631.671 : 551.577.3 (547.1 GUJ & MAH)

RAINFED WATER RESOURCES FOR THE STATES OF GUJARAT AND MAHARASHTRA

1. The variability of southwest monsoon rainfall is of prime importance for planning of the various operations of the interest of policy makers, the scientific communities and the farmers at large. The intraseasonal variations of the monsoon rainfall over different meteorological sub-divisions are not alike and therefore, there is a need to study for inter-correlation coefficient (CC) of monthly rainfall amongst all the meteorological sub-divisions to look for sustainable and dependable direct or indirect correlationship. Such relationships of monthly rainfall amongst nearby meteorological sub-divisions would be helpful to plan for tapping water resources in various regions for further water requirements for various uses. According to Rao (1997), the future water need for 2000 and 2025 years would be around 750 and 1050 km^3 for India in comparison to 552 km^3 of 1990. Here the inter CC amongst the monthly rainfall of 35 meteorological sub-divisions have been obtained and the salient features are highlighted. The study may provide some inputs for water resources assessment for various areas within India.

2. The monthly rainfall of 35 meteorological sub-divisions for the period of 40 years (1951-90) were obtained for the months of June to September from the National Data Centre, Pune of India Meteorological Department IMD. The inter-correlation coefficients for each of the month of June to September were obtained by relating monthly rainfall of each meteorological sub- divisions of the Gujarat and Maharashtra States with the remaining 34 meteorological subdivisions for the same month. A list of names and numbers of 35 meteorological sub-divisions as given by IMD is produced here in Appendix A for reference.

3. The intercorrelation coefficients of the monthly rainfall of meteorological sub-divisions of Gujarat State (21, 22) and of Maharashtra State (23, 24, 25 and 26) individually Vs. rest of meteorological sub-divisions are shown in Table 1 to 6. The salient features of the tables are given below for each of the meteorological sub-divisions :

(a) Features of correlation between Gujarat Region, Daman, Dadra and Nagar Haveli (21) Vs. remaining meteorological sub-divisions:

(*i*) There is an inverse correlationship of monthly rainfall of meteorological sub-division number 21 with meteorological sub- divisions of 2, 11, 12 13, 14, 15, 26, 29 and 32 during June to September (Table 1) and a high correlation between -0.5 and -1 is observed against meteorological sub-divisions of 15, 29 and 32 in all the above 4 months and with 22 during July to September.

(*ii*) Monthly rainfall of meteorological sub-divisions 21 has direct correlation with meteorological sub-divisions of 3,5,24,30,33 and 34 during June to September and with 4, 23 during July to September. The correlation is 0.5 and more against meteorological sub-divisions of 24,30,33 and 34 in all the four months and with 23 during July to September.

(b) Features of correlation between Saurashtra, Kutch and Diu (22) Vs. remaining meteorological sub-divisions.

TABLE 1(a)

Correlation coefficients between monthly rainfall of meteorological sub division 21 v/s remaining sub-divisions (1951- 90)

21	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Jun	M.1135	M.0809	0.3531	M.1439	0.4628	M.0237	0.3208	0.4719	M.2681	0.0721	M.1331	M.4319	M.5854	M.1593	M.6866	M.2171	0.7647
Jul	M.1259	M.3275	0.2248	0.1015	0.0654	0.7986	0.3414	0.5966	M.3277	M.0082	M.3759	M.2491	M.6281	M.4942	M.5747	M.0118	M.1808
Aug	0.1495	M.2473	0.1873	0.1420	0.2626	0.4691	0.3492	0.4132	0.5199	M.5087	M.3828	M.4045	M.3738	M.0301	M.5360	0.1690	0.1673
Sep	0.1401	M.2362	0.3541	0.2328	0.3803	M.2861	M.1191	M.1470	M.1139	M.1649	M.3577	M.4497	M.2780	M.6197	M.6732	M.3315	M.6637

TABLE 1(b)

Correlation coefficients between monthly rainfall of meteorological sub division 21 v/s remaining sub-divisions (1951- 90)

