

Assessment of Hydroclimatic Condition in Extensive Groundwater Mining Area, Southern India

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ABSTRACT

The study highlights the climatic water balance, drought assessment and agricultural potentiality of Uppar Odai sub-basin located in the Southern part of India, Tamil Nadu state. The average annual precipitation in the sub-basin is 625 mm, which is much lower than the state average rainfall (970 mm). It has been observed that the intensive agricultural practices and extensive groundwater mining lead to the groundwater decline in the sub-basin. Rainfall data were collected from 1971-2011 for five rain gauge stations. The hydroclimatic potentialities such as precipitation, temperature and water holding capacity are the three primary parameters considered to derive water balance parameters. The secondary water balance components, namely potential evapotranspiration (PET), actual evapotranspiration (AET), water deficit (WD) and water surplus (WS) were derived from these primary parameters. The PET and AET were calculated using Thornthwaite's (1948) and Thornthwaite and Mather (1955) methods respectively. Four water balance indices, namely index of aridity (Ia), index of humidity (I_h), index of moisture (Im) and index of moisture adequacy (Ima) were calculated from secondary water balance components. From the derived indices, drought condition, climatic shift and agricultural potentiality were assessed. The results have indicated that drought condition prevails during every alternate year in the sub-basin.

INTRODUCTION

The hydroclimatic potentialities include precipitation, temperature, water holding capacity, potential evapotranspiration, actual evapotranspiration, water surplus and water deficit. These parameters control the agricultural activities right from nursery to harvesting. Precipitation plays a major role in modulating the climate stress. The quantified annual rainfall in India is estimated as 4000 cubic km. About 3000 cubic km is derived from southwest monsoon that prevails for a period of 18 weeks (Sharma and Sivaram, 2011). The hydroclimatic aspects over India for the monsoon period is based on weekly temperature and rainfall data through the revised water balance model of Thornthwaite & Mather (1955). Climatic water balance studies, especially the drought assessment were conducted in parts of South India (Subrahmanyam and Subramanyam, 1964; Subrahmanyam and Sastri, 1969). Sreedevi (2002) conducted climatic water balance study for understanding the drought condition and recommended suitable drought resistant crops in the Pageru river basin, Andhra Pradesh. The concept of hydroclimatic potentialities focuses on understanding the moisture status of a region. It also reveals that how climate changed in a region over a period of time. The adopted procedure helped us to evaluate the 'water need', 'water use', 'water surplus' and 'water deficit' in the study area. This was done climatologically by analyzing monthly meteorological data over a certain time period for different meteorological stations. In the present

study, Uppar Odai sub-basin is identified to address the specific problem cited above. Though the available canal water supply in the basin is significant, major portion still depends on groundwater source. The relatively inadequate rainfall (625 mm) and extensive groundwater pumping lead to stress on water table condition. The hydroclimatic study was conducted with an objective to assess periodic drought condition and climatic shift in the sub-basin.

STUDY AREA

The study area Uppar Odai sub-basin is in part of Amaravati river basin and covered by 1280 sq.km area, located in between longitudes 77°06'36"E to 77°32'24"E and latitudes 10°26'40"N to 10°55'48"N. The sub-basin falls in Tiruppur and Coimbatore districts of Tamil Nadu, India (Fig.1). Uppar odai sub-basin is mostly covered by Precambrian gneissic terrain. The major rock types in the sub-basin are calc gneiss, charnockite, ultrabasic rocks, migmatite, granite, felsic porphyry and hornblende boitite gneiss (Narayanasamy, 1975). Subtropical climate prevails throughout the region. The maximum temperature ranges from 27°C to 35°C and minimum temperature vary from 17°C to 23°C. There are four distinct seasons namely southwest monsoon, northeast monsoon, winter season and hot weather period prevailing in the study area. However, the precipitation is slightly higher in the central and western part of the sub-basin and less in the northern and eastern part of the sub-basin. The highest average

annual rainfall of 738 mm is observed in the central part and the lowest average of 573 mm rainfall in the northern part of the sub-basin.

Groundwater condition

Groundwater occurs in almost all geological formations in the sub-basin at an average depth of 10 m below ground level (bgl). During the pre monsoon period, the water level reaches to maximum extent of 18 m bgl. Though such water level declination is believed due to extensive pumping and continuous demand, another important reason is complex interaction of climatic factors such as precipitation and evaporation.

The groundwater storage in the sub-basin could be estimated through the following equation (Ragunath, 1987).

$$I + P - AE - O = \text{BGWR} \quad (1)$$

Where,

I = Inflow to the basin,

P = Rainfall over the basin,

AE = Average evapotranspiration from the basin,

O = Outflow from the basin and

BGWR = Balance for Groundwater recharge (+ve) or discharge (-ve).

The monthly cumulative groundwater storage for the basin was calculated using equation (1). The estimation has shown that the maximum ground water recharge of 117.6 M.m³ occurred in the month of September and minimum recharge of 3.39 M.m³ occurred during June. The maximum ground water discharge of -84.88 M.m³ was estimated in October and minimum discharge of -4.12 M.m³ in April. Cumulative ground water storage is estimated at 171.58 M.m³ (Table 1). In general, the ground water storage in most of the months has shown a negative trend.

