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Water Balance Estimation in the Papagni River Basin, India

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Abstract

Water balance of a region is related to applied climatology, hydrometeorology and agro-meteorology. Of all the climatic parameters rainfall is an important input, which controls the total cropped area in a region. Water balance estimation is essential to make agriculture sustainable in view of increasing population, domestic use, industrial purpose and agriculture activities. Hydrogeomorphologically, the Papagni river floodplain with a subsurface cover of recent alluvium with a mix of gravel and calcareous tuff has an excellent ground water potential. Although, mean annual rainfall in the basin is 720mm, annual potential evapotranspiration, average annual actual evapotranspiration and the average annual water deficit are high and the basin primarily depends on rain for irrigation and agriculture. Any serious departure from the normal rainfall leads to a great stress. The current study focuses on the estimation of water balance from a huge rainfall database for stations in and around the basin.

Introduction

Water balance is a comparative study of water input in the form of rainfall and water loss in the formof evaporation and evapotranspiration. It is a part of applied climatology used for identification of water surplus and water deficit zones in a region or basin. The water balance studies (Shastri,1984; Subramanyam,1982 & 1956; Rao,1984; Subramanyam and Dhal, 1984;Ojo,1984) are applied in various fields like hydrology, agriculture, ecology and earth sciences. It is well established that water supply in a region is primarily through precipitation and water loss is entirely due to evaporation and evapotranspiration. The wetness and dryness of a region is determined by the magnitudes of water balance elements. India is a developing country where agriculture is the main economic activity. With increasing population and decreasing per capita availability of water there is a need for careful planning and utilization of water resources. Water balance plays a crucial role in the optimum utilization and conservation of water resources.

The major elements of water balance are rainfall and potential evapotranspiration. Rainfall is measured through rain gauge stations. Potential evapotranspiration can be measured directly only if pan evaporation and pan evapotranspiration instruments are installed. However, they are installed in few locations in India to measure evaporation and evapotranspiration (Penman, 1956). In India, the water balance methodology given by Thornthwaite and Mather (1955) has been used widely by Prof. Subramanyam (1956).

The studies of hydrometeorology and agro-meteorology are gaining importance in India in connection with conservation and optimum utilization of water resources (Ramamohan and Nair,1984). Water balance as a concept is finding an increasing application to the problems of water resources and agricultural development (Krishnaiah, 2013). With increasing population and decreasing per captia availability of water, optimum utilization and conservation of water resources have become problems of vital importance in which water balance plays a crucial role. Water balance method gives a highly realistic idea of the arid and wet conditions of the India. Water balance method is an investigation of quantities of water moving through the hydrological cycle (Subramanyam, 1983; Krishnaiah, 2010). Thornthwaite and Mather (1955) have evolved an elegant book keeping procedure for computing water balance parameters. They are precipitation, potential evapotranspiration, actual evapotranspiration, water surplus, water deficit, moisture adequacy, Aridity Index and Moisture Index. These elements play an important role in agriculture, water resources, forest resources and ecological studies. The major income is the precipitation and expenditure is the evaporation and evapotranspiration. The potential evapotranspiration is expressed as an exponential function of the mean, monthly temperature. Moisture input is a function of spatial temporal characteristics of precipitation. When precipitation and potential evapotranspiration are exactly equal in amount there is neither deficiency of moisture nor surplus for wasteful run-off. When the precipitation is greater than potential evapotranspiration, the humid climate prevails. When the potential evapotranspiration is greater than precipitation, the result is arid climate (Bora, 1984; Sharma, 2012; Thornthwaite, 1983). The relation between water surplus and water deficit constitute the index of the humidity. The index humidity is the ratio between water deficiency and water need. Moisture index is calculated by taking into account the seasonal and annual water surplus in counter ,acting the effects of drought through stored up soil moisture.(The)Rainfall is an important input for irrigation (Hargreaves, 1977; Kayastha et al, 1984) inrainfed areas in crop seasons. The main sources of irrigation aresurface water and ground water. For irrigation purpose water balance estimation plays a crucial role.

