRT) (lat/long 40.69391°N, 77.91888°W, dug 5/29/14)

The Leading Ridge Ridgetop Soil Pit (LRRT) was observed to be characterized by sandstone colluvium parent material with a spodic horizon. Rock fragments and roots were observed throughout the profile. Large rock fragments were observed mostly in the upper 20 cm of the profile and roots were observed to be prominent in the upper 40 cm. Rock fragments are blocky in the upper 14 cm and smaller gravel size rock fragments were observed between 20 and 40 cm. Standing water in the bottom of the pit (observed shortly after digging) precluded deeper description. Deeper excavation than 105 cm was hindered by large blocks of sandstone that could no longer be cracked by hand with a breaker bar. These boulders (tens of cms in dimension) were cemented in place by clay or were bedrock. At the bottom of the pit there were large sandstone blocks with fine-grained material between blocks. The ridgetop at the location of the pit had <2% slope. Within one week of digging this pit, it was filled with water and remained filled until pit was back-filled.

+7 – 0 cm	Oe	Organic horizon; moderately decomposed leaf material. 5YR 2.5/1 (black) color. Abundant find roots.
0 – 10 cm	E	Very gravely fine sandy loam (~10% clay, ~60% rock fragments). 10YR 6/2 (light brownish gray) color. Abrupt wavy horizon boundary. Weak sub-angular blocky structure, very friable moist consistency. Abundant fine roots. Disoriented large rock fragment clasts. Abundant fine roots.
10 – 14 cm	Bhs	Very gravely sandy loam (~12% clay, ~45% rock fragments), 7.5YR 3/3 (dark brown) color. Abrupt wavy horizon boundary. Weak sub-angular blocky structure, very friable moist consistency. Moderate fine roots.
14 – 20 cm	Bs	Gravely sandy loam (~15% clay, ~20% rock fragments), 10YR 5/6 (yellowish brown) color. Clear wavy horizon boundary. Weak sub-angular blocky structure, very friable moist consistency. Moderate fine roots. Few large rock fragments, mostly small rock fragments.
20 – 32 cm	Bw_1	Loam (~17% clay, ~10% rock fragments), 10YR 6/6 (brownish yellow) color. Clear straight horizon boundary. Moderate sub-angular blocky structure, friable moist consistency. Few moderate redoximorphic concentrations. Small rock fragments. Possibly faint clay bridges.

Table S2 (continued).

32 – 65+ cm	Bw_2	Loam (~18% clay, ~10% rock fragments), 10YR 6/6 (brownish yellow) color. Weak prismatic structure, very friable moist consistency. Few moderate redoximorphic concentrations. Small rock fragments. Possibly faint clay bridges. Large laterally-growing roots in upper part of horizon (32 – 40 cm). Large blocks of sandstone in this horizon with fine-grained material present between blocks.

Leading Ridge Midslope Soil Pit (LRMS) (lat/long 40.6949°N, 77.92004°W, dug 6/2/14 to 6/3/14)

The Leading Ridge Midslope Soil Pit (LRMS) was characterized by sandstone colluvium parent material with a spodic horizon. Rock fragments and roots were observed throughout profile. Roots are mostly observed in the upper 26 cm but fine roots extend to the bottom of the pit (145 cm). Large rock fragments are present from 0 – 12 cm and again from 26 – 145 cm, with rock fragment size increasing in size with depth. Ponded water was observed in the bottom of the pit but did not obstruct description. The pit was dug on a 25% slope located at the bottom of the convex-upward part of the hillslope. Digging was similar to LRRT but with fewer large boulders. Clay rinds on rock fragments, when observed, also appeared smaller than those at the LRRT. The pit was dug to 165 cm but sampled only to 140 cm.