METHODOLOGY

The water balance parameters were computed on the basis of procedure adopted by Thornthwaite and Mather (1955). The rainfall and temperature data were collected from five rain gauge stations located within the study area, namely, Udumalaipettai (1971-2011), Sultanpettai (1980-2011), Uppar Dam (1977-2011), Vettaikaranpudur (1986-2011) and Rudhravathi (1975-2011). The field capacity or water holding capacity in the sub-basin was assumed to be 215 mm, based on depth of the soil root zone, the texture of the soil, percentage of rocks and gravel, textural layers, and compaction. The potential evapotranspiration (PET) was calculated from the mean monthly temperature data. The actual evapotranspiration (AET), water deficit (WD) and

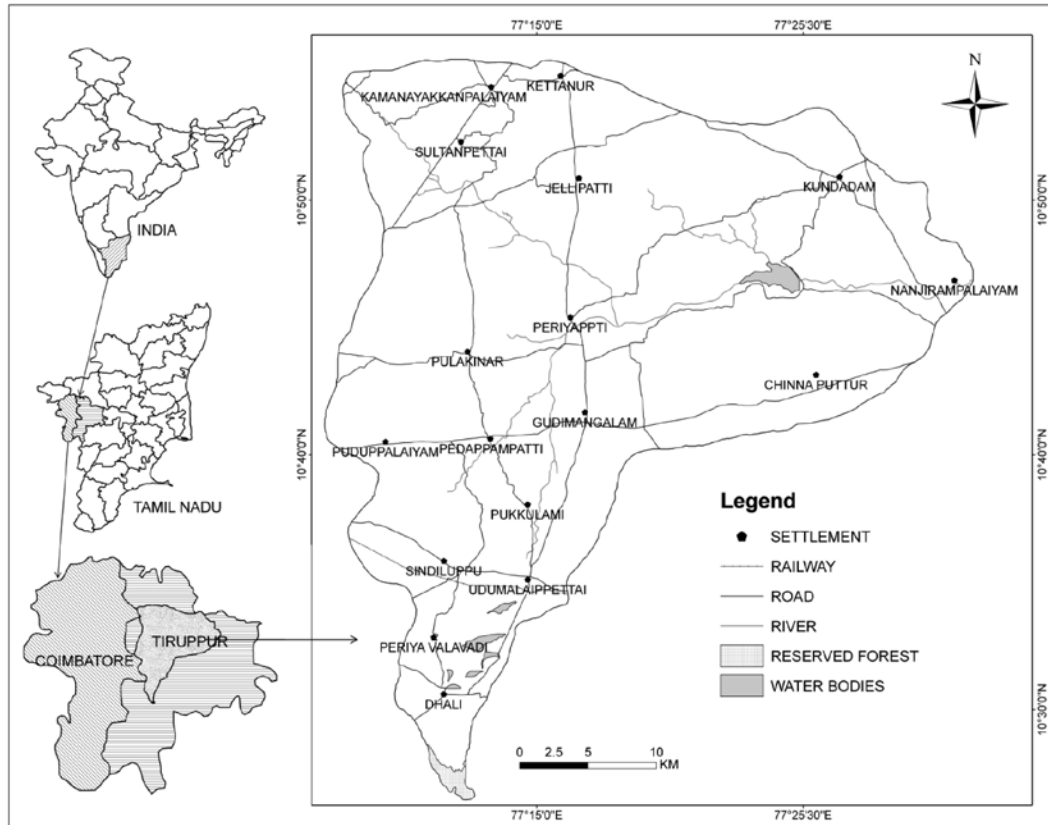


Figure 1. Location map of the UpparOdai sub-basin

Table 1. Monthly ground water balance of the UpparOdai sub-basin

Month	Canal Inflow in the UpparOdai sub-basin (I) M.m ³	Rainfall over the basin (P) mm	Average Evapotranspiration from the basin (Et) M.m ³	Outflow & seepage of the basin (O) M.m ³	Balance ground water recharge (+ve) or discharge (-ve) I+P-Et-O M.m ³	Cumulative ground water storage M.m ³
Jan	5.41	32.65	3.52	50.70	-16.16	-16.16
Feb	17.38	41.91	3.13	45.05	11.11	-5.05
Mar	19.24	-	17.19	28.08	-26.03	-31.08
April	19.16	-	49.95	17.07	-46.83	-77.91
May	18.03	34.21	38.96	17.40	-4.12	-82.03
June	9.78	32.96	25.96	13.39	3.39	-78.64
July	-	15.66	22.52	9.50	-16.36	-95
Aug	-	90.21	28.29	7.45	54.47	-40.53
Sept	12.9	148.02	35.96	7.81	117.6	77.07
Oct	14.5	9.56	100.24	8.70	-84.88	-7.81
Nov	16.95	131.07	79.26	6.26	62.5	54.69
Dec	12.69	133.32	22.74	6.38	116.89	171.58

water surplus (WS) were estimated using precipitation (P), PET and field capacity. From the water balance components, the water balance graphs were prepared for each station. From these components, the water balance indices such as index of moisture (Im), index of aridity (Ia), index of humidity (Ih) and index of moisture adequacy (Ima) were derived. From indices, drought condition, climatic shift and agricultural potentiality and agricultural drought intensity were assessed for sustainable ground water development in the study area.

