

Water Balance and Climatic Classification of the Cauvery River Basin, India

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Abstract: *The Cauvery basin covering an area of about 81, 155 km² has been studied with view to explain the spatial distribution of water balance elements like potential evapotranspiration, actual evapotranspiration, water deficit, water surplus, moisture adequacy, Aridity Index and Moisture Index. From about 37 stations the mean monthly rainfall and mean monthly temperature is collected over a period of fifty years. Applying Thornthwaite and Mather (1955) book keeping procedure the monthly, seasonal and annual water balance elements of the Cauvery basin are worked out and mapped. The annual recharge of the Cauvery basin has been worked out using rainfall recharge method. From the analysis it is found that the Western Ghats, Nilagiris and Kodaikanal hills of the Cauvery basin experiences water surplus. The central and eastern plains of the basin experience water deficit. From the analysis of water balance it is found that out of total surface water resources of 105, 109, 725, 000 m³ about 10% is stored in surface tanks, ponds and reservoirs, 15.06% is recharged to ground water, 30% is lost in the form of surface run-off and 44.94% of the water is lost in the form of evaporation and evapotranspiration. The Western Ghats, Nilagiris and Kodaikanal hills experience to per humid and humid type of climate. The Mysore plateau region experiences wet sub humid and dry sub humid types of climate. The central and eastern plains of the Cauvery basin experience dry sub humid type of climate.*

Keywords: precipitation, potential evapotranspiration, actual evapotranspiration, water deficit, water surplus, Aridity Index

1. Introduction

Water balance is the study of water input in the form of precipitation and water loss in the form of evaporation and evapotranspiration. Thornthwaite and Mather (1955) have developed a book keeping procedure to work out water balance of elements namely potential evapotranspiration, actual evapotranspiration, water deficit, water surplus, moisture adequacy and Aridity Index. Hemamalini (1979) has studied the eco-climatology of Andhra Pradesh. Subrahmanyam (1982) has published a monograph on water balance and its applications. Aridity Index studies on water balance elements of Tamil Nadu state are carried out, by Ram Mohan (1978 and 1980), Sambasiva Rao (1984, 1996 and 2002), Padmini (1989) and Sambasiva Rao and Kalavathy (1983). Rajeswari (1990) described the water balance elements and cropping pattern of Madurai, Ramanathapuram and Pudukkothai districts of Tamil Nadu. Madhuramma (1991 and 1992) has studied the water balance elements and cropping pattern of Nellore district, Andhra Pradesh. Suresh Babu (1993) has studied the water balance and drought climatology of Anantapur district, Andhra Pradesh. Samuel Raju (1996) has studied the drought climatology, water balance and development of land and water resources of Kurnool district, Andhra Pradesh. Raveendra (2013) has studied the water balance, drought analysis and watershed development of the Anantapur district of Andhra Pradesh. Somanna (2013) has studied the water balance and cropping pattern of the Rayalaseema region. The water balance studies of river basins are carried out by Subramanyam et al. (1970), Subrahmanyam and Kamaraju (1983), Subrahmanyam and Venkatesh (1984) and Sambasiva Rao (2002, 2005 & 2012).

2. Study Area

The Cauvery river basin covers an area of about 81, 155 km². It lies in Karnataka, Kerala, Tamil Nadu and Pondicherry states of southern India. The basin is located in between 10⁰-05' North and 13⁰-30' North latitudes and 75⁰-30' East and 79⁰-45' East longitudes. About 54.05% of the Cauvery basin covering 43, 867 km² falls in the Tamil Nadu state, about 42.23% of the basin covering 34, 273 km² lies in the Karnataka state, about 3.53% covering an area of about 2, 866 km² falls in Kerala state and about 0.18% covering an area of about 149 km² lies in the Pondicherry state. The mean annual rainfall of the basin is 1295 mm. Geologically the basin is formed of Precambrian rocks consisting of Dharwar peninsular granitic gneisses, charnockites, and clospet granites. The basin is divided into three major physiographic regions namely the Western Ghat area, the plateau of Mysore and all the undulating, rolling and deltaic plains. The major tributaries of the Cauvery river are Kabani, Kadanur, Kummahole, Harangi, Hemavathi, Shimsha, Arkavathy, Lakshmanathirtha, Kabbari, Suvarnavathi, Bhavani, Noyyal and Amaravathi.

Climatologically the western part of the basin enjoys humid climate, and the northern, central and eastern part of the basin enjoys dry-humid climate.

3. Objectives

The main objectives of the present study are;

- 1) To study the mean of monthly, seasonal and annual rainfall and evaluate the surface water resources of the Cauvery basin,
- 2) To describe the seasonal and annual water balance elements of the Cauvery basin,

- 3) To bring out the annual recharge and the water balance of the Cauvery basin and
- 4) To describe the climatic classification of the Cauvery basin.

4. Methodology

The data pertaining to monthly rainfall over a period of hundred years has been collected from 39 stations from Indian Meteorological department (IMD), Government of India, Pune and local Meteorological stations. Similarly the data pertaining to monthly temperature for a period of fifty years has been collected from IMD (Indian Meteorological department) and local Meteorological stations. The monthly data of rainfall and temperature is used to work out water balance elements applying Thornthwaite and Mather (1955) book keeping procedure. The monthly potential evapotranspiration (PE), actual evapotranspiration (AE), water deficit (WD) and water surplus (WS) are worked out. Basing on the monthly values of potential evapotranspiration and actual evapotranspiration the monthly moisture adequacy is worked out. Similarly basing on the values potential evapotranspiration and water deficit, the Aridity Index is worked out. The Moisture Index of each station on monthly, seasonal and annual is worked out. Basing on the values of Moisture Index the climatic classification of the Cauvery basin is brought out. The recharge is worked out adopting Radhakrishna et al. (1974) method, U.S. Geological (1985) method, Seghal (1970) method and Krishna Rao (1970) method. The recharge is worked out for 38 stations using four different methods and average of the four methods is taken as the annual recharge of the Cauvery basin.

