Dear Authors,

Thank you for your corrections to the previous version of the manuscript. I spent quite some time going over your manuscript again and found that while your revision is an improvement, several issues still need to be clarified:

L/G: median L /median G or median L/G? There is a difference. In McGuire 2005 they use median L/median G. You say in Table S3 that you use median (L/G) – why? Explain what this means for your results. Especially as you are now using a different measure than previous studies.

Also – you should state in the methods that you are using median values. Throughout the text it is not clear when you are talking about L or G or H if you are referring to the median or not. This needs to be clarified.

Why is L/G a good proxy for residence time? If you base this on Darcy's law it would be good to explain this better than the currently slightly confusing sentence: "Note that G can also be regarded as a surrogate of flow velocity (most equations used for estimating flow velocity needs gradient to represent the conversion from potential to kinetic energy). Therefore, the composite ratio, L/G [m], can be a proxy for residence time (McGuire et al., 2005; Tetzlaff et al., 2009) and as a means to comprehend the interplay between landscape features and climate impacts on residence time (Seybold et al., 2017)." Instead I would suggest something similar to this (if this is indeed what you mean): As the velocity of gravity-driven flow is usually proportional to the gradient: v = L/T ~ H/L this results in time T being proportional to L/G: T~L^2/H=L/G. Therefore, L/G could be a potential proxy for residence time. In terms of a catchment this relates to the ratio of the medians of L and G.

What do you mean by composite ratio? What is the difference between composite ratio and ratio? Why is a simple ratio not enough? This needs to be explained.

You are citing that Harman et al. 2009 found that heterogeneity between hillslopes increased with catchment area. However, they compare a single hillslope to a catchment of 10 ha and a catchment with a catchment area of 41 ha, so a maximum scale of not even 0.5 km². In your study, catchment areas only begin at 77 km². Does this relationship still hold at this very different spatial scale? This should be discussed.

Table 3 in the supplement – here the language can be simplified/clarified and there are also still some expressions that should be corrected:

- Definition of DD: fast not faster
- Water body coverage
- Forest coverage
- Agricultural land coverage

Please also see my comments to the supplementary material and within the pdf of your response.

I am glad to see the major improvements in this manuscript over the course of the review and am hoping that we can resolve these issues with a last round of minor revisions. Given that there are still some issues with the language I have been in touch with the English copy-editing department of Copernicus and they will assist you with final improvements on this front. Unfortunately, even your revised abstract still needs work, as the sentences have the tendency to be convoluted and confusing.

Looking forward to bringing this review process to a close and moving your manuscript forward towards publication!

All the best,

Theresa

Reply to Editor's Comment

Dear Authors,

unfortunately quite a few of your recent corrections in response to the reviewer's comments still require some work. In several instances it is not really possible to understand the meaning of what you are trying to say.

I have added some comments in your response as well as at the beginning of the track changes document, but please also go over the remaining changes and clarify and correct the english where necessary. Some of my comments appear only in the response but also apply to the manuscript.

Please also make sure that the corrections are made not only in the one line the reviewer references but also in the other instances throughout the manuscript.

Please note that you need to download the pdf to see all the comments as not all of them appear when viewing the pdf in the browser

Once these things have been clarified and corrected I will review the manuscript again.

All the best,

Theresa

Reply:

Dear Theresa,

We extend our gratitude for your meticulous review of our manuscript. We have addressed all the comments you highlighted in our previous communication and made necessary revisions to the manuscript. We thoroughly revised the manuscript and clarified the ambiguous sentences. Mainly revisions are in the abstract, landscape variable [L82-92], and discussion 4.2.1 [L279-289]. Also, Table S3 which illustrated the definitions and calculations of hydrologic-event and landscape variables was clarified and revised. We have also ensured that all responses in the manuscript are correspond to the appropriate corrections.

Best regards,

Jr-Chuan (River) Huang

SPECIFIC COMMENTS

(in response)

"Also, we conducted a comprehensive review of the vocabulary and grammar throughout the entire manuscript."

This still needs to be improved, especially in the newly added text.

Reply: We have diligently refined the revised manuscript and engaged a native speaker to further enhance the precision of our text.

"Without considering this contrasting response, which is contingent upon landscape structure, it leads to a misjudgment of the recession nonlinearity in response to rainfall amount and needs further clarification, particularly for use in assessing regional recession in ungauged catchments under climate change."

This sentence is not clear and needs to be rephrased.

