

SUPPLEMENTARY MATERIAL

Optimizing nature-based solutions by combining social equity, hydro-environmental efficiency, and economic costs through a novel Gini coefficient

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Table S.1. Atlas 14 rainfall coefficients for Houston, Texas, USA.

Rainfall Frequency	b (inches)	d (minutes)	e
2-Year (50% AEP)	47.25	8.94	0.7263
5-Year (20% AEP)	54.09	8.34	0.7051
10-Year (10% AEP)	55.26	7.30	0.6752
25-Year (4% AEP)	56.72	6.12	0.6397
50-Year (2% AEP)	57.94	5.47	0.6166
100-Year (1% AEP)	56.68	4.46	0.5857

Table S.1. Pollutant load parameters for modeling total suspended solids (TSS).

Land Use	TSS (mg/L)	Removal Efficiency (%)		
		<i>Porous Pavement</i>	<i>Bioretention Cell</i>	<i>Tree Box</i>
Industrial	145.43	60%	50%	50%
Residential	146.00			
Mixed Use	72.93			
Commercial	92.56			
Open Space	211.33			

Table S.2. Water balance zones represented in the WOB case study.

NBS Feature	Surface	Soil	Storage	Underdrain
Porous Pavement	X		X	X
Bioretention Cell	X	X	X	X
Tree Box	X	X	X	

Table S.4. PCSWMM LID Control Editor parameter inputs. BIOR: “Bioretention cell”, PMPV: “Permeable pavement”, TRBX: “Tree box”.

		NBS Feature			Units
Parameter		BIOR	PMPV	TRBX	
Surface	Berm height	9	0	12	Inch
	Vegetation volume	0	0	0.2	Fraction
	Surface roughness	0.1	0.1	0.1	-
	Surface slope	1.0	1.0	1.0	Percent
Pavement	Thickness	-	4	-	Inch
	Void ratio	-	0.15	-	Voids/solids
	Impervious surface	-	0	-	Fraction
	Permeability	-	100	-	Inch/hour
Soil	Thickness	18	0	21	Inch
	Porosity	0.5	0.5	0.5	Volume fraction
	Field capacity	0.2	0.2	0.2	Volume fraction
	Wilting point	0.1	0.1	0.1	Volume fraction
	Conductivity	5	0.5	50	Inch/hour
	Conductivity slope	10	10	10	-
	Suction head	3.5	3.5	3.5	Inch
Storage	Thickness	12	24	6	Inch
	Void ratio	0.75	0.75	0.75	Voids/solids
	Seepage rate	0.5	5	0.5	Inch/hour
	Clogging factor	0	0	0	-
Drain	Drain coefficient	5	100	50	Inch/hour
	Drain exponent	0.5	0.5	0.5	-
	Drain offset height	12	8	0	Inch

