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Landscape structures regulate the contrasting response of recession along rainfall amounts

Jun-Yi Lee et al.

Correspondence to: Jr-Chuan Huang (riverhuang@ntu.edu.tw)

Supplementary Material

Table S1. Summary of empirical power-law recession studies. The number of references corresponds to Table 1 in the main text. The parameter a and â represent decorrelated and original values, respectively. T_0 represents recession timescale at the median flow. CTS and VTS represent constant and variable time intervals for sampling (Q, dQ/dt) pairs, respectively.

No	Reference	Data pool	Temporal scale	Location	Number of basins	Number of events	Basin area (km^2)	Unit of flow	Initial time of recession segment (day after Q_p)	Sampling way (Q, dQ/dt)	*b*	Target parameters
1	Mathias et al. (2016)	Point-cloud	Long-term	UK	120	n.a.	1.1-1700	L T^{-1}	0	CTS	1.68-1.99	â, b
2	Patnaik et al. (2018)	Median	Long-term	Eastern USA	212	n.a.	n.a.	L^3 T^{-1}	1	CTS	1-6	b
3	Tashie et al. (2019)	Median	Monthly	North Carolina	1	382	0.6	L T^{-1}	1	CTS	4-20	a, b
4	Bart and Hope (2014)	Events	Event	California	4	n.a.	119-632	L T^{-1}	7	CTS	1.8-2.1	â
5	Biswal and Nagesh Kumar (2014)	Events	Event	USA	67	n.a.	10-8858	L^3 T^{-1}	0	CTS	1.47-4.57	â
6	Biswal and Marani (2014)	Events	Event	Eastern USA	4	n.a.	41-583	L^3 T^{-1}	1	CTS	1.91-2.23	â
7	Clark et al. (2009)	Point-cloud	Long-term/event	Georgia	3	n.a.	0.001-0.41	L T^{-1}	0	VTS	1-3	b
8	Ghosh et al. (2016)	Events	Event	Georgia	1	23	0.41	L T^{-1}	0.25	CTS	2.5-7.8	â, b
9	Patnaik et al. (2015)	Median/Events	Long-term/Event	USA	358	n.a.	2-3247	L^3 T^{-1}	7	CTS	n.a.	â
10	Millares et al. (2009)	Point-cloud	Long-term	Spain	3	n.a.	n.a.	L^3 T^{-1}	0	CTS	1.15-1.30	â
11	Sayama et al. (2011)	Point-cloud	Long-term	California	17	n.a.	3-112	L T^{-1}	0	CTS	n.a.	b
12	Shaw and Riha (2012)	Events	Event	New York	7	80	100-6415	L^3 T^{-1}	0	VTS	1.31-5.34	â
13	Shaw et al. (2013)	Events	Event	New York	9	72	287	L^3 T^{-1}	0	VTS	0.98-2.42	â
14	Tague et al. (2004)	Point-cloud	Long-term	Oregon	22	n.a.	7.3-1337	L^3 T^{-1}	0	CTS	1.38-3.16	â, b
15	Tashie et al. (2020)	Events	Event	USA	1027	155309	n.a.	L^3 T^{-1}	0	CTS	1.1-7.3	b
16	Yan et al. (2022)	Point-cloud	Long-term	Eastern China	382	n.a.	34-18211	L^3 T^{-1}	2	CTS	0.57-3	â, b
17	Ye et al. (2014)	Point-cloud	Long-term	Eastern USA	50	n.a.	66-9062	L T^{-1}	3	CTS	0.99-1.91	â, b
18	McMillan et al. (2014)	Median/Point-cloud	Long-term/monthly/event	New Zealand	28	n.a.	n.a.	L T^{-1}	0.5	VTS	1.5-4.0	T_0, b
19	Biswal and Nagesh Kumar (2013)	Events	Event	USA	39	5486	9.6-5457	L^3 T^{-1}	0	CTS	1.52-2.61	b
20	Chen and Krajewski (2015)	Events	Event	Iowa	25	n.a.	66-16854	L T^{-1}	12	CTS	0.75-1.6	â, b
21	Bogaart et al. (2016)	Point-cloud	Annual	Sweden	316	n.a.	3-33000	L T^{-1}	3	CTS	0.5-2.1	â, b

22	Dralle et al. (2017)	Events	Event	California/Oregon	16	n.a.	17-5457	$L^3 T^{-1}$	vary	CTS	0.1-3.7	a
23	Santos et al. (2019)	Events	Annual/Event	Switzerland	5	n.a.	50-352	$L T^{-1}$	vary	CTS	1.73-2.4	a, b
24	Karlsen et al. (2019)	Events	Seasonal/Event	Northern Sweden	14	163	12-6790	$L T^{-1}$	2	VTS	1-10	T_0, b

Table S2. Landscape and landcover variables of the selected catchments.

