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WATER BALANCE AND CLIMATIC CLASSIFICATION OF THE PENNAR RIVER BASIN

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ABSTRACT

Water balance is an applied climatology used for delimitation of water surplus and water deficit zones. Water balance is the comparative study of rainfall and evapotranspiration. It plays an important role in agriculture, hydrology and especially for water resources development and management. It is well established that water supply to a region is through precipitation and water loss is due to evaporation and evapotranspiration. The former one is measured throughout the India through a good network of rain-gauge stations and the later the potential evapotranspiration or water loss is a very difficult parameter to measure. In view of geographic location of Pennar basin in bad climate, it is noticed that there is high water deficit in the basin. In the present study an attempt in made to describe measures for conservation and optimum utilization of water resources of the Pennar basin. The Pennar basin covering an area of about 58,479 km² has been studied with a view to work-out the water balance elements, water resources and climatic classifications. About 55 stations have been taken to work out the water balance elements based on average monthly rainfall, and average monthly temperature adopting Thronthwaite and Mathar (1955) method.

KEY WORDS: ***potential evapotranspiration, Actual evapotranspiration, water deficit, water surplus, moisture adequacy.***

INTRODUCTION

Land embraces the atmosphere, the soils and the underlying geology, the hydrology and the plants, above and below a specific area of the earth's surface. It includes the result of the past and present human activities as well as animals within this area, in so far as they exert a significant influence upon the present and future uses of man.

Land and water resources evaluation includes both qualitative and quantitative assessment. Drainage basin forms the most convenient, as well as most appropriate spatial units for the study of natural resources particularly the basic land and water resources.

Water balance, is an applied climatology deals with water input and water loss in the form of evaporation and evapotranspiration. The major input is precipitation. Based on water input and water loss, the water surplus and water deficit zones can be identified. Cropping pattern is the proportion of area of various crops in a district or group of districts. Cropping pattern includes identification of most efficient crops of the region, which is considered a homogenous of soil and climatic belts. In the present study an attempt is made to describe the geomorphic evolution, evaluation of land and water resources, water balance and cropping pattern of the Pennar River basin.

STUDY AREA

The Pennar River basin covers an area about 55,213km² and lies in between 10^0 and 16^0 North latitude and 77^0 and 81^0 East longitude. The river originates in northern part of Karnataka state in Nandi hills and passes through the Anantapuramu and Cuddapah districts of Rayalaseema region and empties into Bay of Bengal, 30km ENE of Nellore after passing through the Pennar delta of Nellore district. The average annual rainfall of the Pennar basin is 732.11mm. The average minimum temperature is about 18^0C and the average maximum temperature is about 42^0C. The basin enjoys semiarid, dry sub-humid and wet sub-humid types of climate.

OBJECTIVES

- to describe the water balance characteristics and evaluate the water balance elements of the Pennar basin and
- to describe the climatic classification of the Pennar river basin.

Data Sources & Methodology: The secondary data related to Rainfall for the entire Pennar river basin was collected for 100 years (1910 – 2010) and temperature for official records of the meteorological department, district planning office and statistical department. Simple statistical techniques and percentage analysis have been applied for the data analysis. For mapping the water balance elements Arc-GIS software has been applied. The water balance technique given by the Thornthwaite and Mather has been applied to assess the water surplus and water deficit zones. In India, the formula devised by Thornthwaite and Mather (1955) has been extensively used because it gives accurate values of potential evapotranspiration. It requires average monthly temperature data over a period of time and the geographical location of the station. Water balance elements of Pennar basin for 55 stations have been worked out using average monthly rainfall over a period of hundred years and average monthly temperature data available for the current year 2010-11.

RESULTS

SEASONAL AND ANNUAL ANALYSIS OF WATER BALANCE ELEMENTS OF THE PENNAR RIVER BASIN

Winter

During the winter period the values of potential evapotranspiration (PE) vary from 150 mm to 289mm. The average PE value is 218mm. The spatial distribution shows that the PE value is less than 200mm in the southern, southwestern and northeastern parts of basin. The PE values vary from 200mm to 250mm in the northern and central partsof the basin. The PE values exceed 250mm in eastern part of the basin. (Fig:1 & Table:1). The actual evapotranspiration (AE) varies from 44mm to 208mm. The average AE value is 107mm. The AE values range from 50mm to 100mm in western, northern and southwestern parts of the basin. The AE values range from 100mm to 150mm in the central, northeastern and southern parts of the basin. The AE values exceed 200mm in the eastern part of the basin. There is no water surplus in the basin during winter season. There is water deficit (WD) in the winter season. It ranges from 35mm to 203mm. The average WD is 111mm. The spatial distribution shows that the WD values are less than 100mm in the southwestern, northeastern and eastern parts of the basin. The WD values vary from 100mm to 150mm in the northwestern, western, northern and southeastern parts of the basin and more than 150mm in the central parts of the basin. The moisture adequacy Index (Ima) values during winter period vary from 17% to 84%. The average moisture adequacy is 49% in the basin. The spatial distribution shows that Ima is less than 40% in northwestern part of the basin. The Ima value ranges from 40% to 60% in the southern, southwestern and central parts of the basin and more than 60% in the northeastern and eastern parts of the basin. Climatologically during winter period the basin experiences semiarid type of climate in the northwestern, western and northern parts of the basin. The dry sub-humid type of climate is noticed in the southern, southwestern, northeastern and eastern parts of the basin.

Table No.1

WATER BALANCE ELEMENTS OF THE PENNAR BASIN (Winter)

