ASSESSMENT OF SEDIMENT TRANSFER BASED ON DISCHARGE INDICES FOR CAUVERY RIVER BASIN, INDIA

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- Introduction
- Methodology
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INTRODUCTION

- **Mechanism of Sediment Transport**
- **Magnitude Frequency Analysis (MFA)**
- **Lognormal and Gamma distribution based approaches**
- **Reliable estimates of Discharge Indices**
  - **Effective discharge**
  - **Fraction-load discharge and**
  - **Functional-equivalent discharge**

INTRODUCTION…

- **Indices provide information on long-term transport of sediments through river networks and**
- **Are linked to the exponent of sediment rating curve**
- **Fraction-load discharges computed by considering various fractions of sediment loads ranging from 10% to 90%**
- **Plots of cumulative sediment yield prepared for both approaches and compared with empirical cumulative sediment yield**

METHODOLOGY

- **Power-law relationship between sediment load and discharge**

$$S = aq^b$$

- **Flow frequency and Transport effectiveness**
  - ✓ **Log-normal distribution**

$$f^{LN}(q) = \frac{1}{q\sigma_x\sqrt{2\pi}} e^{-\left(\ln q - \alpha\right)^2/2\sigma_x^2} \qquad TE^{LN} = \frac{aq^b}{q\sigma_x\sqrt{2\pi}} e^{-(\ln q - \alpha)^2/2\sigma_x^2}$$

  - ✓ **Gamma distribution**

$$f^G(q) = \frac{\lambda^\beta q^{\beta-1} e^{-\lambda q}}{\Gamma(\beta)} \qquad TE^G = \frac{a\lambda^\beta q^{b+\beta-1} e^{-\lambda q}}{\Gamma(\beta)}$$

METHODOLOGY…

- **Effective discharge**
  - ✓ **Log-normal distribution**

$$Q_e = \exp[\alpha + (b - 1)\sigma_x^2]$$

(α and σ_x are mean and standard deviation of log-transformed discharge)

  - ✓ **Gamma distribution**

$$Q_e = \frac{1}{\lambda}\left[b + \left(\beta - 1\right)\right]$$

(β and $1/\lambda$ are shape and scale parameters of Gamma distribution)

METHODOLOGY…

- **Mean sediment load**
  - **Log-normal distribution**

$$\mu_S^{LN} = \int_0^{\infty} \frac{aq^b}{q\sigma_x\sqrt{2\pi}} e^{-(\ln q-\alpha)^2/2\sigma_x^2} dq \qquad \mu_S^{LN} = a.\exp\left(b^2\sigma_x^2 / 2 + b\alpha\right)$$

  - **Gamma distribution**

$$\mu_S^G = \int_0^{\infty} \frac{a\lambda^{\beta} q^{b+\beta-1} e^{-\lambda q}}{\Gamma(\beta)} dq \qquad \mu_S^G = \frac{a}{\lambda^b}\frac{\Gamma(\beta+b)}{\Gamma(\beta)}$$

METHODOLOGY…

➢ Fraction-load discharge

- ✓ **Log-normal distribution**

$$\left.\begin{aligned} Q_f^{LN} &= \exp\left(\alpha + \sigma_x\left(b\sigma_x + Z_f\right)\right) \\ f &= \Phi\left[\frac{\ln\left(Q_f\right) - \alpha - b\sigma_x^2}{\sigma_x}\right] \end{aligned}\right\}$$

- ✓ **Gamma distribution**

$$\left.\begin{aligned} &\mu_S^G \mathrm{x}\ f = \mu_S^G\ \gamma\left((b+\beta), \lambda Q_f^G\right) \\ &\Rightarrow \gamma\left((b+\beta), \lambda Q_f^G\right) = f \end{aligned}\right\}$$

METHODOLOGY…

- **Functional-equivalent discharge**
  - ✓ **Log-normal distribution**

$$\left.\begin{aligned} \mu_S^{LN} &= a\left(Q_{fed}^{LN}\right)^b \\ Q_{fed}^{LN} &= \left(\frac{\mu_S^{LN}}{a}\right)^{1/b} \end{aligned}\right\}$$

  - ✓ **Gamma distribution**

$$\left.\begin{aligned} \mu_S^{G} &= a\left(Q_{fed}^{G}\right)^b \\ Q_{fed}^{G} &= \left(\frac{\mu_S^{G}}{a}\right)^{1/b} \end{aligned}\right\}$$

