Supplement of Hydrol. Earth Syst. Sci., 22, 1735–1748, 2018
https://doi.org/10.5194/hess-22-1735-2018-supplement

Hydrology and
Earth System
Sciences
Open Access

Supplement of

Scaling properties reveal regulation of river flows in the Amazon through a “forest reservoir”

Juan Fernando Salazar et al.

Correspondence to: Juan Fernando Salazar (juan.salazar@udea.edu.co)

Contents

1. River flow data: Table S1
2. Estimation of power laws: Figures S1 to S6, and Table S2.
3. Tests for the difference between the values of the scaling exponents and the critical value 1: Tables S3 to S8.
4. Scaling results using A as the scale parameter: Figures S7–S9, Tables S9–S15.

River flow data

Details about the river flow records and gauges used in this study are given in Supplementary Table S1. The locations of the 85 gauges is indicated in Figure 1. Mean and extreme river flows were computed from daily records. Any year with less than 320 daily records was discarded. The lengths of the records that were used in the calculations vary between 26 and 47 years, with an average of 38 years. Drainage areas vary between 1,617 km^2 at Pari Cachoeira and 4,680,000 km^2 at Obidos.

Table S1: River flow gauges provided by the SO-HYBAM project (formerly ORE-HYBAM project, www.ore-hybam.org).

ID	Code	Name	River	Initial date	Final date	Record length (yr)	Lat. (°)	Lon. (°)	Drainage area (km^2)
1	14300000	Pari Cachoeira	Tiquie	7/7/1980	4/29/2014	34	0.25	-69.78	1,617
2	18250000	Uruara	Para do Uruara	12/14/1978	4/29/2014	36	-3.68	-53.55	2,628
3	14540000	Fazenda Bandeira Branca	Cotingo	10/2/1970	4/29/2014	44	4.63	-60.47	3,075
4	15050000	Pontes e Lacerda	Guapore	8/21/1971	7/30/2014	43	-15.22	-59.35	3,140
5	15565000	Jaru	Jaru	6/22/1981	3/30/2012	31	-10.45	-62.47	3,965
6	14310000	Cunuri	Tiquie	8/15/1982	4/29/2014	32	0.21	-69.38	4,198
7	14220000	Louro Poco	Aiari	8/2/1982	10/30/2008	26	1.34	-68.69	4,708
8	17230000	Lucas do Rio Verde	Verde	8/17/1973	4/16/2007	34	-13.05	-55.90	5,327
9	14550000	Maloca do Contao	Cotingo	9/5/1975	4/29/2014	39	4.17	-60.53	5,815
10	18280000	Apalai	Paru de Este	7/25/1980	9/29/2012	32	1.22	-54.66	5,902
11	15750000	Humboldt	Aripuana	5/25/1979	6/29/2014	35	-10.17	-59.46	6,653
12	15430000	Ariquemes	Jamari	7/16/1970	5/30/2014	44	-9.93	-63.06	7,295
13	14526000	Bom Fim	Tacutu	7/7/1984	4/29/2014	30	3.38	-59.82	9,744
14	12360000	Foz do Breu	Jurua	6/21/1982	6/1/2012	30	-9.40	-72.70	10,141
15	14350000	Jusante da Cachoeira do Caju	Curicuriari	6/2/1982	3/30/2014	32	-0.25	-67.01	10,228
16	13550000	Xapuri	Acre	2/17/1968	1/30/2014	46	-10.65	-68.51	11,765
17	15558000	Pimenta Bueno	Apedia	5/30/1980	7/30/2014	34	-11.68	-61.19	12,346
18	15550000	Santa Isabel	Candeias	3/10/1976	6/29/2014	38	-8.80	-63.71	12,640

— Continues in the next page —

— Come from previous page —

19	14680001	Fe d Esperanca	Mucajai	12/8/1973	4/29/2014	41	2.87	-61.44	13,658
20	12880000	Estirao da Santa Cruz	Tefe	2/10/1981	3/30/2014	33	-4.29	-65.20	13,708
21	15910000	Sucunduri	Sucunduri	10/24/1973	9/29/2013	40	-6.80	-59.04	13,938
22	14440000	Posto Ajuricaba	Demeni	5/29/1982	4/29/2014	32	0.88	-62.62	14,756
23	12650000	Feijo	Envira	9/26/1980	5/19/2012	32	-8.15	-70.37	15,329
24	12370000	Taumaturgo	Jurua	4/14/1981	5/31/2012	31	-8.93	-72.78	16,581
25	18200000	Arapari	Maicuru	7/1/1972	2/27/2014	42	-1.78	-54.40	17,072
26	15120001	Vila Bela da Santis Trindade	Guapore	7/1/1976	7/30/2014	38	-15.01	-59.95	18,412
27	14230000	Missao Icana	Icana	7/17/1980	3/30/2014	34	1.07	-67.59	22,282
28	17090000	Boca do Inferno	Curua	3/29/1973	9/29/2013	40	-1.50	-54.87	22,500
29	13600002	Rio Branco	Acre	8/9/1967	5/30/2014	47	-9.98	-67.80	22,670
30	16500000	Estirao da Angelica	Mapuera	11/22/1970	4/29/2014	44	-1.10	-57.06	26,040
31	15560000	Ji-Parana	Jiparana	12/16/1977	7/30/2014	37	-10.87	-61.94	33,012
32	13650000	Floriano Peixoto	Acre	7/26/1967	4/29/2014	47	-9.05	-67.37	33,469
33	18650000	Cajueiro	Curua	11/20/1975	11/29/2011	36	-5.65	-54.52	34,693
34	17120000	Porto dos Gauchos	Arinos	9/15/1973	5/30/2014	41	-11.54	-57.42	36,913
35	14495000	Fazenda Cajupiranga	Uraricoera	8/10/1979	3/30/2014	35	3.44	-61.04	37,430
36	13886000	Bacaba	Cuniua	12/15/1979	3/20/2014	35	-6.32	-64.88	38,270
37	12500000	Cruzeiro do Sul	Jurua	8/24/1967	6/4/2012	45	-7.61	-72.68	38,537
38	17280000	Cachoeirao	Teles Pires	11/18/1975	7/30/2014	39	-11.65	-55.70	39,000
39	14260000	Uaracu	Uaupes	12/3/1977	11/29/2011	34	0.48	-69.13	40,506

— Continues in the next page —

— Come from previous page —

40	18500000	Boa Esperanca	Fresco	1/23/1976	11/29/2013	37	-6.72	-51.78	43,030
41	14280001	Taraqua	Uaupes	5/23/1977	4/29/2014	37	0.13	-68.54	44,732
42	15800000	Boca do Guariba	Aripuana	12/12/1977	12/30/2011	34	-7.68	-60.30	47,773
43	15130000	Pimenteiras	Guapore	6/26/1983	7/30/2014	31	-13.48	-61.05	50,055
44	14515000	Fazenda Passarao	Uraricoera	5/2/1977	2/27/2014	37	3.21	-60.57	50,985
45	19150000	Sao Francisco	Jari	7/2/1972	3/21/2014	42	-0.57	-52.58	51,340
46	17093000	Fontanilhas	Juruena	1/27/1978	6/29/2014	36	-11.36	-58.34	52,200
47	12520000	Ipixuna	Jurua	10/10/1981	6/14/2012	31	-7.05	-71.68	55,806
48	15580000	Tabajara	Jiparana	12/13/1977	5/30/2014	37	-8.93	-62.05	60,212
49	14110000	Cucui	Negro	7/23/1980	4/29/2014	34	1.22	-66.85	61,781
50	13410000	Seringal da Caridade	Purus	8/2/1967	4/29/2014	47	-9.04	-68.57	63,166
51	17340000	Indeco	Teles Pires	11/2/1975	8/30/2014	39	-10.11	-55.57	64,650
52	12550000	Eirunepe-Montante	Jurua	2/23/1979	6/20/2012	33	-6.68	-69.90	77,136
53	13710001	Valparaiso	Purus	2/27/1975	4/29/2014	39	-8.68	-67.40	103,285
54	15830000	Prainha Velha	Aripuana	6/3/1974	9/29/2013	39	-7.25	-60.40	108,578
55	15150000	Pedras Negras	Guapore	12/18/1980	7/30/2014	34	-12.85	-62.90	109,788
56	14250000	Sao Felipe	Negro	12/9/1977	4/29/2014	37	0.37	-67.31	110,862
57	14710000	Caracarai	Branco	1/2/1967	5/30/2014	47	1.82	-61.12	124,980
58	12700000	Santos Dumont	Jurua	4/17/1981	5/30/2014	33	-6.44	-68.24	142,234
59	17420000	Tres Marias	Teles Pires	12/2/1975	3/30/2014	39	-7.61	-57.95	144,400
60	12840000	Gaviao	Jurua	6/23/1972	1/30/2014	42	-4.84	-66.85	162,000
61	14330000	Curicuriari	Negro	11/28/1977	3/30/2014	37	-0.20	-66.80	194,462
62	12845000	Vila Bittencourt	Japura	1/27/1980	2/27/2014	34	-1.40	-69.42	197,136
63	18460000	Boa Sorte	Xingu	1/24/1977	11/29/2013	36	-6.75	-51.98	206,863