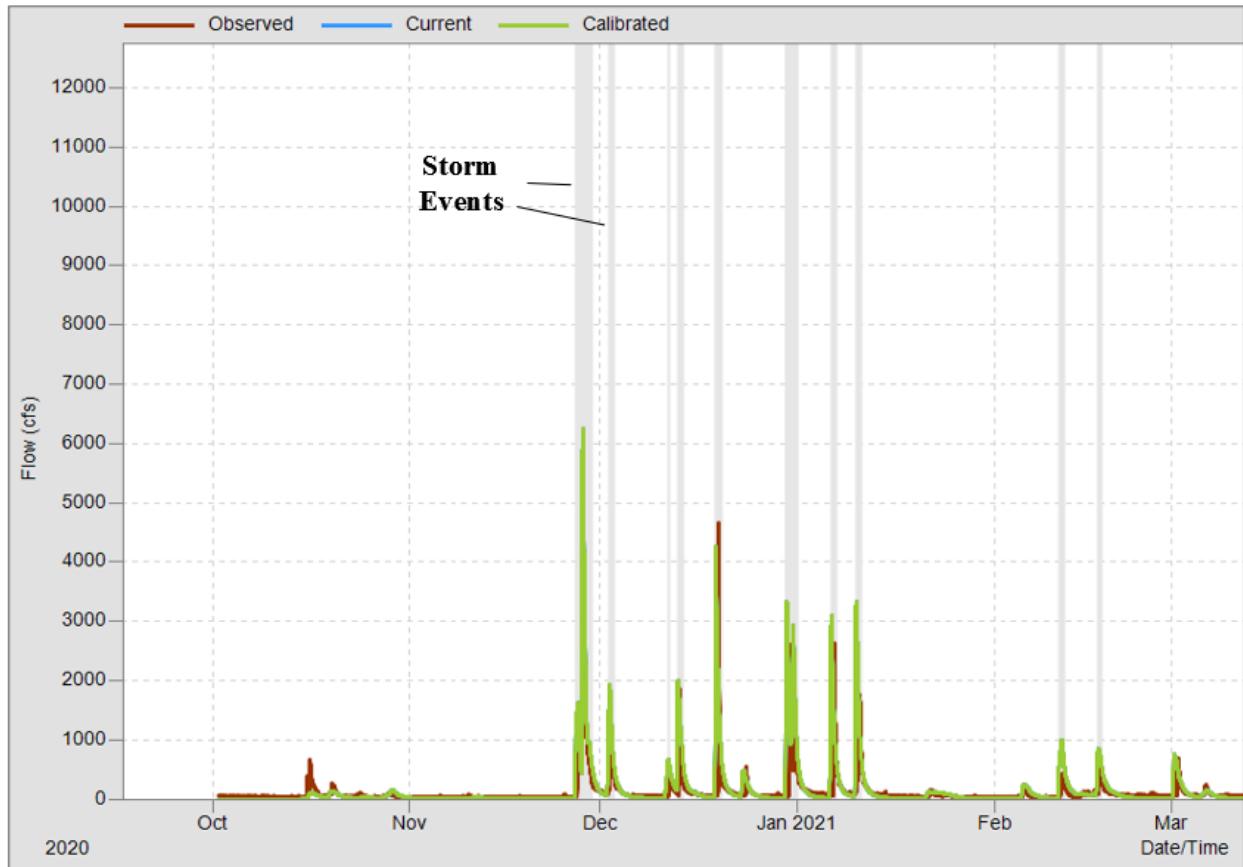


Figure S.1. Sample of storm event selection in PCSWMM.

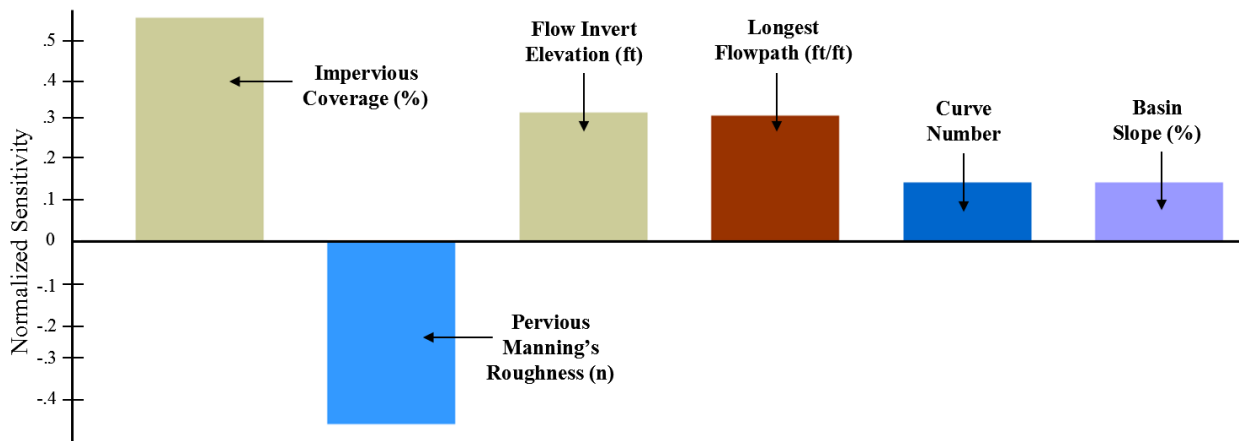


Figure S.2. Normalized sensitivity analysis output for primary variables.