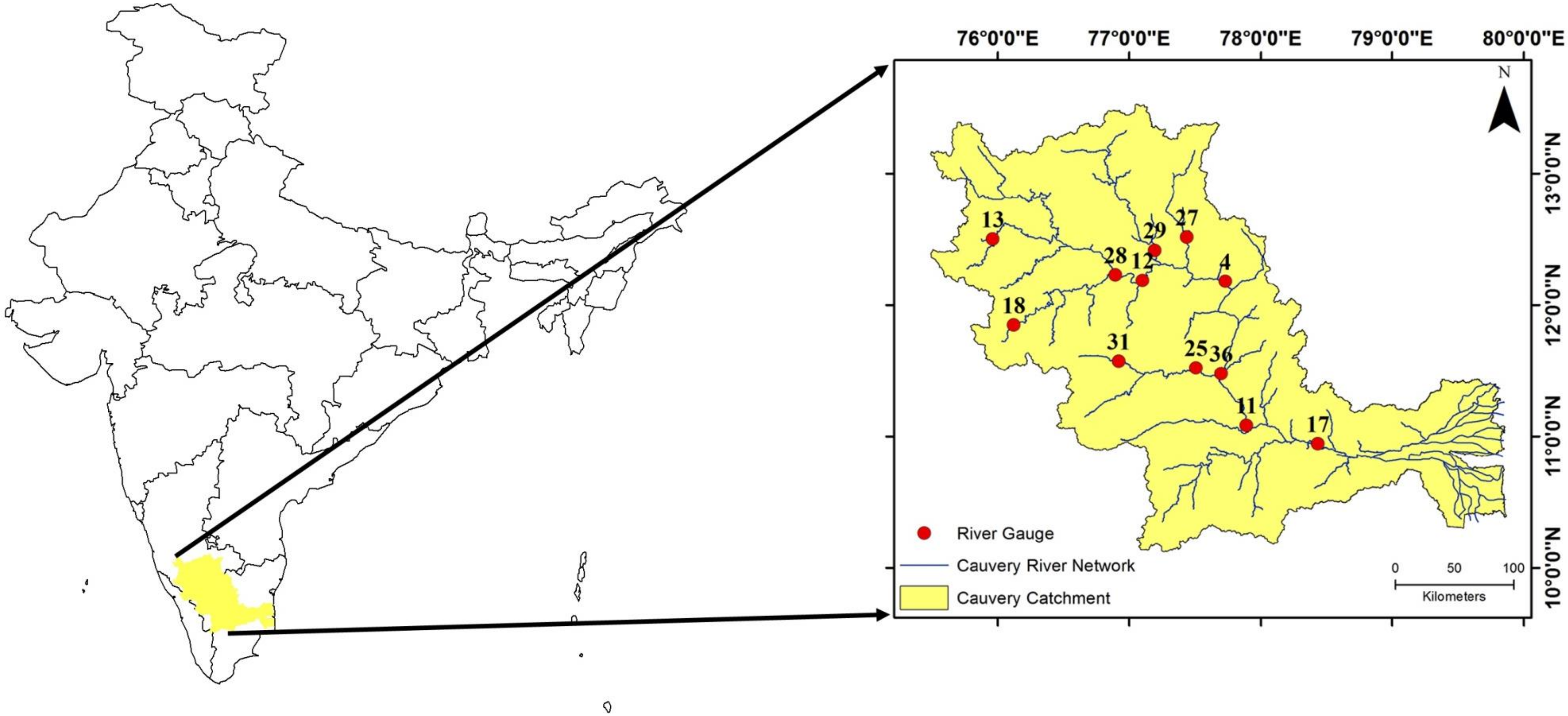
DATA USED

- **Gauge-Discharge (cubic meter per second)**
- **Sediment Concentration (gram per liter)**
- **Source of data**
- **http://www.india-wris.nrsc.gov.in/HydroObservationStationApp.html**

(Water Resources Information System (WRIS), Government of India)

