Data Availability

Raw XCT data are available upon request. Data generated from the analysis of the XCT images and the available energy measurements are available under the following DOI: 10.17632/436m8s3bpm.2.

Statistics used for Supplementary Tables

A two-tailed t-test was used to determine if there were significant differences between available energy metrics within a given pore network architecture (Table S2). Tukey's honest significant difference test in RStudio [version 1.0.136, 1] was used to determine if there were significant differences between the mean values from each PNA (n = 9, p-values adjusted for multiple comparisons) for (i) the available energy metrics and (ii) the pore network metrics for each volume of interest (Tables S3 - S5).

Figure S1. Experimental set up, consisting of 9 PVC rings filled with soil and instrumented with Pt-electrodes in a fiberglass tub. Treatments are Random (top row, n=3), Large Aggregate (center row, n=3) and Small Aggregate (bottom row, n=3). Blue tarp liner for easy removal of autoclaved sand.

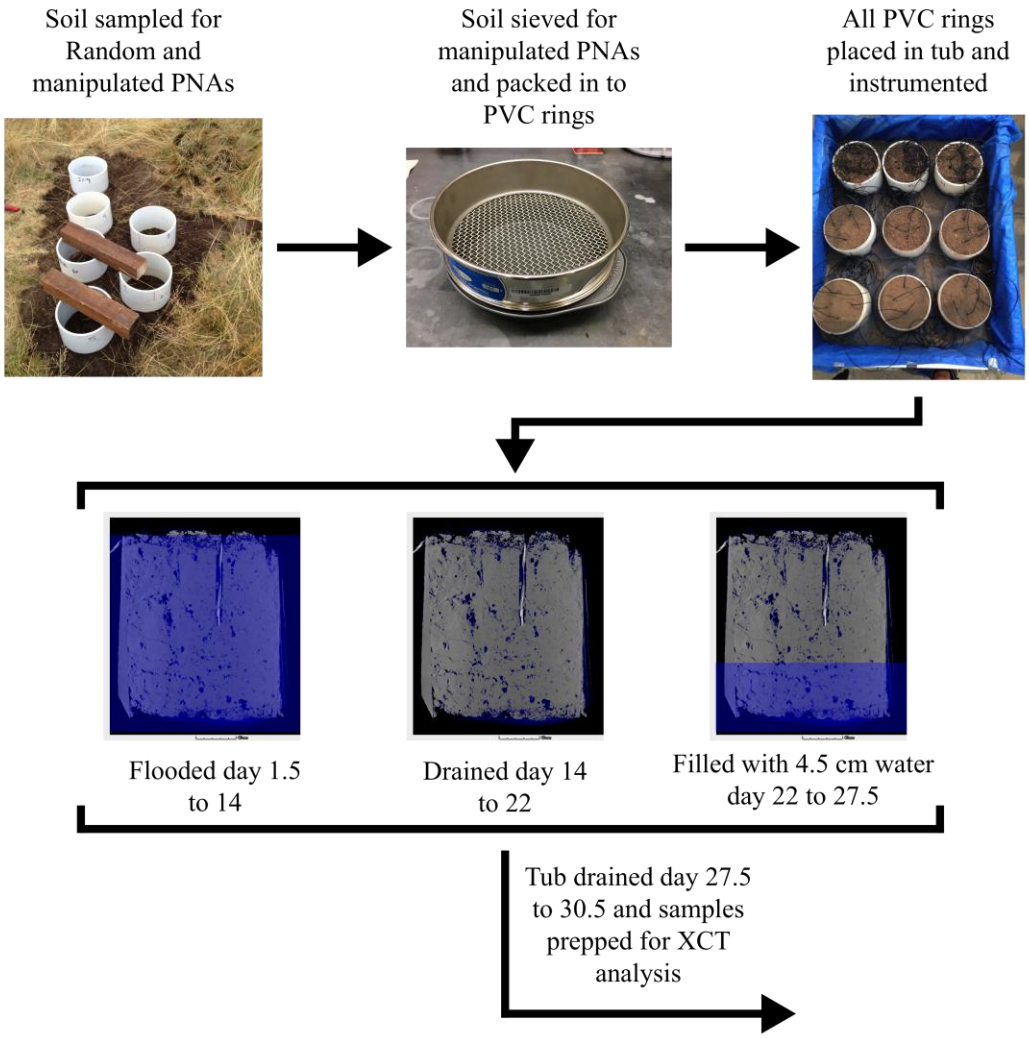

Figure S2. Visual timeline of water saturation conditions. Using an example XCT image, a time line of saturation conditions is shown (blue shading). The level of the blue shading indicates the level of water in the tub. Timing of changes in and duration of conditions are indicated.

a

b

Figure S3. Sub sampling process. Panel a shows the PVC ring itself being cut. Panel b shows one of the sub samples (n = 27) created from the larger PVC rings (N = 9) using acrylic glass panels to create isometric subsections for subsequent XCT analysis. The Pt-electrode was kept at the center of each sub sample to maintain sample integrity.