Computation of Water Balance Components

The yearly water balance was estimated for Udumalaipettai and Sultanpettai stations. For remaining three stations monthly averages were used to compute the water balance parameters in the study area. The average annual rainfall for Udumalaipettai is 650 mm and 573 mm for Sultanpettai station which are very low compared to the state average annual rainfall (970 mm).

Potential evapotranspiration (PET) or “water need” is the amount of water that would be evaporated under an optimal set of conditions, among which the important one is an unlimited supply of water. It was calculated using Thornthwait's (1948) formula:

$$E = 1.6 (10T / I)^a \quad (2)$$

Where,

E = monthly potential evapotranspiration (cm)

T = mean monthly temperature (°C)

I = a heat index for a given area which is the sum of 12 monthly index values i .

i is derived from mean monthly temperatures using the following formula:

$$i = (T / 5)^{1.514} \quad (3)$$

a = an empirically derived exponent which is a function of I

$$a = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.79 \times 10^{-2} I + 0.49 \quad (4)$$

The average annual PET of all the stations is computed as 1709 mm. The peak values are observed during the month of April (215 mm) and the low values are observed in the month of December (92 mm). The water balance graph has shown that the monthly PET gradually increases from January onwards and reaches maximum in April. The computed average annual AET for Udumalaipettai and Sultanpettai station are 437 mm and 433 mm respectively.

Water deficit was calculated by subtraction of AET from PET (Thornthwaite and Mather, 1955). The annual average water deficit of Sultanpettai is 1276 mm and for Udumalaipettai, it is 1272 mm. It is observed that the water deficit is maximum in the month of March and May respectively for Udumalaipettai and Sultanpettai station.

The annual computation of the WS for Udumalaipettai station reveals that out of 41 years from 1971 to 2011, only 12 years enjoyed water surplus conditions. The highest WS of 306 mm occurred in the year 1977 and the lowest surplus of 27 mm in the year 2010. It is also found that there is no WS during the 33 year period. WS of Sultanpettai is mostly ‘zero’, though sometimes it is in the range of 11 to 18 mm (Table 2).

Water balance graphs were prepared in radar plot for all five stations, based on P, PET and AET parameters (Fig.2). The graphical representations of all stations reveal that water deficit is there in all the months except in October and November. During these WS months, the excess water

Table 2. Water balance components and Indices derived for UpparOdai sub-basin

Sl.No	Station name	Water Balance Components					Indices			
		PET	P	AET	WD	WS	Ia%	Ih%	Im%	Ima%
1	Udumalaipettai	1709	650	437	1272	0	74.44	0	-72.82	25.56
2	Sultanpettai	1709	573	433	1276	0	74.65	0	-74.60	25.35
3	Uppar Dam	1709	613	444	1265	0	74.01	0	-72.88	25.99
4	Vettaikaranpudur	1709	738	558	1151	0	67.34	0	-66.47	32.66
5	Rudhravathi	1709	578	392	1317	0	77.04	0	-76.10	22.96

(PET-Potential Evapotranspiration, P-Precipitation, AET-Actual Evapotranspiration, WD-Water Deficit WS-Water Surplus, Ia-Index of aridity, Ih-Index of humidity, Im-Index of moisture, Ima-Index of moisture adequacy)

infiltrates into the soil and portion of water accumulates as soil moisture storage. During the WD months, depletion of soil moisture takes place from the moisture stored and again during the WS months, soil moisture becomes replenished. However, this limited 'WS' does not contribute much to groundwater aquifers.

Water Balance Indices

Water balance indices were derived based on the standard formula (Thornthwaite and Mather 1955) viz., index of aridity (Ia), index of humidity (Ih), index of moisture (Im) and index of moisture adequacy (Ima). Index of aridity is the percentage of water deficit with reference to potential evapotranspiration i.e.

$$Ia = WD / PET \times 100\% \quad (5)$$

The values of 'Ia' fall in between 48.24% and 92.62% for Udumalaipettai station. For Sultanpettai station, the minimum of 'Ia' is 55.52% and maximum of 90.90%. The index of humidity (Ih) is an important parameter to know the moisture condition of the climate. It is the percentage of water surplus to the water need. Hence,

$$Ih = WS / PET \times 100\% \quad (6)$$

This parameter is useful to define the climate of the region as 'moist' or 'dry'. From Table 2, we can observe that 'Ih' is mostly zero. It indicates that the basin enjoys a completely dry climate. The Index of moisture (Im) was obtained from the index of humidity and index of aridity i.e.,

$$Im = (Ih - Ia) \quad (7)$$

The 'Im' values are negative for all five stations. It shows high values of aridity in the basin. 'Im' is very low for Sultanpettai station (-90.90% to -54.85%) compared to Udumalaipettai (-88.59% to -48.24%). The Index of moisture adequacy (Ima) is an important parameter to

suggest potential agriculture. It is the percentage ratio of AET to PET. Hence,

$$Ima = AET / PET \times 100\% \quad (8)$$

The nine years 'Ima' value of Sultanpettai station varies from 9% in the year 1987 and 44% in the year 1994, whereas for Udumalaipettai, it is slightly higher and vary from 7% to 52%. 'Ima' for Sultanpettai are mostly less than 44%, indicating poor moisture status for agriculture in the northern part of the basin (Table 3 and 4).