STUDY AREA

- **12 Catchments (Cauvery River Basin)**



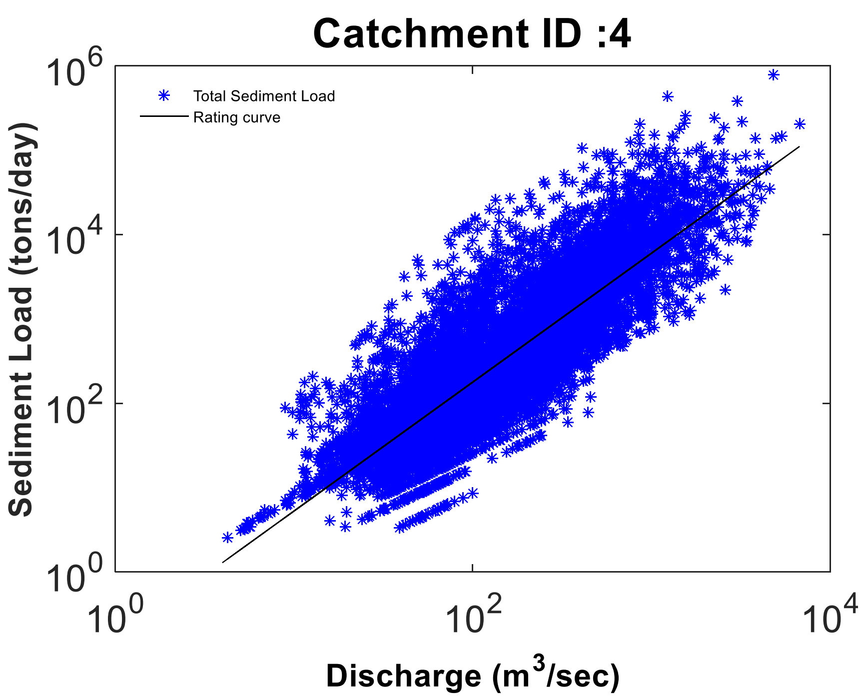
STUDY AREA …

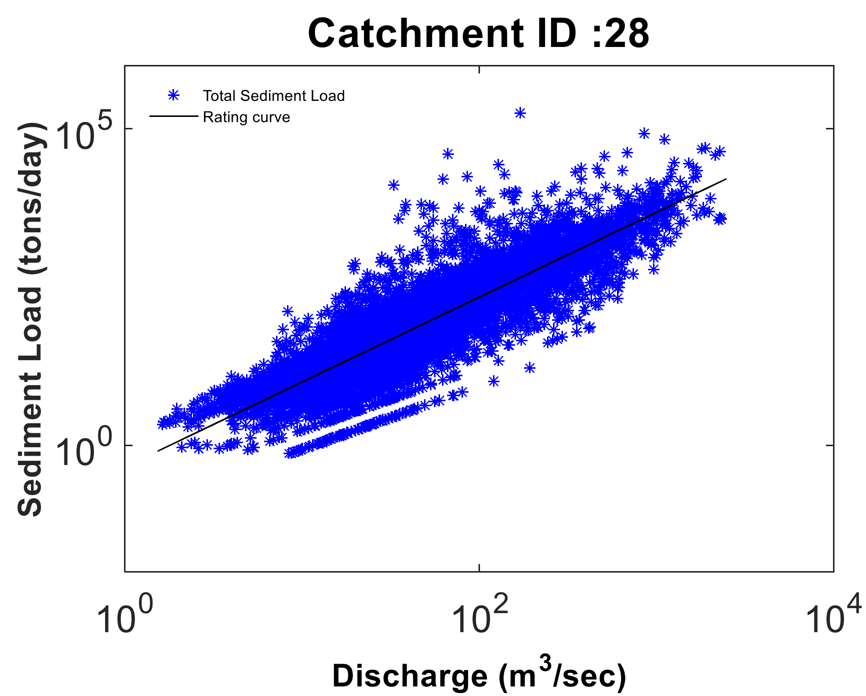
ID #	Catchment Name	Elevation (m)	Area (km^2)	Data length Q (days)	Mean Q (m^3/sec)	α	β	Skewness	Kurtosis
4	'Biligundulu'	255	36682	13149	238.5	4.83	1.08	0.43	2.80
11	'Kodumudi'	130	53233	13148	275.4	4.89	1.35	-0.33	2.46
12	'Kollegal'	622	21082	11689	199.9	4.55	1.16	0.18	3.82
13	'Kudige'	809	1934	6209	89.6	3.18	1.64	0.17	2.75
17	'Musiri'	89	66243	12418	260.8	4.44	1.80	-0.29	1.82
18	'Muthankera'	705	1260	13879	77.4	2.92	2.12	-1.20	6.06
25	'Savandapur'	189	5776	10958	20.3	2.72	0.77	-1.04	8.36
27	'Tbekuppe'	600	3500	365	6.0	1.72	0.38	0.95	4.50
28	'Tnarasipur'	635	7000	10957	92.1	3.69	1.26	0.02	3.88
29	'Tkhalli'	580	7890	6209	23.3	1.92	1.94	-1.40	5.94
31	'Thengumarahada'	345	1370	2557	12.3	2.12	0.81	0.11	5.79
36	'Urachikottai'	168	44100	3652	193.7	1.79	4.52	-0.37	1.25

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

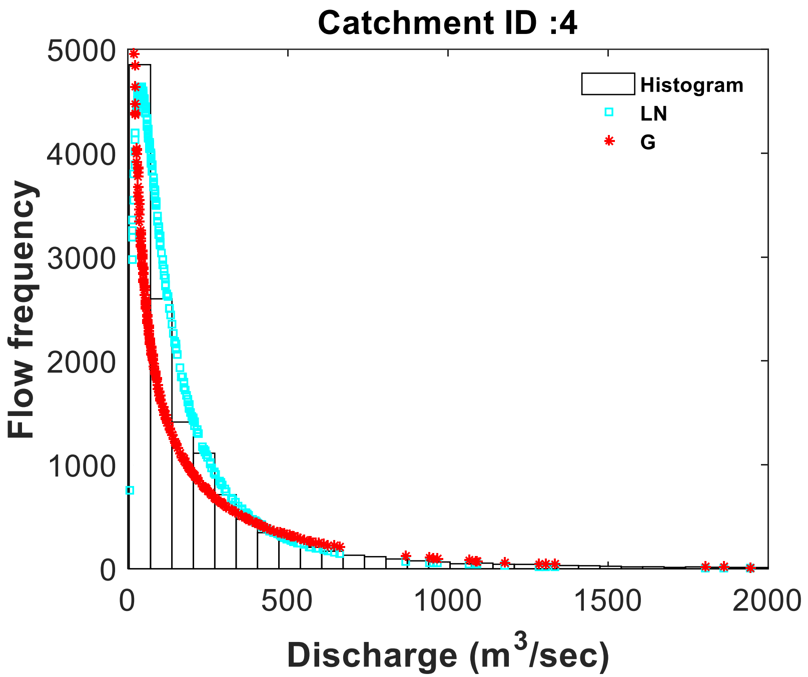
➢ **Power-law relationship (2 typical catchments)**

