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Hydro-Climatic Assessment and Crop Planning for Semi-Arid Basins in Southern India

Dr A.Manjunath
MVSR Engineering College,
Hyderabad.

Sankara Lokeswari
Matrusri Engineering College,
Hyderabad.

Dr KVR Satya Sai
TKR College of Engineering &
Technology, Hyderabad.

Abstract - The Pandameru and Tadakaleru sub-basins, situated in the semi-arid region of southern India, experience limited annual rainfall (~537 mm) and high temperature variability, making them particularly vulnerable to droughts and agricultural stress. This study presents a hydro-climatic assessment and crop planning analysis based on water availability derived from actual and potential Evapo-transpiration (AE/PE) values across fourteen stations. The year is classified into four periods-Humid, Wet, Moderately Dry, and Dry-based on AE/PE ratios, following the method proposed by Raman and Srinivasa Murthy (1971).

Results reveal significant spatial and seasonal variation in water availability, with most areas receiving sufficient water for crop cultivation only between September and January. The southern and southeastern parts of the basin exhibit favorable conditions for double cropping under supplemental irrigation, while central and northern regions are suitable for a single crop during the Kharif season. Despite the critical role of irrigation, only 14.2% of the area is currently irrigated, predominantly through wells tapping into limited groundwater resources in fractured Archaean and Proterozoic formations.

The study underscores the importance of water availability calendars for guiding crop selection and scheduling. It recommends integrated watershed management, rainwater harvesting, and micro-irrigation techniques to enhance water use efficiency and agricultural sustainability. This research provides actionable insights for adaptive agricultural planning in drought-prone, water-scarce basins.

Study Area:

The study area is a part of Anantapur district. In this area there are three important rivers, namely Pandameru, Tadakaleru and Kuthaleru. The Pandameru and Tadakaleru rivers basin is a sub basin of Pennar river. It covers an area of about 2050.125 km^2. It is located in the part of Anantapur and a part of Tumkur district of Karnataka state. It is located between 14^0 15' to 14^0 57' 30" North latitude, 77^0 19' to 77^0 54' East Longitude (Fig 1).

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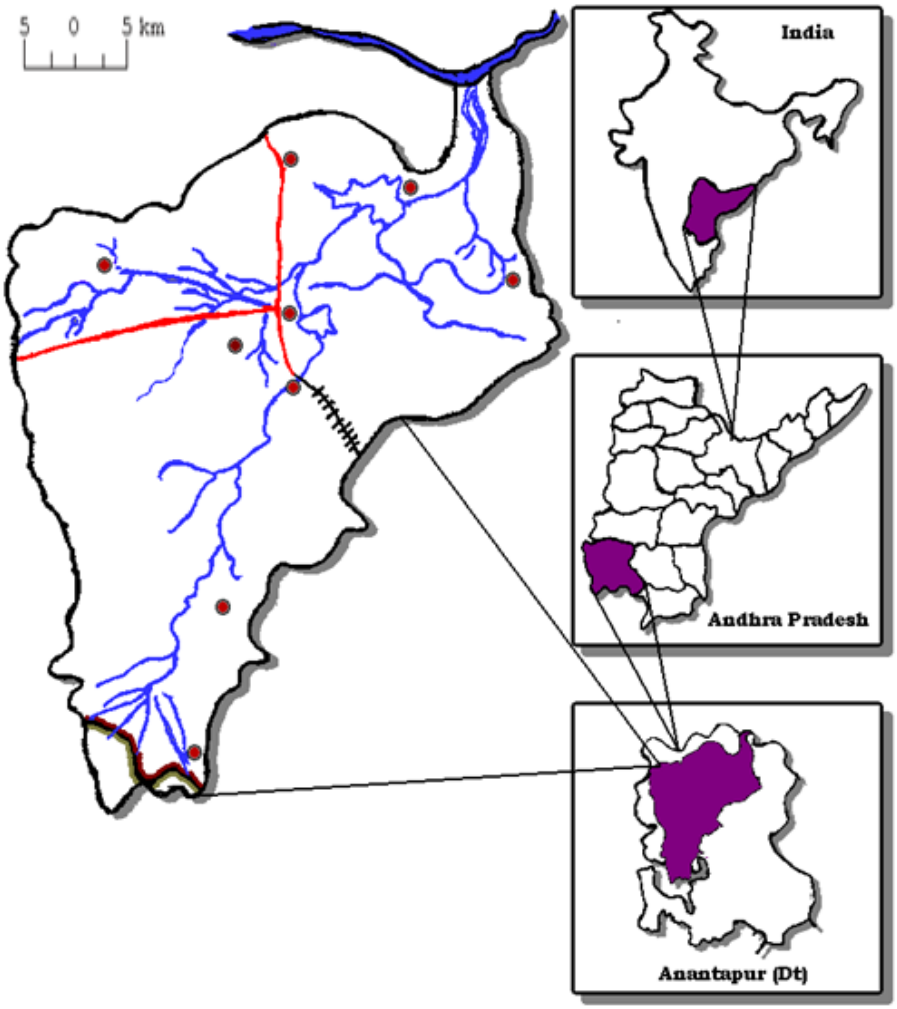

Fig 1: Location Map of the Pandameru and Tadakaleru River Basin

The Pandameru flows in the northern direction and meet the Anantapur tank. It flows a further northern direction and meet Tadakaleru at Neelampalli village. The Tadakaleru flows east taking a curve immediately by the side of an abandoned Arrack factory and almost flowing straight in the north and meeting the Singanamala tank. The Kuthaleru starts from Narpala and flows in the northern direction and meets Pandameru and Tadakaleru at Narsapuram village and join Pennar River at Ulikalu. There are about 10 mandals located in Anantapur and one taluk (Pavagada) in Karnataka state (Fig 3).