S.NO	Stations	P in MM	PE in MM	AE in MM	WD in MM	WS in MM	Ima in %	Ia in %	Im in %	CC
1	Allagadda	10	208	80	128	0	38	62	-37.2	D
2	Aluru	10	186	93	93	0	50	50	-30	C1
3	Atmakur (ATP)	4	243	44	199	0	18	82	-49.2	D
4	Anantapur	6	222	58	164	0	26	74	-44.4	D
5	Badvel	11	287	135	154	0	47	53	-31.8	C1
6	Bagepalli	5	151	90	61	0	60	40	-24	C1
7	Bangarupalem	13	150	104	46	0	69	31	-18.6	C1
8	Bukkapatnam	6	190	52	138	0	27	73	-43.8	D
9	Chandragiri	8	228	123	105	0	54	46	-28	C1
10	Chick Ballapur	7	151	92	59	0	61	39	-23.4	C1
11	Cuddapah	10	287	121	166	0	42	58	-34.8	D
12	Darmavaram	6	215	36	179	0	17	83	-49.8	D
13	Dhone	8	184	76	108	0	41	59	-35.4	D
14	Giddalur	6	260	144	116	0	55	45	-27	C1
15	Guduru	86	266	202	64	0	76	24	-14.4	C1
16	G.Bramheswaram	22	182	134	48	0	74	26	-15.6	C1
17	Gooty	4	172	73	99	0	42	58	-34.8	D
18	Gowri Bindanur	8	151	94	57	0	62	38	-22.8	C1
19	Hindupur	8	162	77	85	0	48	52	-31.2	C1
20	Isakapalli	77	221	176	45	0	80	20	-12	C1
21	Jammalamadugu	6	280	87	193	0	31	69	-41	D
22	Atmakur	9	223	80	143	0	36	64	-38.4	D
23	Kadiri	9	180	92	88	0	51	49	-29.4	C1
24	Kalahasti	9	225	146	79	0	65	35	-21	C1
25	Kalyandrug	7	184	64	120	0	35	65	-39	D
26	Kamalapuram	7	276	117	159	0	42	58	-35	D
27	Kavali	27	264	180	84	0	68	32	-19.2	C1
28	Koilkuntla	9	236	82	154	0	35	65	-39	D

29	Krishna Patnam	74	221	186	35	0	84	16	-9.6	C1
30	Kuderu	3	243	40	203	0	17	83	-49.8	D
31	Madakasira	8	158	73	85	0	46	54	-32.4	C1
32	Madanapalli	5	161	106	55	0	66	34	-20	C1
33	Nandikotkur	9	220	67	153	0	30	70	-42	D
34	Nandyal	7	233	85	148	0	36	64	-38.4	D
35	Nellore	54	266	204	42	0	84	16	-9.6	C1
36	Atmakur (Nellore)	68	273	200	73	0	73	27	-16.2	C1
37	P. Ahobilam	12	197	131	66	0	66	44	-20.4	C1
38	Pathikonda	10	192	80	112	0	41	59	-34.8	D
39	Pavagada	5	157	90	67	0	57	43	25.8	C1
40	Penukonda	8	171	77	94	0	45	55	-33	C1
41	Proddutur	6	282	94	188	0	33	67	-40.2	D
42	Pulivendula	7	272	103	169	0	38	62	-37.2	D
43	Punganur	8	156	108	46	0	69	31	-19	C1
44	Rajampet	15	287	143	144	0	50	50	-30	C1
45	Rapur	98	287	208	79	0	72	28	-16.8	C1
46	Rayachoti	10	267	103	164	0	39	61	-36.6	D
47	Rayadurg	5	186	59	127	0	32	68	-40.8	D
48	Sidhout	14	287	151	136	0	53	47	-28.2	C1
49	Srisailam	16	170	129	41	0	76	24	-14.4	C1
50	Tadipatri	6	224	74	150	0	33	67	-40.2	D
51	Tumkur	7	154	90	67	0	58	42	-25.2	C1
52	Udaygiri	91	289	174	115	0	60	40	-24	C1
53	Uravakonda	6	189	74	115	0	39	61	-36.6	D
54	Vailpadu	9	233	123	110	0	53	47	-28.2	C1
55	Yadiki	5	216	71	145	0	33	67	-40.2	D

P: Precipitation, PE: Potential evapotranspiration, AE: Actual evapotranspiration, WD: Water deficit WS: Water surplus, Ima: Moisture adequacy Index, Ia: Aridity index, CC: Climatic classification, A: Per Humid, B1-B4: Humid,C1: Dry sub-humid, C2: Moist sub-humid, D: Semiarid, E: Arid.

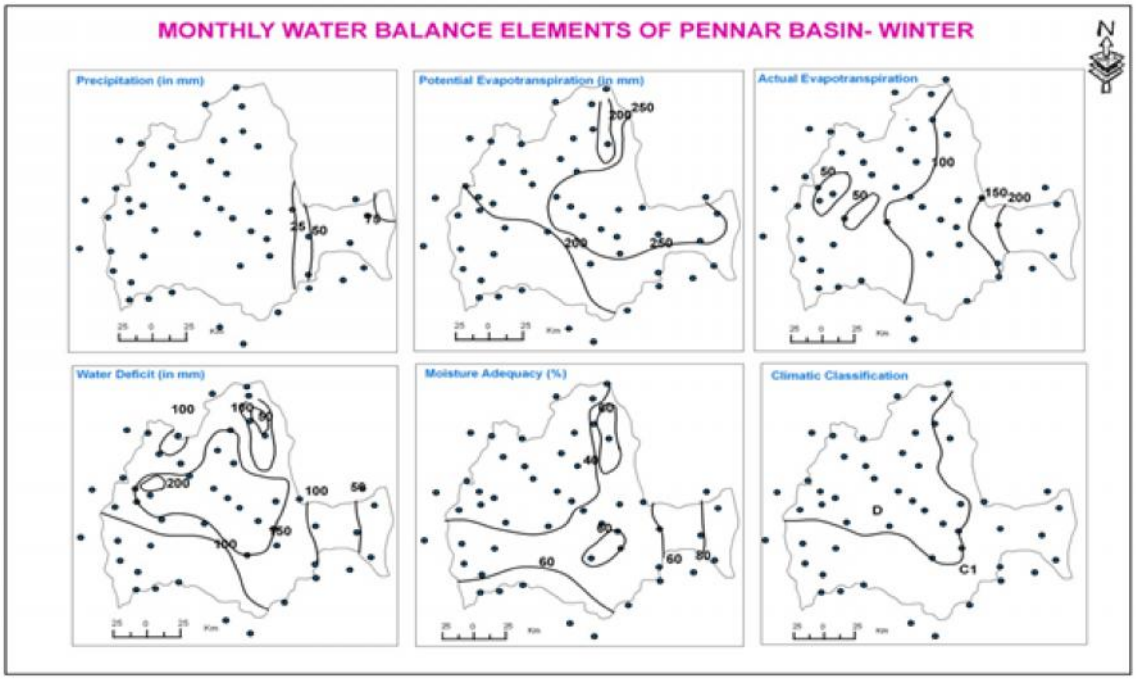

Fig.1

Summer

During the summer period the values of potential evapotranspiration (PE) vary from 446mm to 632mm. The average PE value is 535mm. The spatial distribution shows that the PE value is less than 500mm in the southwestern and western parts of basin. The PE values vary from 500mm to 600mm in northern, northeastern, central and southeastern parts of the basin. The PE value is more than 600mm in the eastern part of the basin. (Fig:2 & Table:2). The values of actual evapotranspiration (AE) range from 69mm to 235mm. The average AE value is 143mm. The AE value is less than 150mm in the southern, southwestern and northern parts of the basin. The AE ranges from 150mm to 200mm in the central and northeastern parts of the basin. The AE is more than 200mm in the eastern part of the basin. There is no water surplus in the basin during summer season. There is water deficit (WD) in the summer season. It ranges from 282mm to

