INFLUENCE OF CLIMATE ON WATERBALANCE OF A RIVERBASIN – A CASE STUDY

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ABSTRACT: An attempt has been made to know the climatic control over water balance of Pillaperu river basin, Nellore district, Andhra Pradesh. The meteorological data states that the climate of this region is shifting towards dry category. The aridity index explains that this region is shifting from moderate drought to severe type. Moisture adequacy denotes that this region is suitable for cultivation of dry crops like millets, pulses etc.

KEY WORDS: Evapotranspiration, Index of Humidity, Aridity Index, Moisture Adequacy.

INTRODUCTION:

The increasing need of water for agricultural and as well as industrial purposes, necessitates for water resource studies has been increased. One of the fundamental problems in groundwater resources management is the fact that the natural water supply does not synchronize with the variations in spatial and temporal water demands. Adequate knowledge of the available precipitation and water resources of a region is prerequisite for wise planning and successful harnessing. A careful appraisal of these resources is required as basis for safer and fuller utilization in which a balance has to be struck between the demand and supply. The water balance of any region helps to recognize the prevailing climatic conditions of that region from which one can deduce the 'wet' or 'dry' nature of that area.

LOCATION:

The Pillaperu river rises from the Veikinda hill ranges in Udayagiri taluk of Nellore district, and flows in a southeasterly direction and joins the Peratla vagu near Gandipalem villege. The basin which includes three sub-basins with drainage area of about 406 km^2, and it lies inbetween the North latitudes 14^{o} 50′ and 15^{o}07′ and the East longitudes 70^{o} 05′ and 79^{o} 18′ (Fig.1).

Fig. 1: Drainage basin of Pillaperu river

METHODOLOGY:

The rainfall data have been collected from six rain-gauge stations in and around the basin and analyzed to compute the water balance parameters after Thornthwailte and Mather (1955). The field capacity or water holding capacity of the basin region is considered to be 200mm determined from the Thornthwaite tables based on the soil texture and type of vegetation. The monthly temperature data available has been used to calculate the thermal efficiency or the potential evapotranspiration (PE) using Thornthwaite and Mather's (1957) water balance formula. Using both precipitation and potential evapotranspiration data, the actual evaporanspiration (AE), water deficit (WD), water surplus (WS), Index of Humidity (Ih), Index of moisture (Im), index of arildity (Ia), and index of moisture adequacy (Ima) for each station has been worked out (Tables 1 & 2).

TABLE: 1 RAINFALL STRATISTICAL PARAMETERS OF UPPER PILLAPERU RIVER BASIN

Raingauge station	Period	Yearly mean	Monthly mean	Standard deviation	Co-efficient of Variation	Lowest value	Year of occurrence	Highest value	Year of occurrence	Rainfall ratio
1 Giddalur	1975-1991	676	56	156	23	406	1985	1001	1991	88
2 Cumbum	1985-1991	698	58	203	29	428	1985	991	1990	81
3 Kanigiri	1975-1992	740	62	245	33	415	1992	1413	1979	135
4 Seetharampuram	1981-1993	746	62	280	29	398	1985	1130	1991	98
5 Udayagiri	1872-1993	870	73	306	35	287	1976	1901	1986	185
6 Atmakur	1976-1993	845	71	320	38	114	1976	2291	1983	256