ID	HID	*H* (m)	*L* (m)	*G* (-)	*L/G* (m)	*A* (km^2)	*DD* (km/km^2)	S_m (%)	*HI* (-)	*ELO* (-)	C_W (%)	C_F (%)	C_A (%)
W1	1140H085	91	256.1	0.38	699.3	110	0.994	1.33	0.395	0.386	1.0	90.7	4.8
W2	1140H086	124	260.0	0.48	549.2	79	0.933	1.86	0.423	0.456	0.6	68.5	1.5
W3	1300H013	169	291.2	0.57	526.7	147	0.875	7.63	0.381	0.686	1.0	89.9	4.3
W4	1340H008	74	247.4	0.38	712.3	298	1.037	3.99	0.214	0.427	1.4	80.9	9.9
W5	1350H001	127	260.8	0.51	557.7	244	1.073	4.56	0.266	0.503	0.8	83.3	10.4
W6	1350H012	77	241.7	0.37	764.5	471	1.030	2.84	0.208	0.394	1.4	74.6	13.5
W7	1420H034	208	286.4	0.72	404.8	105	0.856	10.19	0.355	0.648	0.9	92.1	3.3
W8	1430H028	36	201.0	0.22	1109.3	265	1.191	1.18	0.203	0.545	2.4	41.1	29.4
W9	1430H030	131	269.1	0.55	561.0	1043	0.962	2.36	0.285	0.399	1.1	69.0	20.6
W10	1510H063	204	277.8	0.74	383.6	2089	0.924	2.22	0.432	0.421	0.5	84.8	4.3
W11	1540H014	7	200.0	0.05	3200.0	83	1.285	2.85	0.097	0.304	0.0	25.0	7.7
W12	1540H029	4	180.0	0.03	3600.0	220	1.539	1.14	0.103	0.424	3.0	18.8	53.2
W13	1580H001	148	282.8	0.52	545.3	81	1.157	6.66	0.391	0.541	1.9	11.8	70.9
W14	1660H010	23	208.8	0.12	1951.2	140	1.350	0.29	0.182	0.338	3.0	56.2	22.4
W15	1730H031	211	280.7	0.75	375.9	812	0.915	3.09	0.426	0.321	0.7	85.5	3.1
W16	2200H011	167	268.3	0.65	457.1	1573	0.919	2.36	0.383	0.433	2.6	59.2	19.4
W17	2370H017	157	260.8	0.65	475.8	1527	0.945	2.91	0.329	0.459	1.9	79.7	9.5
W18	2420H043	148	260.0	0.64	518.7	563	1.015	4.51	0.349	0.445	1.0	75.5	12.1
W19	2560H001	188	269.1	0.69	424.9	450	0.934	5.25	0.335	0.473	1.9	88.8	2.3

Here, *H* is the median of flow-path heights, *L* is the median of flow-path lengths, *G* is the median of flow-path gradients, L/G is the median of ratios between flow-path length and gradient. *A* is the drainage area, *DD* is the drainage density, S_m is the gradient of main stem, *HI* is the hypsometric integral, ELO is the basin elongation, C_W, C_F, C_A is the coverage of water body, forest, and agricultural land, respectively.

Table S3. Definition and calculation of hydrologic event and landscape variables.