5. Results

Mean monthly, seasonal and annual rainfall of the Cauvery basin:

The mean monthly rainfall of the Cauvery varies from a minimum of 14 mm in the month of February to a maximum of 202mm in the month of July. The mean rainfall is less than 50mm in January, February and March months. It varies from 50mm to 100mm in April, May and December months. The mean monthly rainfall of the basin ranges from 150mm to 200mm in June, August, September, October and November months. The mean monthly rainfall exceeds 200mm in July month only. The mean seasonal analysis of the rainfall of the basin depicts that the basin receives minimum rainfall of 33mm in winter period and the maximum rainfall of 676mm is noticed in southwest monsoon period. During summer period the mean rainfall is 174mm and in northeast monsoon period it is 412mm. The mean annual rainfall of the Cauvery basin is 1295mm (Table. 1 and Fig. 1). The spatial distribution of the average annual rainfall is more than 2000mm in Western Ghats and Nilagiris parts of the basin. It ranges from 1000mm to 2000mm in the Mysore plateau region, 750mm to 1000mm in the eastern plateau and central parts of the basin and more than 1000mm in the eastern parts of the basin. The total surface water resources of the Cauvery basin is worked out as 105, 095, 725, 000m³ (Geographical area of the basin X Mean annual rainfall of the basin)

Potential evapotranspiration

The potential evapotranspiration (PE) is actual water need or water loss in the form of evapotranspiration. The average monthly PE values of the basin vary from 96mm in December month to a maximum of 155mm in May month. The seasonal potential evapotranspiration values range from 219mm in winter period to a maximum of 570mm in southwest monsoon period. The average potential evapotranspiration value in summer period is 439mm and in northeast monsoon period it is 318mm. The average annual potential evapotranspiration value of the basin is 1546mm. The spatial distribution shows that the annual potential evapotranspiration value is less than 1300mm in western parts of the basin in Western Ghats and the average annual potential evapotranspiration values range from 1300mm to 1500mm in Nilagiris and Mysore plateau region. The average annual potential evapotranspiration values vary from 1500mm to 1700mm in central parts of the Cauvery basin and it is more than 1700mm in the eastern parts of the Cauvery basin. (Table. 2 and Fig. 2)

Actual evapotranspiration (AE)

The actual evapotranspiration is the actual water available for evapotranspiration. The average monthly actual evapotranspiration varies from a minimum of 69mm in the March month to a maximum of 119mm in the October month. The seasonal average of actual evapotranspiration values range from 166mm in winter period to a maximum of 366mm in southwest monsoon period. In the summer period the average actual evapotranspiration value is 220mm and in northeast monsoon period it is 312mm. The average annual actual evapotranspiration is 1064mm. The spatial distribution shows that the actual evapotranspiration values are more than 1200mm in the western parts of Nilagiris and Kodaikanal hills of the Cauvery basin, 1000mm to 1200mm in the Mysore plateau region and in the eastern parts of the basin. It is less than 1000mm in central parts of the basin. (Table. 3 and Fig. 3)

Water Deficit (WD)

The water deficit (WD) is the difference between potential evapotranspiration and actual evapotranspiration. The average monthly water deficit values vary from 0 mm in October to a maximum of 79mm in June months. The average monthly water deficit values are less than 50mm in January, February, January, September, October, November, and December months. The monthly water deficit values range from 50mm to 75mm in March April, May, July, and August months. The average water deficit value is more than 75mm in June month. The average seasonal water deficit values range from a minimum of 11mm in winter period to a maximum of 250mm in southwest monsoon period. The average water deficit value is 34mm in winter period and 208mm in summer period. The spatial distribution shows that there is no water deficit in the Western Ghats, Nilagiris and Kodaikanal hills of the Cauvery basin. The average water deficit is 500mm to 800mm in the central and eastern parts of the basin. (Table.4 and Fig. 4)

Water Surplus

The positive difference between precipitation and potential evapotranspiration is the water surplus. The average monthly water surplus is found in October and November months and

it varies from 51.90mm to 53.3mm. There is no water surplus in January, February, March, May, June, July, August, September and December months. The water surplus is found in Western Ghats Nilagiris and Kodaikanal hills of Cauvery basin. (Table.5 and Fig.5)

Moisture adequacy (Ima)

The moisture adequacy (Ima) is the ratio in the percentage between actual evapotranspiration and potential evapotranspiration. It depicts the amount of moisture available for crop growth. The average Ima values vary from 45% in June month to a maximum of 100% in October and November months. The average Ima value is less than 50% in April, June and July months. The Ima values range from 50% to 75% in February, March, May, August and September months. The Ima values vary from 75% to 100% in January, October, November and December months. The seasonal Ima values range from 52% in summer period to a maximum of 96% in northeast monsoon period. The average annual moisture adequacy value is 67%. The spatial distribution shows that the Ima value is 100% in Western Ghats, Nilagiris and Kodaikanal hills. It varies from 60% to 90% in Mysore plateau region and it is less than 60% in central and northeastern parts of the basin. In the southeastern parts the Ima value is more than 60%.

Aridity Index (Ia)

The Aridity Index (Ia) is the ratio in the percentage between water deficit and potential evapotranspiration. The average Ia value varies from 0% in October and November months to a maximum of 55% in June month. The average Ia value is less than 50% in January, February, March, May, August, September, October, November and December months. The average Ia value is more than 50% in April, June and July months. The seasonal analysis of Ia values indicate that they vary from 4% in northeast monsoon to a maximum of 48% in summer period. The value of Ia is 17% in winter period and 45% in northeast monsoon period. The average annual Ia is 33%. The spatial distribution shows that the Ia value is 0 percent in Western Ghats Nilagiris and Kodaikanal hills of the basin. It is less than 40% in the Mysore plateau region and more than 40% in the central and eastern parts of the basin.

Moisture Index

The Moisture Index is the index of moisture effectivity given by the equation.

$$Im = Ih - 0.6 Ia$$

Where Im is Moisture Index, Ih = Humidity Index (which is ratio in percentage of water surplus and potential evapotranspiration and Ia is the Aridity Index). For computation of Moisture Index the values of water surplus, water deficit and potential evapotranspiration are required. The annual Moisture Index values vary from -33% in Namakkal to +84.06% in Mereca. The annual moisture Index value in the western part of the hilly terrain varies from +23.97% in Kodaikanal station to a maximum of +84.06% in the Heggada, Devakote station. In the Mysore plateau region the annual values of Moisture Index ranges from -24.4% in Mandya station to -5.4% in Gudalur station. In the central part of the Cauvery basin the annual values of Moisture Index vary from -33.0% in Namakkal station to -22.8% in salem station.

The seasonal Moisture Index values show that during winter period the Im values range from -24.0% in Thiruchi station to -1.2% in Mereca station. In southwest monsoon the values of Im in the hilly terrain range from +17.97% in Madikera to +276.52% in Mereca. In the Mysore plateau the values of Im vary from -30.0% in Mandya to -9.6% in Bangalore station. In the central parts of the Cauvery basin they range from -45.0% in Bavani sagar station to -27.6% in Salem station. During northeast monsoon the values of Im in hilly terrain range from -1.2% in Mysore to +92.27% in Udagamandalam. In Mysore plateau region the Im values vary from -22.2% in Bangalore to -5.4% in Mandya. In the central part of the Cauvery basin the Im values range from -2.4% in Karur, Mettur and Salem stations to -10.53% in Dindigul station. In the eastern parts of the Cauvery basin in northeast monsoon the Im values vary from 8.69% in Thiruchi station to +181.09% in Vedaranyam station.