TABLE: 2: WATER BALANCE COMPUTATION FOR SIX RAINGUAGE STATIONS OF UPPER PILLAPERU RIVER BASIN

Field capacity assumed = 200mm All values are in mm

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DEC	ANNUAL
	GIDDALURU STATION (1975-1991)												
PE	89	126	158	178	200	194	186	178	165	155	106	81	1816
P	4	2	7	15	39	62	113	110	107	109	101	7	676
P-PE	-85	-124	-151	-163	-161	-132	-73	-68	-58	-46	-5	-74	-1140
APWL	-85	-209	-360	-523	-684	-816	-889	-957	-1015	-1066	-1066	-1140	-
ST	130	69	32	14	6	4	2	2	1	1	1	1	-
ΔST	130	-61	-37	-18	-8	-2	-2	0	-1	0	0	0	-
AE	89	63	44	33	47	64	115	110	108	109	101	7	890
WD	0	63	114	145	153	130	71	68	57	46	5	74	926
WS	0	0	0	0	0	0	0	0	0	0	0	0	0
RO	0	0	0	0	0	0	0	0	0	0	0	0	0
CUMBUM STATION (1985-1992)													
PE	89	126	158	178	200	194	186	178	165	155	106	81	1816
P	7	2	16	14	31	71	99	68	120	141	101	22	692
P-PE	-82	-124	-142	-164	-169	-123	-87	-110	-45	-14	-5	-59	-1124
APWL	-82	-206	-348	-512	-681	-804	-891	-1001	-1046	-1060	-1065	-1124	-
ST	132	70	34	15	6	4	2	1	1	1	1	1	-
ΔST	131	-62	-36	-16	-9	-2	-2	-1	0	0	0	0	-
AE	89	64	52	33	40	73	101	69	120	141	101	22	905
WD	0	62	106	145	160	121	85	109	45	14	5	59	911
WS	0	0	0	0	0	0	0	0	0	0	0	0	0
RO	0	0	0	0	0	0	0	0	0	0	0	0	0

KANIGIRI STATION (1975-1992)													
PE	89	126	158	178	200	194	186	178	165	155	106	81	1816
P	13	7	8	9	51	43	87	73	127	148	161	13	740
P-PE	-76	-119	-150	-169	-149	-151	-99	-105	-38	-7	55	-68	-1076
APWL	-144	-263	-413	582	-731	-882	-981	-1086	-1124	-1131	0	-68	-
ST	96	53	25	10	5	3	2	1	1	1	56	142	-
ΔST	-46	-43	-28	-15	-5	-2	-1	-1	0	0	55	86	-
AE	59	50	36	24	56	45	88	74	127	148	106	81	894
WD	30	76	122	154	144	149	98	104	38	7	0	0	922
WS	0	0	0	0	0	0	0	0	0	0	0	0	0
RO	0	0	0	0	0	0	0	0	0	0	0	0	0
UDAYAGIRI STATION (1872-1993)													
PE	89	126	158	178	200	194	186	178	165	155	106	81	1816
P	20	9	14	25	54	39	70	69	104	196	203	69	872
P-PE	-69	-117	-144	-153	-146	-155	-116	-109	-61	41	97	-12	-944
APWL	-81	-198	-342	-495	-641	-796	-912	-1021	-1082	0	0	-12	-
ST	133	73	35	16	8	4	2	1	1	42	139	188	-
ΔST	-55	-60	-38	-19	-8	-4	-2	-1	0	41	97	49	-
AE	75	69	52	44	62	43	72	70	104	155	106	81	933
WD	14	57	103	134	138	151	114	108	61	0	0	0	883
WS	0	0	0	0	0	0	0	0	0	0	0	0	0
RO	0	0	0	0	0	0	0	0	0	0	0	0	0
SETHARAMPURAM STATION (1981-1993)													
E	89	126	158	178	200	194	186	178	165	155	106	81	1816
P	7	6	9	6	32	40	117	84	101	145	163	36	746
P-PE	-82	-120	-149	-172	-168	-154	-69	-94	-64	-10	57	-45	-1070
APWL	-127	-247	-396	-568	-736	-890	-959	-1053	-1117	-1127	0	-45	-
ST	105	57	27	11	5	2	2	1	1	1	58	159	-
ΔST	-54	-48	-30	-16	-6	-3	0	1	0	0	57	101	-
AE	61	54	39	22	38	43	117	85	101	145	106	81	892
WD	28	72	119	156	162	151	69	93	64	10	0	0	924
WS	0	0	0	0	0	0	0	0	0	0	0	0	0
RO	0	0	0	0	0	0	0	0	0	0	0	0	0
ATMAKUR (1976-1993)													
PE	89	126	158	178	200	194	186	178	165	155	106	81	1816
P	15	7	8	13	43	36	64	62	102	202	216	81	849
P-PE	-74	-119	-150	-165	-157	-158	-122	-116	-63	47	110	0	-967
APWL	-155	-274	-427	-589	-746	-904	-1026	-1142	-1205	0	0	-81	-
ST	91	50	23	10	5	2	1	1	1	48	158	133	-
ΔST	-42	-41	-27	-13	-5	-3	-1	0	0	47	110	-25	-
AE	57	48	35	26	48	39	65	62	102	155	106	81	824
WD	32	78	123	152	152	155	121	116	63	0	0	0	992
WS	0	0	0	0	0	0	0	0	0	0	0	0	0
RO	0	0	0	0	0	0	0	0	0	0	0	0	0