Variable	Definition and meaning	Calculation method
Hydrologic event		
AP_{7day} [mm]	7-day antecedent precipitation, used to assess the saturation status of the watershed before the rainstorm.	Sum of rainfall amounts over the previous seven days leading up to the start of the rising limb.
P [mm]	Total precipitation.	Sum of rainfall amounts throughout the defined cumulative rainfall window[a]
D [hr]	Duration of precipitation.	Length of the cumulative rainfall window
I_{avg} [mm hr^{-1}]	Averaged precipitation intensity.	P/D
Q_{tot} [mm]	Total specific discharge.	Total discharge divided by the drainage area.
Q_{ant} [mm]	Antecedent streamflow. Recorded flow rate before the start of the rising limb.	
Q_p [mm]	Peak flow. The highest recorded flow rate during a rainstorm.	
Q_{tot}/P [-]	Ratio of total streamflow to precipitation, also called runoff coefficient. It indicates the efficiency of the conversion from rainfall to runoff.	
Landscape		
H [m]	Median of flow path heights, which is related to the potential energy of water.	Compute the elevation differences between hillslope cells and stream cell along the flow path. Then, determine the median of these difference across the catchment.
L [m]	Median of flow path lengths, which is related to flow accumulation from hillslopes.	Compute the distances between hillslope cells and stream cell along the flow path. Then, determine the median of these distances across the catchment.
G [-]	Median of flow path gradients, which could be regarded as a surrogate of flow velocity.	Calculate the gradients between hillslope cells and the stream cell along the flow path. Then, ascertain the median of these gradients across the catchment.
L/G [m]	Median of ratios between flow-path length and gradient, which is related to the mean residence time.	Calculate the ratios of flow path length to gradient for each cell, and subsequently, determine the median of these ratios across the entire catchment.
A [km^2]	Drainage area, which could be linked to how much total water volume could be stored.	Total area of cells that can route to the outlet.
DD [km km^{-2}]	Drainage density. It is related to how fast the catchment can drain water via stream.	Ratio of total stream length to the drainage area
S_m [%]	Gradient of main stem, which is related to water velocity in main stem.	The changes in elevation along the main stem.
HI [-]	Hypsometric integral. It represents how much a catchment can contain water storage.	Calculate the area under the hypsometric curve, which relates elevation and cumulative area
ELO [-]	Basin elongation measures catchment shape and affects surface flow travel time.	Measure the ratio of the length of the longest axis of a catchment to the length of the perpendicular axis across it.
C_W [%]	Water body coverage, which is negatively related to the recession exponent.	Percentage of the area of water bodies divided by drainage area.
C_F [%]	Forest coverage, which is negatively related to the recession coefficient.	Percentage of the forest area divided by drainage area.
C_A [%]	Agricultural land coverage, which is related to the field capacity.	Percentage of the agricultural area divided by drainage area.

[a]Cumlative rainfall window is defined as the elapsed time from 6 h before the rising flow to the peak flow.

[b]Flow path is defined as the trajectory taken by water from a hillslope grid point, as it follows the surface flow direction toward the channel.

Table S4. Descriptions of the selected catchments and events

ID	HID	N	AP_{7day} (mm)			P (mm)			I_{avg} (mm h^{-1})			Q_{ant} (mm h^{-1})			Q_{tot} (mm)			Q_p (mm h^{-1})			Q_{tot}/P (-)		
			median	min	max	median	min	max	median	min	max	median	min	max	median	min	max	median	min	max	median	min	max
W1	1140H085	15	70	3	282	246	131	904	7.3	3.7	11.7	0.32	0.02	2.35	205	100	697	8.7	4.9	27.2	0.76	0.49	1.05
W2	1140H086	18	60	1	294	272	98	854	7.1	3.1	17.5	0.24	0.02	1.91	190	99	650	8.8	4.6	27.1	0.80	0.52	1.04
W3	1300H013	16	56	3	248	239	25	1012	10.0	5.6	23.6	0.34	0.07	2.16	111	26	537	8.6	0.9	37.5	0.52	0.26	1.02
W4	1340H008	21	51	0	498	206	58	865	7.4	3.9	21.6	0.13	0.01	1.06	122	16	670	12.6	1.6	31.8	0.71	0.23	1.00
W5	1350H001	20	53	0	272	352	127	1247	5.4	1.3	13.4	0.19	0.05	0.89	191	51	749	10.5	2.4	52.2	0.61	0.20	0.94
W6	1350H012	18	45	9	489	336	155	596	5.9	3.5	11.3	0.14	0.01	0.86	221	55	424	8.0	2.1	32.9	0.54	0.24	1.06
W7	1420H034	11	38	4	186	558	189	651	10.3	5.4	12.1	0.34	0.08	1.03	302	104	691	11.9	4.9	22.8	0.63	0.32	1.08
W8	1430H028	26	81	4	355	343	89	934	6.5	3.6	13.8	0.23	0.12	0.46	138	38	458	13.6	4.0	65.4	0.41	0.21	0.70
W9	1430H030	13	84	3	923	415	87	674	4.7	1.9	8.7	0.40	0.11	0.76	150	43	446	3.6	1.5	14.0	0.34	0.23	1.03
W10	1510H063	15	31	8	102	471	105	1276	6.2	2.6	10.4	0.11	0.05	0.70	237	46	964	5.8	1.6	19.1	0.51	0.21	0.91
W11	1540H014	9	80	17	187	164	85	364	7.1	3.0	10.3	0.25	0.03	0.63	137	30	304	13.0	3.2	22.2	0.73	0.36	1.10
W12	1540H029	12	69	13	237	158	28	581	6.2	4.0	11.9	0.33	0.19	0.70	112	16	591	8.4	1.6	28.1	0.75	0.27	1.02
W13	1580H001	24	65	2	396	712	61	2558	9.7	4.2	20.3	0.44	0.04	1.27	368	37	1736	24.9	1.6	84.5	0.56	0.25	1.08
W14	1660H010	17	80	11	707	201	24	982	6.6	3.2	13.6	0.16	0.02	3.22	137	14	946	11.7	1.7	27.4	0.72	0.31	1.10
W15	1730H031	10	106	26	317	507	186	820	7.6	4.8	17.0	0.28	0.11	0.66	254	101	628	9.8	2.2	28.8	0.67	0.38	1.00
W16	2200H011	10	66	21	175	236	65	716	4.9	2.4	9.4	0.20	0.03	0.92	156	27	583	5.2	1.0	18.8	0.67	0.25	0.99
W17	2370H017	10	28	4	124	456	225	840	5.2	4.4	10.8	0.10	0.05	0.68	369	59	512	10.9	2.6	21.3	0.76	0.22	1.11
W18	2420H043	21	49	0	358	333	102	813	4.9	2.7	13.8	0.30	0.01	0.85	187	34	602	10.1	1.5	47.6	0.58	0.28	0.98
W19	2560H001	5	58	48	59	255	196	484	5.0	4.1	9.5	0.12	0.03	0.46	109	82	277	4.9	2.0	11.5	0.43	0.42	0.57
	Average		62			340			6.7			0.24			194			10.1			0.61		