+8 – 0 cm	Oe	Organic horizon; moderately decomposed leaf material. 5YR 2.5/2 (dark reddish brown) color. Abundant fine roots.
0 – 12 cm	E	Extremely gravely loamy sand (~10% clay, ~65% rock fragments). 10YR 6/2 (light brownish gray) color. Abrupt wavy horizon boundary. Weak sub-angular blocky to granular structure, very friable moist consistency. Abundant fine roots. Disoriented large rock fragment clasts.
12 – 15 cm	Bhs	Very gravely loamy sand (~12% clay, ~45% rock fragments), 7.5YR 3/3 (dark brown) color. Abrupt wavy horizon boundary. Weak sub-angular blocky structure, very friable moist consistency. Moderate fine roots.
15 – 26 cm	Bs	Very gravely loamy sand (~14% clay, ~50% rock fragments), 7.5YR 4/6 (strong brown) color. Abrupt wavy horizon boundary. Weak sub-angular blocky structure, very friable moist consistency. Moderate fine to medium roots. Abundant small rock fragments.

Table S2 (continued).

26 – 50 cm	Bw_1	Gravely loam (~18% clay, ~20% rock fragments), 10YR 5/6 (yellowish brown) color. Clear straight horizon boundary. Moderate sub-angular blocky structure, friable moist consistency. Very large rock fragments. Fine-grained material between large rocks. Few fine roots, roots often smashed on rock faces and dark in color.
50 – 72 cm	Bw_2	Gravely loam (~20% clay, ~30% rock fragments), 10YR 5/6 (yellowish brown) color. Clear straight horizon boundary. Moderate sub-angular blocky structure, friable moist consistency. Large blocks with fine-grained material present between blocks. Few fine roots.
72 – 145+ cm	C	Extremely gravely loamy sand (~8% clay, ~90% rock fragments). 10YR 5/6 (yellowish brown) color. Weak sub-angular blocky to granular structure, loose to friable moist consistency. Very large rock fragments, appear to be oriented somewhat horizontally with fine-grained material between blocks. Water ponded at bottom of pit.

Leading Ridge Valley Floor Soil Pit (LRVF) (lat/long 40.69617°N, 77.92138°W, digging commenced 6/4/14 and proceeded by hand to 90 cm; digging re-commenced 6/23/14-6/24/14 with a jackhammer until 180cm)

The Leading Ridge Valley Floor Soil Pit (LRVF) was dug in the footslope and was characterized by sandstone colluvium over sandstone residuum parent material with a spodic horizon. Roots are mostly present in the upper 45 cm, with abundant fine roots concentrated in the upper 10 cm. Very few roots were observed below 50 cm. Angular rock fragments are abundant in the upper 10 cm and decrease in size from 10 – 33 cm depth. Large rock fragments are observed from 95 – 138 cm depth, with some rounded rock fragments. Redoximorphic iron concentrations are observed between 14 – 138 cm and increase in size and distinction with depth. Most redoximorphic features are present as circular depletions surrounded by a concentration halo. Rotten sandstone is present below 138 cm in some places. Some water present at the bottom of the pit.

+8 – 0 cm	Oe	Organic horizon; moderately decomposed leaf material. 5YR 2.5/2 (dark reddish brown) color. Abundant find roots.
0 – 5 cm	E	Extremely gravely sandy loam (~12% clay, ~65% rock fragments). 7.5YR 6/1 (gray) color. Abrupt wavy horizon boundary. Weak sub-angular blocky to granular structure, very friable moist consistency. Abundant fine roots. Disoriented large rock fragment clasts.

Table S2 (continued).