21	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Jun	0.6467	0.5440	0.8507	0.1640	M.5581	0.7874	0.5601	M.0666	0.6528	M.3365	M.7609	0.7836	M.8368	M.7824	0.7769	0.6427	0.1443
Jul	0.0265	0.2998	0.7769	M.6356	0.7518	0.7764.	M.0730	M.451	M.4832	0.2093	M.8415	0.4999	0.2837	M.837 0	0.7345	0.7812	0.4830
Aug	M.4180	M.5036	M.0223	M.8052	0.5143	0.6015	M.1668	M.6701	0.6990	M.7893	M.7510	0.5554	0.4479	M.7723	0.6745	0.7078	0.2547
Sep	M.4029	M.6770	M.2904	M.6785	0.6379	0.6149	0.1939	M.6169	0.7595	0.2311	M.5940	0.7273	M.5549	M.7310	0.5817	0.5703	M.1524

TABLE 2(a)

Correlation coefficients between monthly rainfall of meteorological sub division 22 v/s remaining sub-divisions (1951- 90)

22	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Jun	0.1302	0.0526	0.1132	M.0743	0.1359	0.1155	0.0422	0.0817	0.0204	0.0427	M.0752	0.1792	M.1057	M.1283	M.0283	M.2638	0.0907
Jul	0.3080	0.0336	M.4179	M.1676	M.1434	M.4075	0.0497	M.6463	M.2882	0.1033	0.4155	0.3859	0.5460	0.2020	0.5641	M 1756	0.5765
Aug	M.1733	0.0913	M.2537	M.2876	M.0833	M.4165	M.2064	M.5753	M.3548	0.6079	0.4872	0.3664	0.4922	M.0174	0.4251	M.1869	M.3308
Sep	M.2063	M.1576	M.4313	M.2708	M.4133	0.4721	0.3944	0.1583	0.1893	0.5116	0.2933	0.5241	0.4297	0.5811	0.7746	0.3049	0.7127

TABLE 2(b)

Correlation coefficients between monthly rainfall of meteorological sub division 22 v/s remaining sub-divisions (1951- 90)

22	18	19	20	21	23	24	25	26	27	28	29	30	31	32	33	34	35
Jun	0.0505	M.0850	M.0410	0.1640	0.2771	M.0671	0.1543	M.1423	M.1102	0.1914	0.1222	0.0127	0.0371	0.1145	M.0063	M.2965	M.2720
Jul	0.3380	0.0531	M.6773	M.6356	M.6809	M.7218	0.3339	0.4658	0.6851	0.0625	0.7702	M.4072	M.3659	0.6702	M.7990	M.7218	M.4010
Aug	0.6590	0.3270	0.3141	M.8052	M.7036	M.8103	0.4205	0.7784	M.7081	0.8426	0.8193	M.6535	M.4046	0.8561	M.8465	M.8484	M.3009
Sep	0.5989	0.7349	0.6493	M.6785	M.5856	M.7324	M.1524	0.7320	M.9012	0.1194	0.8197	M.8656	0.6230	0.8486	M.8032	M.3550	0.3563

Note : 'M' refers to minus sign

TABLE 3(a)

Correlation coefficients between monthly rainfall of meteorological sub division 23 v/s remaining sub-divisions (1951- 90)

23	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Jun	M.0216	0.3065	M.2483	M.0775	M.2038	0.4249	M.2537	M.2992	M.0007	0.2513	M.0828	0.4055	0.4425	M.0702	0.4363	0.3835	M.6283
Jul	M.1767	M.1789	0.3358	M.2440	0.0666	0.5980	0.1577	0.5962	0.2521	M.1960	M.3688	M.2932	M.7185	M.4005	M.4468	0.1612	M.2105
Aug	0.3451	0.1423	0.3481	0.3037	0.0686	0.1022	M.0143	0.3989	0.1970	M.5920	M.3715	M.5671	M.3768	0.2229	M.3399	0.3735	0.2520
Sep	0.0493	M.1598	0.3085	0.3325	0.4556	M.6423	M.4402	M.2752	M.1340	M.4817	M.3580	M.4871	M.6904	M.8458	M.5843	M.2697	M.8070

TABLE 3(b)

Correlation coefficients between monthly rainfall of meteorological sub division 23 v/s remaining sub-divisions (1951- 90)