— Continues in the next page —

— Come from previous page —

64	13870000	Labrea	Purus	7/5/1967	5/30/2014	47	-7.25	-64.80	220,351
65	13880000	Canutama	Purus	1/2/1973	3/30/2014	41	-6.53	-64.38	230,012
66	12850000	Acanaui	Japura	7/9/1973	2/27/2014	41	-1.82	-66.60	242,259
67	14420000	Serrinha	Negro	11/30/1967	3/30/2014	47	-0.48	-64.83	279,945
68	17430000	Barra Do Sao Manuel Jusante	Tapajos	11/2/1975	3/30/2014	39	-7.34	-58.16	330,900
69	15200000	Principe Da Beira	Guapore	4/22/1983	7/30/2014	31	-12.43	-64.43	342,833
70	17650000	Jatoba	Tapajos	12/21/1972	4/14/2012	40	-5.15	-56.85	389,300
71	18850000	Altamira	Xingu	6/6/1968	4/29/2014	46	-3.21	-52.21	446,203
72	17730000	Itaituba	Tapajos	2/13/1968	3/30/2014	46	-4.28	-55.98	451,600
73	15250000	Guajara-Mirim	Mamore	8/9/1970	6/29/2014	44	-10.79	-65.35	589,497
74	15320002	Abuna	Madeira	6/28/1976	6/29/2014	38	-9.70	-65.36	899,761
75	15400000	Porto Velho	Madeira	4/11/1967	1/30/2014	47	-8.74	-63.92	954,285
76	11400000	Sao Paulo de Olivenca	Solimoes	7/19/1973	12/30/2011	38	-3.45	-68.75	990,781
77	15630000	Humaita	Madeira	4/19/1967	4/13/2014	47	-7.51	-63.02	1,066,240
78	15700000	Manicore	Madeira	4/25/1967	2/27/2014	47	-5.82	-61.30	1,123,670
79	11500000	Santo Antonio do Ica	Solimoes	7/15/1973	2/27/2014	41	-3.08	-67.93	1,134,540
80	15860000	Fazenda Vista Alegre	Madeira	5/3/1967	2/27/2014	47	-4.90	-60.03	1,324,730
81	13150000	Itapeua	Solimoes	4/5/1971	1/30/2014	43	-4.06	-63.03	1,769,000
82	14100000	Manacapuru	Solimoes	6/29/1972	1/30/2014	42	-3.31	-60.61	2,147,740
83	15040000	Careiro	Parana do Careiro	8/30/1977	2/27/2014	37	-3.20	-59.82	2,853,080
84	15030000	Jatuarana	Amazonas	8/27/1977	2/27/2014	37	-3.05	-59.68	2,854,290
85	17050000	Obidos	Amazonas	2/23/1968	1/30/2015	47	-1.95	-55.51	4,680,000

Estimation of power laws

The scaling relations given by power laws $E[Q^k] = \gamma A^\delta$ (equivalent to Equation (1) with $S = A$) and $E[Q^k] = \alpha LA^\beta$ (equivalent to Equation (7)), respectively, are equivalent to the linear functions

$$\ln(E[Q^k]) = \ln(\gamma) + \delta \ln(A), \tag{S1}$$

and

$$\ln(E[Q^k]) = \ln(\alpha) + \beta \ln(LA), \tag{S2}$$

where the scaling exponent (δ or β) and coefficient (γ or α) can be estimated from linear regressions between $\ln(E[Q^k])$ and either $\ln(A)$ or $\ln(LA)$. $E[Q^k]$ is the kth order statistical moment of the probability distribution function of mean or extreme river flows, A is the drainage area, and LA is the cumulative leaf area of the river basin. These linear regressions were computed through standard least-squares methods. The statistical moments $E[Q^k]$ were estimated from time series of annual mean and extreme (floods and low flows) river flows obtained from the daily records described in Table S1. The cumulative leaf area associated with each gauge was estimated as $LA = A \times \overline{LAI}$ where $\overline{LAI}$ is the long-term (1981–2012) average leaf area index spatially averaged over A, using published data of annual LAI. Figure 1 shows the resulting $\overline{LAI}$ map.

Figures S1 to S6 show that mean flows, low flows and floods, scale with drainage area (we will refer to this as *hydrological scaling*) as well as with leaf area (*ecohydrological scaling*), in the whole Amazon river basin (Fig. S1) and in its five major sub-basins treated as independent systems: the Negro, Solimoes, Madeira, Tapajos and Xingu (Figs. S2–S6).

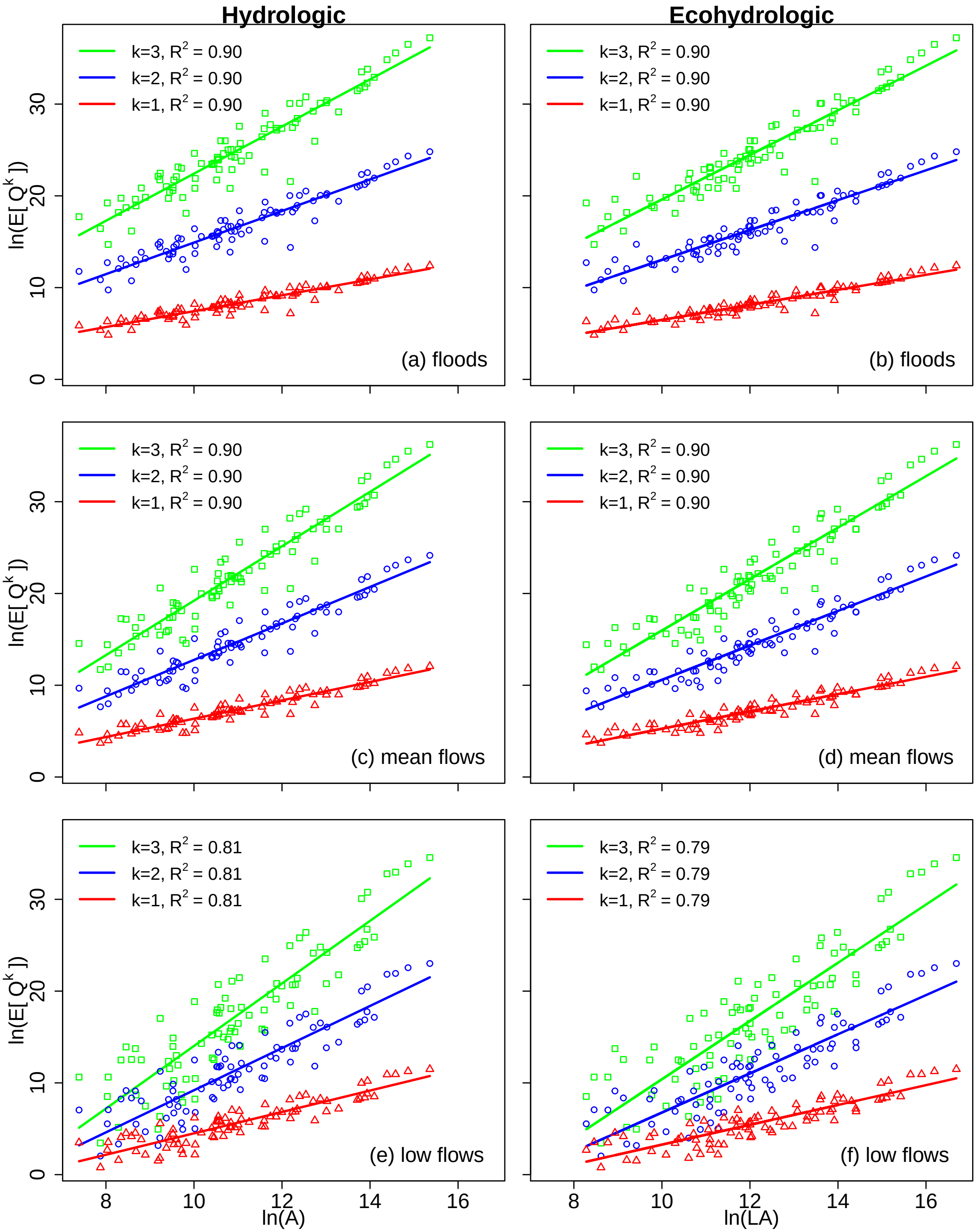

Figure S1. Hydrologic (left) and ecohydrologic (right) scaling power-law relations for floods (top), mean flows (middle) and low flows (bottom), in the whole Amazon basin, for different orders (k) of the statistical moments.