*ID is the identifier of catchments in this study, HID is the identifier of catchments named by the Taiwan Water Resource Agency, N is the number of events. Values in each column present the median and range of the events in the corresponding catchments. Numbers in parentheses indicate the lower and upper limit among the events in the specific catchment.

Table S5. Median, minimum, and maximum values of the recession coefficient and exponent for each catchment.

ID	HID	*a* [hr^{-1}]			*b* [-]			1/*a* [h]		
		median	min	max	median	min	max	median	min	max
W1	1140H085	0.033	0.019	0.067	1.73	1.30	2.38	30.0	14.9	53.7
W2	1140H086	0.035	0.018	0.049	1.82	1.30	2.38	28.8	20.4	54.2
W3	1300H013	0.046	0.011	0.156	1.94	1.00	2.74	21.9	6.4	93.8
W4	1340H008	0.074	0.028	0.172	1.62	1.19	1.99	13.6	5.8	35.2
W5	1350H001	0.022	0.010	0.094	1.96	1.62	2.53	45.0	10.7	95.5
W6	1350H012	0.068	0.020	0.129	1.56	0.90	1.92	14.6	7.8	50.0
W7	1420H034	0.016	0.010	0.041	1.92	1.58	2.37	62.5	24.3	102.2
W8	1430H028	0.068	0.025	0.166	1.63	1.26	2.39	14.6	6.0	40.3
W9	1430H030	0.026	0.010	0.102	2.34	1.37	2.98	37.9	9.8	99.4
W10	1510H063	0.031	0.013	0.116	1.51	1.12	2.05	32.6	8.7	77.4
W11	1540H014	0.110	0.048	0.144	1.30	0.95	1.60	9.1	6.9	21.0
W12	1540H029	0.089	0.052	0.156	1.63	0.91	2.95	11.2	6.4	19.4
W13	1580H001	0.031	0.003	0.273	1.67	1.19	4.39	32.2	3.7	303.8
W14	1660H010	0.094	0.049	0.218	1.29	1.05	1.63	10.6	4.6	20.6
W15	1730H031	0.025	0.009	0.087	1.71	1.25	2.39	40.1	11.5	108.8
W16	2200H011	0.036	0.026	0.164	1.74	1.32	1.96	28.1	6.1	38.0
W17	2370H017	0.029	0.015	0.087	1.67	1.16	1.95	34.6	11.6	64.9
W18	2420H043	0.054	0.020	0.180	1.60	0.97	2.21	18.4	5.6	49.0
W19	2560H001	0.055	0.021	0.202	1.30	1.05	1.72	18.1	5.0	47.1

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