23	18	19	20	21	22	24	25	26	27	28	29	30	31	32	33	34	35
Jun	M.2117	M.5528	M.6703	M.5581	0.2771	M.7301	0.0493	M.0846	M.6051	0.6552	0.8315	M.7518	0.7425	0.7937	M.6648	M.7218	M.3293
Jul	M.1837	0.3234	0.7456	0.7518	M.6809	0.8778	M.2547	M.0532	M.6504	0.2086	M.8061	0.5343	0.2786	M.6676	0.7561	0.7477	0.4543
Aug	M.5920	M.1517	M.5676	0.5143	M.7036	0.6722	M.1696	M.7812	0.4560	M.6774	M.5532	0.5994	0.4432	M.5333	0.6559	0.6040	0.0014
Sep	M.7811	M.8528	M.4658	0.6379	M.5856	0.8548	0.3923	M.9001	0.6989	M.1594	M.6368	0.6974	M.9249	M.7223	0.5855	0.6785	M.4437

TABLE 4(a)

Correlation coefficients between monthly rainfall of meteorological sub division 24 v/s remaining sub-divisions (1951- 90)

24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Jun	0.0318	M.0802	0.4226	0.0238	0.4136	M.3211	0.5034	0.5986	M.0811	0.0313	0.0221	M.4282	M.7511	M.2377	M.4335	M.2076	0.8684
Jul	M.0863	M.3152	0.4406	0.3302	0.0237	0.5522	0.1023	0.6114	0.3947	M.1700	M.3978	M.2620	M.6665	M.4742	M.4912	0.1089	M.2132
Aug	0.3366	M.1845	0.4337	0.5013	0.0825	0.5220	0.0433	0.6594	0.1892	M.6606	M.4852	M.2448	M.5783	M.1304	M.0620	0.3063	0.5590
Sep	0.2871	M.0129	0.5908	0.4981	0.3494	M.7365	M.5550	M.2818	M.2731	M.5851	M.4407	M.6274	M.5864	M.8013	M.6792	M.1741	M.8271

TABLE 4(b)

Correlation coefficients between monthly rainfall of meteorological sub division 24 v/s remaining sub-divisions (1951- 90)

24	18	19	20	21	22	23	25	26	27	28	29	30	31	32	33	34	35
Jun	0.5190	0.7920	.9193	0.7814	M.0671	M.7301	0.2290	0.1180	0.5359	M.2858	M.8505	0.8074	M.8063	M.8099	0.8324	0.7739	0.3849
Jul	M.3042	0.4313	0.7595	0.7764	M.7218	0.8778	M.3412	M.0225	M.6251	0.2180	M.8668	0.6651	0.3421	M.7290	0.8303	0.7988	0.5501
Aug	M.8349	M.1024	M.3111	0.6015	M.8103	0.6722	M.5996	M.7859	M.4887	M.8028	M.8804	0.7573	0.1421	M.7823	0.8187	0.8524	0.2362
Sep	M.8933	M.8242	M.6960	0.6149	M.7324	0.8548	0.4352	M.8935	0.8192	M.1451	M.8018	0.8606	M.8040	M.7874	0.7394	0.6112	M.4819

Note: 'M' refers to minus sign

TABLE 5(a)

Correlation coefficients between monthly rainfall of meteorological sub division 25 v/s remaining sub-divisions (1951- 90)

25	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Jun	M.2465	0.1021	0.2064	M.3985	0.3115	0.4651	M.2148	0.0518	M.3060	0.2925	M.0566	M.0442	M.1625	M.3536	M.5244	M.1163	0.2628
Jul	M.0532	M.0832	M.1488	M.3594	0.2661	0.0569	0.1781	M.6519	M.4882	0.0339	0.0278	M.0957	0.5353	0.2145	M.1253	M.0381	M.1264
Aug	0.0258	0.1437	M.1263	M.3462	0.1038	M.4363	0.0806	M.6498	M.0346	0.3265	0.3146	M.2754	0.6764	0.4357	M.1772	M.1336	M.3248
Sep	0.1338	M.1225	0.6279	0.6730	M.1919	M.4192	M.2766	0.0902	M.1387	0.0190	M.1817	M.2245	M.2599	M.3676	M.2071	M.0383	M.1938

TABLE 5(b)

Correlation coefficients between monthly rainfall of meteorological sub division 25 v/s remaining sub-divisions (1951- 90)