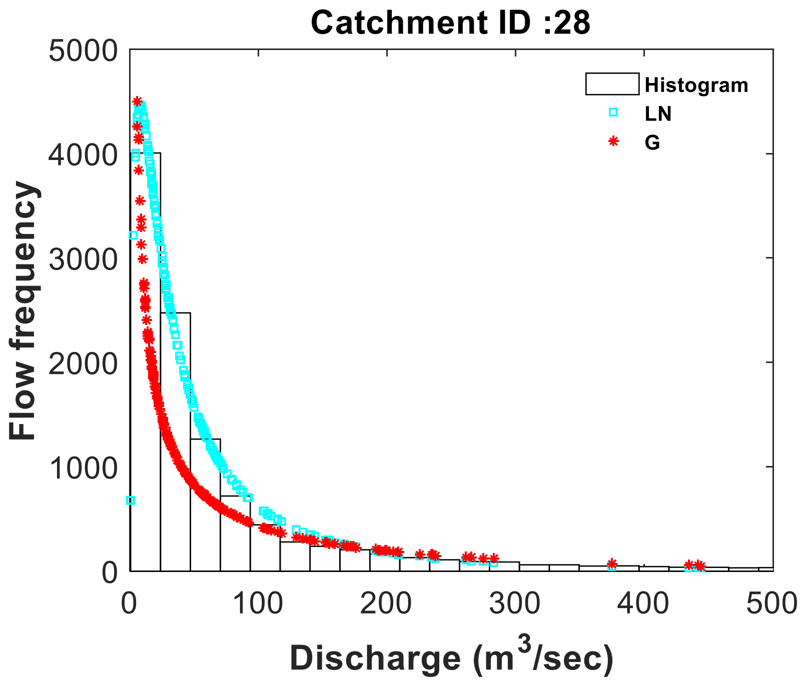




RESULTS AND DISCUSSION…

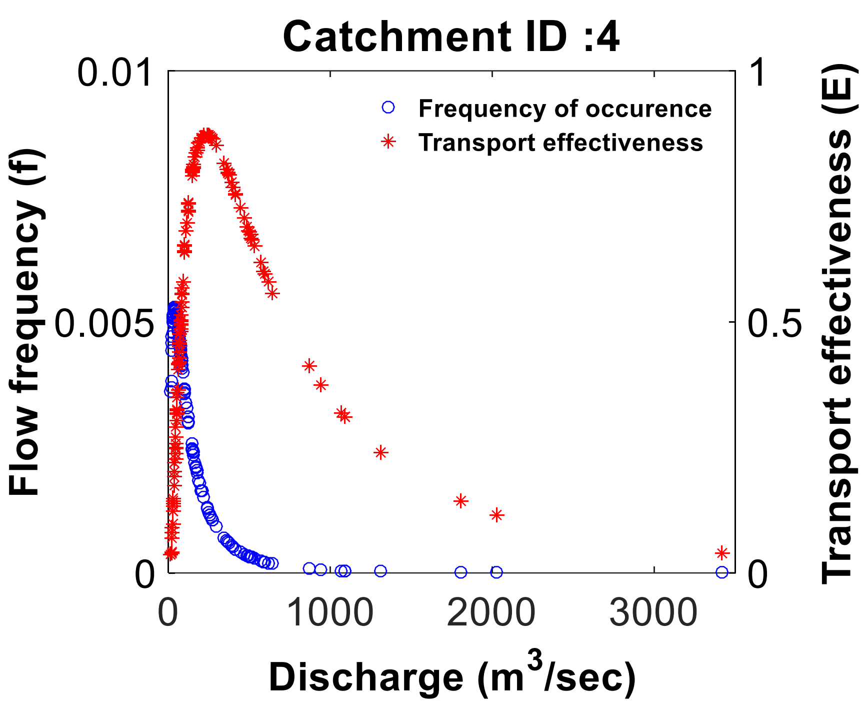
- **Histogram with PDFs (2 typical catchments)**