5 – 7 cm	Bhs	Gravely sandy loam (~14% clay, ~20% rock fragments), 7.5YR 3/2 (dark brown) color. Abrupt wavy horizon boundary. Weak sub-angular blocky structure, friable moist consistency. Abundant fine roots.
7 – 14 cm	Bs	Gravely sandy loam (~15% clay, ~20% rock fragments), 10YR 6/6 (reddish yellow) color. Abrupt wavy horizon boundary. Weak sub-angular blocky parting to granular structure around roots, very friable moist consistency. Abundant fine roots.
14 – 33 cm	Bw_1	Gravely sandy clay loam (~26% clay, ~20% rock fragments), 10YR 6/6 (brownish yellow) color. Clear wavy horizon boundary. Moderate sub-angular blocky to weak granular structure, very friable moist consistency. Few faint redoximorphic Fe depletions and concentrations, mostly observed as depletions with a concentration halo. Increased abundance of roots in this horizon.
33 – 60 cm	Bw_2	Very gravely sandy clay loam (~32% clay, ~50% rock fragments), 10YR 5/4 (yellowish brown) color. Clear straight horizon boundary. Moderate sub-angular to angular blocky structure, friable moist consistency. Few distinct redoximorphic iron depletions and concentrations, mostly observed as depletions with a concentration halo (Round, penny-sized features). Mn concentrations present. Large roots present to 45 cm, very few roots below 50 cm.
60 – 95 cm	Bt	Very gravely sandy clay loam (~24% clay, ~50% rock fragments). 10YR 4/6 (dark yellowish brown) color. Moderate angular blocky structure, friable moist consistency. Few weak clay films. Moderate distinct redoximorphic iron depletions and concentrations, mostly observed as depletions with a concentration halo (i.e., round, penny-sized features). Mn enrichments observed as coatings.
95 – 138 cm	BC	Extremely gravely loamy sand (~8% clay, ~70% rock fragments). 10YR 5/6 (yellowish brown) color. Single grain structure, loose moist consistency. Moderate distinct redoximorphic iron depletions and concentrations, mostly observed as depletions with a concentration halo (Round, 50-cent-sized features). Mn enrichments observed.
138 – 155+ cm	2Cr	Large sandstone blocks, with rotten rock within some sandstone blocks in this horizon. Sandstone appears to be residual.

Table S3. Five Rock Compositions.[1]

Sample	Al_2O_3 (%)	BaO (%)	CaO (%)	Fe_2O_3T (%)[2]	K_2O (%)	MgO (%)	MnO (%)	Na_2O (%)	P_2O_5 (%)	SiO_2 (%)	TiO_2 (%)	LOI (900C)
LRVF 160-170 cm rock (SSHOOOZIY)	0.65	0.00	0.01	0.08	<.02	0.02	0.00	0.09	0.02	96.9	0.08	1.28
LRVF 175cm floor south rock (SSHOOO2JO)	0.61	0.00	0.01	0.10	<.02	0.02	0.00	0.09	<.02	97.8	0.07	1.05
LRMS 85cm south rock	0.79	0.00	0.00	0.47	<.02	0.02	0.00	0.08	0.03	99.3	0.06	0.34
LRRT 60-70cm rock (SSHOOO2JQ)	11.08	0.03	0.02	2.45	2.85	0.54	0.00	0.21	0.05	77.7	1.32	3.41
TMMS 50-70cm rock (SSHOOO2IG)	1.03	0.00	0.03	0.63	0.02	0.04	0.00	0.08	<.02	96.3	0.16	1.25

[1]Compositions of bulk rock as measured by inductively coupled plasma atomic emission spectroscopy after Li metaborate fusion. Each rock is noted to have been sampled from one of the soil pits (see Table S2): the sample ISGN number is also given (i.e., SSHOOOZJY). Of these five rock analyses, sshooo2jq was not used in the bulk average estimate of parent rock because of its anomalous composition.

[2]Total iron presented as ferric oxide (iron speciation was not calculated).

Table S4. Soil Composition.[1]

Your #	Al_2O_3 (%)	BaO (%)	CaO (%)	Fe_2O_3T[2] (%)	K_2O (%)	MgO (%)	MnO (%)	Na_2O (%)	P_2O_5 (%)	SiO_2 (%)	TiO_2 (%)	LOI (900C)
LRVF 0-10cm - SSH0002KG	2.29	0.01	0.03	1.60	0.37	0.10	0.00	0.10	0.13	94.3	0.87	3.69
LRVF 40-50cm - SSH0002KK	6.84	0.02	0.04	2.60	1.03	0.41	0.01	0.15	0.10	84.9	0.76	4.26
LRVF 60-70cm - SSH0002KM	4.13	0.01	0.03	2.23	0.64	0.24	0.01	0.11	0.04	90.0	0.50	2.57
LRVF 110-120cm - SSH0002KR	3.61	0.01	0.04	3.11	0.64	0.21	0.02	0.08	0.08	90.5	0.46	2.07
LRVF 160-170cm - SSH0002KW	2.27	0.01	0.02	1.04	0.39	0.13	0.01	0.05	0.06	95.3	0.39	1.11
LRRT 0-10cm - SSH0002JS	3.63	0.01	0.03	1.17	0.93	0.19	0.01	0.04	0.06	81.9	0.82	12.3
LRRT 10-20cm - SSH0002JT	3.22	0.00	0.02	2.30	0.52	0.12	0.01	0.05	0.22	88.7	0.74	3.99
LRRT 20-30 cm - SSH0002JU	7.18	0.01	0.04	3.02	1.15	0.29	0.02	0.12	0.21	80.5	0.91	6.25
LRRT 30-40cm - SSH0002JV	7.23	0.02	0.04	2.45	1.35	0.34	0.01	0.13	0.13	83.2	0.98	4.05
LRRT 60-70cm - SSH0002JY	11.4	0.03	0.02	2.48	2.85	0.55	0.00	0.16	0.10	76.3	1.36	4.22
LRMS 0-10cm - SSH0002K0	2.67	0.00	0.01	1.20	0.37	0.11	0.00	0.04	0.09	92.2	0.59	4.00
LRMS 20-30cm - SSH0002K2	6.92	0.01	0.03	2.05	0.90	0.27	0.00	0.10	0.12	84.0	0.74	6.07