515mm. The average WD is 392mm in the basin. The spatial distribution shows that the WD values are less than 300mm in the southwestern part of the basin. It ranges from 300mm to 400mm in western, eastern and northwestern parts of the basin. The values of WD vary from 400mm to 500mm in central and northern parts of the basin. The WD is more than 500mm in northeastern part of the basin. The values of moisture adequacy (Ima) during winter period vary from 14% to 42%. The average moisture adequacy is 27% in the basin. The spatial distribution shows that the Ima is less than 20% in the central part of the basin. The value of Ima ranges from 20% to 30% in northern, southwestern and southern parts of the basin. It ranges from 30% to 40% and more than 40% in northeastern and eastern parts of the basin. Climatologically during the summer period this basin experiences semiarid type of climate in all the stations of the basin.

Table No.2

WATER BALANCE ELEMENTS OF THE PENNAR BASIN (SUMMER)										
S.NO	Stations	P in MM	PE in MM	AE in MM	WD in MM	WS in MM	Ima in %	Ia in %	Im in %	CC
1	Allagadda	57	556	107	449	0	19	81	-48.6	D
2	Aluru	53	512	132	380	0	26	74	-44.4	D
3	Atmakur(ATP)	34	500	69	431	0	14	86	-51.6	D
4	Anantapur	75	503	98	405	0	20	80	-48	D
5	Badvel	67	632	120	512	0	19	81	-48.6	D
6	Bagepalli	110	449	167	282	0	37	63	-37.8	D
7	Bangarupalem	80	462	176	286	0	38	62	-37	D
8	Bukkapatnam	79	518	97	421	0	19	81	-48.6	D
9	Chandragiri	66	506	133	373	0	26	74	-44	D
10	Chick Ballapur	122	455	168	287	0	37	63	-37.8	D
11	Cuddapah	60	623	108	515	0	17	83	-49.8	D
12	Darmavaram	73	535	82	453	0	15	85	-51	D
13	Dhone	55	510	111	399	0	21	79	-46.8	D
14	Giddalur	55	552	122	430	0	22	78	-46.8	D
15	Guduru	110	580	201	379	0	34	66	-39.6	D
16	G.Bramheswaram	90	510	210	300	0	41	59	-35.4	D
17	Gooty	69	509	128	381	0	25	75	-45	D
18	Gowri Bindanur	115	458	169	289	0	37	63	-37.8	D
19	Hindupur	98	497	148	349	0	30	70	-42	D
20	Isakapalli	104	542	209	333	0	39	61	-36.6	D
21	Jammalamadugu	68	615	102	513	0	17	83	-49.8	D
22	Atmakur	60	538	104	434	0	19	81	-48.6	D
23	Kadiri	83	514	115	399	0	22	78	-46.8	D
24	Kalahasti	46	498	129	369	0	26	74	-44	D
25	Kalyandrug	82	508	117	391	0	23	77	-46.2	D
26	Kamalapuram	56	610	118	492	0	19	81	-48.6	D
27	Kavali	71	628	187	441	0	30	70	-42	D
28	Koilkuntla	83	524	115	409	0	22	78	-46.8	D
29	Krishna Patnam	100	542	229	313	0	42	58	-34.8	D
30	Kuderu	36	492	105	387	0	21	79	-47.4	D
31	Madakasira	106	492	162	330	0	33	67	-40.2	D
32	Madanapalli	86	482	186	296	0	39	61	-37	D
33	Nandikotkur	65	536	101	435	0	19	81	-48.6	D
34	Nandyal	63	543	117	426	0	21	79	-46.8	D
35	Nellore	86	580	198	382	0	34	66	-39.6	D
36	Atmakur(Nellore)	120	606	224	382	0	37	63	-37.8	D
37	P. Ahobilam	67	533	185	348	0	35	65	-39	D
38	Pathikonda	55	516	111	405	0	22	78	-47.4	D
39	Pavagada	100	446	156	310	0	33	67	-40.2	D
40	Penukonda	87	502	134	370	0	27	73	-43.8	D
41	Proddutur	63	611	100	511	0	16	84	-50.4	D
42	Pulivendula	70	604	113	491	0	19	81	-48.6	D
43	Punganur	88	469	184	284	0	39	61	-37.2	D
44	Rajampet	75	623	133	490	0	21	79	-47.4	D
45	Rapur	130	623	220	403	0	35	65	-39.0	D
46	Rayachoti	72	592	118	474	0	20	80	-48	D

47	Rayadurg	85	490	116	374	0	24	76	-45.6	D
48	Sidhout	69	623	147	476	0	24	76	-45.6	D
49	Srisailam	80	502	208	296	0	41	59	-35.4	D
50	Tadipatri	76	542	127	415	0	23	77	-46.2	D
51	Tumkur	131	459	163	310	0	35	65	-39.0	D
52	Udaygiri	156	621	235	386	0	38	62	-37.2	D
53	Uravakonda	78	518	129	389	0	25	75	-45	D
54	Vailpadu	71	524	137	390	0	26	74	-44	D
55	Yadiki	54	539	105	434	0	19	81	-48.6	D

P: Precipitation, PE: Potential evapotranspiration, AE: Actual evapotranspiration, WD: Water deficit WS: Water surplus, Ima: Moisture adequacy Index, Ia: Aridity index, CC: Climatic classification, A: Per Humid, B1-B4: Humid,C1: Dry sub-humid, C2: Moist sub-humid, D: Semiarid, E: Arid.