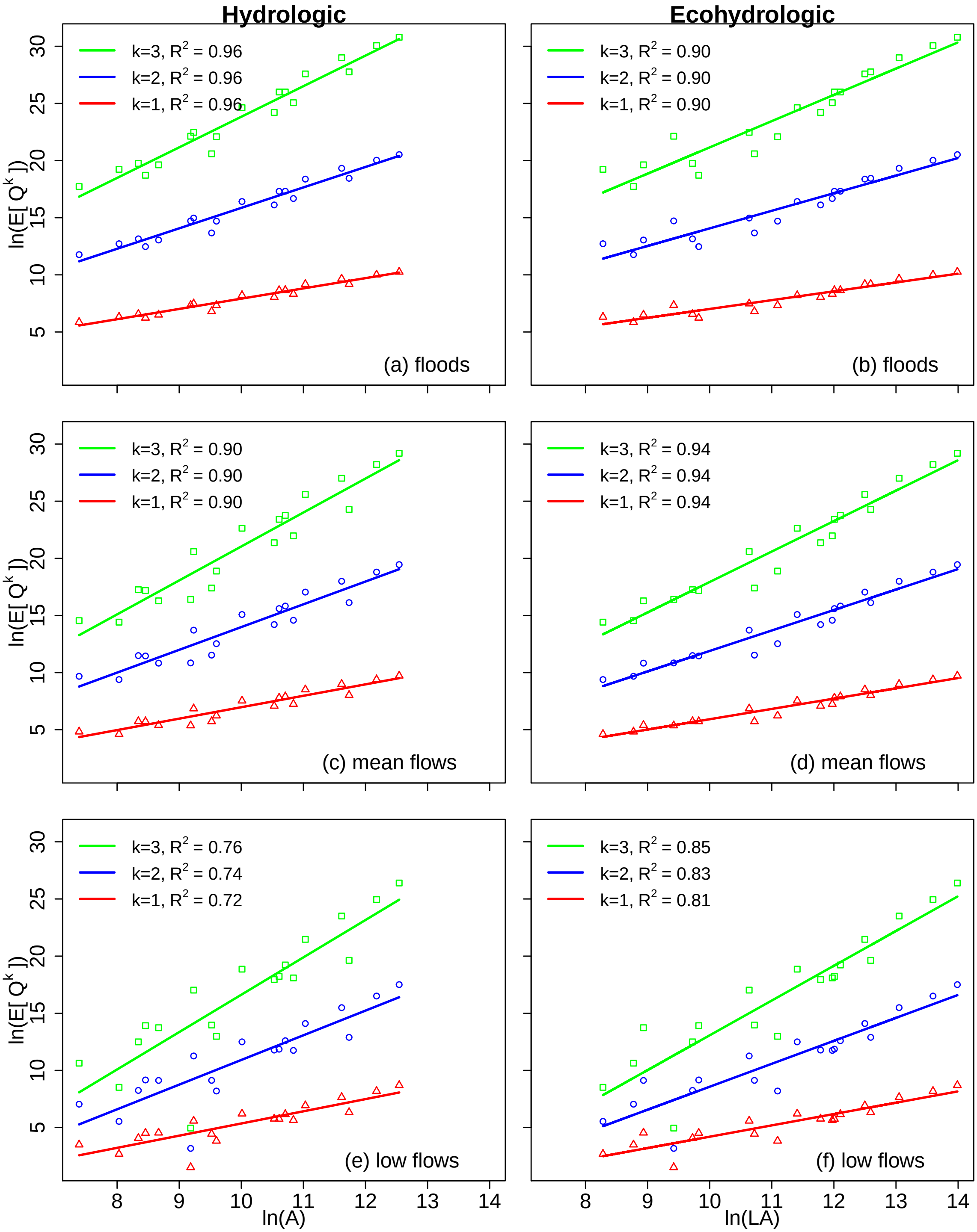

Figure S2. Same as Fig. S1 but for the Negro basin.

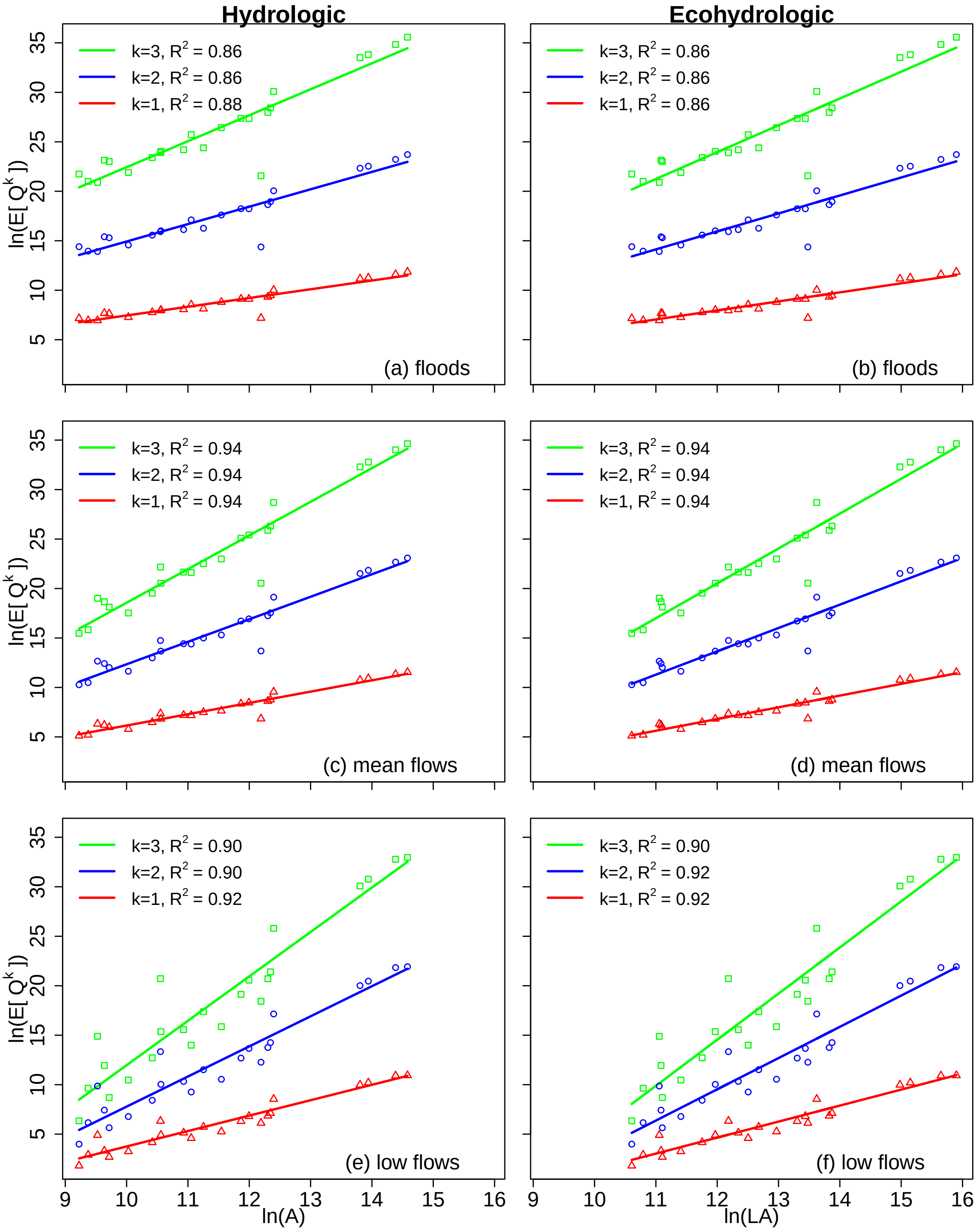

Figure S3. Same as Fig. S1 but for the Solimoes basin.