25	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35
Jun	0.7597	0.1890	0.3977	0.5601	0.1543	0.0493	0.2290	M.0364	0.4385	0.1013	M.1240	0.2135	M.2761	M.1832	0.1637	0.3325	M.0404
Jul	0.5815	M.4716	M.2378	M.0730	0.3339	M.2547	M.3412	M.0431	0.5193	0.2668	0.4504	M.2626	0.2369	0.3300	M.2700	M.1333	M.1206
Aug	0.6737	0.1601	0.0232	M.1668	0.4205	M.1696	M.5996	0.4415	0.0064	0.4252	0.5619	M.2600	M.2299	0.4883	M.3831	M.5593	M.2924
Sep	M.4847	M.1481	M.0960	0.1939	M.1524	0.3923	0.4352	M.2123	0.2811	0.3746	M.3592	0.3679	M.2961	M.3178	0.3331	0.4147	M.2294

TABLE 6(a)

Correlation coefficients between monthly rainfall of meteorological sub division 26 v/s remaining sub-divisions (1951- 90)

26	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Jun	0.0168	M.0599	0.0716	0.1955	0.0342	M.0731	0.0155	0.0855	0.2614	0.2549	0.4748	0.1873	M.1172	M.5239	M.0228	M.0179	0.1118
Jul	M.2296	M.1727	M.2393	0.0986	M.3886	M.0471	0.2169	M.0802	0.0703	0.0866	0.1854	0.2990	0.1504	M.2452	0.2911	M.2535	0.8036
Aug	M.2576	0.1063	M.3209	M.2819	M.3125	M.3015	M.0848	M.5439	M.3225	0.6355	0.3091	0.3698	0.5698	0.0108	0.3064	M.3673	M.1704
Sep	0.0902	0.0909	M.3407	M.3004	M.4213	0.5874	0.4370	0.3837	0.1693	0.6458	0.3092	0.5155	0.6144	0.7728	0.6800	0.3671	0.8816

TABLE 6(b)

Correlation coefficients between monthly rainfall of meteorological sub division 26 v/s remaining sub-divisions (1951- 90)

26	18	19	20	21	22	23	24	25	27	28	29	30	31	32	33	34	35
Jun	0.2464	0.4275	0.0744	M.0666	M.1423	M.0846	0.1180	M.0364	0.1676	0.2884	M.2499	M.0559	0.0421	M.0157	M.0813	0.3428	0.4393
Jul	0.0164	0.6266	M.1522	M.0451	0.4658	M.0532	M.0225	M.0431	0.3026	0.5266	0.0705	0.1024	M.0759	M.0771	M.1614	M.1561	M.0416
Aug	0.6704	0.3370	0.2558	M.6701	0.7784	M.7812	M.7859	0.4415	M.5331	0.8114	0.6953	M.5829	M.2706	0.7274	M.7288	M.7570	M.1378
Sep	0.7674	0.8654	0.6234	0.6169	0.7320	M.9001	M.8935	M.2123	M.7848	0.3441	0.7145	M.7854	0.8880	0.7908	M.6641	M.6054	0.4287

Note: 'M' refers to minus sign

(*i*) There is an inverse correlation meteorological sub-divisions 22 and 4, 24, 33 and 34 during June to September (Table 2) and with 3,5,21,23,30 during July to September. The CC is between -0.5 and -1 for meteorological sub-divisions of 21,23,24 and 33 during these months.

(*ii*) The monthly rainfall of meteorological sub-division 22 has direct correlation with meteorological sub-divisions 10, 12, 18, 28, 29 and 32 during June to September and with 11, 13, 15, 19, 26 during last 3 months of southwest monsoon. The CC is between 0.5 and 1 for meteorological sub-divisions of 29 and 32 during July to September whereas it is 0.3 or more for many meteorological sub-divisions as shown in Table 2.

(c) Features of correlation between Konkan and Goa (23) Vs. remaining meteorological sub-divisions.

(*i*) As shown in Table 3 there is an inverse correlation between monthly rainfall of Konkan-Goa (23) with meteorological sub- divisions numbers 11, 18, 26 during June to September and with sub-division numbers 10, 12, 13, 15, 22, 29 and 32 during July to September. The CC is in between -0.5 and -1 during July to September with meteorological sub-divisions 22, 29 and 32.

(*ii*) There is a direct correlation of meteorological sub-division 23 with sub-divisions 3,4,5,21,24,30,33 and 34 during July to September. The correlation is in between 0.5 and 1 with meteorological sub-divisions 21,24,30,33 and 34 in the same months.

(d) Features of correlation between Madhya Maharashtra (24) Vs. remaining meteorological sub-divisions.