Study Area

The Papagni river basin (8250 km^2) is a sub basin of Pennar River. It is located between 13^0-20' to 14˚40′ N and 77˚50' to 78˚40' E (Fig.1). It covers the districts of Anantapur, Kadapa, and Chittoor of Rayalseema region in Andhra Pradesh and Kolar district of Karanataka. Geologically the major part of Papagni River is located in granitic terrain in the southern part and Proterozoic formations consisting of Vempalle dolomites and shales with basic intrusives and lava flows in the northern part of the basin.

Database and Methodology

To describe the surface water resource, recharge the water balance element,ground water and hydro-geological conditions of the Papagni basin, analysis is done through IRS 1B Geo-coded, LISS-III data, Survey of India Topography Sheets and aerial photographs on 1: 50,000. The water balance of the Papagni basin are delineated using mean rainfall, water stored in ponds, tanks and reservoirs, evaporation and evapotranspiration, run-off and water recharged to sub-surface. The information is generated on certain parameters such as water deficit, water surplus, moisture adequacy, aridity index and climatic classification adopting Thornthwaite and Mather (1955) book-keeping procedure. The work has been done for 16 stations in the basin on monthly, seasonal and annual basis taking the monthly and seasonal variations of actual evapotranspiration and potential evapotranspiration.The water balance elements of the Papagni basin are worked out on monthly, seasonal and annual basis taking mean monthly rainfall and mean monthly temperature over a period of 40 years (1969-2009), for sixteen rain gauge stations.

Analysis of Annual Rainfall

The mean annual precipitation varies from 544 mm in Tadipari station to a maximum 869 mm in Chintamani station (Table.–1). The average annual precipitation of the basin is 720 mm. Spatially the precipitation is less than 650 mm in northern and northeastern parts of the basin (Fig.2). It ranges from 650 mm to 850 mm in northern and southern parts of the basin. The annual potential evapotranspiration ranges from a minimum of 1407 mm in Chickbalapur station to a maximum of 1839 mm in Kadapa station. The average annual potential evapotranspiration of the basin is 1640 mm. The spatial distribution shows that the potential evapotranspiration values increase from 1500 mm to 1800 mm from southern to northeastern parts of the basin. The annual actual evapotranspiration values range from 779 mm in Kaditistation to a maximum of 1008 mm in Vayalpad station. The average annual actual evapotranspiration value of the basin is 893 mm. The spatial distribution shows that the actual evapotranspiration value increases from 850 mm in central part to 900 mm in northern and southern parts of the basin. The annual water deficit ranges from a minimum of 506 mm in Chickbalapur station to a maximum of 948 mm in Tadipatri station. The average annual water deficit of the basin is 747 mm. The spatial distribution shows that the water deficit increases from 600 mm to 900 mm from southern to northwestern parts of the basin. There is no annual water surplus in all the stations. The annual moisture adequacy values ranges from 47% in Tadipatri station to a maximum of 64% Chickbalapur, Chintamani and Siddlaghatta stations. The average annual moisture adequacy of the basin is 55%. The spatial distribution shows that the moisture adequacy increases from 50% to 60% from northwestern part to southern parts of the basin. The Aridity Index value of 36% is found in Chickbalapur, Chintamani and Siddlaghatta stations and the maximum of 52% is found in Proddatur and Pulivendala stations. The average Aridity Index value of the basin is 45%. The annual Aridity Index spatial distribution shows that it increases from 40% to 50% from southern to northwestern parts of the basin. Climatologically the Moisture Index values show dry sub-humid type of climate in all the stations of the Papagni basin.

Water Balance Graphs

The analyses of the water balance graphs reveal that in Bagepalle, Chintamani, Chickbalapur, Siddlaghatta and

Madanapalle stations there is water deficit from January to August. The water surplus is found in September, October, November and December months. Soil moisture use is found from January to May (Fig.3). The water deficit is found from January to August. It ranges from 506 mm in Chickbalapur station to maximum 565 mm in Madanapalle station. The average water deficit in these five stations from January to August is 525 mm. The water surplus ranges from 45 mm in Bagepalle station to a maximum of 57 mm in Chickbalapur station.