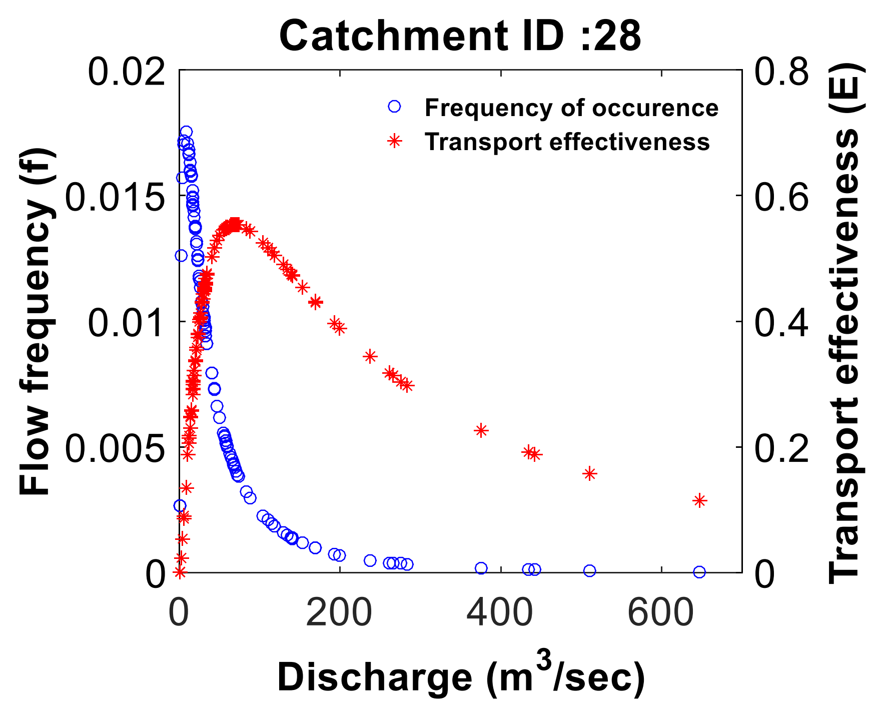




RESULTS AND DISCUSSION

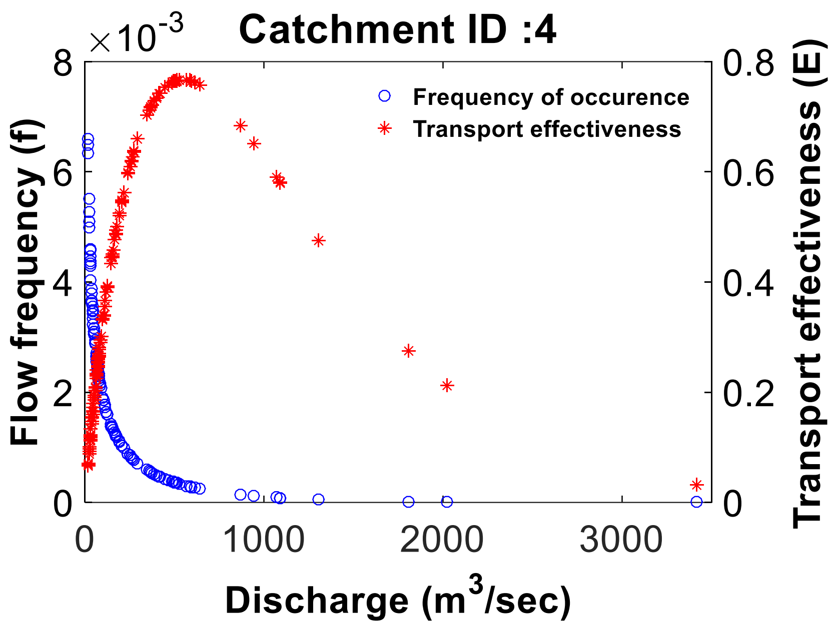
- **Flow frequency and Transport effectiveness (2 typical catchments)**
  - ✓ Lognormal distribution

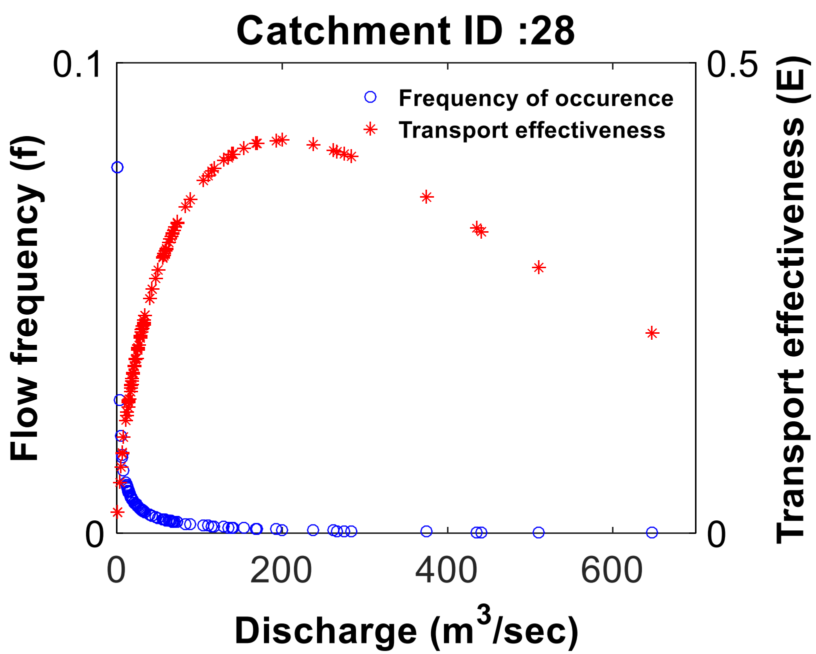




RESULTS AND DISCUSSION

- **Flow frequency and Transport effectiveness (2 typical catchments)**
  - ✓ Gamma distribution