Table S4 (continued).

LRMS 60-70cm - SSH0002K6	4.66	0.01	0.01	1.89	0.68	0.19	0.00	0.04	0.06	89.7	0.47	2.38
LRMS 70-80cm - SSH0002K7	5.36	0.01	0.01	2.05	0.83	0.23	0.00	0.05	0.07	88.3	0.53	2.78
LRMS 130-140cm - SSH0002KD	3.63	0.00	0.01	2.72	0.57	0.15	0.00	0.04	0.10	90.5	0.58	2.01
TMMS 0-10cm - SSH0002L2	1.71	0.00	0.03	0.74	0.18	0.08	0.00	0.04	0.08	94.3	0.28	3.60
TMMS 10-20cm - SSH0002L3	2.63	0.00	0.02	1.05	0.22	0.09	0.00	0.05	0.10	91.2	0.38	3.54
TMMS 20-30cm - SSH0002L4	2.38	0.00	0.02	1.22	0.16	0.07	0.00	0.04	0.13	93.6	0.29	2.35
TMMS 30-40cm - SSH0002L5	2.80	0.00	0.02	1.43	0.21	0.10	0.00	0.05	0.10	94.0	0.30	2.46
TMMS 60-70cm - SSH0002L8	2.91	0.00	0.02	1.19	0.29	0.13	0.01	0.05	0.06	93.9	0.29	1.92

[1]Compositions of bulk rock as measured by inductively coupled plasma atomic emission spectroscopy after Li metaborate fusion. Each rock is noted to have been sampled from one of the soil pits (see Ta sample ISGN number is also given (i.e., sshooozjy). Of these five rock analyses, sshooo2jq was not used in the bulk average estimate of parent rock because of its anomalous composition.

[2]Total iron presented as ferric oxide (iron speciation was not calculated).