The average water surplus is 53 mm in these five stations from October to December months. In Mulakalcheruvu station (Fig.3) the water deficit is found from January to September. The total water deficit from January to September is 714 mm. In October and November months there is neither water surplus nor water deficit. In Galivedu, Kadiri, Kadapa, Kamalapuram, Rayachoti, Vayalpad and Tadipatri stations (Fig.3 & 4) there is water deficit from January to December months. However in Kadiri, Kadapa and Kamalapuram there is neither water deficit nor water surplus in October and November months. In Vayalpad and Rayachoti stations the water surplus is very low during October and November months. The water deficit is also found in Proddatur, Pulivendala and Vempalle stations (Fig.4). From the analysis of water balance graphs it is found that the northern and central parts of the basin experienced water deficit throughout the year. In northern and central parts of the basin the water deficit is very low during September, October and November months and very high during March, April, May and June months. In southern part of the basin water deficit is found from January to August and water surplus is found from September to December months.

Water Balance of the Papagni basin

1. Total surface of the water resources: = 5,940,000,000 m^3
2. Surface water resources stored in ponds, lakes, reservoirs etc = 594,000,000 m^3
3. Surface water resources recharged to ground water = 738,705,000 m^3
4. Surface run-off = 1,188,000,000 m^3
5. Waterloss through evaporation and evapotranspiration = 3,419,295,000 m^3

Conclusion

The annual water balance elements show that the basin receives the average annual rainfall of 720 mm. The mean annual potential evapotranspiration is 1640 mm. The mean annual actual evapotranspiration of the basin is 893 mm. The average annual water deficit is 747 mm. There is no water surplus in the basin. The mean annual moisture adequacy value is 55% and aridity index value is 45%. Climatologically the basin experiences dry sub-humid type of climate. From the analysis of water balance of the Papagni basin it transpires that, out of the total surface water resources of 5,940,000,000 m^3 about 10% is stored in surface lakes, ponds, reservoirs etc., 12.43% recharged to the ground water, 20% is lost in the form of surface run-off and 57.57% in lost in the form of evaporation and evapotranspiration. The water lost in the form of surface run-off has to be stored adopting watershed management programmes in the basin by constructing check dams, percolation ponds and water harvesting structures.

The basin experiences high water deficit due to low rainfall and high loss of water due to evaporation and evapotranspiration. The majority of the farmers in Papagni river basin hold less than five hectares of land. They are illiterate and do not have knowledge of modern technological equipmentin agricultural and irrigation sectors. The farmers have to be educated about the advantages of the use of high yield varieties of crops, optimum use of fertilizers, pesticides, bio-fertilizers and use of credit facilities in nationalized bank. To adopt one village in each mandal for development of modern irrigation, practices like sprinkler, drip and trickle irrigation has to be practised. Finally the optimum utilization of land and water resources could be carried out by adoptation of micro watershed management programmes in the Papagni River basin. Therefore, to avoid the scarcity of water in the basin it becomes mandatory to harvest every drop of rain water for domestic use and agriculture activities.

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Table - 1: Water Balance Elements of the Papagni River Basin (Annual)

S. No.	*Station*	P (mm)	PE (mm)	AE (mm)	WD (mm)	WS (mm)	Ima (%)	Ia (%)	Im (%)	CC
1	Bagepalli	814	1428	893	535	0	63	37	-22.2	C1
2	Chikabalapur	853	1407	901	506	0	64	36	-21.6	C1
3	Chintamani	869	1420	908	512	0	64	36	-21.6	C1
4	Galivedu	645	1653	816	837	0	51	49	-29.4	C1
5	Kadapa	763	1839	990	844	0	54	46	-26.7	C1
6	Kadiri	615	1582	779	803	0	49	51	-30.6	C1
7	Kamalapuram	635	1790	924	866	0	52	48	-28.6	C1
8	Madanapalle	749	1454	899	555	0	62	38	-17.0	C1
9	Mulakalacheruvu	800	1604	953	651	0	59	41	-24.6	C1
10	Proddatur	632	1804	873	931	0	48	52	-31.0	C1
11	Pulivendala	604	1768	842	926	0	48	52	-30.8	C1
12	Rayachoti	671	1719	845	874	0	49	51	-29.9	C1
13	Siddlaghatta	860	1413	904	509	0	64	36	-21.6	C1
14	Tadipatri	544	1778	830	948	0	47	53	-31.8	C1
15	Vayalpad	778	1772	1008	764	0	57	43	-25.0	C1
16	Vempalle	688	1807	920	887	0	51	49	-29.4	C1

Source: Compiled by the Author

P = Precipitation, PE = Potential Evapotranspiration, AE = Actual Evapotranspiration, WD = Water Deficit, WS = Water Surplus, Ima = Moisture Adequacy, Ia = Aridity Index,
CC = Climatic Classification:
A: Per-humid, B1-b4: Humid, C1:Dry sub-humid, C2: Moist sub-humid, D: Semi arid, E: Arid.