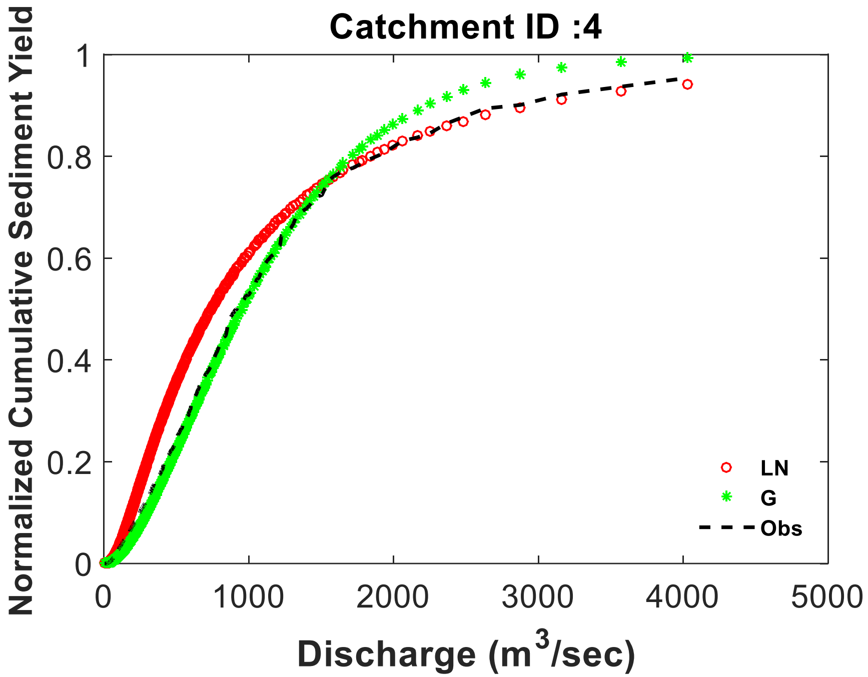


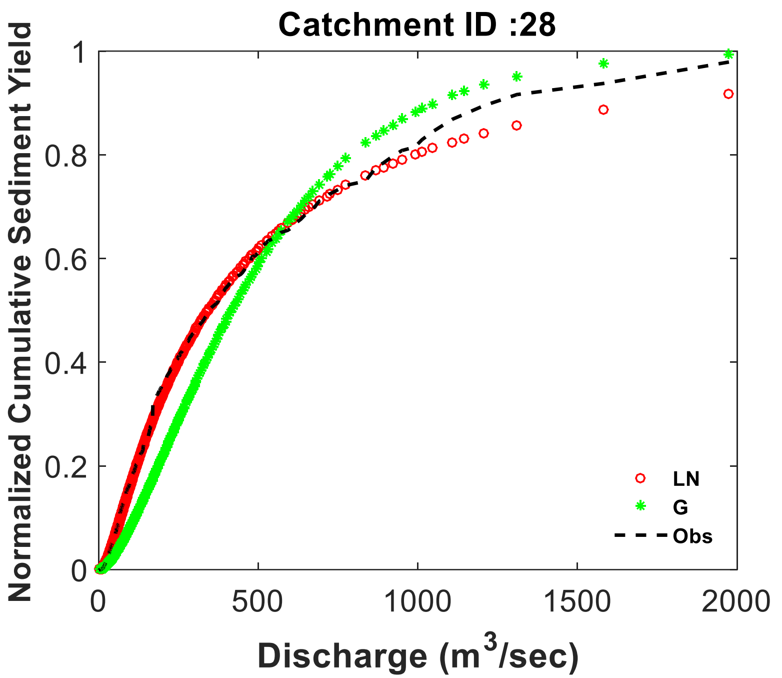


RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

- **Cumulative Sediment Yield (2 typical catchments)**





RESULTS AND DISCUSSION…

❖ Effective discharge and Functional-equivalent discharge

Catchment ID #	Q_{eff}^{LN} (m^3/sec)	Q_{eff}^{G} (m^3/sec)	Q_{fed}^{obs} (m^3/sec)	Q_{fed}^{LN} (m^3/sec)	$AR-bias$ $\left(Q_{fed}^{LN}\right)\%$	Q_{fed}^{G} (m^3/sec)	$AR-bias$ $\left(Q_{fed}^{G}\right)\%$
4	231.6567	549.3538	549.231	304.4186	44.57367	346.4939	36.9129
11	241.9038	392.9908	447.6665	446.3335	0.297772	322.5249	27.9542
12	161.8716	477.464	379.2267	243.2191	35.86445	286.5119	24.44839
13	41.08484	168.3969	205.3546	121.1745	40.99256	112.0613	45.43036
17	300.8945	430.5892	509.435	802.3756	57.50304	325.5543	36.09501
18	50.09198	135.115	126.5778	289.9375	129.0588	95.49648	24.5551
25	17.69987	29.9031	38.81366	22.10757	43.04177	23.89721	38.43092
27	5.572618	6.03963	7.698198	5.986537	22.23457	6.042167	21.51192
28	69.04756	199.8753	168.2746	116.834	30.56942	125.9345	25.16129
29	17.7173	60.83826	67.93706	71.94333	5.89703	32.64584	51.94694
31	10.82629	25.82619	21.5284	13.18368	38.76145	16.80405	21.94474
36	9.995126	204.7599	655.2463	211380.7	32159.72	197.5666	69.8485

RESULTS AND DISCUSSION…

❖ Fraction-load discharges (2 Catchments)