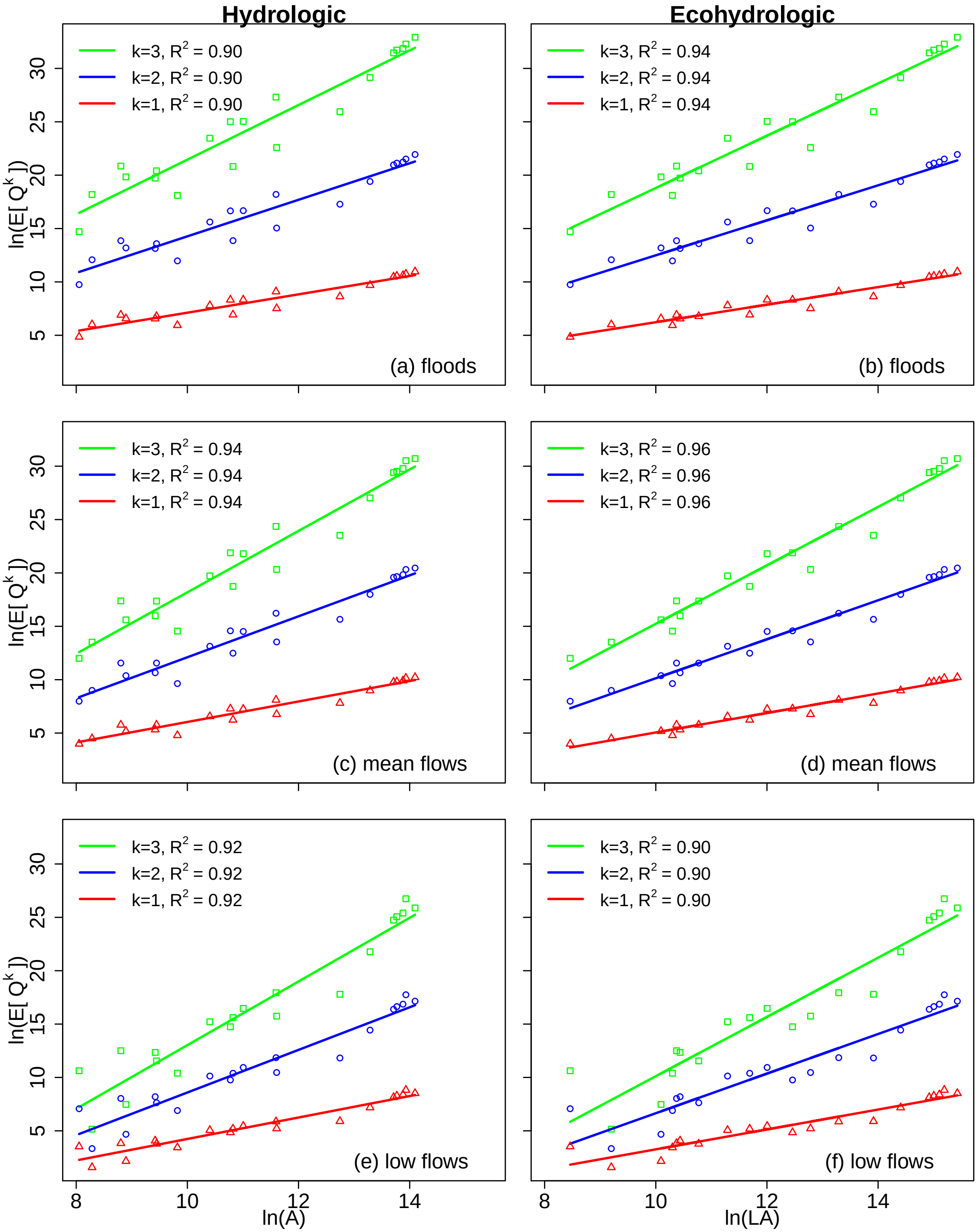

Figure S4. Same as Fig. S1 but for the Madeira basin.

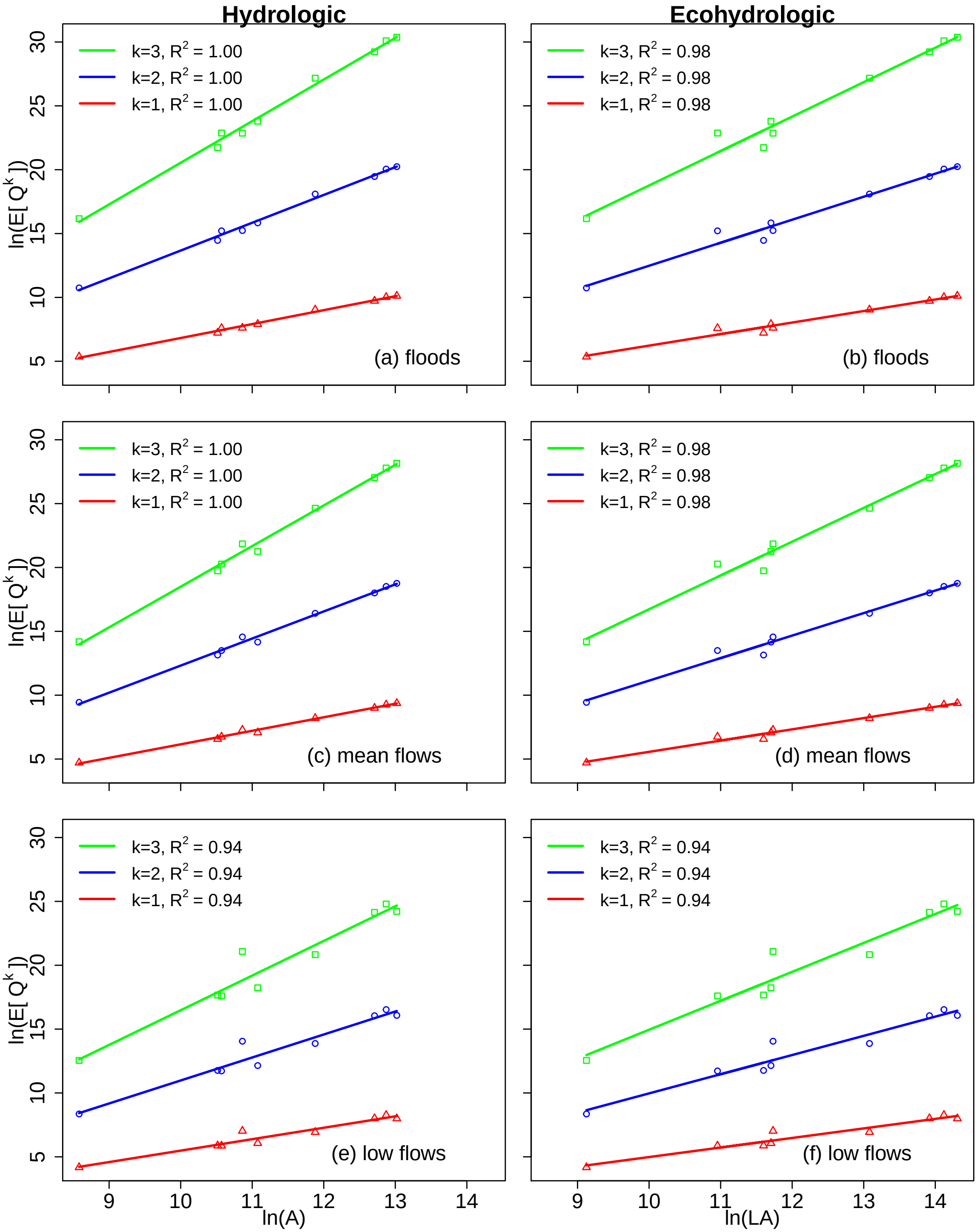

Figure S5. Same as Fig. S1 but for the Tapajos basin.