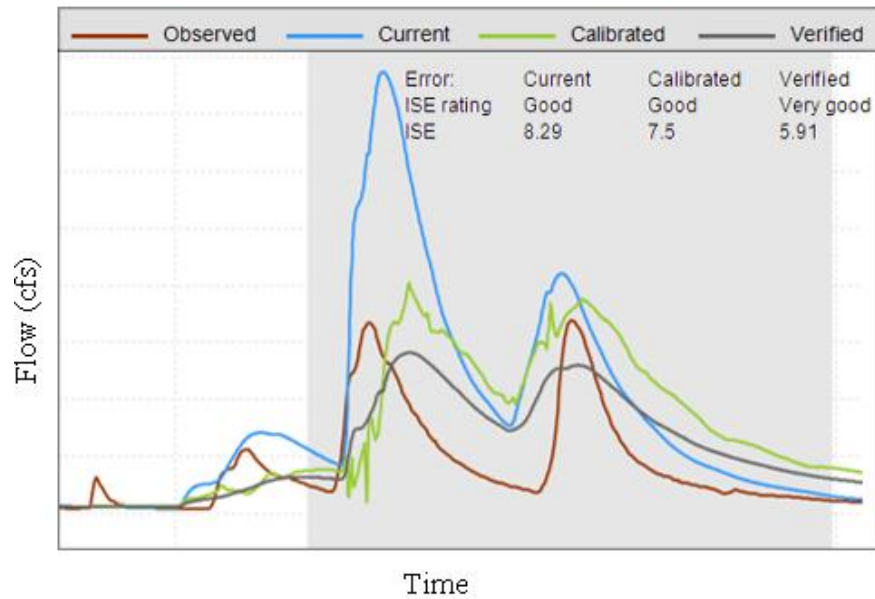


Figure S.3. Validation output hydrographs for select storm event (Mar. 2021 to Aug. 2021).

Table S.5. ISE statistics between simulated and observed flows for calibration.

Storm Event No.	Date	Gauge No. 08074500	Gauge No. 08074020
		Rating (ISE)	
1	Nov. 27, 2020	Good (8.4)	Good (6.3)
2	Dec. 2, 2020	Good (8.9)	Good (10.0)
3	Dec. 11, 2020	Good (9.3)	Fair (11.3)
4	Dec. 13, 2020	Fair (13.7)	Good (6.3)
5	Dec. 19, 2020	Very Good (5.9)	Good (8.3)
6	Dec. 30, 2020	Good (10.0)	Very Good (6.0)
7	Jan. 6, 2021	Good (10.7)	Fair (11.0)
8	Jan. 10, 2021	Good (7.2)	Good (7.5)
9	Feb. 11, 2021	Good (8.3)	Good (7.5)
10	Feb. 17, 2021	Very Good (4.6)	Good (7.1)

Table S.6. ISE statistics between simulated and observed flows for validation.

Storm Event No.	Date	Gauge No. 08074500	Gauge No. 08074020
		Rating (ISE)	
1	Apr. 30, 2021	Very Good (4.7)	Very Good (5.9)
2	May 16, 2021	Very Good (5.9)	Very Good (5.9)
3	May 22, 2021	Very Good (4.8)	Very Good (4.9)
4	Jun. 2, 2021	Good (6.8)	Good (7.6)
5	Jun. 27, 2021	Good (8.8)	Very Good (4.6)
6	Jul. 3, 2021	Very Good (4.5)	Very Good (4.9)
7	Jul. 8, 2021	Very Good (5.2)	Good (9.0)
8	Jul. 15, 2021	Very Good (5.6)	Good (6.4)

Table S.7. GreenPlan-IT Optimization Tool subcatchment input file. BIOR: “Bioretention cell”, PMPV: “Permeable pavement”, TRBX: “Tree box”.