Reply: In this version, we rephrased the abstract thoroughly and highlighted our three new findings. For the last two sentences, now it reads, "Our finding that *L/G* and drainage area might regulate the contrasting response of recession along rainfall amounts requires additional validation in different regions since recession response is crucial when assessing regional recession in ungauged catchments under the influence of climate change." [L20-24]

"For example, it is not enough to only state that the value of b decreases as L/G increases. What is the significance of L/G? What does it represent with regards to what influences the flow of water through the catchment What does it imply in terms of subsurface flow that b decreases as L/G increases?"

This should be answered in the manuscript and explained in more detail.

Reply:

To clarify the composite L/G ratio, we have revised several sections of the manuscript, including the abstract, material and methods, and discussion.

In the abstract [L16-17], we added a short definition of *L* and *G*. Now it reads, "(*L*: median of flow-path lengths within a catchment; *G*: median of flow-path gradients within a catchment)".

In the material and methods [L82-92], we rewrote the paragraph to provide a clear definition, explanation, and simple calculation of flow path variables. It is, "In addition to the primary landscape variables described above, we incorporated flow path associated variables into our study, as flow path is an explicit proxy for aquifer systems. Within a gridded DEM, the flow path is defined as the route followed by water from a grid cell, following the surface flow direction towards the channel cell (see detail in Tetzlaff et al., 2009). Specifically, flow path length *L* [m] is the length of this route, flow path height *H* [m] is the elevation difference between a specific cell to the channel cell, and *G* is the flow-path gradient [-], defined as ~~defined as~~ the flow path height divided by flow path length. As such, every grid cell possesses distinct values for *L*, *H* and *G*. Within a catchment, the medians of the *L*, *H*, and *G* distributions serve as representative flow path characteristics. Note that *G* can also be regarded as a surrogate of flow velocity (most equations used for estimating flow velocity needs gradient to represent the conversion from potential to kinetic energy). Therefore, the composite ratio, *L/G* [m], can be a proxy for residence time (McGuire et al., 2005; Tetzlaff et al., 2009) and as a means to comprehend the interplay between landscape features and climate impacts on residence time (Seybold et al., 2017). The detailed definition and calculation of the flow path associated variables are illustrated in Table S3 in the supplement."

In discussion 4.2.1 [L279-289], now it reads, "Our variable *H*, which exhibits a negative correlation with the recession coefficient, likely suggests that our groundwater flow paths possess greater depth and length, consequently leading to slower drainage rates. Although flow path height, *H*, denoting potential energy is a component of gradient, it does not necessarily correspond to hydraulic gradient due to the geologic and soil settings varying across regions (Karlsen et al., 2019). Besides, high *DD* and short *L* indicate shorter flow paths and thus lead to a higher recession coefficient. In our cases, Type C catchments are characterized by short *L* and very small *H* and thus have high *L/G* ratios and recession coefficients (solid orange dots in Fig. 7c). Individually, extended *L* or gentle *G* is conducive to flow accumulation. Thus, the *L/G* ratio, which integrates both length and gradient, serves as a good proxy for estimating residence time (McGuire et al., 2005; Asano and Uchida, 2012). While the equivalent composite ratio can result from either *L* or *G*, the relationship between recession parameters and *L/G* has the potential to establish a further linkage between recession parameters and water residence time."

Hope the revised text expresses the intended meaning more effectively.

"landscape structure"

Not clear.

Reply: Landscape structure in our study is interpreted by hillslope hydraulics (L/G) and inter-hillslope heterogeneity (A). While we have introduced this term in the introduction to convey the general concept, we employed the terms L/G and A in the main body of the text to provide specific emphasis.

"Therefore, we addressed it in L81-88 and added a new Table S3 in supplementary for describing the definition and calculation of landscape and rainstorm variables."

Not enough.

Reply: Please see reply above. Besides, Table S3 has been revised.

"Specifically, from the aspect of aquifer hydraulics (Rupp and Selker, 2006), spatial heterogeneity (Harman et al., 2009) and drainage network (Biswal and Marani, 2010) have been observed that these

recession parameters are influenced by the aforementioned factors."

Sentence does not work, needs to be fixed.

Reply: We have removed this sentence since the following sentences explained the works.

"Additionally, theoretical works have shown that the dependence of streamflow recession parameters on antecedent storage or rainstorms."

Needs to be fixed.

Reply: Fixed. Now it reads, "Additionally, theoretical studies have demonstrated that streamflow recession parameters are subject not only to the influences of landscape and aquifer systems but also to the interplay with antecedent storage and rainfall events" [L39-40]

"the downstream"

Not a noun.

Reply: We replaced "the downstream" with "the downstream channel" [L44] and [L45].