Climatic Classification

The Climatic classification of the Cauvery basin is brought out using the values of Moisture Index on seasonal and annual basis. During winter season the entire basin experiences dry sub-humid climate in all the stations of the basin. In summer season the central part of the basin experiences semi-arid climate and in other parts of the basin dry sub-humid type of climate is noticed. In southwest monsoon period the central and eastern parts of the basin experiences semi-arid type of climate and in Mysore plateau region dry sub-humid type of climate is found. The western hilly terrain possessed wet sub-humid, humid and per-humid climates. During northeast monsoon period the western hilly terrain experiences wet sub humid type of climate. The Mysore plateau region possessed dry sub-humid climate. In the central part of the Cauvery basin dry sub humid and wet sub-humid types of climate is found and in the eastern parts of wet sub humid, humid and per humid types of climate is noticed. The annual Moisture Index values show humid type of climate in the western hilly terrain, and dry sub-humid type of climate in Mysore plateau, central and eastern parts of the Cauvery basin.

Annual recharge of surface water resources of the Cauvery basin:

The annual recharge of the Cauvery basin is worked out for 38 stations in the basin using Radhakrishna et al. (1974) method U.S. Geological method, (1985), Segal method (1970) and Krishna Rao method (1970). The average of the four methods of 38 stations is taken as annual recharge of the Cauvery basin. According to Radhakrishna et al method (1974) the annual recharge is worked out as 10% of the annual rainfall. The annual recharge varies from 65.40mm in Madya station to a maximum of 222.90mm in Meraca station. The average annual recharge according to Radhakrishna et al. (1974) is 108.08mm (Table.2). According the U.S. Geographical method (1985) the annual recharge is 15% of the annual rainfall. The annual rainfall recharge according to this method varies from 98.10mm in Madya station to a maximum of 334.35mm in Mereca station. The average annual recharge is 162.12mm. According to Segal (1970) method the ground water recharge is $2.5 (P-16)^{0.5}$ where P is Precipitation in inches. According to the method the annual recharge ranges from 125.38mm in Madya station to a maximum of 340.19mm in

Mereca station. The average annual recharge is 206.94mm. According to Krishna Rao method (1970) the annual ground water recharge is $G=K(P-X)$, where $G=0.2(P-400\text{mm})$ when the annual rainfall ranges from 400mm to 600mm, $G=0.3(P-500\text{mm})$ when the annual rainfall varies from 1000mm to 2000mm. According to this method the annual recharge varies from 50.80mm in Madya station to a maximum of 518.70mm in Mereca station. The average annual recharge according to this method is 174.24mm.

The average annual recharge of the four methods worked out for 37 stations of the Cauvery basin varies from a minimum of 84.92mm in Madya station to a maximum of 354.03mm in Mereca station. The average annual recharge of the four methods of the 37 stations of the Cauvery basin is 162.84mm which amounts to 15.06% of the average annual rainfall of 1080.82mm of the Cauvery basin.

Water Balance of the Cauvery Basin:

- 1) The total annual surface water resources of the Cauvery basin : 105, 095, 725, 000m³
- 2) The total annual surface water resources stored in the ponds, tanks, lakes, and reservoirs: 10, 509, 572, 500m³(10%)
- 3) Total annual surface water resources recharged to groundwater : 15, 827, 416, 185m³(15.06%)
- 4) Total annual surface water resources lost in the form of run-off : 31, 528, 717, 500m³(30%)
- 5) Total annual surface water resources lost in the form of evaporation and potential evapotranspiration: 47, 230, 018, 815 m³(44.94%)

From the analysis of water balance of the Cauvery basin it is found that out of total surface water resources of 105, 095, 725, 000m³ available, about 10% is stored in the ponds, tanks, lakes and reservoirs, 15.06% of the water resources is recharged annually to ground water, 30% of the total surface water resources is lost in the form of run-off and 44.94% of them is lost in the form of evaporation and evapotranspiration. From the analysis it is found that 74.94% of the total surface water resources is lost in the form of surface run-off and evaporation and potential evapotranspiration. The water resources lost in the form of surface run-off have to be carefully stored in the ponds, lakes, tanks and reservoirs through watershed development activities by constructing check dams, percolation ponds and water harvesting structures.

6. Conclusions

From the analysis of mean monthly rainfall it is found that during January, February and March months the mean monthly rainfall is less 50mm. It varies from 50mm to 100mm in April, May, June and December and it exceeds 100mm in July, August, October and November months. The mean rainfall is more than 450mm in southwest monsoon. The analysis of mean monthly potential evapotranspiration (PE) revealed that the mean PE is less than 100mm in December month. It varies from 100mm to 150mm in February, March, April, May, July, August, September, October and November months. The mean monthly PE is more than 150mm in May month. The mean PE is more than 500mm in southwest monsoon period. The

mean monthly actual evapotranspiration (AE) is less than 100mm in January, February, March, April, May, June, July, August, September and December months. It is more than 100mm in October and November months. The mean actual evapotranspiration is more than 300mm in southwest and northeast monsoon periods. The mean water deficit (WD) is less than 50mm in January, February, September and December months. The mean WD is more 50mm in March, April, May, June, July and August months. The mean water surplus is found in October and November months. The water deficit exceeds 200mm in summer and southwest monsoons. The mean moisture adequacy is less than 50% in April, June and July months. It is 100% in October and November months. In January, February, March, May, August, September and December months the Ima varies from 50% to 100%. The mean Ima exceeds 80% in winter and northeast monsoon periods. The mean Aridity Index is less than 20% in January, October, November and December months. It varies from 20% to 50% in February, March, May, August and September months. It exceeds 50% in April, June and July months. The mean Ia is more than 40% in summer and southwest monsoon period. Climatologically the Cauvery basin as a whole experiences dry sub humid climate in January, February, March, April, May, June, July, August, September and December months. In November and December months humid type of climate is found. The average annual recharge is 162.84mm which accounts to 15.06% of the mean annual rainfall.