RESULTS AND DISCUSSION

Assessment of drought condition

The estimation of water balance is not only a proven technique for determining the moisture status of the soil in a basin, but also helps in assigning the drought condition and severity (Sreedevi 2002). In the present study, index of aridity is the most important parameter to carry out drought assessment.

The percentage of standard deviation of 'Ia' from the mean was calculated and categorized into drought intensity zones as $< 1/2\sigma$ - Moderate, $< 1/2\sigma$ to σ - Large, σ to 2σ - Severe and $> 2\sigma$ - Disastrous condition (Subrahmanyam et al, 1965). The scenario of drought condition is clearly depicted in Fig.3. During the study period (1971 to 2011), the Udumalaipettai station experienced 19 drought years, out of which, 6 moderate, 4 large, 8 severe and 1 disastrous condition. The Sultanpettai station experienced 18 drought years during 32 years time period (1980-2011), out of which 7 moderate, 6 large, 3 severe and 2 disastrous conditions.

Climatic Variability

Study of climatic variability is one of the important aspects for long-term economic planning. The 'Im' values of Udumalaipettai and Sultanpettai stations were plotted for individual year to understand the climatic shifts of the UpparOdai river basin. Index of moisture values were

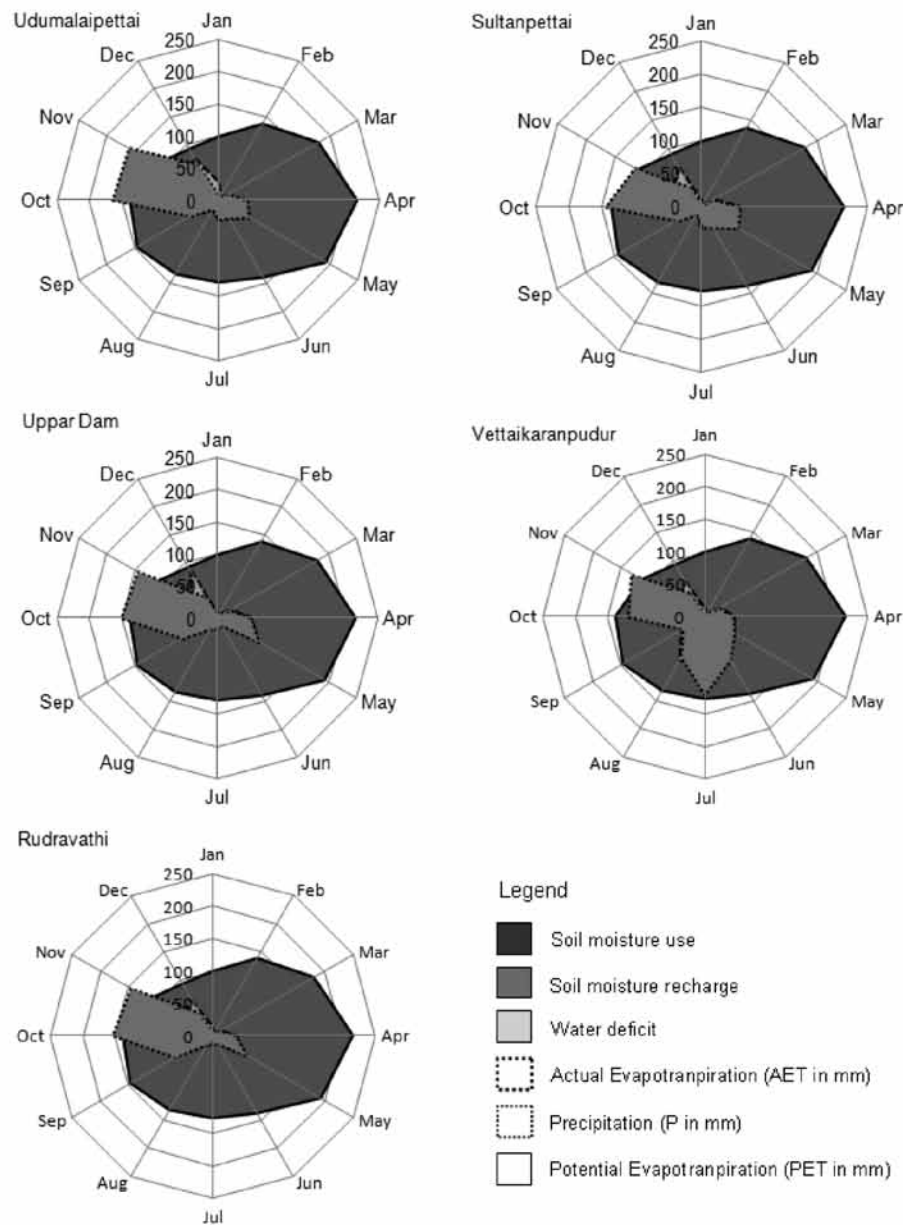


Figure 1. Location map of the UpparOdai sub-basin

considered as suitable parameter to trace climatic shifts, based on Thornthwaite's classification (Table 5). From the study, it is clearly depicted that the arid to semiarid climate prevails in the basin (Fig. 4).