"Replied above."

Where? should be stated in the manuscript text

Reply: In the introduction section of this version, paragraph #2 and #3 demonstrated the theoretical works and paragraph #4 expressed the empirical studies.

"point-cloud"

this also needs to be explained in the methods section, where you suddenly switch from single recession curves to the so-called point cloud.

Reply: In the methods section, we have revised the sentence introducing the term "point-cloud": "One approach involves fitting the lower envelope of a collection of multiple recession curves, which is referred to as point-cloud (Brutsaert and Nieber, 1977)."[L150-151]

"The flow path is defined as the hillslope grid point following the surface flow direction toward channel."

Not clear. A point cannot be a path

Reply: Please see reply above. We rephrased the paragraph [L82-92] to interpret the definition and calculation of flow path associated variables.

"Among them, the composite ratio of L/G, which represent the distance effect of flow-path under different gradient holds hydrologic significance as it can serve as a proxy for water residence time (McGuire et al., 2005; Tetzlaff et al., 2009)."

Explain why this can serve as a proxy for residence time and what you mean by composite ratio.

Reply: We rephrased the sentences in [L88-91]: "Note that *G* can also be regarded as a surrogate of flow velocity (most equations used for estimating flow velocity needs gradient to represent the conversion from potential to kinetic energy). Therefore, the composite ratio, *L/G* [m], can be a proxy for residence time (McGuire et al., 2005; Tetzlaff et al., 2009) and as a means to comprehend the interplay between landscape features and climate impacts on residence time (Seybold et al., 2017)."

"detailed"

Reply: Revised as suggested [L92].

Table S3: This table contains errors in units and definitions. The explanations for how variables are calculated are often not clear and need to be improved.

Reply: Revised thoroughly. Please see the new Table S3.

"the supplement"

Reply: Revised as suggested [L92].

"Is G = H/L? Is L/G, therefore, simply L/(H/L) = L^2/H? If so, what does L^2/H say about landscape structure that simply G (or 1/G = L/H) alone does not?"

I have the same question and don't feel that you answer it below. We need a better explanation for the calculation and meaning of L/G.

Reply:

L and G are the length and gradient of the flow path. Since the gradient is an important variable for estimating velocity, the composite L/G ratio could be imagined as a kind of time due to distance over velocity. Therefore, L/G represent the hillslope hydraulics and it explained why L/G is a good proxy for water residence time at catchment scale.

For variable selection, the variables of H, L, L/G and DD shown in Fig. 7 are highly correlated with recession parameters. Our focus on the composite L/G ratio aims to underscore its potential in establishing a linkage between recession parameters and water residence times.

"The composite L/G ratio represents the distance effect of flow path under different gradient"

I don't understand this.

Reply: Replied above.

"Given how much of the discussion on the results centers on L/G, it is important that its geomorphic/hydrologic/hydraulic significance be stated. Reply: Replied."

Need a better explanation than what you gave above

Reply: Replied above.

How does a large value of L/G imply a "short-and-gentle" hillslope?

This does not answer the question and the correction in the ms is missing.

Reply: Apologies for the unclear interpretation. The large L/G value certainly is derived from a long flow path or gentle G. However, our Type C catchments are characterized by short *L* (Fig. 7b) and very small *H* (Fig. 7a) and thus have high *L/G* ratios (Fig. 7c). We have rewritten this paragraph [L279-289] for clarification.

"Actually, "b" is the slope in a plot of log(-dQ/dt) vs log(Q)."

This should be corrected throughout the ms and not just in this one line!

Reply: Our apologies. This time, we have checked throughout the manuscript and made the necessary corrections [L31].

"Reply: We observed that when the drainage area larger than 800 km2, the point-cloud derived coefficients become similar to the third quantile of the coefficient distribution from individual segments [L197]."

Explanation should be added to ms.

Reply: We had added the following sentence to the manuscript in [L201-202]: "Notably, when the catchment size exceeds approximately 500 km^2 (W19), the point-cloud-derived coefficients become similar to the third quantile of the coefficient distribution from individual segments."

"described the calculation methods"

Needs to be improved and in part corrected

Reply: We improved Table S3. We modified the gridlines of Table S3, correcting the unit of DD to [km km-2], changing the "meaning" column to "definition and meaning." We have also rephrased the calculation methods for each variable.

"the superimposition of recession events on antecedent flows"

Not clear, please rephrase

"The negative correlation between b and peak flow does not necessarily imply a consistent response across all catchments."