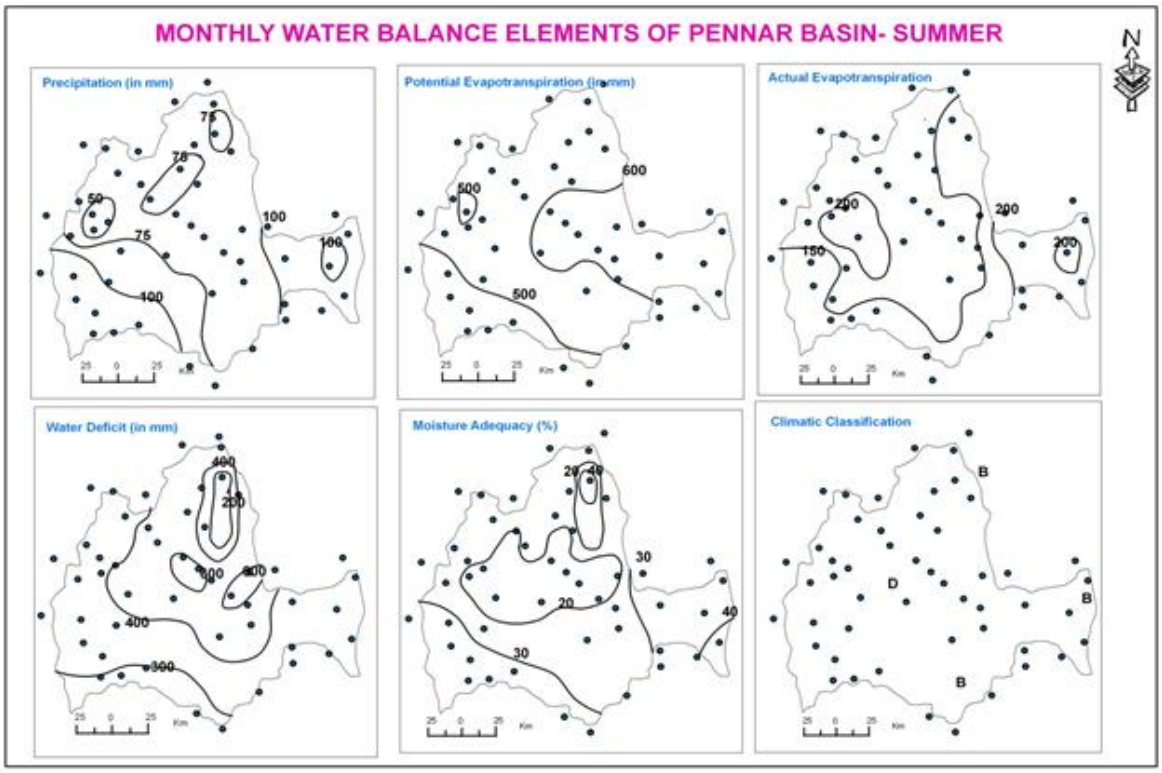

Fig.2

SOUTHWEST MONSOON PERIOD

During the southwest monsoon period the values of potential evapotranspiration (PE) vary from 511mm to 734mm. The average PE value is 607mm. The spatial distribution shows that the PE value is less than 600mm in the southwestern, central and northeastern parts of basin. The PE values vary from 600mm to 700mm in the northern, western, central and southern parts of the basin. The PE values exceed 700mm in the eastern part of the basin. (Fig:3 & Table.3). The actual evapotranspiration (AE) ranges from 261mm to 564mm. The average AE value is 366mm. The AE value is less than 300mm in the western part of the basin. The AE values ranges from 300mm to 400mm in the central and eastern parts of the basin. The AE value is more than400mm in the northeastern and eastern part of the basin. Only two stations have the water surplus in the basin during the southwest monsoon period. They are Gundla Bramheswaram and Srisailam. There is water deficit (WD) in the southwest monsoon period. It ranges from 61mm to 423mm. The average WD is 241mm in the basin. The spatial distribution shows that the WD values are less than 200mm in the northeastern, southwestern and central parts of the basin. The WD values range from 200mm to 300mm in the central, northern and southeastern parts of the basin and more than 300mm in the eastern part of the basin. The moisture adequacy (Ima) value during southwest monsoon period varies from 42% to 100%. The average moisture adequacy is 60% in the basin. The spatial distribution shows that Ima is less than 50% in the western and eastern parts of the basin. The Ima value ranges from 50% to 60% in western and central parts of the basin. It varies from and 60% to 80% in the northern and northeastern parts of the basin. Climatologically during southwest monsoon period the basin experiences dry sub-humid type in majority of the stations and in a few stations semiarid type of climate is noticed.

Table No.3

WATER BALANCE ELEMENTS OF THE PENNAR BASIN (SOUTH WEST MONSOON)

S.NO	Stations	P in MM	PE in MM	AE in MM	WD in MM	WS in MM	Ima in %	Ia in %	Im in %	CC
1	Allagadda	497	683	475	208	0	69	31	-18.6	C1
2	Aluru	370	609	361	248	0	59	41	24.6	C1
3	Atmakur(ATP)	201	595	277	318	0	47	53	-31.8	C1
4	Anantapur	314	603	313	290	0	52	48	-28.8	C1
5	Badvel	373	599	377	222	0	63	37	-22.2	C1
6	Bagepalli	347	520	356	164	0	68	32	-19.2	C1
7	Bangarupalem	221	539	357	182	0	66	34	-20.4	C1
8	Bukkapatnam	362	636	355	281	0	55	45	-27.0	C1
9	Chandragiri	407	637	416	221	0	65	35	-21.0	C1
10	Chick Ballapur	356	521	358	163	0	68	32	-19.2	C1
11	Cuddapah	459	610	446	164	0	73	27	-16.2	C1
12	Darmavaram	302	665	321	344	0	48	52	-31.2	C1
13	Dhone	346	584	350	234	0	60	40	-24.0	C1
14	Giddalur	322	584	355	229	0	60	40	+24.0	C1
15	Guduru	300	666	312	354	0	47	53	31.8	C1
16	G.Bramheswaram	751	506	476	0	245	100	0	+29.4	B1
17	Gooty	360	603	362	246	0	60	40	-24.0	C1
18	Gowri Bindanur	341	525	364	161	0	69	31	-18.6	C1
19	Hindupur	321	566	315	251	0	55	45	-27.0	C1
20	Isakapalli	293	734	311	423	0	42	58	-34.8	D
21	Jammalamadugu	371	586	363	223	0	62	38	-22.8	C1
22	Atmakur	581	639	564	75	0	88	12	-7.2	C1
23	Kadiri	334	610	340	270	0	58	42	-25.2	C1
24	Kalahasti	345	625	356	269	0	57	43	-25.8	C1
25	Kalyandrug	274	607	290	317	0	48	52	-31.2	C1
26	Kamalapuram	392	578	394	184	0	68	32	-19.2	C1
27	Kavali	302	731	308	423	0	42	58	-34.8	D
28	Koilkuntla	392	652	399	253	0	61	39	-23.4	C1
29	Krishna Patnam	333	734	360	374	0	49	51	30.6	C1
30	Kuderu	203	601	261	340	0	43	57	-34.2	D
31	Madakasira	286	557	292	265	0	52	48	-28.8	C1
32	Madanapalli	350	598	364	204	0	64	36	-21.6	C1
33	Nandikotkur	484	644	486	158	0	75	25	-15.0	C1
34	Nandyal	537	677	516	161	0	76	24	-14.4	C1
35	Nellore	304	666	314	352	0	47	53	-31.8	C1
36	Atmakur(Nellore)	266	699	284	415	0	41	59	-35.4	D
37	P. Ahobilam	597	619	558	61	0	90	10	-6.0	C1
38	Pathikonda	394	618	379	239	0	61	39	-23.4	C1
39	Pavagada	275	541	333	208	0	61	39	-23.4	C1
40	Penukonda	349	598	316	282	0	53	47	-28.2	C1
41	Proddutur	395	584	394	190	0	67	33	-19.8	C1
42	Pulivendula	333	570	333	237	0	58	42	-25.2	C1
43	Punganur	395	549	400	149	0	73	27	-16.2	C1
44	Rajampet	349	591	354	237	0	60	40	-24.0	C1
45	Rapur	295	611	305	306	0	50	50	-30.0	C1
46	Rayachoti	349	551	350	201	0	63	37	-22.2	C1
47	Rayadurg	262	511	289	222	0	57	43	-25.8	C1
48	Sidhout	449	591	445	146	0	75	25	-15.0	C1
49	Srisailam	681	489	456	0	192	100	0	+23.4	B1
50	Tadipatri	336	667	368	299	0	55	45	-27.0	C1
51	Tumkur	343	527	353	174	0	67	33	-19.8	C1
52	Udaygiri	290	651	302	349	0	46	54	-32.4	C1
53	Uravakonda	313	621	320	301	0	51	49	-29.4	C1
54	Vailpadu	375	647	383	264	0	59	41	24.6	C1
55	Yadiki	325	658	351	307	0	53	47	-28.2	C1