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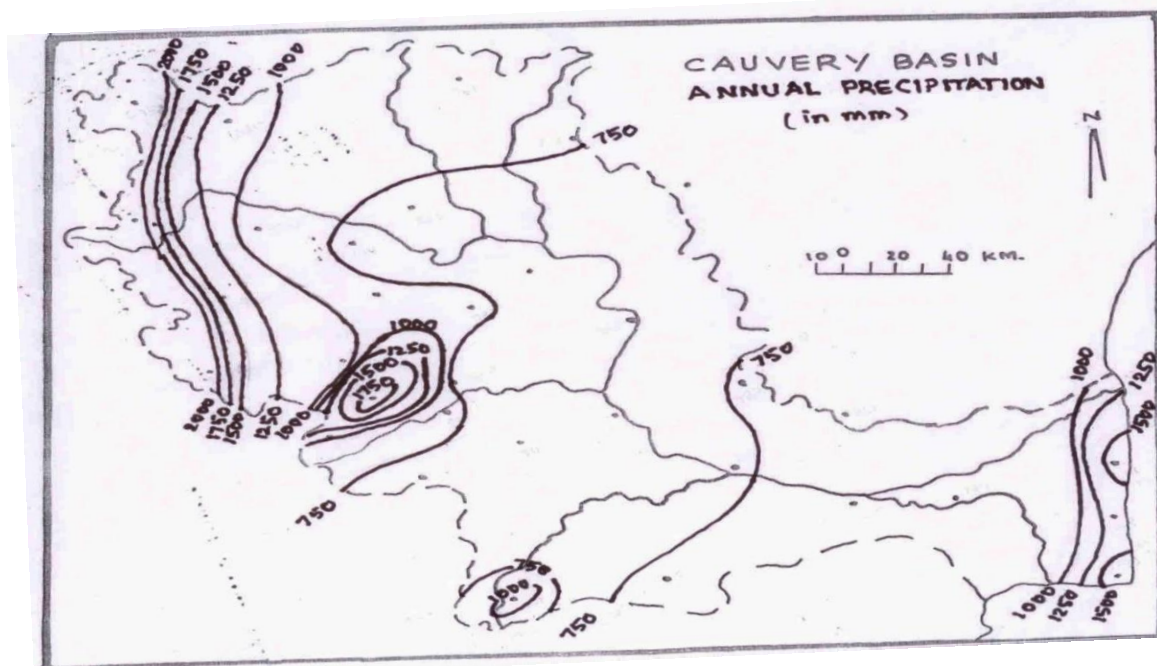