PE = Potential Evapotranspiration
APWL = Accumulated Potential Water Loss
ΔST = Change in Soil Moisture
WD = Water Deficit
RO = Water Runoff
P = Precipitation
ST = Soil Storage
AE = Actual Evapotranspiration
WS = Water Surplus

RESULTS:

From the analysis of rainfall data it is revealed that the annual distribution is more controlled by the physiography of the region. The mean annual average rainfall values of seven stations range from a minimum of 676mm at Giddalur to a maximum of 870mm at Udayagiri.

Potential evapotranspiration or water need of the basin has been computed based on the available temperature data. The average annual PE of all the stations computed is 1816mm.

From the monthly potential evapotranspiration values, it is observed that PE is as high as 200mm in May and a minimum of 81mm in December. In general, the water need of the basin is uniform except in the hilly terrain which requires very low amounts of water when compared to the plain regions.

Analysis of AE indicates that a maximum value of 9331 mm for Udayagiri station and minimum of 824mm for Atmakur station. It is observed that the annual values of AE are an high as 1178mm in the year 1944 and as low as 404mm in the year 1876. The difference between the AE and PE in any month is the water deficit (WD). The studies of annual water deficit in the six stations revel that all the stations have water deficit of more than 739mm per year. The computed annual average water deficit is as high as 992mm for Atmakur and minimum of 883mm for Udayagiri station. It is also noticed that the annual water deficit is as high as 1412mm in the 1876 and as low as 410mm in the year 1984. From the computed monthly values of all the stations the maximum water deficit is observed during March to June months.

Water surplus (WS) is excess precipitation after the soil moisture reaches its maximum field capacity of 200mm for the river basin. The overall analysis reveals that there is no average annual water surplus in any of the stations of the basin.

The important derivative element in the water balance study is index of humidity (Ih). It is the percentage ratio of water surplus and the water need. Index of humidity helps to determine the climate of the region to the moist or dry. From the computed normal year's data of all stations, the index of humidity observed is Zero indicating the climate of the basin as 'dry'. The highest value of humidity index (42mm) is observed in the year 1986 indicating the maximum water surplus year during the study period.

The moisture index (Im) can be derived from the equation (Im = Ih – Ia) indicating the difference between humidity index and aridity index. The index of moisture values are all negative except in the years 1984 and 1986. The negative values of Im vary from as low as 78 in the year 1876 to as high as 3 in the year 1925.

From this analysis it is clear that there has been water deficit in all the months except October and November months in this river basin. The surplus water during these months infiltrates into the soil and accumulated as soil moisture storage. During the water deficit months depletion of soil moisture takes place from the moisture stored and during the surplus months soil moisture gets completely replenished.

DISCUSSION:

Water balance and Droughts:

The water balance is not only a handy technique for determining the moisture status of the soil in a particular region, but also helps in assessing the drought conditions and their severities. A drought is climatic hazard which will have drastically adverse effect on vegetation and agriculture. Drought occurs due to deficit of water which happens when precipitation fails to meet the demands of the potential evapotranspiration.

The aridity index (Ia) is the most suitable parameter for the analytical study of drought conditions with special reference to their frequency. Intensity of drought can be noticed from the percentage departures of aridity index from the median value. The study shows the nature and degree of drought conditions experienced by the region during the study period. Categorization of drought may be done based on standard deviation technique (Table-3) employed by Subramanyam, Subba Rao and Subramanian (1965).

TABLE- 3 : CATEGORIZATION OF DROUGHTS

Departure of the Ia from the median value	Drought Intensity
<1/2 σ	Moderate
1/2 σ to 1 σ	Large
1σ TO 2 σ	Severe
> 2 σ	Disastrous

By employing this technique it came to know that the percentage departure of Ia from the median shows considerable variation in drought conditions of the region. Durilng the study period, the basin experienced 60 drought years out of which 20 years are moderate, 17 years serious, 16 years severe, and 7years disastrous. Identification of drought years of different sevearities will be of immense help for drought which and to evolve management systems.