P: Precipitation, PE: Potential evapotranspiration, AE: Actual evapotranspiration, WD: Water deficit WS: Water surplus, Ima: Moisture adequacy Index, Ia: Aridity index, CC: Climatic classification, A: Per Humid, B1-B4: Humid,C1: Dry sub-humid, C2: Moist sub-humid, D: Semiarid, E: Arid.

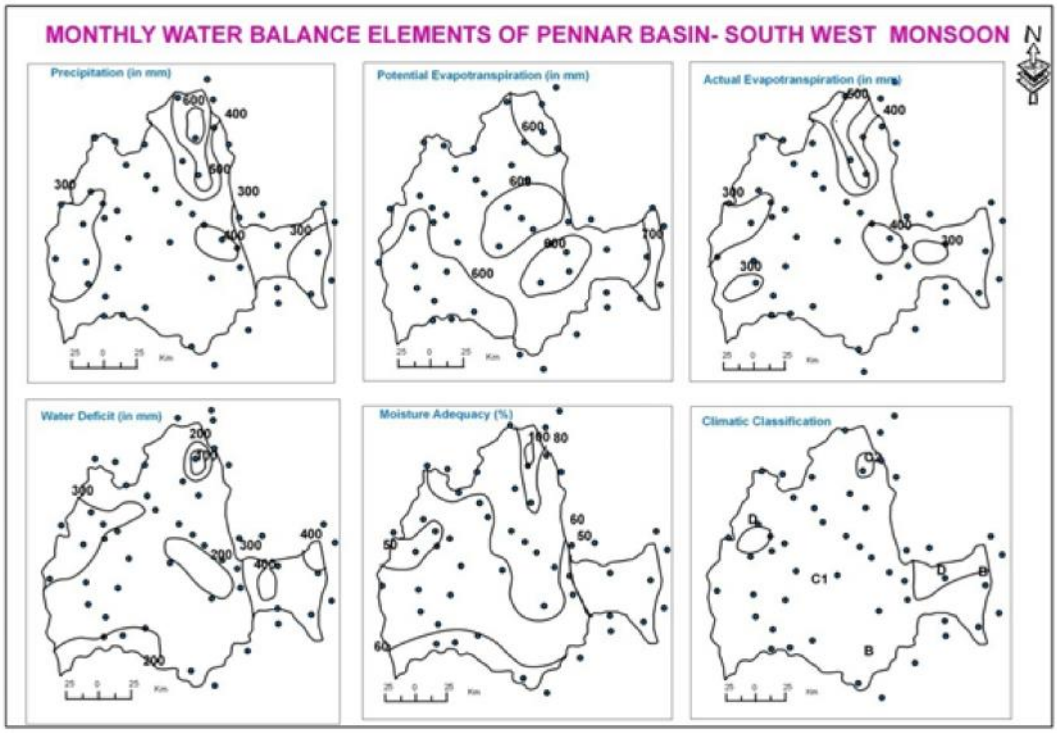

Fig.3

NORTHEAST MONSOON PERIOD

During the northeast monsoon period the values of potential evapotranspiration (PE) vary from 231mm to 393mm. The average PE value is 309mm. The spatial distribution shows that the PE value is less than 300mm in the southwestern, western and northeastern parts of basin. The PE values vary from 300mm to 350mm in the northern and central parts of the basin. The PE values exceed 350mm in the eastern and northern parts of the basin. (Fig: 4 & Table. 4). The actual evapotranspiration (AE) ranges from 170mm to 393mm. The average AE value is 283mm. The AE value is less than 250mm in the southwestern, western and northwestern parts of the basin. The AE values range from 250mm to 300mm in the northern and central parts of the basin. The AE value is more than 350mm in the eastern and northeastern parts of the basin. There is water surplus in the northeastern and eastern parts of the basin during northeast monsoon period. The water surplus varies from 31mm to 434mm. The average water surplus is 54mm. The water deficit is low (WD) in the northeast monsoon period. It ranges from 02mm to 144mm. The average WD is 26mm in the basin. The WD is found in the western, southern, northern and central parts of the basin. The moisture adequacy (Ima) values during northeast monsoon period vary from 55% to 100%. The average moisture adequacy is 92% in the basin. The spatial distribution shows that Ima is less than 75% in western part of the basin. The Ima value ranges from 75% to 100% in the northern and central parts of the basin. The Ima value is 100% in the northeastern, eastern and southern parts of the basin. Climatologically during northeast monsoon period the basin experiences dry sub-humid type of climate in majority of the stations and in a few stations in the northeastern, eastern and southwestern parts of the basin the humid and moist sub-humid type of climate is found.