Figure 1

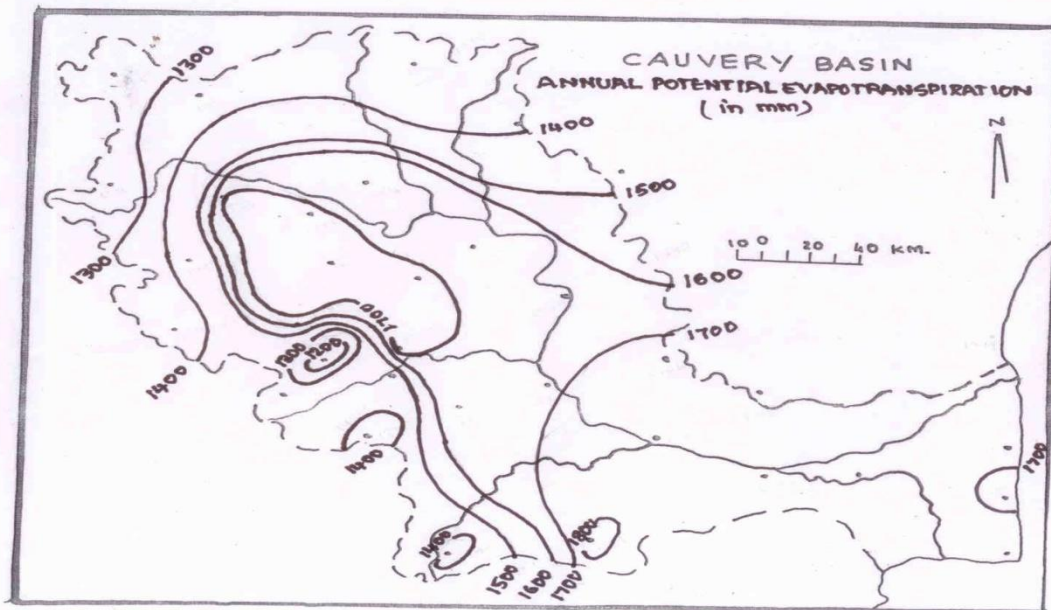


Figure 2

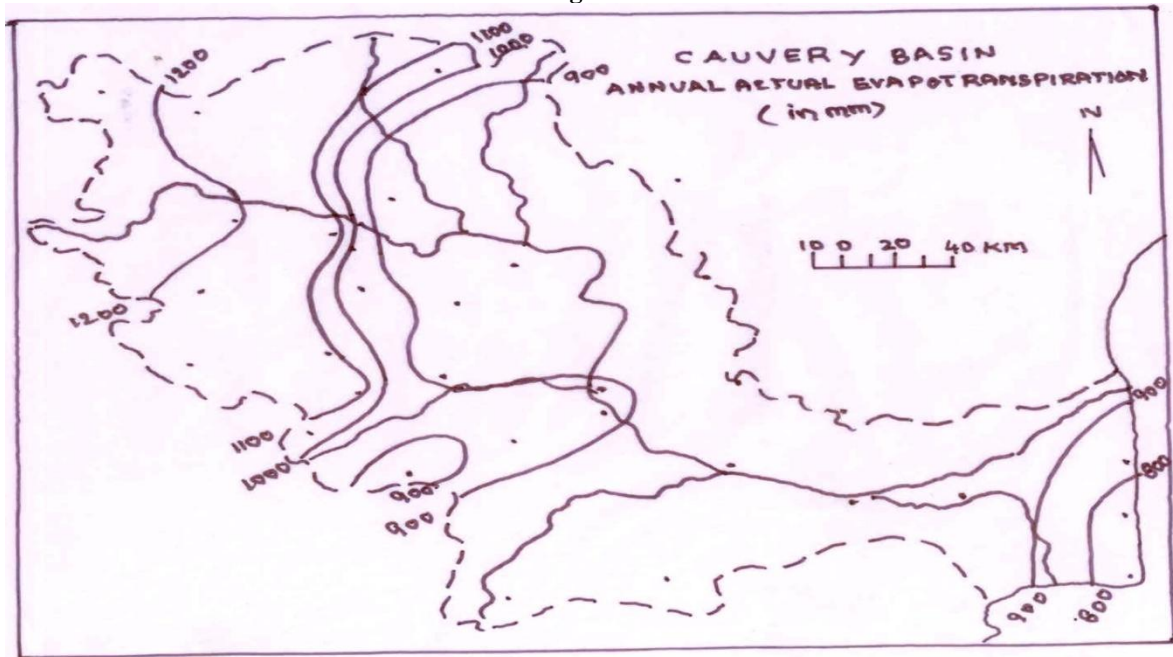


Figure 3

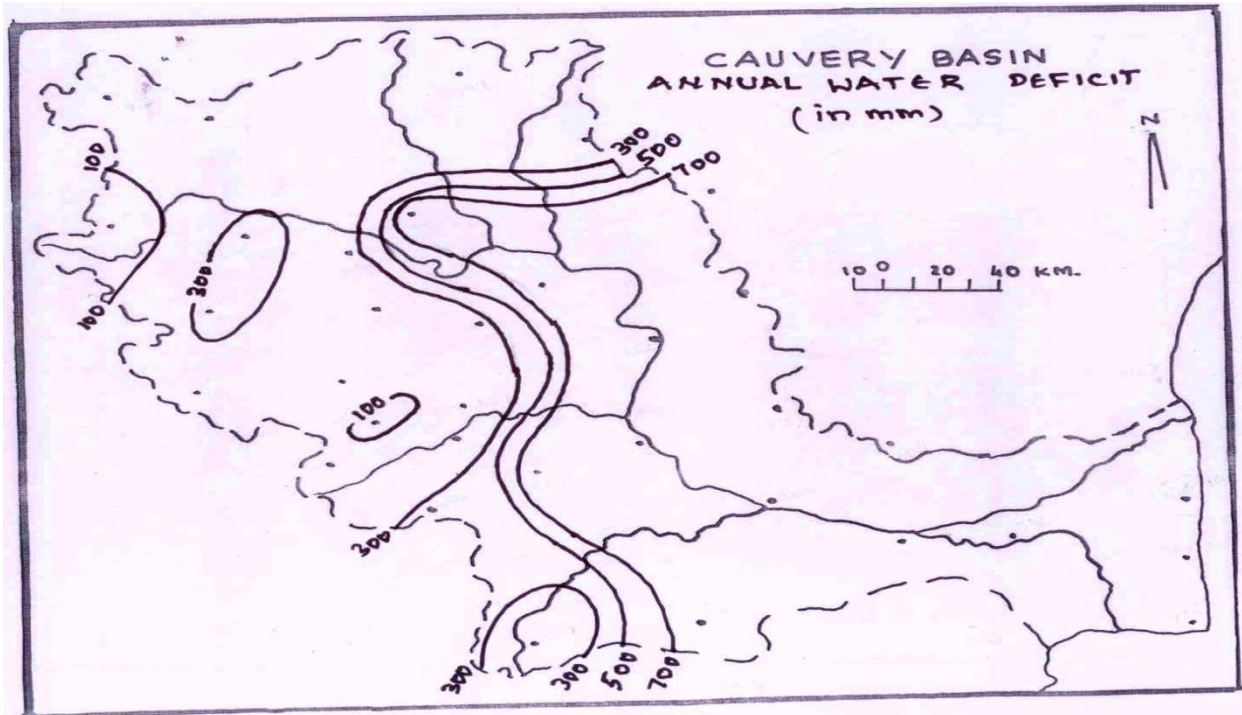


Figure 4

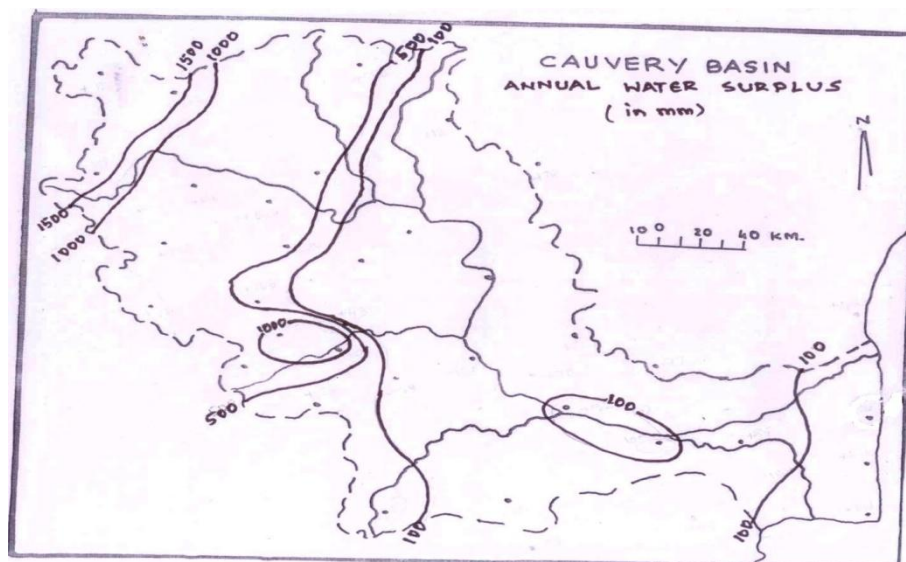


Figure 5

Table 1: Average Monthly, Seasonal and Annual Precipitation Values of the Stations of the Cauvery Basin In Mm

S.No	Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Summer	South West Monsoon	North East Monsoon	Annual
1	Avanashi	6	4	17	57	102	36	36	59	97	179	101	47	10	176	228	327	741
2	Bangalore	2	2	15	43	103	84	108	168	116	94	88	15	4	161	476	197	838
3	Belur	3	8	57	57	90	402	650	293	290	166	120	18	11	204	1635	304	2754
4	Bhavani Sagar	8	14	18	51	103	68	78	37	73	177	105	65	22	172	256	347	797
5	Charmajanagar	8	10	25	85	82	246	365	203	205	170	113	17	18	195	1019	300	1532
6	Coimbatore	9	12	18	56	78	233	242	147	92	176	130	45	21	152	714	351	1238
7	Cuddalore	50	39	30	32	30	60	90	100	90	200	380	249	89	92	340	829	1350
8	Dharmapuri	10	12	18	56	78	63	72	77	68	176	130	45	22	152	280	351	805
9	Dindigul	23	11	16	61	77	32	31	67	91	191	164	65	34	154	221	420	829
10	Erode	15	11	17	54	93	30	33	64	86	168	114	34	26	162	213	316	717
11	Gudalur	3	5	30	92	91	94	176	175	135	125	87	10	8	215	580	222	1025
12	Gundulper	2	4	41	81	75	82	100	109	110	124	85	8	7	197	401	217	717