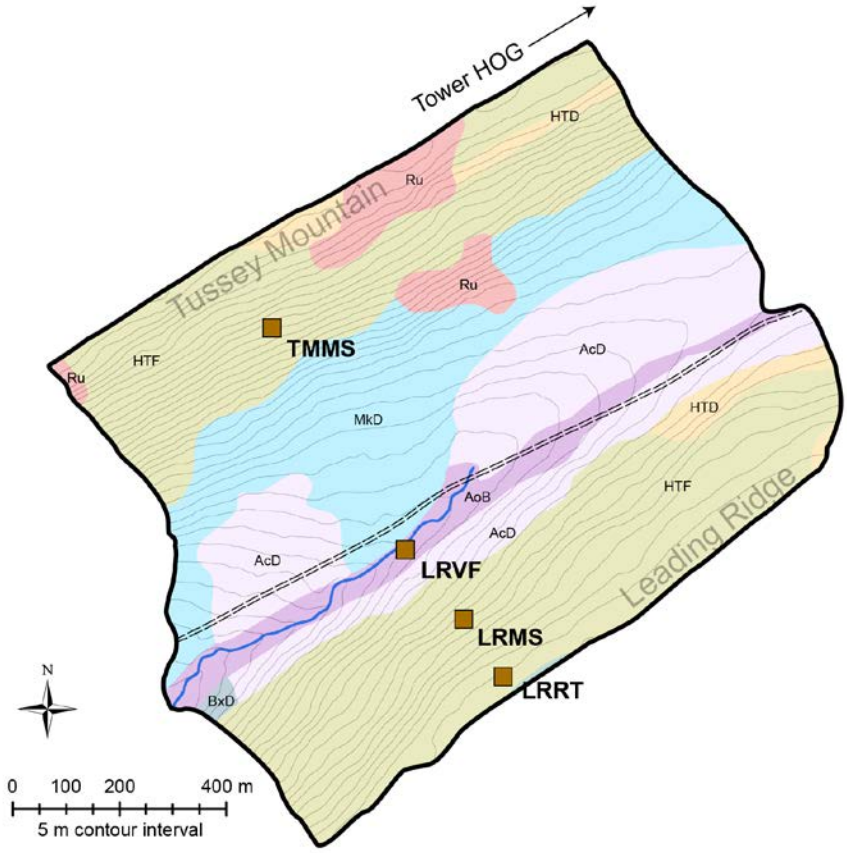

Figure S1. US Department of Agriculture soil series map of Garner Run subcatchment showing location of soil pits TMMS, LRVF, LRMS, and LRRT (brown squares). Data sourced from the Soil Survey Geographic (SSURGO) database (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/). AcD – Albrights very stony silt loam, 8-25% slopes; AoB – Andover extremely stony loam, 0-8% slopes; BxD – Buchanan extremely stony loam, 8-25% slopes; HTD – Hazelton-Dekalb association, moderately steep, 0-; HTF – Hazelton-Dekalb association, steep; MkD – Meckesville very stony silt loam, 8-25% slopes; Ru – Rubble land.

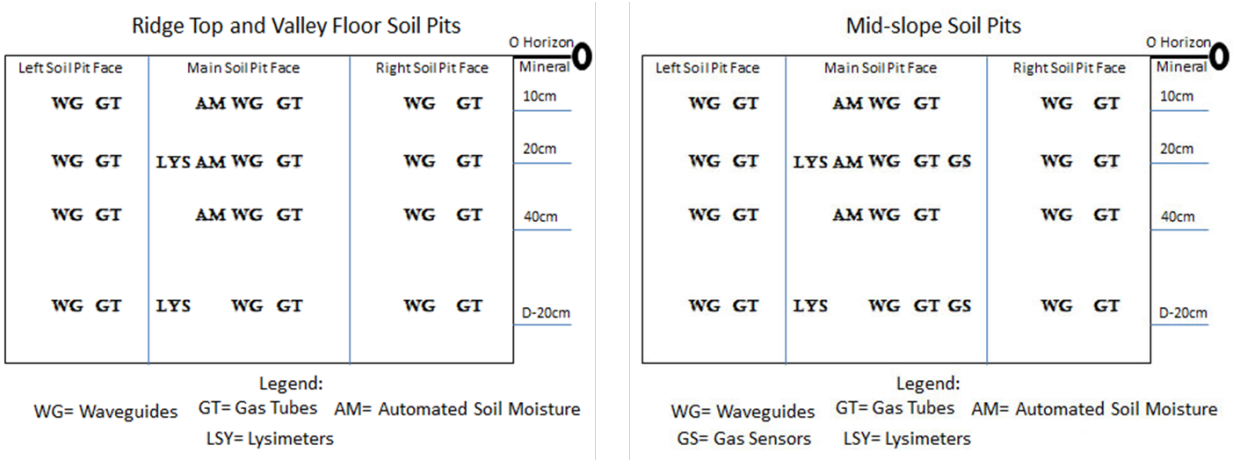

Figure S2. Schematic summary of all the sensors deployed as Ground HOG, including where the sensors are deployed. D-20cm refers to a position 20 cm above the bottom of the pit (see Table S2). See text for further description of the deployment.

Figure S3. Photographic montage of depth intervals of the TMMS pit in the Garner Run subcatchment. The five images from top to bottom show the following depth intervals: 0 to 30 cm, 30 to 60 cm, 60 to 90 cm, 90 to 120 cm, and 120 cm to bottom. Soil description is summarized in Table S2. Photos show decreasing root density and increasing rock size with depth. The uppermost layer of large rocks can also be seen.