Catchment ID #	*fraction (f)*	Q^{obs} (m^3/sec)	Q^{LN} (m^3/sec)	$AR-bias$ $\left(Q^{LN}\right)\%$	Q^{G} (m^3/sec)	$AR-bias$ $\left(Q^{G}\right)\%$
4	***0.1***	2869.4	2943.5	2.58241	2227.054	22.38608
	0.2	1862.794	1832.253	1.639547	1707.801	8.320464
	0.3	1400.9	1301.764	7.076571	1386.632	1.018491
	0.4	1142.829	972.0414	14.94428	1145.934	0.271696
	0.5	917.37	739.8154	19.35474	947.7929	3.316317
	0.6	754.5	563.0694	25.37184	774.31	2.625585
	0.7	591.3	420.45	28.89396	614.4492	3.91497
	0.8	421.8	298.718	29.18019	458.7221	8.753461
	0.9	247.4	185.9442	24.84065	292.8581	18.37433
11	***0.1***	3903	8401.794	115.265	1449.197	62.86967
	0.2	1785.513	4641.718	159.9655	1121.406	37.19416
	0.3	1075.5	3025.965	181.3542	917.5755	14.68382
	0.4	834	2099.384	151.7247	764.046	8.387772
	0.5	695.7	1491.734	114.422	636.9936	8.438469
	0.6	593.3	1059.964	78.65562	525.0913	11.4965
	0.7	521.723	735.3922	40.95452	421.2361	19.26058
	0.8	440.3	479.4066	8.881818	319.1066	27.52518
	0.9	317.11	264.8566	16.478	208.716	34.18184

RESULTS AND DISCUSSION…

❖ Fraction-load discharges (2 Catchments)

Catchment ID #	*fraction (f)*	Q^{obs} (m^3/sec)	Q^{LN} (m^3/sec)	$AR-bias$ $\left(Q^{LN}\right)\%$	Q^{G} (m^3/sec)	$AR-bias$ $\left(Q^{G}\right)\%$
12	***0.1***	3250	2752.816	15.29798	2391.765	26.40723
	0.2	2164.73	1652.248	23.67416	1802.366	16.73945
	0.3	1437.4	1143.438	20.45093	1441.564	0.289689
	0.4	1094.029	834.8646	23.68899	1173.813	7.292713
	0.5	770.8	622.2177	19.27637	955.6875	23.98644
	0.6	594.8	463.7338	22.03534	766.9512	28.9427
	0.7	455.2	338.5884	25.61767	595.5161	30.82516
	0.8	302.2	234.32	22.46193	431.6823	42.84657
	0.9	172	140.6396	18.23279	262.362	52.53605
13	***0.1***	1413	5044.832	257.0299	1186.525	16.02793
	0.2	1068.2	2447.421	129.1164	875.0544	18.08141
	0.3	895	1452.757	62.31924	686.8262	23.25965
	0.4	741.1	930.3445	25.53562	548.8707	25.93837
	0.5	616.556	613.3918	0.513208	437.9744	28.96438
	0.6	525.4	404.4195278	23.02635558	343.4802059	34.62500839
	0.7	367.7	258.9899194	29.56488457	259.2527677	29.49340013
	0.8	251.5	153.733044	38.87354114	180.7831596	28.11802799
	0.9	116.9	74.58116769	36.20088307	102.9054378	11.97139626

RESULTS AND DISCUSSION…

❖ Fraction-load discharges (2 Catchments)

Catchment ID #	*fraction (f)*	Q^{obs} (m^3/sec)	Q^{LN} (m^3/sec)	$AR-bias$ $\left(Q^{LN}\right)\%$	Q^{G} (m^3/sec)	$AR-bias$ $\left(Q^{G}\right)\%$
17	***0.1***	3650	76192.32	1987.461	1679.034	53.99907
	0.2	2858.3	34553.76	1108.892	1292.217	54.79072
	0.3	1744.5	19537.47	1019.947	1052.451	39.67033
	0.4	1262.3	12002.74	850.8623	872.3979	30.88823
	0.5	901	7612.265	744.8685	723.8653	19.65979
	0.6	734	4827.780898	557.7358171	593.5069323	19.14074492
	0.7	593.041	2965.91995	400.1205566	473.0381842	20.23516346
	0.8	484.8	1676.997604	245.9153473	355.2365356	26.72513705
	0.9	360.9	760.530438	110.7316259	229.0178198	36.54258249
18	***0.1***	878.6	68601.84	7708.085	825.3373	6.062225
	0.2	662.1	26971.94	3973.695	613.6684	7.314843
	0.3	526.963	13758.57	2510.917	485.1262	7.939231
	0.4	431.8	7740.701	1692.659	390.4671	9.572244
	0.5	355	4521.733	1173.728	313.9844	11.55369
	0.6	281	2641.371957	839.9900204	248.428198	11.59138863
	0.7	209.2	1486.061233	610.3543178	189.5670484	9.384776083
	0.8	141.118	758.0498216	437.1744367	134.1854852	4.912565971
	0.9	84.31	298.0397074	253.5045752	78.34787151	7.071674171

RESULTS AND DISCUSSION…

❖ Fraction-load discharges (2 Catchments)