Agricultural Potentiality

Knowledge of climatology is important for agricultural planning in an area. Soil moisture is dependent on rainwater recharge and one of the key parameters for agricultural practice. Agricultural potentiality was assessed for the basin area based on 'Index of moisture adequacy' (Ima).

Suitability of crops based on 'Ima' by Subrahmanyam (1963) was used to suggest the crop pattern in the absence of supplemental irrigation.

From the 'Ima' values of both the stations, it is suggested that Udumalaipettai and Sultanpettai areas are suitable only for a few drought resistant crops e.g. jowar, ragi, bajra. However, in the present condition, the crops grown in the basin are both wet and dry crops, such as paddy, sugarcane, groundnut, jowar, bajra with overexploitation of groundwater for irrigation against the status of moisture condition of the basin leading to more extraction than annual net recharge in the basin and finally

Table 3. Percentage departure of yearly aridity index (Ia) and moisture adequacy (Ima) from the median of Udumalaipettai station

	Ia%	Actual	%	Ima%	Actual	%
1971	73.36	-2.39	-3.16	26.64	1.08	4.23
1972	71.36	-4.39	-5.80	28.64	3.08	12.06
1973	75.75	0.00	0.00	24.25	-1.31	-5.11
1974	74.99	-0.76	-1.01	25.01	-0.55	-2.14
1975	76.06	0.31	0.40	23.94	-1.62	-6.32
1976	69.00	-6.75	-8.91	31.00	5.44	21.27
1977	86.23	10.48	13.83	13.77	-11.79	-46.12
1978	85.45	9.70	12.80	14.55	-11.01	-43.06
1979	48.24	-27.51	-36.32	51.76	26.20	102.50
1980	76.58	0.83	1.10	23.42	-2.14	-8.37
1981	80.35	4.60	6.07	19.65	-5.91	-23.10
1982	83.75	8.00	10.56	16.25	-9.31	-36.43
1983	83.10	7.35	9.70	16.90	-8.66	-33.86
1984	78.08	2.33	3.08	21.92	-3.64	-14.24
1985	75.81	0.06	0.08	24.19	-1.37	-5.36
1986	81.48	5.73	7.56	18.52	-7.04	-27.54
1987	92.62	16.87	22.27	7.38	-18.18	-71.13
1988	59.13	-16.62	-21.94	40.87	15.31	59.88
1989	71.40	-4.35	-5.74	28.60	3.04	11.88
1990	80.00	4.25	5.62	20.00	-5.56	-21.77
1991	67.03	-8.72	-11.51	32.97	7.41	28.98
1992	58.68	-17.07	-22.53	41.32	15.76	61.64
1993	62.03	-13.72	-18.11	37.97	12.41	48.54
1994	70.79	-4.96	-6.54	29.21	3.65	14.27
1995	75.28	-0.47	-0.62	24.72	-0.84	-3.28
1996	65.27	-10.48	-13.84	34.73	9.17	35.89
1997	56.91	-18.84	-24.87	43.09	17.53	68.57
1998	85.74	9.99	13.19	14.26	-11.30	-44.20
1999	78.59	2.84	3.75	21.41	-4.15	-16.25
2000	84.24	8.49	11.21	15.76	-9.80	-38.34
2001	76.78	1.03	1.36	23.22	-2.34	-9.15
2002	75.19	-0.56	-0.74	24.81	-0.75	-2.94
2003	87.08	11.33	14.95	12.92	-12.64	-49.44
2004	69.82	-5.93	-7.83	30.18	4.62	18.08
2005	75.99	0.24	0.32	24.01	-1.55	-6.08
2006	77.28	1.53	2.01	22.72	-2.84	-11.10
2007	83.28	7.53	9.94	16.72	-8.84	-34.58
2008	64.95	-10.80	-14.26	35.05	9.49	37.14
2009	69.35	-6.40	-8.44	30.65	5.09	19.90
2010	69.24	-6.51	-8.59	30.76	5.20	20.33
2011	75.61	-0.14	-0.19	24.39	-1.17	-4.57
'Ia' median Value = 75.75, 'Ia' standard deviation = 9.20, 'Ima' median Value = 25.56, 'Ima' standard deviation = 9.20						

Table 4. Percentage departure of yearly aridity index (Ia) and moisture adequacy (Ima) from the median of Sultanpettai station