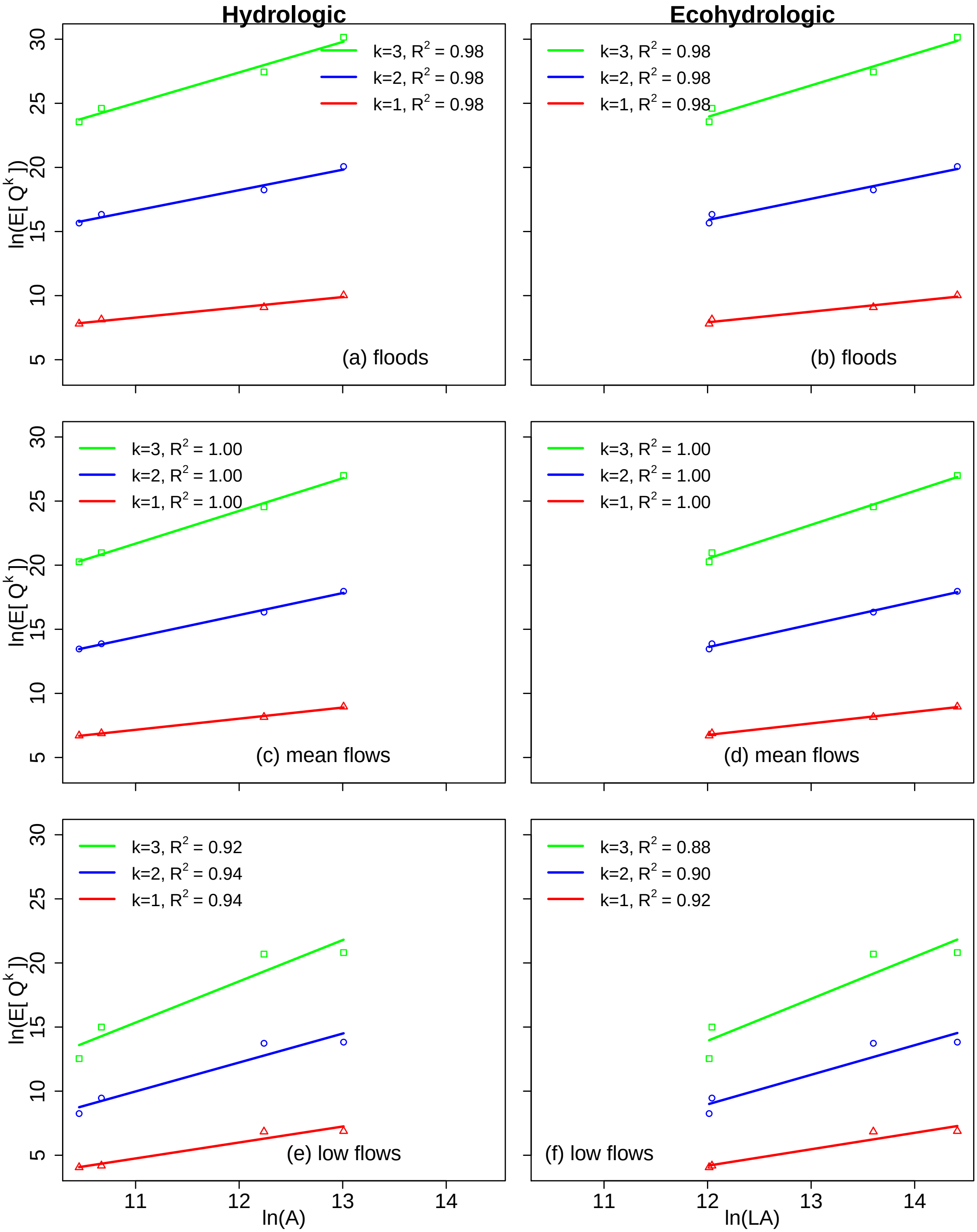

Figure S6. Same as Fig. S1 but for the Xingu basin.

The statistical significance of the ecohydrological scaling (Equation (7)) was evaluated through the determination and correlation coefficients (R^2 and r, Fig. 1 and Figs. S1–S6), as well as by testing the hypothesis that $\ln(E[Q^k])$ and $\ln(LA)$ are not linearly related, i.e. the null hypothesis $H_0 : \beta = 0$, through standard t-tests. All the t-tests show that $\ln(E[Q^k])$ and $\ln(LA)$ have a statistically significant ($p < 0.05$) linear relation (Table S2).

Table S2. t-tests for the significance of the regressions in the ecohydrological scaling for the first statistical moment of river flows. In all cases the null hypothesis, H_0 is rejected, so the alternative hypothesis, H_a, is accepted.

Basin	**Q type**	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Amazon	Flood	$\beta_F = 0$	$\beta_F \neq 0$	1.60E-43	reject H_0	$\beta_F \neq 0$
	Mean flow	$\beta_M = 0$	$\beta_M \neq 0$	4.30E-44	reject H_0	$\beta_M \neq 0$
	Low flow	$\beta_L = 0$	$\beta_L \neq 0$	4.14E-29	reject H_0	$\beta_L \neq 0$
Negro	Flood	$\beta_F = 0$	$\beta_F \neq 0$	2.12E-10	reject H_0	$\beta_F \neq 0$
	Mean flow	$\beta_M = 0$	$\beta_M \neq 0$	5.05E-12	reject H_0	$\beta_M \neq 0$
	Low flow	$\beta_L = 0$	$\beta_L \neq 0$	1.60E-07	reject H_0	$\beta_L \neq 0$
Solimoes	Flood	$\beta_F = 0$	$\beta_F \neq 0$	9.54E-11	reject H_0	$\beta_F \neq 0$
	Mean flow	$\beta_M = 0$	$\beta_M \neq 0$	6.17E-14	reject H_0	$\beta_M \neq 0$
	Low flow	$\beta_L = 0$	$\beta_L \neq 0$	3.92E-13	reject H_0	$\beta_L \neq 0$
Madeira	Flood	$\beta_F = 0$	$\beta_F \neq 0$	8.49E-13	reject H_0	$\beta_F \neq 0$
	Mean flow	$\beta_M = 0$	$\beta_M \neq 0$	9.17E-13	reject H_0	$\beta_M \neq 0$
	Low flow	$\beta_L = 0$	$\beta_L \neq 0$	2.32E-10	reject H_0	$\beta_L \neq 0$
Tapajos	Flood	$\beta_F = 0$	$\beta_F \neq 0$	8.41E-07	reject H_0	$\beta_F \neq 0$
	Mean flow	$\beta_M = 0$	$\beta_M \neq 0$	2.15E-07	reject H_0	$\beta_M \neq 0$
	Low flow	$\beta_L = 0$	$\beta_L \neq 0$	2.38E-05	reject H_0	$\beta_L \neq 0$
Xingu	Flood	$\beta_F = 0$	$\beta_F \neq 0$	1.00E-02	reject H_0	$\beta_F \neq 0$
	Mean flow	$\beta_M = 0$	$\beta_M \neq 0$	2.00E-03	reject H_0	$\beta_M \neq 0$
	Low flow	$\beta_L = 0$	$\beta_L \neq 0$	4.00E-02	reject H_0	$\beta_L \neq 0$

Tests for the difference betweeen the values of the scaling exponents and the critical value 1, using LA as the scale parameter

Figure 3 indicates whether the values of the scaling exponents (β_i, $i = L, M, F$) are significantly ($p < 0.05$) different, either higher or lower, from the critical value 1. This is based on the t-tests results showed in Tables S3–S8. Why 1 is regarded as a critical value is explained in the main text. In the Xingu basin, the hypothesis that all exponents are equal to 1 cannot be rejected (this is indicated by the black dots in Fig. 3). This can be attributed to the small number of degrees of freedom given by the number of gauges within this basin. However, we keep some of the results for this river basin because the scaling relation given by Equation (7) is still statistically significant ($p < 0.05$) for mean and extreme river flows (Table S2).

Table S3. t-tests for the difference between the critical value 1 and the scaling exponents for floods (β_F), mean flows (β_M), and low flows (β_L) in the Amazon basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\beta_F = 1$	$\beta_F \neq 1$	2.45E-08	reject H_0	Floods are dampened, $\beta_F < 1$
	$\beta_F \geq 1$	$\beta_F < 1$	1.22E-08	reject H_0	
Mean flow	$\beta_M = 1$	$\beta_M \neq 1$	**9.79E-02**	do not reject H_0	Mean flows are not amplified, $\beta_M \leq 1$
	$\beta_M \geq 1$	$\beta_M < 1$	**4.89E-02**	reject H_0	
Low flow	$\beta_L = 1$	$\beta_L \neq 1$	2.00E-01	do not reject H_0	Low flows are not dampened, $\beta_L \geq 1$
	$\beta_L \geq 1$	$\beta_L < 1$	1.00E-01	do not reject H_0	

Table S4. Same as Table S3 but for the Negro basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\beta_F = 1$	$\beta_F \neq 1$	1.17E-03	reject H_0	Floods are dampened, $\beta_F < 1$
	$\beta_F \geq 1$	$\beta_F < 1$	5.83E-04	reject H_0	
Mean flow	$\beta_M = 1$	$\beta_M \neq 1$	8.26E-02	do not reject H_0	Mean flows are not amplified, $\beta_M \leq 1$
	$\beta_M \geq 1$	$\beta_M < 1$	4.13E-02	reject H_0	
Low flow	$\beta_L = 1$	$\beta_L \neq 1$	9.45E-01	do not reject H_0	Low flows are not dampened, $\beta_L \approx 1$
	$\beta_L \geq 1$	$\beta_L < 1$	4.72E-01	do not reject H_0	