(*i*) There is an inverse relationship between monthly rainfall of Madhya Maharashtra (24) with meteorological sub-divisions of 2, 12, 13, 14, 15, 22, 29 and 32 during June to September (Table 4) and with 10, 11, 26 during July to September. The correlation coefficient is in between -0.5 and -1 for 13, 29 and 32 in all the four months and with 22 during July to September.

(*ii*) The monthly rainfall of Madhya Maharashtra (24) has direct relationship with meteorological sub-divisions of 3,4,5,21,30,33 and 34 during June to September and with 23 during July to September. The CC is in between 0.6 and 1 with 21, 30, 33 and 34 during June to September.

(e) Features of correlation between Marathwada (25) and remaining meteorological sub-divisions

(*i*) The Table 5 shows the correlation coefficient of Marathwada with the remaining sub-divisions. The CC is inverse with meteorological sub-divisions of 12, 15 and 16 during June to September and with 17 duing July to September.

(*ii*) The monthly rainfall of Marathwada is directly related with monthly rainfall of sub-division number 10, 27 and 28 during June to September and with 18 during June to August. The correlation coefficient is in between 0.5 and 0.8 with sub-division number 18 during June to August.

(f) Features of correlation between Vidarbha (26) and remaining meteorological sub-divisions

(*i*) There is an indirect relationship of sub-division number 26 with the monthly rainfall of sub-division 21, 23 and 33 during June to September (Table 6) and with 24 and 34 during June to September. The CC is in between -0.5 and -1 with 21, 23,24,27,30,33 and 34 during August to September.

(*ii*) The monthly rainfall of Vidarbha is directly related with monthly rainfall of sub-divisions 10,11,12,18,19 and 28. The correlationship is above 0.5 during August and September with the sub-divisions 10, 13, 18, 22, 29 and 32.

4. The correlationship between monthly rainfall of each of the meteorological sub-divisions of Gujarat and Maharashtra states with the remaining sub-divisions have been tested at 99 percent level of significance and all the CC (direct or inverse) lying between ±0.423 and ± 1 qualify for it. At 95 percent level of significance, the critical value of CC is ± 0.304. Based on these two levels of significance, following useful inferences can be drawn :

(a) The monthly rainfall of Gujarat region (21) is inversely related with Saurashtra and Kutch (22) during July to September and with East Rajasthan (18) and west Madhya Pradesh (19) during August and September.

(b) The Saurashtra and Kutch (22) is inversely related with the Gujarat region (21) and Konkan - Goa (23) during July to September.

(c) The Madhya Maharashtra (24) is inversely related with north Interior Karnataka (32) during June to September with Marathwada (25) in July and August and with Vidarbha (26) in August and September.

(d) The Vidarbha (26) is inversely related with Madhya Maharashtra (24) and Konkan - Goa (23) both during August and September.

(e) The significant direct and inverse correlationship of monthly rainfalls amongst neighbouring meteorological sub- divisions may be useful for Govt. agencies and water resource management bodies for their long term planning to achieve allround sustainable development by linking rainfed water resources with the drought prone areas.

APPENDIX A

List of meteorological sub-divisions of India

S. No.	Name of sub-division
1.	A.& N.Islands
2.	Arunachal Pradesh
3.	Assam & Meghalaya
4.	Nagaland, Manipur, Mizoram & Tripura
5.	SHWB & Sikkim
6.	Gangetic West Bengal
7.	Orissa
8.	Bihar Plateau
9.	Bihar Plains
10.	East U.P.
11.	Plains of West U.P.
12.	Hills of West U.P.
13.	Harayana, Chandigarh & Delhi
14.	Punjab
15.	Himachal Pradesh
16.	Jammu & Kashmir
17.	West Rajasthan
18.	East Rajasthan
19.	West Madhya Pradesh
20.	East Madhya Pradesh
21.	Gujarat Region, Dnb. & Daman
22.	Saurashtra, Kutch & Diu
23.	Konkan & Goa
24.	Madhya Maharashtra
25.	Marathwada
26.	Vidarbha
27.	Coastal Andhra Pradesh
28.	Telangana
29.	Rayalaseema
30.	Tamilnadu & Pondicherry
31.	Coastal Karnataka
32.	North Interior Karnataka
33.	South Interior Karnataka
34.	Kerala
35.	Lakshadweep

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21 May 1998, Modified 17 November 1998