Subcatchment No.	Area (AC)	Impervious Cover (%)	No. Possible NBS Features		
			BIOR	PMPV	TRBX
1	709.4	43.7	4904	96	7761
2	1420.5	45.4	18158	317	17632
3	683	40.7	8178	37	10573
4	363.1	47.6	1449	43	9745
5	588.5	33.5	6639	229	214
6	358.6	51.5	1815	4	9404
7	712	32.5	17376	93	3208
8	815	46.5	12339	362	4034
9	913	43.7	11430	157	14351
10	432.8	40.9	4932	96	387
11	584.9	52	4521	133	9299
12	62.4	32.6	1385	4	22
13	86.7	47.8	937	0	1984
14	1018.4	34.8	7250	192	11130
15	519.2	50.7	6103	194	8295
16	358.4	33.9	4273	38	3359
17	270.7	54.7	1537	35	8309
18	256.3	59	680	17	10540
19	871.2	59	6796	333	12400
20	300.7	24.7	1780	123	259
21	197.7	59.1	1602	195	231
22	399.5	64.3	3392	313	5719
23	519	31.4	8859	55	0
24	382.5	42.9	3635	183	547
25	226.8	52.6	1843	18	3654
26	447.7	41.8	6841	87	643
27	502.9	59.5	5273	217	7760
28	358.4	39.2	3186	143	168
29	282.3	20.1	4122	10	0
30	614.4	41.7	6045	7	4934
31	42.5	65.9	284	69	154
32	153.3	31.6	3360	0	1519
33	340.4	51.1	6349	341	131
34	83.4	62.3	1074	63	145
35	261.7	44	1175	7	488

Table S.7 (continued):

Subcatchment No.	Area (AC)	Impervious Cover (%)	No. Possible NBS Features		
			BIOR	PMPV	TRBX
36	458.3	54.5	3629	44	11804
37	966.4	51.6	12159	287	9376
38	279.7	43.4	1746	87	968
39	1004	37.3	5286	31	1553
40	47	28.4	1330	0	105
41	480.7	43.8	6856	215	857
42	169.6	38.6	2098	0	4163
43	391	31.5	1486	13	1441
44	341.4	51.6	5228	174	157
45	413.6	43.5	4583	31	1472
46	69.5	18.6	1041	0	339
47	467.3	49.7	4184	311	302
48	1197.9	51.8	11504	399	16692
49	590.3	52.2	4907	96	14166
50	250.2	53.9	1181	88	6201
51	562	41.4	5508	23	12750
52	549.5	42.9	4888	28	11791
53	312.8	57.8	1122	14	10247
54	333.8	38.6	5519	51	884
55	108.4	39.6	1592	77	0
56	431.6	41.5	4998	8	8551
57	349.6	22.6	3603	30	1829
58	712.5	43.2	5598	60	11214
59	96.6	37.1	1051	0	2461
60	35.2	54.9	443	0	64
61	358.6	37.3	3386	24	6237
62	318.4	63.7	3010	343	866
63	61.4	42.8	352	0	909
64	302.1	42.1	1288	32	2621
65	811.4	47.7	6421	248	6760
66	182.1	49.6	2088	121	2277
67	0.7	13.8	25	0	0
68	326.9	49.4	1317	29	3681
69	1903.1	55.1	13296	1533	18592
70	171.7	61.5	1461	135	1313
71	1017	29.8	21837	97	6886

Table S.7 (continued):