Table S5. Same as Table S3 but for the Solimoes basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\beta_F = 1$	$\beta_F \neq 1$	2.70E-01	do not reject H_0	Floods are not amplified, $\beta_F \leq 1$
	$\beta_F \leq 1$	$\beta_F > 1$	1.34E-01	do not reject H_0	
Mean flow	$\beta_M = 1$	$\beta_M \neq 1$	1.34E-02	reject H_0	Mean flows are amplified, $\beta_M > 1$
	$\beta_M \leq 1$	$\beta_M > 1$	6.74E-03	reject H_0	
Low flow	$\beta_L = 1$	$\beta_L \neq 1$	5.53E-06	reject H_0	Low flows are amplified, $\beta_L > 1$
	$\beta_L \leq 1$	$\beta_L > 1$	2.76E-06	reject H_0	

Table S6. Same as Table S3 but for the Madeira basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\beta_F = 1$	$\beta_F \neq 1$	1.33E-03	reject H_0	Floods are dampened, $\beta_F < 1$
	$\beta_F \geq 1$	$\beta_F < 1$	6.65E-04	reject H_0	
Mean flow	$\beta_M = 1$	$\beta_M \neq 1$	4.33E-02	reject H_0	Mean flows are dampened, $\beta_M < 1$
	$\beta_M \geq 1$	$\beta_M < 1$	2.16E-02	reject H_0	
Low flow	$\beta_L = 1$	$\beta_L \neq 1$	3.70E-01	do not reject H_0	Low flows are not amplified, $\beta_L \leq 1$
	$\beta_L \leq 1$	$\beta_L > 1$	1.85E-01	do not reject H_0	

Table S7. Same as Table S3 but for the Tapajos basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\beta_F = 1$	$\beta_F \neq 1$	1.26E-01	do not reject H_0	Floods are not amplified, $\beta_F \leq 1$
	$\beta_F \leq 1$	$\beta_F > 1$	6.29E-02	do not reject H_0	
Mean flow	$\beta_M = 1$	$\beta_M \neq 1$	3.27E-02	reject H_0	Mean flows are dampened, $\beta_M < 1$
	$\beta_M \geq 1$	$\beta_M < 1$	1.63E-02	reject H_0	
Low flow	$\beta_L = 1$	$\beta_L \neq 1$	1.27E-02	reject H_0	Low flows are dampened, $\beta_L < 1$
	$\beta_L \geq 1$	$\beta_L < 1$	6.33E-03	reject H_0	

Table S8. Same as Table S3 but for the Xingu basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\beta_F = 1$	$\beta_F \neq 1$	2.30E-01	do not reject H_0	$\beta_F \approx 1$
	$\beta_F \geq 1$	$\beta_F < 1$	1.10E-01	do not reject H_0	
Mean flow	$\beta_M = 1$	$\beta_M \neq 1$	1.40E-01	do not reject H_0	$\beta_M \approx 1$
	$\beta_M \geq 1$	$\beta_M < 1$	7.00E-02	do not reject H_0	
Low flow	$\beta_L = 1$	$\beta_L \neq 1$	3.80E-01	do not reject H_0	$\beta_L \approx 1$
	$\beta_L \leq 1$	$\beta_L > 1$	1.90E-01	do not reject H_0	

Scaling results using A as the scale parameter

This section presents the results of the scaling analysis when using A instead of LA as the scale parameter. Overall, the results are consistent between models. Here we use power law (hydrological scaling)

$$E[Q_i] = \gamma_i A^{\delta_i}, \tag{S3}$$

5 which is equivalent to Equation (1) with $S = A$ and $k = 1$.

Table S9. t-tests for the significance of the regressions in the hydrological scaling for the first statistical moment of river flows. In all cases the null hypothesis, H_0 is rejected, so the alternative hypothesis, H_a, is accepted.

Basin	**Q type**	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Amazon	Flood	$\delta_F = 0$	$\delta_F \neq 0$	<2.20E-16	reject H_0	$\delta_F \neq 0$
	Mean flow	$\delta_M = 0$	$\delta_M \neq 0$	<2.20E-16	reject H_0	$\delta_M \neq 0$
	Low flow	$\delta_L = 0$	$\delta_L \neq 0$	<2.20E-16	reject H_0	$\delta_L \neq 0$
Negro	Flood	$\delta_F = 0$	$\delta_F \neq 0$	9.14E-13	reject H_0	$\delta_F \neq 0$
	Mean flow	$\delta_M = 0$	$\delta_M \neq 0$	6.25E-10	reject H_0	$\delta_M \neq 0$
	Low flow	$\delta_L = 0$	$\delta_L \neq 0$	3.82E-06	reject H_0	$\delta_L \neq 0$
Solimoes	Flood	$\delta_F = 0$	$\delta_F \neq 0$	6.18E-11	reject H_0	$\delta_F \neq 0$
	Mean flow	$\delta_M = 0$	$\delta_M \neq 0$	7.68E-14	reject H_0	$\delta_M \neq 0$
	Low flow	$\delta_L = 0$	$\delta_L \neq 0$	5.57E-13	reject H_0	$\delta_L \neq 0$
Madeira	Flood	$\delta_F = 0$	$\delta_F \neq 0$	8.96E-11	reject H_0	$\delta_F \neq 0$
	Mean flow	$\delta_M = 0$	$\delta_M \neq 0$	1.93E-12	reject H_0	$\delta_M \neq 0$
	Low flow	$\delta_L = 0$	$\delta_L \neq 0$	2.58E-11	reject H_0	$\delta_L \neq 0$
Tapajos	Flood	$\delta_F = 0$	$\delta_F \neq 0$	4.78E-09	reject H_0	$\delta_F \neq 0$
	Mean flow	$\delta_M = 0$	$\delta_M \neq 0$	6.62E-09	reject H_0	$\delta_M \neq 0$
	Low flow	$\delta_L = 0$	$\delta_L \neq 0$	1.97E-05	reject H_0	$\delta_L \neq 0$
Xingu	Flood	$\delta_F = 0$	$\delta_F \neq 0$	1.10E-02	reject H_0	$\delta_F \neq 0$
	Mean flow	$\delta_M = 0$	$\delta_M \neq 0$	1.64E-03	reject H_0	$\delta_M \neq 0$
	Low flow	$\delta_L = 0$	$\delta_L \neq 0$	3.10E-02	reject H_0	$\delta_L \neq 0$