Table S1. Woodburn series characteristics for A_p horizon, 0 – 20 cm

Classification[a]	Texture[a]	sand/silt/clay[c]	Porosity[b]	Pore volume[c]	pH[d]	C_{org}[d]	N_{org}[d]	CEC_{eff}[d]
		%	%	L m^{-2}		%	%	$mmol_c$ kg^{-1}
Fine-silty, mixed, superactive, mesic Aquultic Argixeroll	Silt loam	5.7/79.5/15.3	48	96	5.6	1.3	0.2	237

[a]Soil classification and texture follow the US Taxonomy data [*Staff, 2015]*.

[b]Percent porosity was calculated as $100 - [\left(\frac{D_b}{D_p}\right) * 100]$, where D_p = 2.65 g/cm^3

[c]Pore volume was calculated as % porosity * horizon thickness (in dm)

[d]Soil characteristic data was collected following methods detailed in Kellogg Soil Survey Laboratory Methods Manual [2]

Table S2. Significant differences (two tailed t-test) between available energy metrics within the pore network architectures. R1,2,3 = "Random + PVC mesocosm number" PNA; LA1,2,3 = "Large Aggregate" PNA; SA1,2,3 = "Small Aggregate" PNA.

EA metric	R1 and R2	R1 and R3	R2 and R3	LA1 and LA2	LA1 and LA3	LA2 and LA3	SA 1 and SA 2	SA1 and SA3	SA2 and SA 3
a	---	---	---	---	---	---	---	---	*
b	---	---	---	---	---	---	---	---	***
c	---	---	---	---	---	**	---	---	---
d	---	---	---	---	---	---	---	---	**
e	---	---	---	---	---	---	---	---	*
f	---	---	---	---	---	---	---	---	---
g	---	---	---	*	---	---	---	---	---
h	---	---	---	---	---	---	---	---	---
i	---	---	---	---	---	---	---	---	---
j	---	---	---	---	---	---	---	---	---

Significance levels: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Table S3. Significant differences in pore network metrics across pore network architectures for **VoI_{100}**, values are mean and (coefficients of variation) with n = 9.