Subcatchment No.	Area (AC)	Impervious Cover (%)	No. Possible NBS Features		
			BIOR	PMPV	TRBX
73	501.5	39.8	6885	29	3604
74	909.5	55.3	13125	525	3490
75	237.6	73	1157	241	52
76	596.7	51.5	8741	299	2639
77	275.4	40.3	2623	12	3336
78	1023.3	52.4	8928	816	9392
79	404.2	59.7	3704	442	3597
80	93.8	48.5	542	36	376
81	163.5	73.3	534	164	1366
82	1398	62.6	6316	1408	15463
83	314.7	55.6	3722	141	1979
84	123.5	34.2	1365	4	828
85	551.8	49.5	4846	335	2798
86	388.8	32.5	5615	7	2605
87	564.6	40	6756	103	2275
88	1.2	58.9	14	0	11
89	1190.6	55.6	7910	463	18147
90	489.7	65.1	3051	472	4521
91	634.5	40.4	5931	143	2033
92	293.6	54.7	3685	215	233
93	814.7	67.1	3245	915	6251
94	407.7	38.4	6199	48	5144
95	448.8	59.3	2304	301	2699
96	484.7	35.2	11246	123	2632
97	142.4	43.8	1735	27	915
98	317.7	47.5	2468	87	6240
99	488.3	62.1	4068	354	5290
100	219.5	48.7	1717	80	2722
101	375.6	61	4213	207	2548
102	627.4	47.2	3638	141	8215
103	185.9	44.6	1712	23	2889
105	103.5	54.8	913	61	701
106	90.2	59	339	19	1367
107	604.3	51	2368	221	12431
108	947.3	55	5377	183	18362
109	589.4	46.3	2149	195	6186

Table S.7 (continued):

Subcatchment No.	Area (AC)	Impervious Cover (%)	No. Possible NBS Features		
			BIOR	PMPV	TRBX
111	339.2	68.4	1326	371	2715
112	236.7	61.1	621	115	7151
113	45.8	72.1	72	68	339
114	518.8	53.8	2244	150	12494
116	278.7	47.1	1650	42	3050
117	11.1	44.5	18	0	26
118	350.3	55.5	1165	186	4659
119	413.9	38.5	6706	26	4730
120	150.9	64.9	572	207	2181
121	264.1	43.1	1289	101	1848
123	144.6	56	528	98	984
124	383.9	56.2	2068	186	3162
125	252.5	60.8	637	141	4223
126	10.6	47.9	7	0	0
127	24.6	72.9	50	52	57
128	489	48.5	1604	91	2793
129	258	59	403	159	2750
130	367.1	58.1	1306	232	2556
131	6.4	53.2	11	0	119
132	284.7	60.3	765	233	3487
133	314.7	60.6	532	155	3444
134	296.5	63.3	1974	206	1981
135	484.7	51.3	1866	255	4755
136	335.2	80.9	486	687	3635
137	1051.4	63.4	2509	880	16024
138	753.6	56.7	2267	471	10215
139	448.8	80.6	617	921	3912
140	721.4	57.3	2162	329	11066
141	291.7	59.4	1007	126	2480
143	263.4	64.1	824	212	4076
144	747.2	68.3	345	698	23024
145	725.4	60.9	1298	395	15412
146	247.3	47.2	1255	23	5297
147	38.5	43	307	6	478
148	411.3	65.1	81	110	16841
149	147.6	68.7	107	96	4682

Table S.7 (continued):

Subcatchment No.	Area (AC)	Impervious Cover (%)	No. Possible NBS Features		
			BIOR	PMPV	TRBX
151	392.6	65.1	154	61	17508
152	379.4	55.9	916	171	9809
153	10.9	33.6	114	0	225
154	540.7	68.2	1114	314	10807
155	820.9	64.3	3071	998	12983
156	593.4	60.4	223	37	23936
157	94.3	56.3	596	13	2427
158	218	56.1	874	23	8214
159	177.2	55.1	982	62	4267
160	660.5	64.6	2867	750	13880
161	483.1	69	1038	559	8147
162	486.4	70.5	590	395	11047