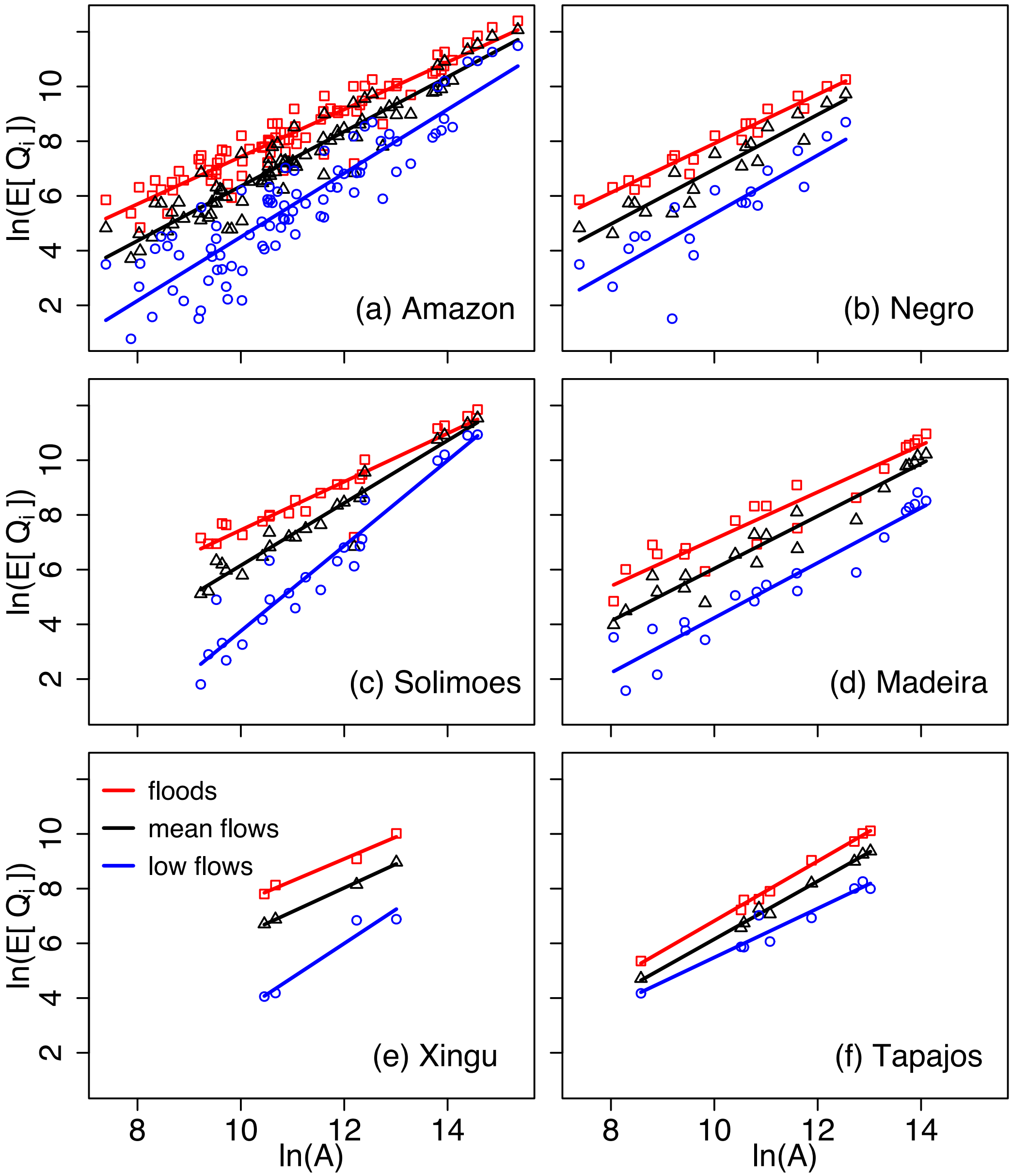

Figure S7. Same as Fig. 2 but using A instead of LA. Power laws of the form $E[Q] = \gamma_i A^{\delta_i}$ (equivalent to Equation (1) with $S = A$ and $k = 1$) for low flows ($i = L$), mean flows ($i = M$), and floods ($i = F$). Points are observed river flows and lines are the scaling relations (in all cases $r > 0.88$ and $p < 0.05$). **(a) Amazon:** $E[Q_L] = \exp(-7.16)LA^{1.17}$; $E[Q_M] = \exp(-3.63)LA^{1.00}$; $E[Q_F] = \exp(-1.22)LA^{0.86}$. **(b) Negro:** $E[Q_L] = \exp(-5.31)LA^{1.07}$; $E[Q_M] = \exp(-3.03)LA^{1.00}$; $E[Q_F] = \exp(-1.07)LA^{0.90}$. **(c) Solimoes:** $E[Q_L] = \exp(-11.83)LA^{1.55}$; $E[Q_M] = \exp(-5.26)LA^{1.14}$; $E[Q_F] = \exp(-1.38)LA^{0.88}$. **(d) Madeira:** $E[Q_L] = \exp(-5.81)LA^{1.00}$; $E[Q_M] = \exp(-3.55)LA^{0.96}$; $E[Q_F] = \exp(-1.48)LA^{0.86}$. **(e) Xingu:** $E[Q_L] = \exp(-8.93)LA^{1.24}$; $E[Q_M] = \exp(-2.39)LA^{0.86}$; $E[Q_F] = \exp(-0.53)LA^{0.80}$. **(f) Tapajos:** $E[Q_L] = \exp(-3.47)LA^{0.89}$; $E[Q_M] = \exp(-4.45)LA^{1.06}$; $E[Q_F] = \exp(-4.09)LA^{1.09}$. For convenience, γ_i is expressed as $\exp(\ln(\gamma_i))$.

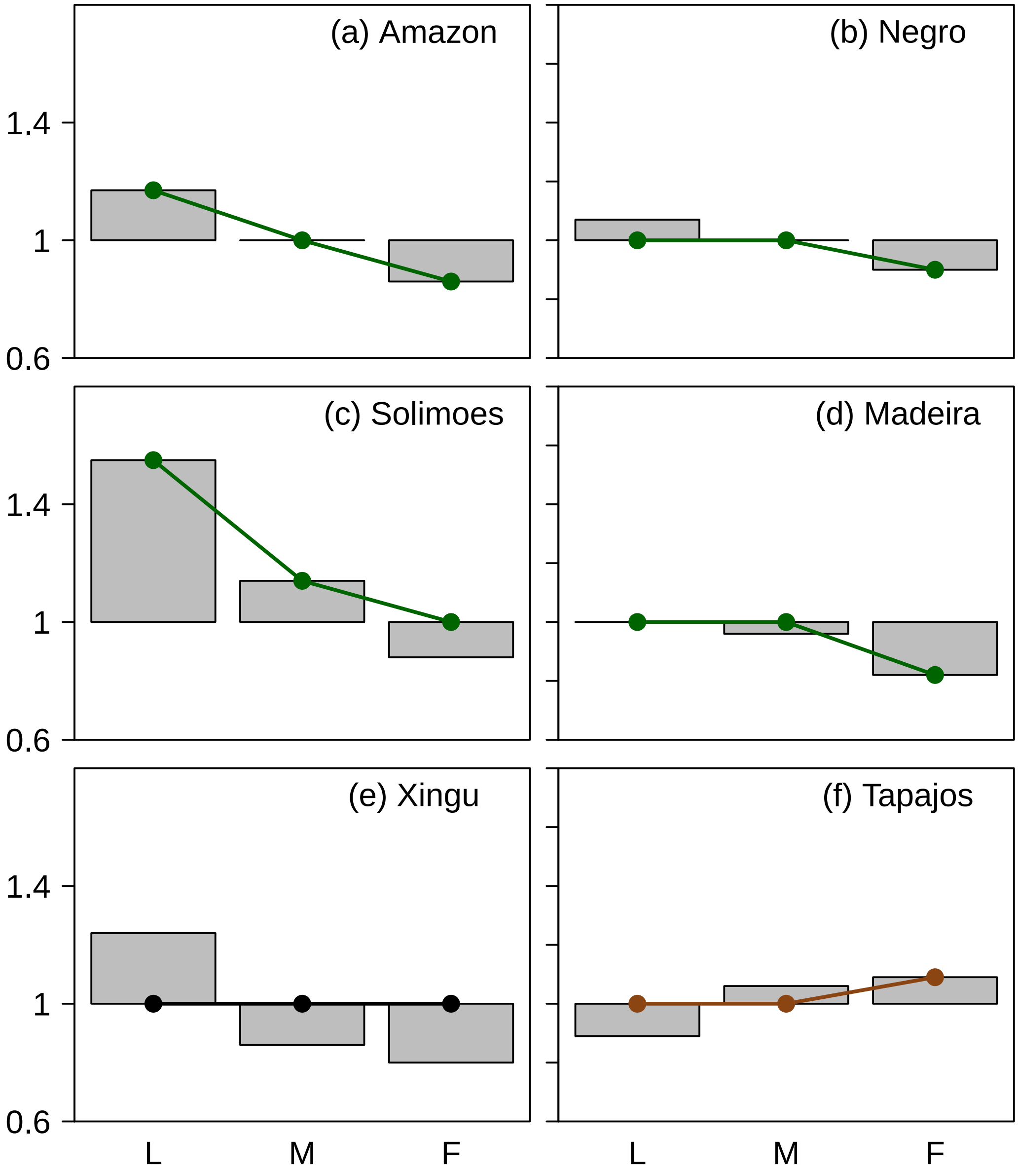

Figure S8. Same as Fig. 3 but using A instead of LA. Observed patterns of the values of the scaling exponents (δ_i) for low flows (L), mean flows (M), and floods (F), in the Amazon basin and its six major sub-basins. Dots over the bars indicate whether the difference between the scaling exponent and 1 is significant ($p < 0.05$, the dot is not over 1) or not (the dot is over 1). Details about the t-tests are in Supplementary Tables S3 to S8. In regulated states (green, a–d), the exponents decrease from low flows to floods; whereas in unregulated states (brown, f), the exponents increase from low flows to floods. In the Xingu river basin (e), the hypothesis that all exponents are equal to 1 can not be rejected ($p > 0.05$) because of the small number of degrees of freedom (gauges).