Table No.4

WATER BALANCE ELEMENTS OF THE PENNAR BASIN (NORTH EAST MONSOON)										
S.NO	Stations	P in MM	PE in MM	AE in MM	WD in MM	WS in MM	Ima in %	Ia in %	Im in %	CC
1	Allagadda	149	370	311	59	0	84	16	-9.6	C1
2	Aluru	147	286	286	0	0	100	0	0	C2
3	Atmakur(ATP)	101	310	170	140	0	55	45	-27.0	C1
4	Anantapur	144	329	266	63	0	81	19	-11.4	C1
5	Badvel	290	337	329	8	0	98	2	-1.2	C1
6	Bagepalli	213	221	221	0	0	100	0	0	C2
7	Bangarupalem	320	245	245	0	75	100	0	+31	B1
8	Bukkapatnam	167	290	242	48	0	83	17	-10.2	C1
9	Chandragiri	430	366	366	0	64	100	0	+17	C2
10	Chick Ballapur	213	224	224	0	0	100	0	0	C2
11	Cuddapah	235	333	315	18	0	94	6	-3.6	C1
12	Darmavaram	144	317	235	82	0	74	26	-15.6	C1
13	Dhone	129	279	246	33	0	88	12	-7.2	C1
14	Giddalur	253	279	279	0	0	100	0	0	C2
15	Guduru	717	361	361	0	356	100	0	+98.6	B4

16	G.Bramheswaram	407	280	280	0	127	100	0	+45	B2
17	Gooty	135	278	245	33	0	88	12	-7.2	C1
18	Gowri Bindanur	204	227	227	0	0	100	0	0	C2
19	Hindupur	156	246	229	17	0	93	7	-4.2	C1
20	Isakapalli	646	393	393	0	253	100	0	+64.3	B3
21	Jammalamadugu	166	332	293	39	0	88	12	-7.2	C1
22	Atmakur	177	337	289	48	0	86	14	+8.4	C1
23	Kadiri	189	278	245	33	0	88	12	-7.2	C1
24	Kalahasti	790	356	356	0	434	100	0	+121.9	A
25	Kalyandurg	151	281	242	39	0	86	14	-8.4	C1
26	Kamalapuram	180	326	295	31	0	90	10	-6.0	C1
27	Kavali	612	384	384	0	228	100	0	+59.37	B2
28	Koilkuntla	172	335	287	48	0	86	14	-8.4	C1
29	Krishna Patnam	743	393	393	0	310	100	0	+85.8	B4
30	Kuderu	106	319	175	144	0	55	45	-27.0	C1
31	Madakasira	161	239	228	11	0	95	5	-3.0	C1
32	Madanapalli	298	243	243	0	55	100	0	+23	B1
33	Nandikotkur	111	335	261	74	0	78	22	-13.2	C1
34	Nandyal	156	357	302	25	0	84	16	-9.6	C1
35	Nellore	671	361	361	0	310	100	0	+85.8	B4
36	Atmakur(Nellore)	499	364	364	0	135	100	0	+37.08	B2
37	P. Ahobilam	384	316	316	0	68	100	0	+22	B1
38	Pathikonda	147	288	257	31	0	89	11	-6.6	C1
39	Pavagada	169	239	222	17	0	93	7	-4.2	C1
40	Penukonda	169	263	245	18	0	93	7	-4.2	C1
41	Proddutur	167	327	285	42	0	87	13	-7.8	C1
42	Pulivendula	192	322	293	29	0	91	9	-5.4	C1
43	Punganur	310	235	235	0	75	100	0	+32	B1
44	Rajampet	301	333	329	4	0	99	1	-0.6	C1
45	Rapur	628	333	333	0	295	100	0	+37.08	B1
46	Rayachoti	240	309	304	5	0	98	2	-1.2	C1
47	Rayadurg	150	284	237	47	0	83	17	-10.2	C1
48	Sidhout	302	333	331	2	0	99	1	-0.6	C1
49	Srisailam	293	262	262	0	31	100	0	+12	C2
50	Tadipatri	126	345	261	84	0	76	24	-14.4	C1
51	Tumkur	208	231	231	0	0	100	0	0	C2
52	Udaygiri	507	370	370	0	137	100	0	+37	B2
53	Uravakonda	127	291	248	43	0	85	15	-9.0	C1
54	Vailpadu	323	365	365	0	0	100	0	0	C2
55	Yadiki	107	333	254	79	0	76	24	-14.4	C1

P: Precipitation, PE: Potential evapotranspiration, AE: Actual evapotranspiration, WD: Water deficit WS: Water surplus, Ima: Moisture adequacy Index, Ia: Aridity index, CC: Climatic classification, A: Per Humid, B1-B4: Humid,C1: Dry sub-humid, C2: Moist sub-humid, D: Semiarid, E: Arid.