Water balance and climatic shifts:

By using the water balance parameters it is possible to specify the climatic conditions of any region. To analyse the bio-geographical elements of a given region it is useful to evaluate its climatic conditions by means of water balance technique. Water balance of any region is not stable over a period of time. It is therefore, essential to study water balance of any region for certain consecutive years to understand the shifts in climate to 'wet' or 'dry' condition.

The moisture index (Im) values of computed date are plotted for individual years to understand the climatic shifts of the basin (Fig.2). The years of wetness and dryness are identified based on the Thornthwaite classification of climates. From the graph it has been shown that the climate of the basin is semiarid type as most of the negative values of Im are in the same category. But in some occasions the climate has shown a shift to arid (E) category during the study period. The study also indicates that the climate of the region has shown a tendency to shift towards a high dry category.

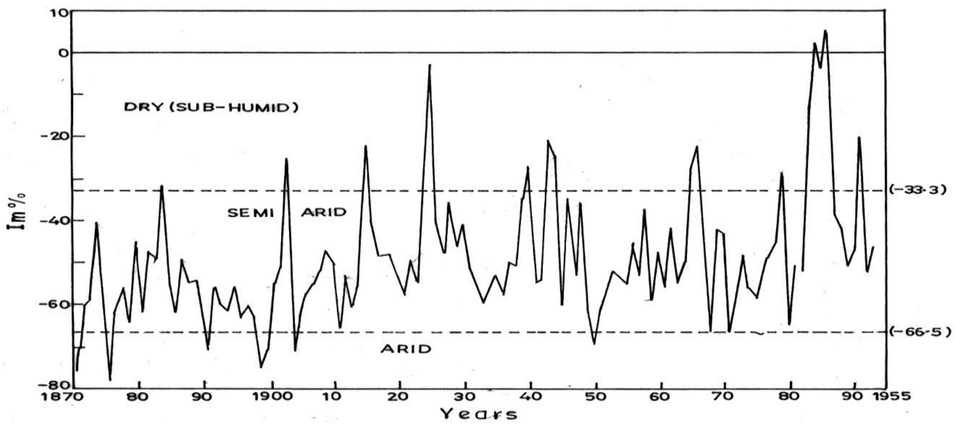

Fig.2: Climatic shifts at study area

Climatic shifts of a region help to understand the extreme conditions of climate which may result as a result of severe floods and droughts depending upon the intensity and duration of water surplus or water deficiency. Even though such shifts may be temporary but are of great use in assessing the groundwater conditions of any region.

Waterbalance and Agriculture:

The index of moisture adequacy (Ima) is an important derivative in the water balance study which indicates the moisture status of the soil useful for crop growth. It is the percentage ratio of AE to PE.

According the Subramanyam et al (1964), index of moisture adequacy values greater than 40% are favorable for crop culture (Table;4).

From the analysis of all the six stations of the river basin it is revealed that the moisture adequacy values vary from 45% to 56%.

TABLE - 4 : MOISTURE ADEQUACY AND SUITABILITY OF CROPS

Index of moisture adequacy percentage (Ima)	Crop suitability
80 – 100	Paddy (high yields)
60 – 100	Paddy (low yields)
< 60	Paddy (un economical)
40 – 60	Millets
20 – 40	Drought resistant crops
< 20	Unsuitable for irrigation

Though it has been suggested that the basin is suitable for cultivation of millet crops, paddy can also be grown with the help of irrigational facilities.

CONCLUSIONS:

The study reveals that the climate of Pillaperu river basin is semiarid which high water deficit. The maximum water deficit is noticed from March to June months. The region is also facing severe drought conditions with different intensities. The study also reveals that the climate of the region is shifting towards high dry category. Based on the studies of water balance it is evident that the region is suitable for cultivation of dry crops such as millets, pulses etc. Modern irrigation methods such as trickle, sprinkler and drip are suggested to meet the problems of groundwater level deterioration.

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