	Ia%	Actual	%	Ima%	Actual	%
1980	73.51	-1.48	-1.97	26.49	1.14	4.50
1981	78.20	3.21	4.28	21.80	-3.55	-14.01
1982	77.06	2.07	2.76	22.94	-2.41	-9.52
1983	70.23	-4.76	-6.34	29.77	4.42	17.43
1984	67.57	-7.42	-9.90	32.43	7.08	27.94
1985	71.67	-3.32	-4.42	28.33	2.98	11.74
1986	87.55	12.56	16.75	12.45	-12.90	-50.90
1987	90.90	15.91	21.22	9.10	-16.25	-64.11
1988	72.51	-2.48	-3.31	27.49	2.14	8.44
1989	76.84	1.85	2.47	23.16	-2.19	-8.64
1990	78.45	3.46	4.62	21.55	-3.80	-15.00
1991	83.34	8.35	11.14	16.66	-8.69	-34.28
1992	66.90	-8.09	-10.79	33.10	7.75	30.57
1993	75.44	0.45	0.61	24.56	-0.79	-3.13
1994	55.52	-19.47	-25.97	44.48	19.13	75.48
1995	81.69	6.70	8.94	18.31	-7.04	-27.77
1996	73.48	-1.51	-2.01	26.52	1.17	4.61
1997	61.78	-13.21	-17.62	38.22	12.87	50.78
1998	79.52	4.53	6.04	20.48	-4.87	-19.20
1999	68.60	-6.39	-8.52	31.40	6.05	23.87
2000	67.88	-7.11	-9.49	32.12	6.77	26.72
2001	74.53	-0.46	-0.61	25.47	0.12	0.48
2002	80.34	5.35	7.13	19.66	-5.69	-22.44
2003	76.33	1.34	1.79	23.67	-1.68	-6.62
2004	78.37	3.38	4.51	21.63	-3.72	-14.67
2005	68.06	-6.93	-9.24	31.94	6.59	25.99
2006	70.68	-4.31	-5.74	29.32	3.97	15.65
2007	69.03	-5.96	-7.94	30.97	5.62	22.15
2008	82.40	7.41	9.88	17.60	-7.75	-30.57
2009	78.69	3.70	4.93	21.31	-4.04	-15.92
2010	78.69	3.70	4.93	21.31	-4.04	-15.92
2011	73.14	-1.85	-2.47	26.86	1.51	5.96

to drastic decline of groundwater table. In Uppar Odai sub-basin, supplementary water is available through canal water irrigation system. However, it is not sufficient.

Agricultural Drought Intensity

Many meteorologists and agricultural scientists suggested that the Index of moisture adequacy (Ima) is one of the standard monitoring tools, which could be applied in combination for drought declaration. 'Ima' values are critical to ascertain agricultural drought (Vittal et al., 2010). The drought impact is related to moisture availability

at certain crop growth stages. The categories of 'Ima' at different growth stages are integrated into a single index value to identify drought impact on a particular crop. The Central Arid Zone Research Institute (CAZRI), Jodhpur monitors agricultural drought in the Indian regions by using 'Ima' (Table 6). Graphs showing the 'Ima' percentage of Udumalaipettai and Sultanpettai stations (Fig.5) help us to assess agricultural drought intensity using Table 6. In most of the years, severe drought conditions prevailed in Udumalaipettai station (few years shown as moderate drought and only one year as mild drought condition). The Sultanpettai station was also affected by severe