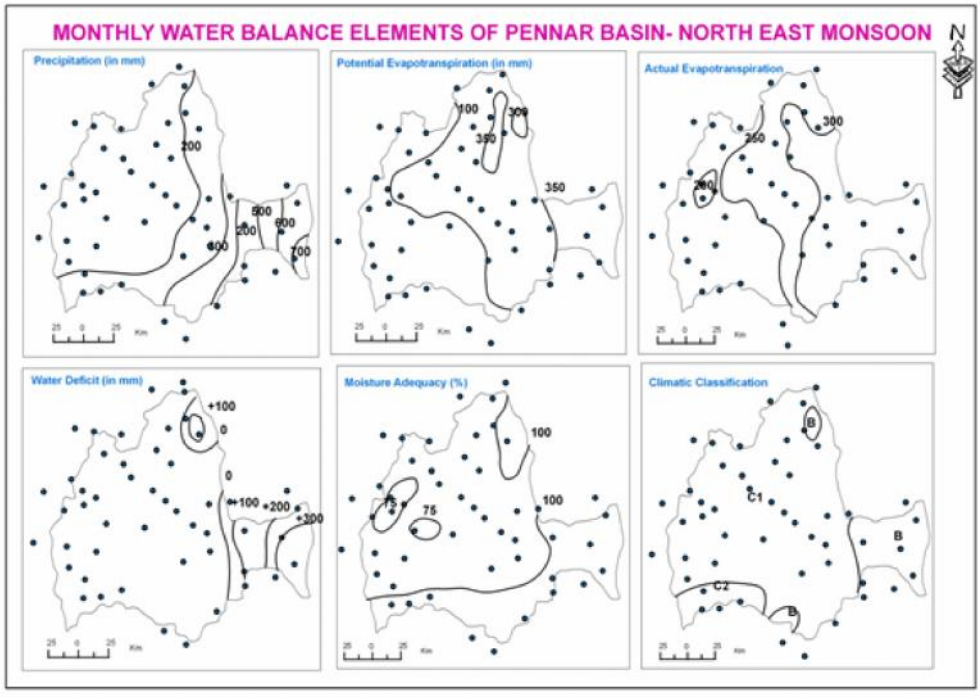

Fig.4

From the analysis of seasonal water balance elements it is found that the average PE value is high (607mm) in southwest monsoon period followed by summer (535mm), northeast monsoon (309) and winter (218mm). The average AE value is found high (366mm) in southwest monsoon, followed by northeast monsoon (283mm), summer (143mm) and winter (107mm). The average water deficit is high (392mm) in summer period followed by 241mm in southwest monsoon period, 111mm in winter period and 26mm in northeast monsoon period. There is no water surplus. Water surplus is found in a few stations in the northeastern part of the basin in Nallamalai hills. In northeast and eastern monsoon period the water surplus is found in northeast part of the basin. The average Ima is high (92%) in northeast monsoon period, followed by 60% in southwest monsoon, 49% in winter period and 27% in summer period. The average Aridity Index value is high (73%) in summer period followed by 51% in winter period, 40% in southwest monsoon and 8% in northeast monsoon period. Climatologically the basin experiences dry sub-humid type of climate in winter, southwest and northeast monsoon periods and semiarid type of climate in summer period.

ANNUAL

The annual the potential evapotranspiration (PE) varies from 1351mm to 1834mm. The average PE value is 1633mm. The spatial distribution shows that the PE value is less than 1400mm in the southwestern and northeastern parts of basin. The PE values vary from 1400mm to 1500mm in the western and northeastern parts of the basin. The PE values range from 1500mm to 1700mm in the central northeastern and northwestern parts of the basin. The PE values exceed 1700mm in eastern and central parts of the basin. (Fig: 5 & Table. 5). The actual evapotranspiration (AE) ranges from 713mm to 1190mm. The average AE value is 869mm. The AE value is less than 800mm in the western part of the basin. The AE values range from 800mm to 1000mm in the northern, central and southern parts of the basin. The AE value is more than 1000mm in the northeastern and southeastern parts of the basin. There is no annual water surplus in this basin. The average annual water deficit (WD) ranges from 370mm to 1088mm in the Pennar basin. The average WD is 764mm in the basin. The WD is less than 700mm in the southwestern and northeastern parts of the basin.The WD varies from 700mm 800mm in the central, northeastern and eastern parts of the basin. The annual moisture adequacy (Ima) values range from 34% to 74%. The average moisture adequacy is 54% in the basin. The spatial distribution shows that Ima is less than 50% in the western and central parts of the basin. The Ima value ranges from 50% to 60% in the northern and eastern parts of the basin. The Ima value varies from 60% to 70% in the southern, southwestern, northern and eastern parts of the basin. It is more than 70% in the northeastern part of the basin. Climatologically the basin experiences dry sub-humid type in majority of the stations. The moist sub-humid type of climate is found in the northeastern part of the basin. The semiarid type of climate is noticed in the three stations in the western part of the Pennar basin

Table No.5

WATER BALANCE ELEMENTS OF THE PENNAR BASIN (ANNUAL)

S.NO	Stations	P in MM	PE in MM	AE in MM	WD in MM	WS in MM	Ima in %	Ia in %	Im in %	CC
1	Allagadda	713	1817	973	845	0	54	46	-23.2	C1
2	Aluru	580	1593	848	745	0	53	47	-28.2	C1
3	Atmakur(ATP)	340	1648	560	1088	0	34	66	-39.6	D
4	Anantapur	539	1657	735	922	0	44	56	-33.4	D
5	Badvel	741	1857	961	896	0	52	48	-23.8	C1
6	Bagepalli	675	1341	834	507	0	62	38	-22.8	C1
7	Bangarupalem	762	1396	802	594	0	57	43	-15	C1
8	Bukkapatnam	614	1634	746	888	0	46	54	-32.4	C1
9	Chandragiri	911	1737	1038	699	0	60	40	-17	C1
10	Chick Ballapur	698	1351	842	509	0	62	38	-22.8	C1
11	Cuddapah	763	1834	990	844	0	54	46	-26.7	C1
12	Darmavaram	525	1732	674	1058	0	39	61	-36.6	D
13	Dhone	538	1557	783	774	0	50	50	-30	C1
14	Giddalur	636	1675	900	775	0	57	43	-25.8	C1
15	Guduru	1127	1607	874	733	0	54	46	-27.6	C1
16	G.Bramheswaram	1270	1478	1100	378	0	74	26	+9.5	C2
17	Gooty	568	1562	808	754	0	52	48	-28.5	C1
18	Gowri Bindanur	668	1361	849	512	0	62	38	-22.8	C1
19	Hindupur	583	1471	769	702	0	52	48	-28.8	C1
20	Isakapalli	1043	1669	913	756	0	55	45	-27.0	C1
21	Jammalamadugu	611	1813	845	968	0	47	53	-31.3	C1
22	Atmakur	818	1737	1037	700	0	60	40	-24	C1
23	Kadiri	615	1582	779	803	0	49	51	-30.6	C1
24	Kalahasti	1190	1704	987	717	0	58	42	-22.7	C1
25	Kalyandrug	514	1580	713	867	0	45	55	-38	C1
26	Kamalapuram	634	1790	924	866	0	52	48	-28.6	C1
27	Kavali	985	1743	879	864	0	50	50	-30.0	C1
28	Koilkuntla	656	1747	883	855	0	51	49	-29.4	C1
29	Krishna Patnam	1176	1669	982	687	0	59	41	-24.6	C1
30	Kuderu	348	1655	581	1074	0	35	65	-39.0	D
31	Madakasira	571	1446	755	701	0	52	48	-28.8	C1
32	Madanapalli	749	1454	899	555	0	62	38	-17	C1
33	Nandikotkur	669	1735	915	809	0	53	47	-28.2	C1
34	Nandyal	763	1810	1020	801	0	56	44	-26.4	C1