PNM	Units	Pore network architecture			Significant differences between PNAs		
		"Random" (R)	"Large Aggregate" (LA)	"Small Aggregate" (SA)	R : LA	R : SA	SA : LA
		$\overline{x}$ (CV)	$\overline{x}$ (CV)	$\overline{x}$ (CV)			
1	count	3.8 (31)	5.0 (87)	3.9 (37)	---	---	---
2	count	1.5 (36)	2.0 (101)	1.5 (45)	---	---	---
3	mm	0.03 (20)	0.04 (21)	0.04 (13)	**	**	---
4	mm	1.0 (41)	1.4 (92)	1.0 (40)	---	---	---
5	count/ml	0.3 (33)	0.5 (116)	0.4 (53)	---	---	---
6	count/ml	0.03 (22)	0.04 (20)	0.04 (14)	*	**	---
7	count	7987.8 (37)	10199.5 (25)	16586.7 (25)	---	***	***
8	count	357.9 (30)	656.5 (34)	1158.4 (24)	*	***	***
9	---	1.3 (10)	1.4 (26)	1.4 (14)	---	---	---
10	mm^3	1.6 (67)	1.6 (93)	0.8 (54)	---	---	---
11	mm^2	5.1 (57)	6.3 (89)	2.4 (130)	---	---	---
12	mm^3	1.5 (69)	1.4 (106)	0.3 (164)	---	(p = 0.076)	---
13	mm	0.3 (11)	0.3 (23)	0.3 (13)	(p = 0.053)	---	---
14	mm	0.014 (29)	0.022 (19)	0.023 (18)	**	***	---
15	mm^{-1}	3.2 (21)	4.5 (35)	2.3 (70)	---	---	**
16	count	9015.9 (37)	12702.3 (31)	18581.7 (17)	---	***	**
17	count	4414.5 (33)	8188.3 (34)	12215.3 (19)	**	***	**
18	%	12.8 (37)	13.6 (47)	12.7 (31)	---	---	---

PNM = pore network metric
Significance levels * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Table S4. Significant differences in pore network metrics across pore network architectures for **VoI_{25},** values are mean and (coefficients of variation) with n = 9

PNM	Units	Pore network architecture			Significant differences between PNAs		
		"Random" (R)	"Large Aggregate" (LA)	"Small Aggregate" (SA)	R : LA	R : SA	SA : LA
		$\bar{x}$ (CV)	$\bar{x}$ (CV)	$\bar{x}$ (CV)			
1	count	4.2 (38)	2.7 (48)	2.2 (74)	---	*	---
2	count	1.7 (46)	1.0 (66)	0.7 (106)	---	*	---
3	mm	0.04 (17)	0.04 (18)	0.03 (13)	---	(p = 0.056)	**
4	mm	1.2 (44)	0.7 (61)	0.5 (94)	---	*	---
5	count/ml	0.3 (54)	0.2 (79)	0.1 (126)	---	*	---
6	count/ml	0.05 (23)	0.05 (19)	0.04 (15)	---	*	*
7	count	825.7 (37)	1786.3 (32)	4695.4 (26)	*	***	***
8	count	43.3 (45)	143.4 (43)	313.7 (37)	*	***	***
9	---	1.3 (3)	1.3 (1)	1.3 (2)	---	---	---
10	mm^3	3.1 (46)	1.1 (71)	0.5 (84)	***	***	---
11	mm^2	9.2 (35)	5.0 (52)	0.9 (70)	**	***	**
12	mm^3	3.0 (48)	1.0 (76)	0.1 (110)	***	***	---
13	mm	0.3 (12)	0.4 (12)	0.3 (8)	*	---	*
14	mm	0.022 (36)	0.030 (22)	0.023 (24)	*	---	(p = 0.078)
15	mm^{-1}	3.2 (18)	4.7 (14)	2.3 (77)	*	---	***
16	count	1018.8 (53)	2095.6 (36)	5243.6 (27)	(p = 0.067)	***	***
17	count	566.5 (36)	1555.4 (32)	3457.9 (29)	**	***	***
18	%	9.8 (0.5)	8.7 (0.5)	8.7 (0.7)	---	---	---

PNM = pore network metric
Significance levels * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Table S5. Significant differences in pore network metrics across pore network architectures for **$VoI_{0.2}$**, values are mean and (coefficients of variation) with n = 9