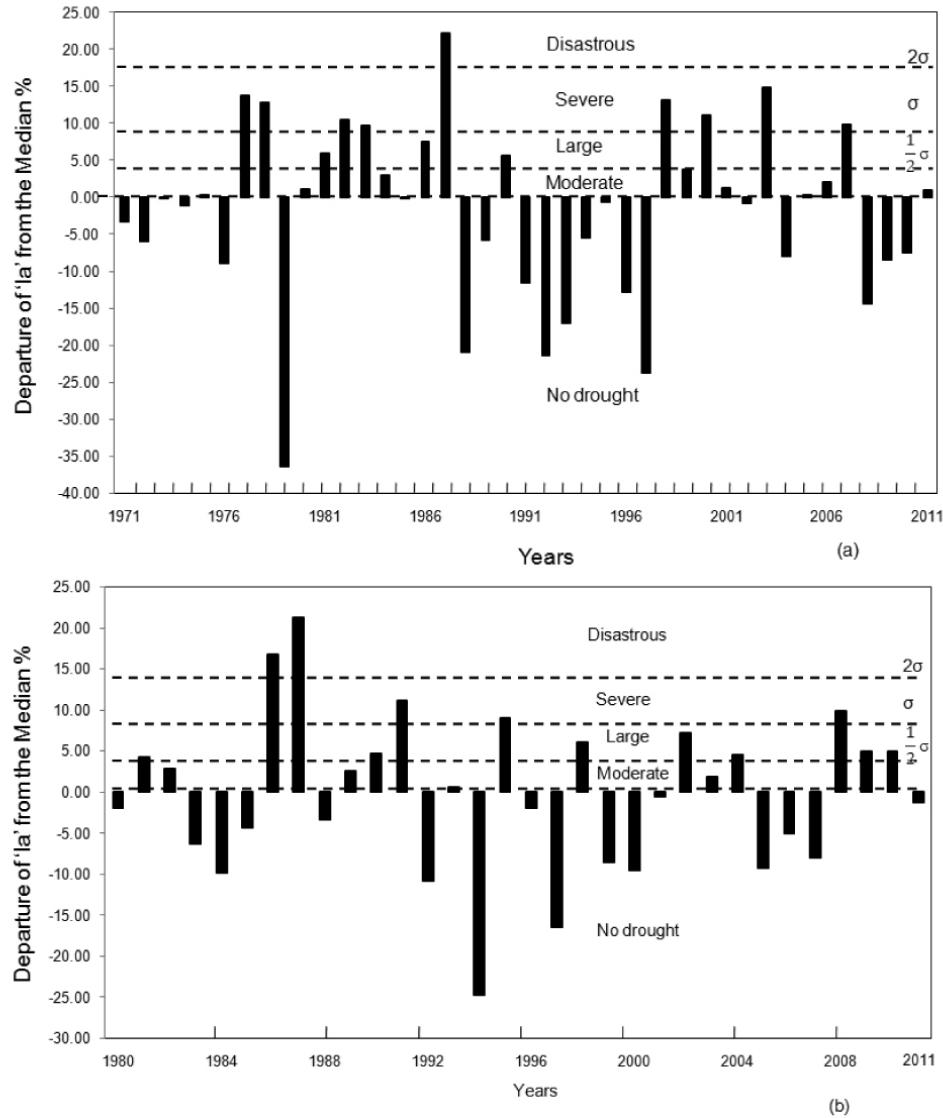


Figure 3. Drought assessments from Ia percentage in UpparOdai, Sub-basin (a) Udumalaipettai and (b) Sultanpettai

Table 5. Classification of moisture regions and their limits for climate change

Moisture Index	Symbol	Climatic Type
100 and above	A	Per-humid
80 to 100	B4	Humid
60 to 80	B3	Humid
40 to 60	B2	Humid
20 to 40	B1	Humid
0 to 20	C	Moist Sub-humid
-33.3 to 0	C1	Dry Sub-humid
-66.7 to -33.3	D	Semi-arid
-100 to -66.7	E	Arid

(Thorntwaite and Mather,1955)

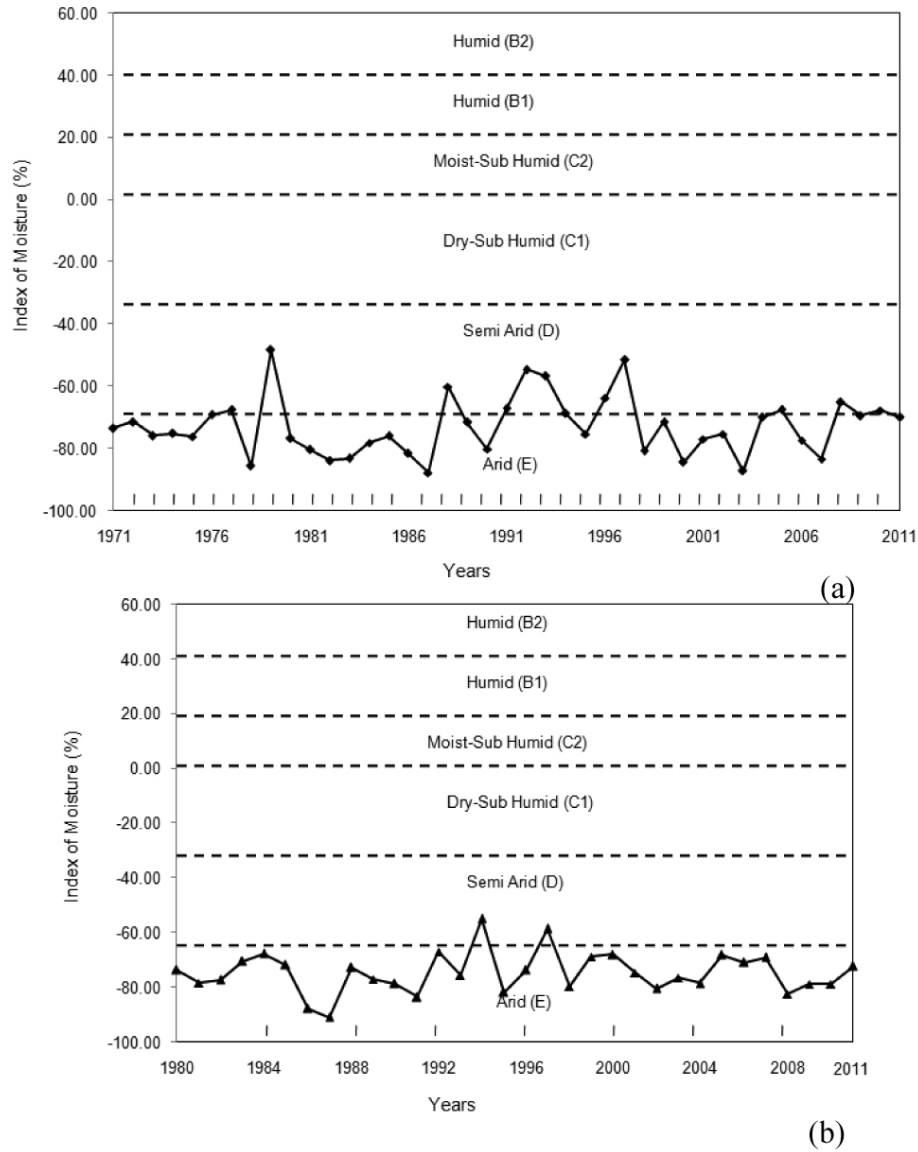


Figure 4. Climatic shifts in UpparOdai, Sub-basin (a) Udumalaipettai and (b) Sultanpettai