Catchment ID #	*fraction (f)*	Q^{obs} (m^3/sec)	Q^{LN} (m^3/sec)	$AR-bias\left(Q^{LN}\right)\%$	Q^{G} (m^3/sec)	$AR-bias\left(Q^{G}\right)\%$
25	***0.1***	318.9	86.97198	72.72751	133.5106	58.13402
	0.2	224.7	61.86283	72.4687	101.5244	54.8178
	0.3	174.2	48.38912	72.22209	81.83851	53.02038
	0.4	120.9	39.22761	67.55367	67.15449	44.45452
	0.5	81.94	32.23967	60.65454	55.1267	32.72309
	0.6	45.73	26.49655595	42.05870118	44.65485862	2.351063595
	0.7	24.82	21.47996384	13.4570353	35.07090179	41.30097418
	0.8	20.031	16.80163291	16.12184658	25.81904904	28.89545724
	0.9	16.52	11.95093584	27.65777335	16.10409041	2.517612534
27	***0.1***	16.653	10.43241	37.35416	11.68504	29.83225
	0.2	11.425	8.834632	22.67281	9.882429	13.50171
	0.3	9.013	7.83664	13.05181	8.7019	3.45168
	0.4	6.978	7.073719	1.371719	7.769997	11.34991
	0.5	6.367	6.427934	0.957028	6.961223	9.332864
	0.6	5.463	5.841105314	6.921202888	6.210936815	13.69095397
	0.7	4.862	5.272455401	8.442110254	5.471013649	12.52599031
	0.8	4.424	4.676859817	5.715637825	4.684550356	5.889474582
	0.9	4.035	3.960573904	1.844512917	3.728825743	7.587961749

RESULTS AND DISCUSSION…

❖ Fraction-load discharges (2 Catchments)

Catchment ID #	*fraction (f)*	Q^{obs} (m^3/sec)	Q^{LN} (m^3/sec)	$AR-bias\left(Q^{LN}\right)\%$	Q^{G} (m^3/sec)	$AR-bias\left(Q^{G}\right)\%$
28	***0.1***	1219	1723.042	41.34877	1052.004	13.69942
	0.2	935.4	988.1507	5.639372	789.9201	15.55269
	0.3	678.6	661.766	2.480694	629.827	7.187297
	0.4	478.1	469.8145	1.733002	511.2655	6.936933
	0.5	347.5	341.0886	1.84501	414.8888	19.39246
	0.6	240.1	247.6326746	3.137307205	331.7054099	38.15302368
	0.7	169	175.8044741	4.026316049	256.3776685	51.70276245
	0.8	115.996	117.7365227	1.500502341	184.6841026	59.21592352
	0.9	65.95	67.52096271	2.382051111	111.0684406	68.41310171
29	***0.1***	801.9	9134.874	1039.154	439.9888	45.13171
	0.2	725.3	3892.369	436.6564	324.0444	55.32271
	0.3	515.4	2104.097	308.2453	254.0344	50.71121
	0.4	440.8	1243.934	182.1991	202.7641	54.00088
	0.5	345	761.0975	120.608	161.5859	53.16351
	0.6	206.8	465.6753862	125.1815214	126.5333273	38.81367151
	0.7	140	275.3054965	96.64678319	95.3279948	31.90857515
	0.8	84.59	148.8217983	75.93308706	66.30489669	21.61615239
	0.9	34	63.41295122	86.50868005	37.57845098	10.52485582

RESULTS AND DISCUSSION…

❖ Fraction-load discharges (2 Catchments)

Gauge ID #	*fraction (f)*	Q^{obs} (m^3/sec)	Q^{LN} (m^3/sec)	$AR-bias$ $\left(Q^{LN}\right)\%$	Q^{G} (m^3/sec)	$AR-bias$ $\left(Q^{G}\right)\%$
31	***0.1***	484.12	58.4485	87.92686	120.6273	75.08318
	0.2	182.034	40.97715	77.48929	91.39188	49.79406
	0.3	115.666	31.71977	72.57641	73.43803	36.50854
	0.4	78.32	25.48611	67.459	60.07371	23.2971
	0.5	42.36	20.77231	50.96245	49.1509	16.0314
	0.6	31.517	16.93034563	46.28186174	39.66476249	25.85196082
	0.7	20.88	13.6031484	34.85082184	31.00922353	48.51160694
	0.8	13.335	10.529982	21.03500559	22.68735304	70.13388105
	0.9	8.27	7.38237441	10.73307848	14.00440293	69.33981782
36	***0.1***	5386.106	2.44E+12	4.53E+10	1360.254	74.74513
	0.2	2872.086	3.34E+11	1.16E+10	1006.42	64.95856
	0.3	2204.35	7.97E+10	3.61E+09	792.1776	64.06299
	0.4	1277.639	2.34E+10	1.83E+09	634.8597	50.30993
	0.5	939.017	7.45E+09	7.93E+08	508.1415	45.88581
	0.6	614.917	2.37E+09	3.85E+08	399.9117	34.96492
	0.7	501.165	6.96E+08	1.39E+08	303.1604	39.50886
	0.8	401.4	1.66E+08	41336192	212.6672	47.01863
	0.9	289.9	22717041	7836065	122.2888	57.81689

CONCLUSIONS

- Effective discharge index represents that single discharge which carries the most amounts of sediments,

- Whereas fraction-load discharge and functional-equivalent discharge indices deal with mean sediment load which considers contribution of entire probability distribution of discharge

- Reliable estimates of discharge indices necessary for stream channel restoration and for eco-hydrologic and geomorphic studies

CONCLUSIONS…

- Gamma distribution-based MFA approach tends to provide close match with the empirical yield and
- Also outperform LN-based approach in determining discharge indices
- Discharge indices also find use in effective planning and functioning of dams/reservoirs

References…

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