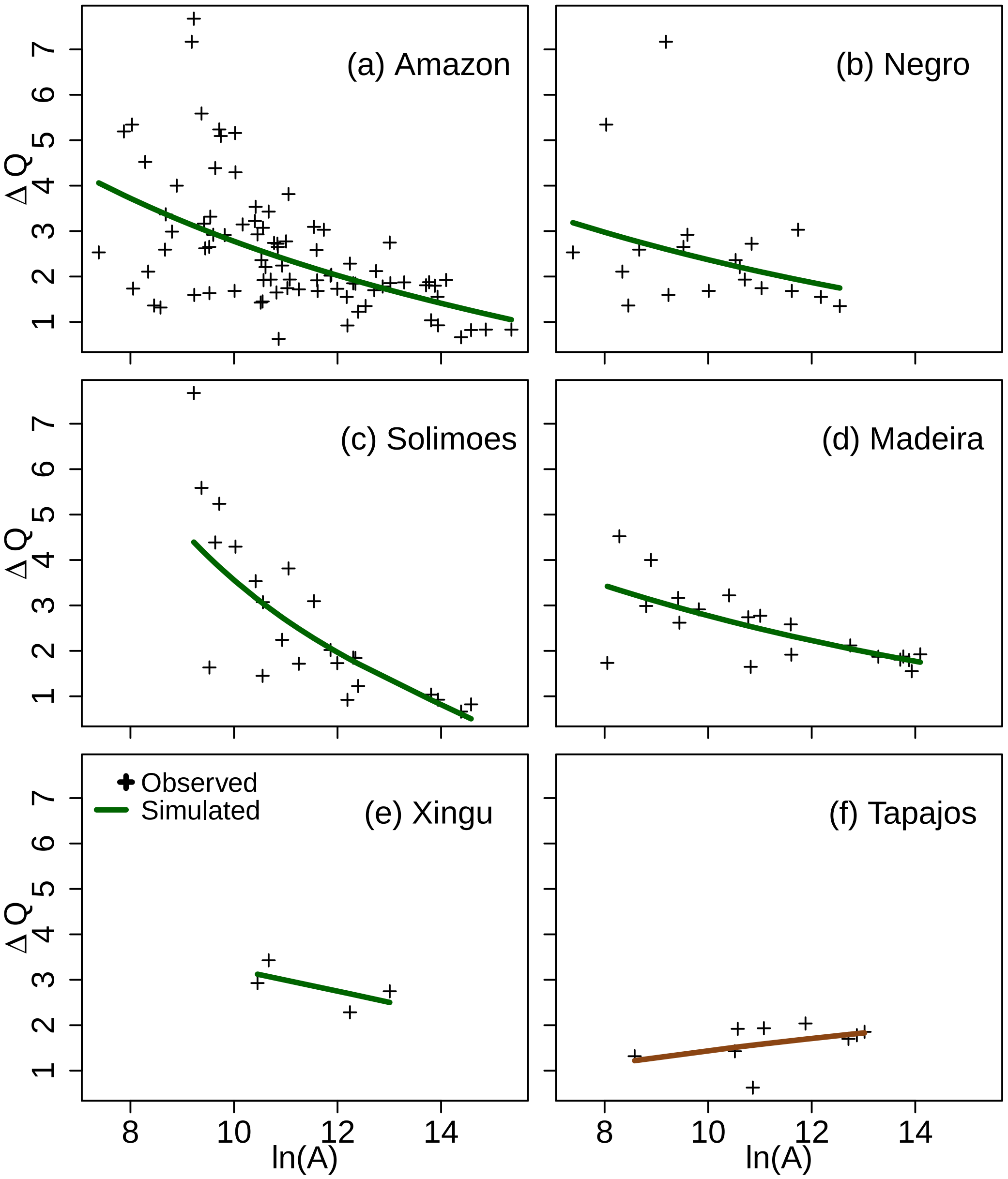

Figure S9. Same as Fig. 4 but using A instead of LA. Extremes amplitude, $\Delta_Q = (E[Q_F] - E[Q_L])/E[Q_M]$, as observed (crosses) and simulated (lines) by $(\gamma_F A^{\delta_F} - \gamma_L A^{\delta_L})/\gamma_M A^{\delta_M}$ (from Eq. 2 with $S = A$), using the scaling parameters of each basin. Δ_Q either decreases or increases with spatial scale (A) depending on whether the river basin is regulated ($\delta_L > \delta_M > \delta_F$, e.g. Solimoes) or unregulated ($\delta_L < \delta_M < \delta_F$, e.g. Tapajos).

Table S10. Same as Table S3 but using A instead of LA. t-tests for the difference between the critical value 1 and the scaling exponents for floods (δ_F), mean flows (δ_M), and low flows (δ_L) in the Amazon basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\delta_F = 1$	$\delta_F \neq 1$	7.70E-05	reject H_0	Floods are dampened, $\delta_F < 1$
	$\delta_F \geq 1$	$\delta_F < 1$	3.85E-05	reject H_0	
Mean flow	$\delta_M = 1$	$\delta_M \neq 1$	9.75E-01	do not reject H_0	$\delta_M \approx 1$
	$\delta_M \geq 1$	$\delta_M < 1$	4.87E-01	do not reject H_0	
Low flow	$\delta_L = 1$	$\delta_L \neq 1$	9.27E-03	reject H_0	Low flows are amplified $\delta_L > 1$
	$\delta_L \leq 1$	$\delta_L > 1$	4.64E-03	reject H_0	

Table S11. Same as Table S10 but for the Negro basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\delta_F = 1$	$\delta_F \neq 1$	4.97E-02	reject H_0	Floods are dampened, $\delta_F < 1$
	$\delta_F \geq 1$	$\delta_F < 1$	2.49E-02	reject H_0	
Mean flow	$\delta_M = 1$	$\delta_M \neq 1$	9.97E-01	do not reject H_0	$\delta_M \approx 1$
	$\delta_M \geq 1$	$\delta_M < 1$	4.99E-01	do not reject H_0	
Low flow	$\delta_L = 1$	$\delta_L \neq 1$	6.83E-01	do not reject H_0	Low flows are not dampened, $\delta_L \geq 1$
	$\delta_L \geq 1$	$\delta_L < 1$	3.41E-01	do not reject H_0	

Table S12. Same as Table S10 but for the Solimoes basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\delta_F = 1$	$\delta_F \neq 1$	1.24E-01	do not reject H_0	Floods are not amplified, $\delta_F \leq 1$
	$\delta_F \leq 1$	$\delta_F > 1$	6.22E-02	do not reject H_0	
Mean flow	$\delta_M = 1$	$\delta_M \neq 1$	4.51E-02	reject H_0	Mean flows are amplified, $\delta_M > 1$
	$\delta_M \leq 1$	$\delta_M > 1$	2.25E-02	reject H_0	
Low flow	$\delta_L = 1$	$\delta_L \neq 1$	1.62E-05	reject H_0	Low flows are amplified, $\delta_L > 1$
	$\delta_L \leq 1$	$\delta_L > 1$	8.09E-06	reject H_0	

Table S13. Same as Table S10 but for the Madeira basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\delta_F = 1$	$\delta_F \neq 1$	4.22E-02	reject H_0	Floods are dampened, $\delta_F < 1$
	$\delta_F \geq 1$	$\delta_F < 1$	2.11E-02	reject H_0	
Mean flow	$\delta_M = 1$	$\delta_M \neq 1$	4.85E-01	do not reject H_0	Mean flows are not amplified, $\delta_M \leq 1$
	$\delta_M \leq 1$	$\delta_M > 1$	2.43E-01	do not reject H_0	
Low flow	$\delta_L = 1$	$\delta_L \neq 1$	9.45E-01	do not reject H_0	$\delta_L \approx 1$
	$\delta_L \geq 1$	$\delta_L < 1$	4.73E-01	do not reject H_0	

Table S14. Same as Table S10 but for the Tapajos basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\delta_F = 1$	$\delta_F \neq 1$	2.46E-02	reject H_0	Floods are amplified, $\delta_F > 1$
	$\delta_F \leq 1$	$\delta_F > 1$	1.23E-02	reject H_0	
Mean flow	$\delta_M = 1$	$\delta_M \neq 1$	1.07E-01	do not reject H_0	Mean flows are not amplified, $\delta_M \leq 1$
	$\delta_M \leq 1$	$\delta_M > 1$	5.37E-02	do not reject H_0	
Low flow	$\delta_L = 1$	$\delta_L \neq 1$	2.77E-01	do not reject H_0	Low flows are not amplified, $\delta_L \leq 1$
	$\delta_L \leq 1$	$\delta_L > 1$	1.38E-01	do not reject H_0	

Table S15. Same as Table S10 but for the Xingu basin.

Q type	H_0	H_a	p**-value**	**Test result**	**Conclusion**
Flood	$\delta_F = 1$	$\delta_F \neq 1$	1.44E-01	do not reject H_0	$\delta_F \approx 1$
	$\delta_F \geq 1$	$\delta_F < 1$	7.19E-02	do not reject H_0	
Mean flow	$\delta_M = 1$	$\delta_M \neq 1$	6.44E-02	do not reject H_0	$\delta_M \approx 1$
	$\delta_M \geq 1$	$\delta_M < 1$	3.22E-02	reject H_0	
Low flow	$\delta_L = 1$	$\delta_L \neq 1$	3.91E-01	do not reject H_0	$\delta_L \approx 1$
	$\delta_L \leq 1$	$\delta_L > 1$	1.95E-01	do not reject H_0	