13	Hassan	2	5	20	77	99	499	478	476	440	326	188	10	7	296	1893	524	2720
14	Geggada	2	8	58	92	76	410	702	272	212	170	120	18	10	226	1596	308	2140
15	Devankote	8	6	16	48	82	345	365	260	276	156	115	30	14	146	1246	301	1707
16	Hosur	55	40	32	45	30	43	51	62	68	135	190	100	95	107	224	425	1851
17	Karur	20	8	17	45	75	32	33	63	80	202	210	83	28	137	208	495	868
18	Kodaikanal	15	15	50	95	85	352	450	250	125	120	120	70	30	230	1177	310	1647
19	Madikeri	30	21	30	72	69	281	287	381	293	199	156	55	51	171	1242	410	1874
20	Madurai	2	6	34	75	67	50	50	58	97	121	86	8	8	176	255	215	654
21	Mandya	10	10	15	52	67	182	190	188	198	266	320	243	20	134	158	829	1741
22	Mereca	4	9	59	93	77	512	700	483	473	176	123	20	13	229	2168	319	2729
23	Mettur	8	11	20	46	68	74	71	79	62	170	125	44	19	134	286	339	778
24	Mettupalayam	4	9	59	93	78	412	705	272	210	172	122	20	13	230	1599	314	2156
25	Mulhole	2	5	42	96	77	260	301	311	315	228	188	50	7	215	1187	466	1875
26	Mysore	60	48	30	50	26	148	160	160	169	230	400	305	108	106	637	935	1768
27	Nagapatnam	10	10	16	48	81	33	33	63	85	265	215	141	20	145	214	625	1000
28	Namakkal	35	5	14	60	73	27	25	37	60	163	160	70	40	147	149	393	729
29	Palani	2	4	19	75	98	103	176	175	140	125	87	10	6	192	594	222	1004
30	Perambalur	39	11	18	41	70	33	38	82	110	159	150	110	50	129	263	419	861
31	Puddukottai	16	9	12	45	95	49	68	90	120	162	160	36	25	152	327	358	862
32	Salem	16	19	20	39	65	34	47	75	90	105	180	132	35	124	246	417	822
33	Thanjavur	17	18	25	62	66	35	39	65	95	185	130	60	35	153	234	375	797
34	Tiruchi	28	12	14	43	77	30	37	92	114	183	180	76	40	134	273	439	886
35	Tumkur	2	4	16	55	94	162	183	201	110	101	84	5	6	165	656	190	1017
36	Udagamandalam	45	25	31	94	251	382	529	370	290	300	188	75	70	376	1541	563	2580
37	Vedapanyam	70	59	40	55	40	50	60	70	80	140	350	236	169	135	260	726	1290

Table 2: average monthly, seasonal and annual **potencial evapotranspiration** values of the stations of the cauvery basin in mm

S.No	Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Summer	SW Monsoon	North East Monsoon	Annual
1	Avanashi	102	113	148	162	173	158	160	162	149	140	110	95	215	483	629	345	1672
2	Bangalore	95	100	115	127	132	122	120	115	110	100	90	80	195	374	467	270	1306
3	Belur	92	98	108	118	128	118	110	108	105	100	90	70	190	354	441	260	1245
4	Bhavani Sagar	116	115	155	168	179	163	166	168	150	134	105	105	231	502	647	344	1724
5	Charmajanagar	97	105	118	128	135	132	135	130	120	110	90	80	202	381	517	280	1395
6	Coimbatore	110	114	154	159	166	141	133	132	145	131	110	108	224	479	551	349	1603
7	Cuddalore	120	128	155	165	170	177	178	175	155	146	120	110	248	490	685	376	1799
8	Dharmapuri	105	110	154	155	160	145	146	140	130	125	110	110	215	469	561	345	1590
9	dindigul	112	115	165	170	180	176	177	178	168	140	130	125	227	515	699	395	1821
10	Erode	102	113	148	162	135	162	158	162	149	140	111	96	215	483	631	347	1674
11	Gudalur	94	98	110	125	173	130	120	115	110	100	85	70	192	370	475	255	1292
12	Gundulper	98	110	115	128	138	132	130	125	120	110	88	80	208	381	507	278	1374
13	Hassan	95	105	118	125	135	120	120	120	120	110	85	75	200	378	480	270	1336
14	Geggada	94	98	120	126	136	120	108	105	105	100	80	70	192	382	438	250	1262
15	Devankote	96	104	150	155	165	135	130	125	120	115	112	90	200	470	510	317	1497
16	Hosur	122	128	156	152	162	166	167	168	170	135	120	110	250	468	671	365	1754
17	Karur	120	118	145	150	160	164	165	167	169	140	110	95	238	455	665	345	1703
18	Kodaikanal	112	120	140	150	160	132	120	115	110	100	110	95	222	450	477	305	1454
19	Madikeri	124	131	151	161	165	162	163	165	155	125	116	115	255	477	645	356	1733
20	Madurai	95	105	115	125	135	138	135	130	120	110	92	85	200	375	523	287	1385
21	Mandya	108	112	152	158	168	150	155	158	158	130	110	105	220	478	621	345	1664
22	Mereca	90	95	105	115	125	122	111	110	100	90	78	70	185	345	443	238	1211
23	Mettur	112	110	151	160	165	145	138	160	158	128	115	103	222	476	601	346	1645
24	Mettupalayam	92	98	108	118	128	124	112	112	110	100	85	70	190	354	458	255	1257
25	Mulhole	96	105	112	125	135	135	125	123	120	110	90	85	201	372	503	285	1361
26	Mysore	120	130	150	160	168	165	166	166	160	130	120	110	250	478	657	360	1745
27	Nagapatnam	105	111	150	158	169	162	164	165	162	140	110	95	216	477	653	345	1691
28	Namakkal	110	126	158	165	170	175	176	178	168	148	125	120	230	493	697	393	1813
29	Palani	94	110	120	130	140	130	125	120	120	110	90	85	204	390	495	285	1374
30	Perambalur	116	128	160	165	175	168	170	172	162	117	115	110	244	500	672	342	1758

31	Puddukottai	110	115	154	160	170	155	158	160	155	135	122	110	225	484	628	367	1704
32	Salem	126	126	152	162	172	165	167	168	158	130	115	115	252	486	658	360	1756
33	Thanjavur	120	132	155	165	172	168	170	172	162	120	110	110	252	492	672	340	1752
34	Tiruchi	120	125	152	162	173	164	165	167	157	133	115	120	245	487	653	368	1753
35	Tumkur	98	102	118	128	138	134	132	130	125	110	90	85	200	384	521	285	1390
36	Udagamandalam	90	95	125	120	130	102	92	90	85	75	75	70	185	355	369	220	1109
37	Vedapanyam	125	129	146	156	172	175	176	178	165	135	120	110	254	474	694	365	1787