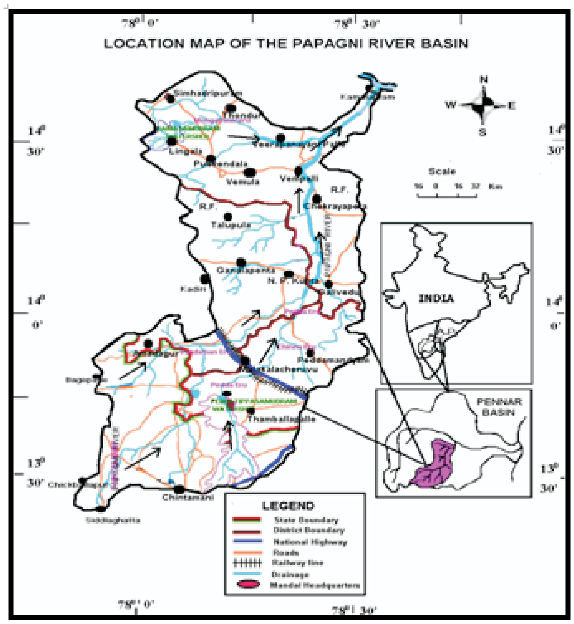

Fig. 1: Location Map of the Papagni River Basin

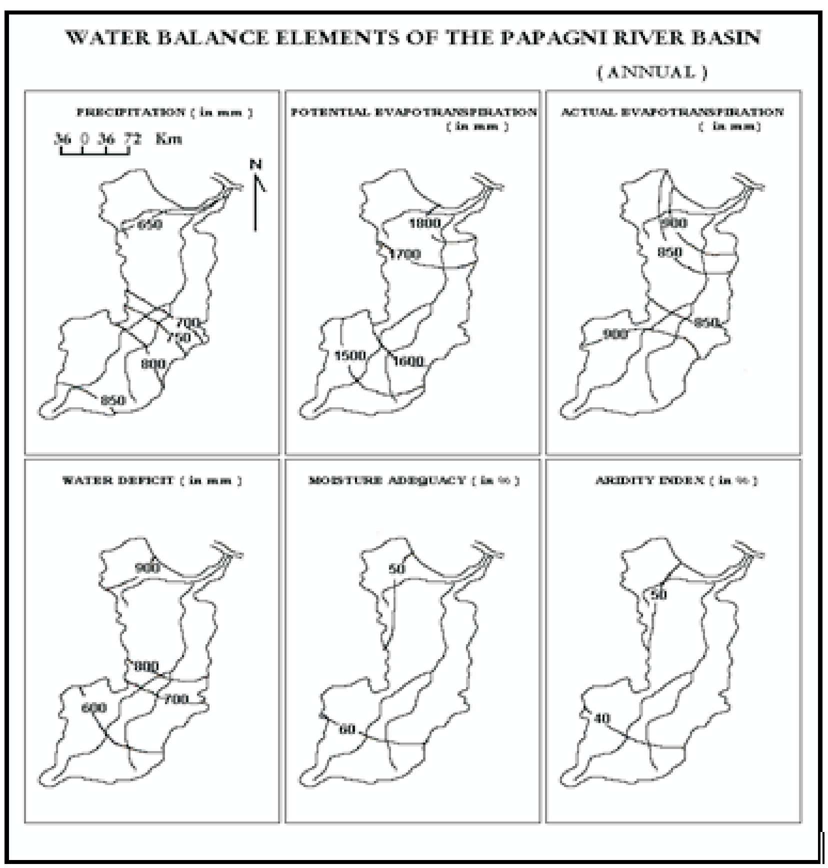

Fig. 2: Water Balance Elements of the Papagni River Basin