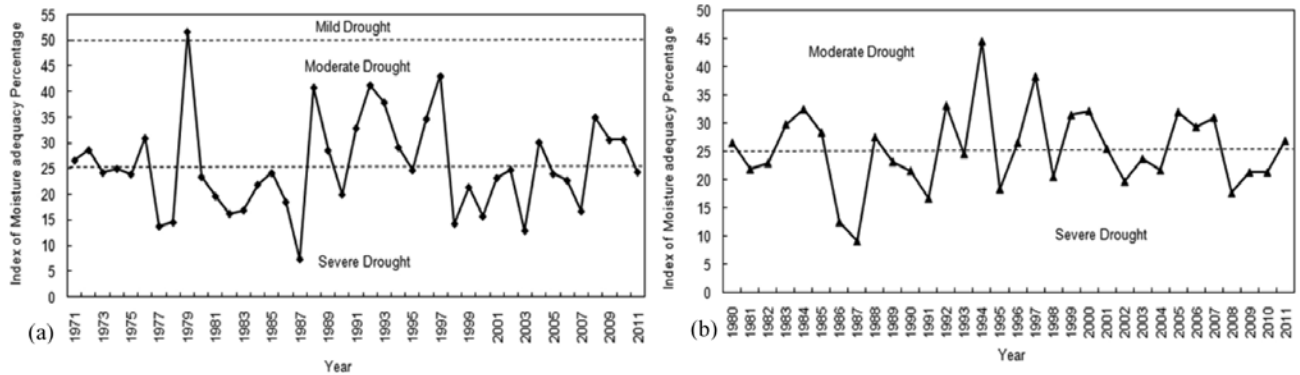


Figure 5. Intensity of Agricultural droughts in UpparOdai, Sub-basin (a) Udumalaipettai and (b) Sultanpettai

Table 6. Intensity of Agricultural Drought

Ima %	Category of Drought	Agricultural Drought code		
		Seeding (S)	Vegetative (V)	Reproductive (R)
76 to 100	No Drought	S ₀	V ₀	R ₀
51 to 75	Mild Drought	S ₁	V ₁	R ₁
26 to 50	Moderate Drought	S ₂	V ₂	R ₂
< 25	Severe Drought	S ₃	V ₃	R ₃
Drought Intensity				
Sl.No	No Drought	Mild Drought	Moderate Drought	Severe Drought
1	S ₀ V ₀ R ₀	S ₀ V ₀ R ₂	S ₀ V ₀ R ₃	S ₀ V ₂ R ₃
2	S ₀ V ₀ R ₁	S ₀ V ₁ R ₂	S ₀ V ₁ R ₃	S ₀ V ₃ R ₂
3	S ₀ V ₁ R ₀	S ₀ V ₂ R ₀	S ₀ V ₂ R ₂	S ₀ V ₃ R ₃
4	S ₁ V ₀ R ₀	S ₀ V ₂ R ₁	S ₀ V ₃ R ₀	S ₁ V ₂ R ₃
5	S ₁ V ₀ R ₁	S ₁ V ₀ R ₂	S ₀ V ₃ R ₁	S ₁ V ₃ R ₃
6	S ₁ V ₁ R ₀	S ₁ V ₁ R ₁	S ₁ V ₀ R ₃	S ₀ V ₂ R ₃
7	S ₀ V ₁ R ₁	S ₁ V ₁ R ₂	S ₁ V ₁ R ₃	S ₂ V ₀ R ₃

Source: Vittal, Kar and Rao, CAZRI, 2010

drought condition in significant number of years. It can be concluded that the UpparOdai sub-basin experienced severe drought condition from the overall observations of agricultural drought intensity assessment.

CONCLUSION

The climatic water balance and drought assessment study in the sub-basin reveals that significant water deficit throughout the year, except during October and November. The available data and analyses have indicated that more than 50% of years fall under moderate to severe drought condition. That means, once in two year drought is recurring in the study area. In Sultanpettai station, witnessed moderate to severe conditions during 16 out of 32 years. Similarly, the moisture index percentages show semi arid to arid climatic condition. The comparison of the present agricultural practices with the results of water balance indices indicates that there is an extensive groundwater mining in the study leading to depletion of groundwater storage. The result of drought assessment, climate change, agricultural potentiality and agricultural drought intensity in the Uppar Odai sub-basin shows decline of water table and severe drought condition. Under these circumstances, the sub-basin needs sustainable groundwater management practices.

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