Table 3: average monthly, seasonal and annual actual evapotranspiration values of the stations of the cauvery basin in mm

S.No	Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Summer	South West Monsoon	North East Monsoon	Annual
1	Avanashi	72	59	60	74	103	42	37	60	98	140	110	90	131	267	237	340	975
2	Bangalore	80	85	75	70	104	66	102	115	110	100	90	40	165	249	393	230	977
3	Belur	90	90	80	75	92	118	110	108	105	100	90	70	180	247	441	260	1245
4	Bhavani Sagar	81	65	60	71	104	20	29	38	75	134	105	105	146	235	162	344	887
5	Charmajanagar	83	80	85	88	87	132	135	130	120	110	90	58	163	260	347	258	1028
6	Coimbatore	85	58	63	62	80	141	133	132	120	131	110	100	143	205	184	341	873
7	Cuddalore	110	78	50	52	32	60	91	110	91	146	120	110	188	134	352	376	1052
8	Dharmapuri	89	70	58	56	80	35	43	48	58	125	110	110	159	212	184	345	900
9	dindigul	82	61	60	61	78	34	32	68	92	140	130	110	143	199	226	380	948
10	Erode	81	56	50	71	95	40	39	66	87	140	111	77	137	219	232	328	916
11	Gudalur	92	90	80	98	98	130	120	115	110	100	85	60	182	273	475	245	1175
12	Gundulper	88	85	80	85	77	84	101	119	120	110	88	55	173	242	424	253	1064
13	Hassan	92	90	82	78	135	120	120	120	120	110	85	75	182	244	482	255	1169
14	Geggada	92	92	80	94	78	120	108	105	105	100	80	70	184	252	438	250	1262
15	Devankote	86	80	60	55	83	135	130	125	120	115	112	90	166	195	251	307	919
16	Hosur	112	98	66	52	32	44	52	63	70	135	120	110	210	150	229	365	954
17	Karur	80	73	55	55	76	33	34	64	82	140	110	95	153	186	213	332	884
18	Kodaikanal	87	70	90	90	88	132	120	115	110	100	110	95	157	276	477	305	1454
19	Madikeri	97	78	73	73	75	162	163	165	155	125	116	115	175	221	247	356	999
20	Madurai	92	85	75	78	69	51	51	59	100	110	92	58	177	222	261	260	920
21	Mandya	90	72	52	54	68	150	155	158	158	130	110	105	162	174	183	333	890
22	Mereca	90	92	85	95	80	122	111	110	100	90	78	70	182	260	443	238	1211
23	Mettur	87	88	73	48	70	35	42	50	54	128	115	94	175	191	181	337	884
24	Mettupalayam	90	95	85	95	80	124	112	112	110	100	85	65	185	260	458	250	1257
25	Mulhole	90	90	75	98	80	135	125	123	120	110	90	85	180	253	406	255	1094
26	Mysore	110	98	85	60	28	150	162	161	160	130	120	110	208	173	223	360	1147
27	Nagapatnam	85	65	60	50	83	34	34	64	87	140	110	95	150	193	219	335	762
28	Namakal	82	60	50	62	75	28	26	38	62	148	125	120	142	187	154	393	876
29	Palani	92	80	80	76	100	130	125	120	120	110	90	60	172	256	495	260	1183
30	Perambalur	97	66	55	50	72	34	39	85	112	117	115	110	163	177	270	342	952
31	Puddukottai	86	69	62	50	98	50	69	95	125	135	122	95	155	210	339	352	1056
32	Salem	82	53	25	40	66	35	40	76	102	130	115	115	135	131	253	360	879
33	Thanjavur	90	80	75	65	68	36	40	68	98	120	110	110	170	208	242	340	960
34	TheniTiruchi	82	66	62	50	78	31	38	97	116	133	115	120	148	190	282	368	998
35	Tumkur	83	80	78	58	96	134	132	130	125	110	90	75	163	232	402	245	1042
36	Udagamandalam	88	85	85	98	130	102	92	90	85	75	75	70	173	313	369	220	1109
37	Vedapanyam	120	80	75	65	42	51	61	71	82	135	120	110	200	178	265	365	1239

Table.4 : average monthly, seasonal and annual water deficit values of the stations of the cauvery basin in mm

S. No	Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Summer	South West Monsoon	North East Monsoon	Annual
1	Avanashi	30	54	88	88	60	116	123	102	51	0	0	5	84	236	392	5	717
2	Bangalore	15	15	40	57	28	56	18	0	0	0	0	40	30	125	74	40	269
3	Belur	2	8	20	43	36	0	0	0	0	0	0	2	10	99	0	2	111
4	Bhavani Sagar	35	40	95	97	75	143	137	130	75	0	0	0	75	267	485	0	827
5	Charmajanagar	14	25	33	40	48	0	0	0	0	0	0	22	39	121	0	22	182