35	Nellore	1061	1607	873	734	0	54	46	-27.6	C1
36	Atmakur(Nellore)	885	1669	872	797	0	52	48	-28.8	C1
37	P. Ahobilam	1060	1665	1190	475	0	71	29	-13.3	C1
38	Pathikonda	606	1614	827	787	0	51	49	-29.4	C1
39	Pavagada	549	1403	801	602	0	57	43	-25.8	C1
40	Penukonda	593	1536	772	764	0	50	50	-30	C1
41	Proddutur	630	1804	873	931	0	48	52	-31	C1
42	Pulivendula	604	1768	842	926	0	48	52	-30.8	C1
43	Punganur	801	1408	927	481	0	66	34	-14	C1
44	Rajampet	779	1834	959	875	0	52	48	-25	C1
45	Rapur	1053	1567	853	709	0	55	45	-27.0	C1
46	Rayachoti	671	1719	845	874	0	49	51	-29.9	C1
47	Rayadurg	502	1571	701	870	0	45	55	-33	C1
48	Sidhout	833	1834	1074	760	0	59	41	-22.4	C1
49	Srisailam	1070	1423	1055	370	0	74	26	+7.9	C2
50	Tadipatri	544	1778	830	948	0	47	53	-31.8	C1
51	Tumkur	689	1371	837	534	0	61	39	-23.4	C1
52	Udaygiri	953	1642	907	735	0	55	45	-27.0	C1
53	Uravakonda	524	1619	771	848	0	48	52	-31.2	C1
54	Vailpadu	781	1772	1008	764	0	57	43	-25	C1
55	Yadiki	485	1746	781	965	0	45	55	-33	C1

P: Precipitation, PE: Potential evapotranspiration, AE: Actual evapotranspiration, WD: Water deficit WS: Water surplus, Ima: Moisture adequacy Index, Ia: Aridity index, CC: Climatic classification, A: Per Humid, B1-B4: Humid,C1: Dry sub-humid, C2: Moist sub-humid, D: Semiarid, E: Arid.

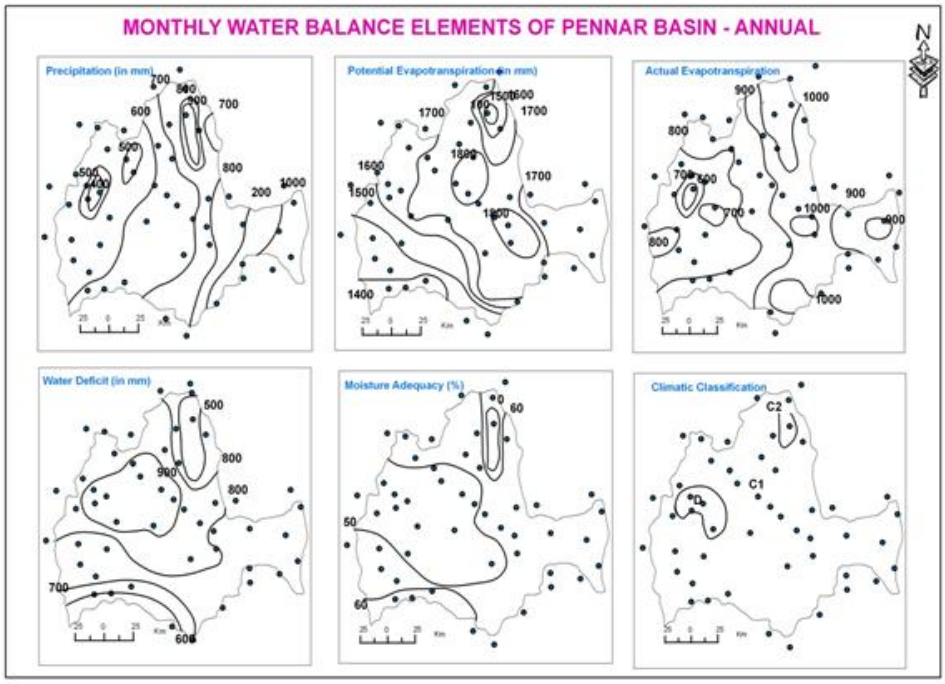

Fig.5

REFERENCES

1. *Bora, L.N., (1976): A study of water balance and drought climatology of Assam and the Vicinity. Unpublished Ph.D thesis submitted to Andhra University, Waltair*
2. *Chinnamani,S and Sakthivadivel,E(1982): "Report- an integrated study of hydrology of the Bhavani basin " center for water resources, college of Engineering, Guindy, Madras.*
3. *Gandhimathi,M.(1988): water balance, soil and soil moisture conditions for sustained growth of paddy in Thanjavur district. Tamilnadu, Unpublished M.phil, dissertation submitted to Bharatidasan University, Tiruchirapalli.*
4. *Gangadri.G. (1999) water balance, land use, cropping pattern and agricultural development of Chittoor district. Andhra Pradesh, India. Unpublished Ph.D. thesis submitted to S.K.University, Anantapr.pp.230.*
5. *Kalavathi,N.V. (1985): Land, water irrigation and Agricultural resources of Changalpattu district, Tamil Nadu. Unpublished M.Phil. dissertation submitted to Madurai Kamaraj University, Madurai. Pp.25.*
6. *Krishnaiah. Y.V (2004): water balance and watershed development of the Papagni river basin, Andhra Pradesh, India, using remote sensing and GIS techniques. Unpublished PhD thesis submitted to Sri Krishna Devaraya University, Anantapur.pp.270.*
7. *Madhuramma, C.H.(1992);water balance, water availability and crop management of the Nellore district, Andhra Pradesh. India. Unpublished thesis submitted to S.K.Univeristy, Anantapur.*

8. *Padmini.R.(1989) water balance land use efficiency and agricultural development of Athoor block, Anna district, Tamil Nadu. M.Phil, thesi, Madurai Kamaraj University, Madurai.*
9. *Raveendra.M (2013): Water balance, drought analysis and watershed development of the Anantapur district, Andhra Pradesh, India. Unpublished PhD thesis submitted to Sri Krishna Devaraya University, Anantapur.pp.247.*
10. *Thornthwaite, C.W. (1948): An approach toward a rational classification of climate, Geogr. Rev.vol.38.no.1. pp55-94.*
11. *Thornthwaite, C.W. and Mathur, J.R.(1955)The water balance Publication in climatology, Laboratory of climatology, centerton (NJ). Vol.8, no.1,pp104.*