I don't understand this

Reply: We rephrased in [L328-332]: "Across all catchments, we observed an augmentation of exponent *b* with antecedent flows, but a decline with peak flow (Fig. 5). This augmentation can be attributed to the overlay of ~~recession event flows~~ onto antecedent flows, amplifying the value of *b* (Jachens et al., 2020). The inverse correlation between *b* and peak flow suggests that in the majority of catchments, the existence of active fast flow paths could potentially reduce the recession nonlinearity.".

Replace "than" with "compared to those derived from"

Reply: Revised as suggested [L235]. Thank you.

"we have a deeper and longer groundwater flow system and thus drainage slowly"

English needs to be fixed, also groundwater flow systems cannot really be long, only flow paths.

Reply: We rephrased it as "our groundwater flow paths possess greater depth and length, consequently leading to slower drainage rates." [L280-281]

(in the track change document)

L10: are these supposed to be two different things? Not clear.

Reply: We rephrased it as "landscape structures and rainstorms are recognized as drivers of recession response" [L10].

L10-11: needs to be rephrased.

L11: Logical flow not clear. Why "yet"?

Reply: We rephrased the first two opening sentences. Now it reads, "Streamflow recession reflects hydrological functioning, runoff dynamics, and storage status within catchments and landscape structures and rainstorms are recognized as drivers of recession response. However, the documented recession ~~responses to~~ landscape structure and rainstorms are inconsistent, and there are fewer studies that concurrently investigate the combined effects of these two factors on recession." [L9-12].

L13: be is the exponent in the equation, I don't think it is called "the nonlinearity"

Reply: Checked. In this version, when talking about equation or parameter, we used exponent b. For describing the recession behavior, nonlinearity is used.

L16: not clear, this is not quantitative and therefore it is not clear how something increases with structure. It is also completely unclear what you mean by landscape structure.

Reply: As suggested, we only used the term "landscape structure" to convey the general concept, but used specific variables like L/G and A to express the relationships. Now it reads, "Our finding that *L/G* and drainage area might regulate the contrasting response...." [L21].

L18: the exponent of the recession model and therefore

L19: replace "Without" with "Not"

L19-21: not clear. Are you saying we normally are just guessing recession model parameters for ungauged basins? Why and under which circumstances would we do that? Not clear what you are trying to say here.

Reply: We rewrote the abstract to increase its readability. Now it reads, "Our finding that *L/G* and drainage area might regulate the contrasting response of recession along rainfall amounts requires additional validation in different regions since recession response is crucial when assessing regional recession in ungauged catchments under the influence of climate change." [L20-24]

L24: not clear. Runoff does not exist in plural form. What do you mean by different runoffs?
L24: the streamflow recession and its link with flow

Reply: We replaced "runoff" with "flow paths" and rephrased as suggested [L26]. Thank you.

L26: why is this equation different to the one in the abstract?

Reply: The recession parameters of the equation in the abstract were decorrelated, which differs from the equation in the original Brutsaert and Nieber (1977) version. For simplification, we eliminated the equation in the abstract.

L26: not the correct term

Reply: We replaced "streamflow declines" with "the rate of change in streamflow" [L28]

L26: describe the recession

Reply: Revised as suggested [L28].

L28-29: this is something that the reviewer corrected (see line 125), Why did you only correct it there but not here?

Reply: Apologies for only revising [L116] earlier. This time, we have checked throughout the manuscript and corrected it [L31].

L32-34: sentence needs to be fixed

Reply: We removed this sentence since the meaning of the sentence had already been explained in the previous statement.

L50: The exponent b slightly increases...

Reply: Revised as suggested [L43].

L52: downstream is not a noun

Reply: We replaced "the downstream" with "the downstream channel" [L44] and [L45].

L59-60: Most previous studies aggregated long-term data to a point-cloud, a collection of multiple recession curves *to* retrieve representative recession parameters

Reply: Revised as suggested [L51-52].

L67: streamflow

Reply: Revised as suggested [L57]

L69: I would not use this as a synonym for b

Reply: We replaced "nonlinearity" with "exponent" [L60]

L124: what is the difference to a?

Reply: $\hat{a} = ak^{b-1}$. We have elaborated on the rationale for this relationship in [L163-167]: "An important concern in recession parameter estimation is the dependence between $\hat{a}$ and b, which confounds the interpretation of parameters (Dralle et al., 2015). The decorrelation method assumes that the observed flow, Q, consists of a scale-free flow $\hat{Q}$ and a constant k ($Q = k\hat{Q}$). Thus, the power law formula can be rewritten as $-dQ/dt = ak^{b-1}\hat{Q}^b$, where a is the scale-free recession coefficient [h^{-1}]. For correcting $\hat{a}$ to a, the observed flow Q was divided by a constant Q_0 (which is ideally equal to $1/k$, see detail in Dralle et al., 2015)".