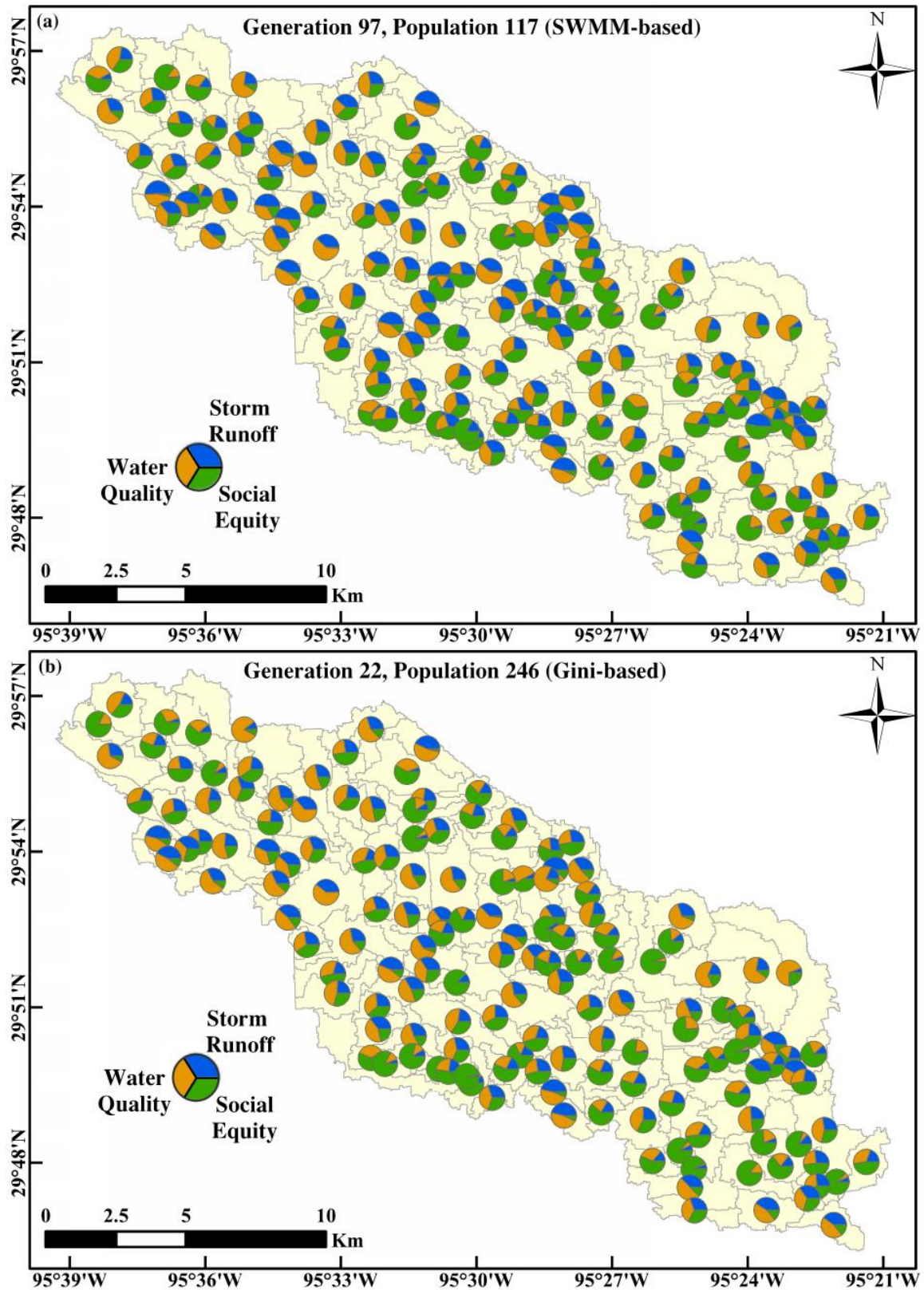


Figure S.4. Proportional representation of evaluation indicator efficiency for (a) SWMM-based optimization model, and (b) Gini-based optimization model.