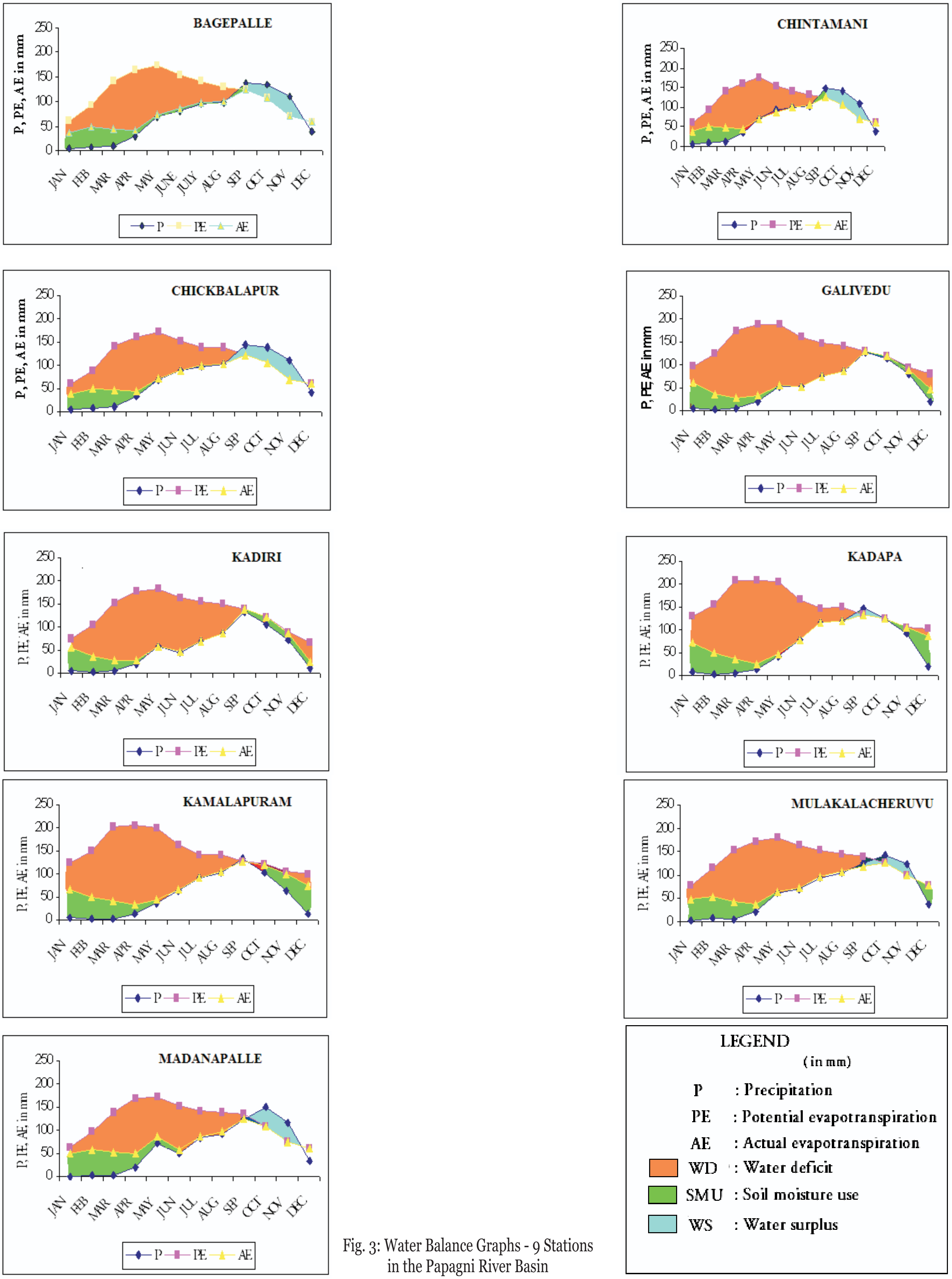

Fig. 3: Water Balance Graphs - 9 Stations in the Papagni River Basin

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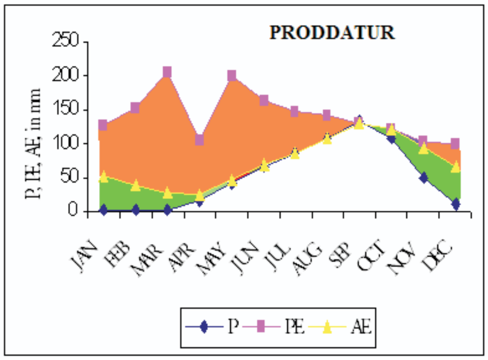