PNM	Units	Pore network architecture (PNA)			Significant differences between PNAs		
		"Random" (R)	"Large Aggregate" (LA)	"Small Aggregate" (SA)	R : LA	R : SA	SA : LA
		$\bar{x}$ (CV)	$\bar{x}$ (CV)	$\bar{x}$ (CV)			
1	count	2.1 (45)	2.4 (43)	1.6 (43)	---	---	---
2	count	0.7 (58)	0.8 (61)	0.4 (70)	---	---	---
3	mm	0.3 (31)	0.4 (32)	0.4 (29)	*	---	---
4	mm	0.5 (27)	0.7 (35)	0.6 (32)	(p = 0.065)	---	---
5	count/ml	0.4 (82)	0.6 (68)	0.3 (61)	---	---	(p = 0.075)
6	count/ml	0.2 (81)	0.1 (55)	0.1 (110)	---	---	---
7	count	60.6 (32)	64.2 (69)	69 (67)	---	---	---
8	count	8.4 (29)	8.6 (58)	7.4 (58)	---	---	---
9	---	1.3 (8)	1.3 (7)	1.2 (6)	---	---	---
10	mm^3	0.4 (99)	0.6 (70)	0.5 (81)	---	---	---
11	mm^2	1.0 (82)	1.4 (63)	1.3 (92)	---	---	---
12	mm^3	0.1 (111)	0.2 (91)	0.2 (125)	---	---	---
13	mm	0.2 (23)	0.3 (12)	0.3 (23)	*	---	---
14	mm	0.03 (38)	0.03 (30)	0.03 (38)	---	---	---
15	mm^{-1}	2.8 (73)	3.0 (75)	2.7 (74)	---	---	---
16	count	68.4 (30)	60.5 (55)	75.9 (61)	---	---	---
17	count	28.5 (21)	30.2 (41)	37.8 (21)	---	---	---
18	%	10.6 (61)	14.2 (34)	11.7 (49)	---	---	---

PNM = pore network metric
Significance levels * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Table S6. Significant differences in available energy metrics across pore network architectures, values are mean and (coefficients of variation) with n = 9

EA metric	Parameter	Unit	Pore network architecture (PNA)			Significant differences between PNAs		
			Random	Large Aggregate	Small Aggregate	R : LA	R : SA	SA : LA
			$\overline{x}$ (CV)	$\overline{x}$ (CV)	$\overline{x}$ (CV)			
a	- slope	mV/hr	-10.4 (42)	-18.0 (18)	-14.5 (33)	**	---	---
b	- slope	mV/hr	-3.5 (66)	-24.8 (53)	-18.3 (96)	**	(p = 0.053)	---
c	min	mV	-48.0 (195)	-166.1 (17)	-156.6 (17)	***	**	---
d	time	hr	292.4 (26)	59.4 (22)	154.6 (82)	***	**	(p = 0.066)
e	elapsed time	hr	22.8 (51)	12.0 (154)	22.6 (98)	---	---	---
f	+ slope	mV/hr	4.2 (24)	2.3 (25)	3.5 (61)	*	---	---
g	max	mV	709.3 (16)	669.4 (23)	614.4 (21)	---	---	---
h	elapsed time	hr	480.8 (6)	437.1 (14)	440.2 (17)	---	---	---
i	- slope	mV/hr	-2.8 (76)	-0.5 (242)	-1.1 (93)	*	---	---
j	+ slope	mV/hr	2.3 (133)	0.2 (148)	0.6 (196)	(p = 0.073)	---	---

Tukey's honest significant difference test (n = 9 per pore network architecture) was used to determine significant differences between available energy metrics. P-values were adjusted for multiple comparisons.
Significance levels: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

References

1. RStudio, T. *Rstudio: Integrated development for r. Rstudio, inc.*, Boston, MA 2015.

2. Staff, S.S. Kellogg soil survey laboratory methods manual. Soil survey investigations report no. 42. Burt, R.; Staff, S.S., Eds. U.S. Department of Agriculture, Natural Resources Conservation Service: 2014.