6	Coimbatore	25	56	91	97	86	0	0	0	87	0	0	8	81	274	87	8	450	
7	Cuddalore	10	50	105	113	138	115	87	65	64	0	0	0	60	356	331	0	747	
8	Dharmapuri	16	40	76	99	80	110	103	92	72	0	0	0	56	255	377	0	688	
9	Dindigul	30	54	105	109	102	142	145	110	76	0	0	15	84	316	473	15	888	
10	Erode	21	57	98	91	40	122	119	94	62	0	0	19	78	229	397	19	723	
11	Gudalur	0	8	30	27	75	0	0	0	0	0	0	10	08	132	0	10	150	
12	Gundulper	10	25	35	43	61	48	29	6	0	0	0	25	35	139	83	25	282	
13	Hassan	3	15	36	47	33	0	0	0	0	0	0	0	18	116	0	0	134	
14	Geggada	2	6	40	32	58	0	0	0	0	0	0	0	8	130	0	0	138	
15	Devankote	10	24	90	100	82	0	0	0	0	0	0	0	34	272	0	0	306	
16	Hosur	10	30	90	100	130	122	115	105	100	0	0	0	40	320	442	0	802	
17	Karur	40	45	90	95	84	131	131	103	87	0	0	0	85	269	452	0	806	
18	Kodaikanal	25	40	50	70	72	0	0	0	0	0	0	0	65	192	0	0	257	
19	Madikeri	27	53	78	88	90	0	0	0	0	0	0	0	80	256	0	0	336	
20	Madurai	3	20	60	47	66	87	84	71	20	0	0	0	27	23	173	262	27	485
21	Mereca	0	3	20	20	45	0	0	0	0	0	0	0	3	85	0	0	88	
22	Mandya	18	40	100	104	100	0	0	0	0	0	0	0	58	304	0	0	774	
23	Mettur	25	22	78	112	95	110	96	110	104	0	0	0	47	285	420	0	752	
24	Mettupalayam	2	3	23	43	48	0	0	0	0	0	0	5	5	114	0	5	124	
25	Mulhole	6	15	37	78	55	0	0	0	0	0	0	0	21	170	0	0	191	
26	Mysore	10	32	65	27	140	10	0	0	0	0	0	0	42	232	10	0	284	
27	Nagapatnam	20	46	90	108	86	128	130	101	75	0	0	0	66	284	434	0	784	
28	Namakkal	28	60	108	103	95	147	150	140	106	0	0	0	88	306	543	0	937	
29	Palani	2	30	40	54	40	0	0	0	0	0	0	25	32	134	0	25	191	
30	Perambalur	19	62	105	115	103	134	131	87	50	0	0	0	81	323	402	0	806	
31	Puddukottai	24	46	92	100	72	105	89	65	30	0	0	15	70	264	289	15	638	
32	Salem	44	73	127	122	106	130	127	92	56	0	0	0	117	355	405	0	877	
33	Thanjavur	30	52	80	100	104	132	130	104	64	0	0	0	82	284	430	0	796	
34	Tiruchi	38	59	190	12	95	133	127	70	41	0	0	0	97	297	371	0	765	
35	Tumkur	15	22	40	70	42	0	0	0	0	0	0	10	37	152	0	10	199	
36	Udagamandalam	2	10	40	22	0	0	0	0	0	0	0	0	12	62	0	0	74	
37	Vedapanyam	5	49	71	91	130	124	115	107	83	0	0	0	54	292	429	0	775	

Table 5: average monthly, seasonal and annual water surplus values of the stations of the cauvery basin in mm

S.No	Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Summer	South West Monsoon	North East Monsoon	Annual
1	Avanashi	0	0	0	0	0	0	0	0	0	+39	0	0	0	0	0	+39	+39
2	Bangalore	0	0	0	0	0	0	0	0	+18	0	0	0	0	0	0	+18	+18
3	Belur	0	0	0	0	0	+274	+548	+185	+185	+66	+30	0	0	0	+1192	+30	+1222
4	Bhavani Sagar	0	0	0	0	0	0	0	0	0	+43	0	0	0	0	0	+43	+43
5	Charmajanagar	0	0	0	0	0	+114	+230	+73	+85	+60	+23	0	0	0	+502	+83	+585
6	Coimbatore	0	0	0	0	0	+92	+109	+15	0	+45	+20	0	0	0	+216	+65	+281
7	Cuddalore	0	0	0	0	0	0	0	0	0	+54	+260	+139	0	0	0	+453	+453
8	Dharmapuri	0	0	0	0	0	0	0	0	0	+51	+20	0	0	0	0	+71	+71
9	Dindigul	0	0	0	0	0	0	0	0	0	+51	+34	0	0	0	0	+85	+85
10	Erode	0	0	0	0	0	0	0	0	0	+28	+03	0	0	0	0	+31	+31
11	Gudalur	0	0	0	0	0	0	+56	+60	+25	+25	0	0	0	0	+141	+25	+166
12	Gundulper	0	0	0	0	0	0	0	0	0	+14	0	0	0	0	0	+14	+14
13	Hassan	0	0	0	0	0	+379	+358	+356	+320	+216	+103	0	0	0	+1413	+319	+1732
14	Geggada	0	0	0	0	0	+290	+594	+167	+107	+70	+40	0	0	0	+1158	+110	+1268
15	Devankote	0	0	0	0	0	+210	+235	+135	+156	+41	+03	0	0	0	+736	+44	+780
16	Hosur	0	0	0	0	0	0	0	0	0	0	+70	0	0	0	0	+70	+70
17	Karur	0	0	0	0	0	0	0	0	0	+62	+100	0	0	0	0	+162	+162
18	Kodaikanal	0	0	0	0	0	+220	+330	+115	0	0	0	0	0	0	+665	0	+665
19	Madikeri	0	0	0	0	0	+192	+287	+85	0	0	0	0	0	0	+564	0	+564
20	Madurai	0	0	0	0	0	0	0	0	0	+11	0	0	0	0	0	+11	+11
21	Mereca	0	0	0	0	0	+390	+589	+373	+373	+86	+45	0	0	0	+1734	+131	+1865
22	Mandya	0	0	0	0	0	+32	+35	+30	+40	+136	+219	+138	0	0	+137	+493	+630
23	Mettur	0	0	0	0	0	0	0	0	0	+58	+10	0	0	0	0	+68	+68
24	Mettupalayam	0	0	0	0	0	+188	+593	+160	+100	+72	+37	0	0	0	+1041	+109	+1150
25	Mulhole	0	0	0	0	0	+125	+177	+188	+195	+118	+98	0	0	0	+685	+216	+901

26	Mysore	0	0	0	0	0	0	0	0	+69	+100	+280	+195	0	0	+69	+595	+644
27	Nagapatnam	0	0	0	0	0	0	0	0	0	+125	+105	+46	0	0	0	+276	+276
28	Namakkal	0	0	0	0	0	0	0	0	0	+25	+45	0	0	0	0	+70	+70
29	Palani	0	0	0	0	0	0	+51	+50	+20	+15	0	0	0	0	+121	+15	+136
30	Perambalur	0	0	0	0	0	0	0	0	0	+42	+35	0	0	0	0	+77	+77
31	Puddukottai	0	0	0	0	0	0	0	0	0	+27	+38	0	0	0	0	+65	+65
32	Salem	0	0	0	0	0	0	0	0	0	0	+65	+17	0	0	0	+82	+82
33	Thanjavur	0	0	0	0	0	0	0	0	0	+65	+20	0	0	0	0	+85	+85
34	Tiruchi	0	0	0	0	0	0	0	0	0	+50	+65	0	0	0	0	+115	+115
35	Tumkur	0	0	0	0	0	+28	+451	+71	0	0	0	0	0	0	+550	0	+550
36	Udagamandalam	0	0	0	0	+121	+280	+437	+280	+205	+225	+113	0	0	0	+1202	+338	+1661
37	Vedapanyam	0	0	0	0	0	0	0	0	0	+05	+230	+26	0	0	0	+261	+261