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 un-decorrelated, respectively. T_0 represents recession timescale at the median flow. CTS and VTS denote constant and various time interval of sampling (Q, dQ/dt) pair, 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/eve nt	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/Ev ent	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-c loud	Long-term/mo nthly/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 flow-path height [L], *L* is the flow-path length [L], *G* is the flow-path gradient [-], *A* is the drainage area [L^2], *DD* is the drainage density [L/L^2], S_m is the gradient of mainstream, *HI* is the hypsometric integral [-], ELO is the basin elongation [-], C_W, C_F, C_A is the land cover of water, forest, and agriculture [-].

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 could be used to present 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 describes the magnitude of a rainstorm.	Sum of rainfall amounts throughout the defined rainfall period[a]
D [hr]	Duration of precipitation indicates how long does the rainstorm last.	Length of time between the start and end of the defined rainfall period.
I_{avg} [mm hr^{-1}]	Averaged precipitation intensity presents the magnitude of rainstorm intensity.	*P*/*D*
Q_{tot} [mm]	Total streamflow represents how much water is exported during a rainstorm	Sum of flow rates during the rainstorm.
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 within a catchment, which is related to 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 within a catchment, 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 within a catchment, 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 within a catchment, which is related to the mean residence time.	Compute the ratios of flow path length to gradient for each cell. Then, determine the median of these ratios across the catchment.
A [km^2]	Drainage area, which could be linked to how much total water volume could be stored.	DEM cell size multiplied by the number of cells that can route to the outlet.
DD [km km^{-2}]	Drainage density. It is related to how faster 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 bodies coverage, which is negatively related to the recession exponent.	The area occupied by water bodies divided by drainage area.
C_F [%]	Forests coverage, which is negatively related to the recession coefficient.	The area occupied by forest divided by drainage area.
C_A [%]	Agriculture land coverage, which is related to the field capacity.	The area occupied by agriculture land divided by drainage area.

[a]Rainfall period 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)		Q_{ant} (mm h^{-1})		Q_{tot} (mm)		Q_p (mm h^{-1})		Q_{tot}/P (-)	
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)
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	(0.2/0.94)
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	(4/65.4)	0.41	(0.21/0.7)
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)	0.34	(0.23/1.03)
W10	1510H063	15	31	(8/102)	471	(105/1276)	6.2	(2.6/10.4)	0.11	(0.05/0.7)	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	(3/10.3)	0.25	(0.03/0.63)	137	(30/304)	13.0	(3.2/22.2)	0.73	(0.36/1.1)
W12	1540H029	12	69	(13/237)	158	(28/581)	6.2	(4/11.9)	0.33	(0.19/0.7)	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	(0.31/1.1)
W15	1730H031	10	106	(26/317)	507	(186/820)	7.6	(4.8/17)	0.28	(0.11/0.66)	254	(101/628)	9.8	(2.2/28.8)	0.67	(0.38/1)
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	(1/18.8)	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	(2/11.5)	0.43	(0.42/0.57)
	Ave.		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 and range of recession rate and nonlinearity for individual catchment.

ID	HID	*a* [hr^{-1}]		*b* [-]		1/*a* [h]	
W1	1140H085	0.033	(0.019/0.067)	1.73	(1.3/2.38)	30.0	(14.9/53.7)
W2	1140H086	0.035	(0.018/0.049)	1.82	(1.3/2.38)	28.8	(20.4/54.2)
W3	1300H013	0.046	(0.011/0.156)	1.94	(1/2.74)	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	(0.01/0.094)	1.96	(1.62/2.53)	45.0	(10.7/95.5)
W6	1350H012	0.068	(0.02/0.129)	1.56	(0.9/1.92)	14.6	(7.8/50)
W7	1420H034	0.016	(0.01/0.041)	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	(6/40.3)
W9	1430H030	0.026	(0.01/0.102)	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	(0.95/1.6)	9.1	(6.9/21)
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)
W17	2370H017	0.029	(0.015/0.087)	1.67	(1.16/1.95)	34.6	(11.6/64.9)
W18	2420H043	0.054	(0.02/0.18)	1.60	(0.97/2.21)	18.4	(5.6/49)
W19	2560H001	0.055	(0.021/0.202)	1.30	(1.05/1.72)	18.1	(5/47.1)

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