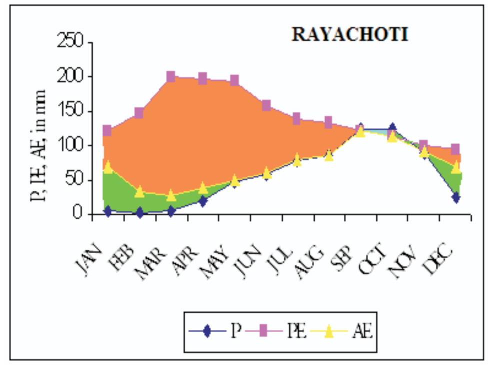

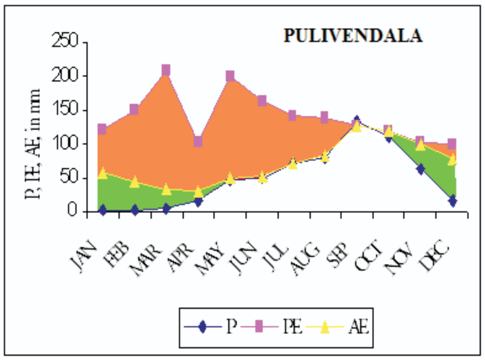

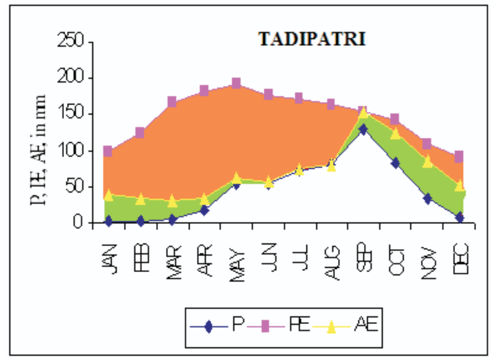

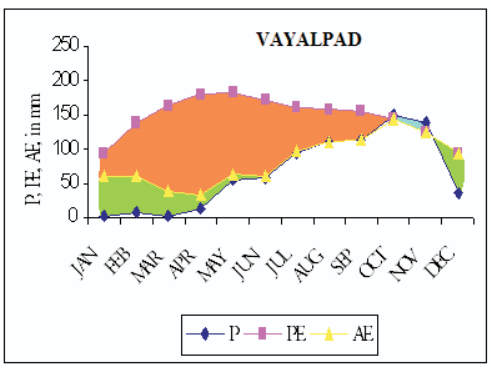

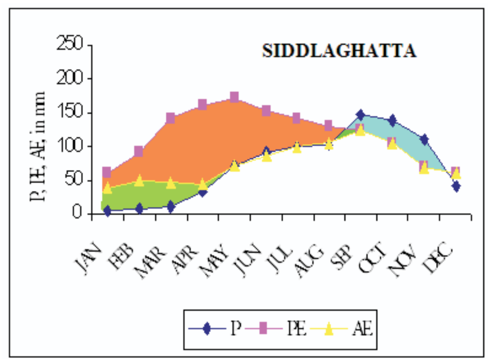

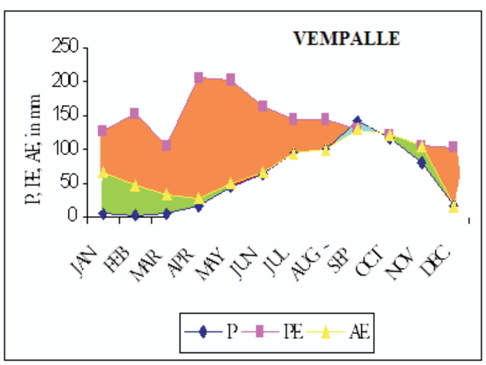

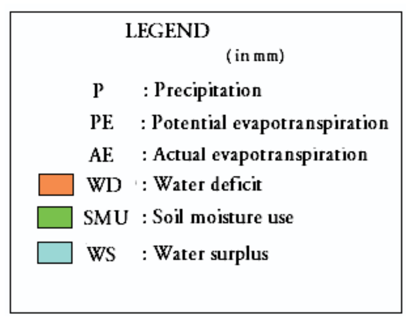

Fig. 4: Water Balance Graphs - 7 Stations in the Papagni River Basin

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