Climate:

The Pandameru and Tadakaleru basin lying of the coast does not enjoy the full benefit of the northeast monsoon and being cut-off by the high Western Ghats, the rainfall from the Southwest monsoon is also prevented. Thus, the basin is deprived of the both the monsoons and subjected to recurrent droughts and bad seasons.

Rainfall:

The average precipitation in the basin is 537 mm per annum, spread over four seasons as follows:

1.	Winter (Jan - Feb)	6.070	mm
2.	Summer (Mar - May)	77.142	mm
3.	South-West Monsoon (June - Sept)	312.357	mm
4.	North-East Monsoon (Oct - Dec)	141.286	mm
	Total	**536.855**	**mm**

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The analysis of the weekly rainfall of the basin indicates the probability of weekly rainfall of over 20 mm is highest in 38 to 39 weeks. But even then, the incidence is only 50%. In 47 weeks, out of 52 weeks, the probability of at least 10 mm of rainfall is less than 50%. In contrast, there is a 20% probability of weekly rainfall exceeding 50 mm occurring in most areas during many weeks of the growing seasons (June – September). Even higher rainfalls are not uncommon. In general, there is only about a 30% probability of weekly rainfall exceeding 20 mm and 20 to 30% probability of weekly rainfall of 50 mm or more during the main growing season. The analysis has relevance for crop scheduling or crop calendar.

Temperature:

The temperature varies from 16^0 to 42^0c. The coolest part of the year is November, December, January and February months. During the summer the temperatures raises up to 42^0c. With the onset of the southwest monsoon by about early June, the temperature drops. After the withdrawal of the southwest monsoon in the October, the temperature begins to decline gradually.

Humidity:

The period from February to May is the driest part of the year, when the relative humidity is 50% to 60% in the mornings and 20% to 30% in the afternoons. It goes up during the southwest monsoon and retreating monsoon seasons.

Geology:

Geological, the major part of the Pandameru and Tadakaleru rivers basin is located in granitic terrain in the southern part and schistose formation of Archaean group rock in south, west and northern part and Proterozoic formations in eastern part of the basin.

The water availability days and calendar of the Pandameru and Tadakaleru basin has been worked out for fourteen stations taking monthly potential Evapo-transpiration and actual Evapo-transpiration values. Raman and Srinivasa Murthy (1971) adopted this method. Based on the ratio of the actual Evapo-transpiration and potential Evapo-transpiration values the year has been divided into four periods. They are Humid Period (when AE = PE), Wet Period (when AE = 1/2th of the PE or more than 1/2th of the PE), Moderate Dry Period (when AE = 1/4th of the PE or more than 1/4th of the PE) and Dry Period (when AE = 1/8th of the PE or more than 1/8th of the PE).

Irrigation is generally defined as the artificial application of water to the plant needs. It is a farming practice designed to supplement deficiency arising out of evaporation and Evapo-transpiration over a region. Irrigation plays a crucial role in the process of agriculture and provides an important technological input for a stable and sustainable agricultural development.

Cropping pattern represents a special crop sequence in a given area at a particular point of time. It indicates the relative proportion of area under different crops at a given point of time. It is a complex and dynamic phenomenon. It reflects the diversified physical, socio-economic, technological and organization factors.

Water Availability Calendar:

The water availability days and calendar of the Pandameru and Tadakaleru basin has been worked out for fourteen stations taking monthly potential Evapo-transpiration and actual Evapo-transpiration values. Raman and Srinivasa Murthy (1971) adopted this method. Based on the ratio of the actual Evapo-transpiration and potential Evapo-transpiration values the year has been divided into four periods. They are Humid Period (when AE = PE), Wet Period (when AE = $1/2^{th}$ of the PE or more than $1/2^{th}$ of the PE), Moderate Dry Period (when AE = $1/4^{th}$ of the PE or more than $1/4^{th}$ of the PE) and Dry Period (when AE = $1/8^{th}$ of the PE or more than $1/8^{th}$ of the PE).

Humid Period:

In Humid period the water availability days vary from a minimum of 0 in Dharmavaram, Narpala, Pamidi, Rapthadu stations to a maximum of 61 days in Kanaganapalli, Ramagiri stations. The water availability days are 30 to 31 days in Anantapur, Atmakur, Garladinne and Uravakonda stations. The water availability days are 61 in Kanaganapalli and Ramagiri stations (Table). The spatial distribution shows that the water availability days vary from 0 to 61 days in Southeast, Eastern and Central parts of the

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basin. There is no water availability (no water surplus) in North, Northwest, Northeastern parts of the basin only 30 days in South 61 days.

Wet Period:

During wet period the water availability days vary from a minimum of 61 days in Kanaganapalli, Ramagiri stations to a maximum of 154 days in Gooty station. The water availability days vary from 92 to 122 in Anantapur, Atmakur, Garladinne, Kudair, Singanamala and Uravakonda stations. In Gooty station the water availability days are 154.

Moderately Dry Period:

During Moderately Dry Period the water availability days vary from a minimum of 120 days in Gooty station to a maximum of 182 days in Kanaganapalli, Pamidi, Ramagiri, Tadipatri and Uravakonda stations. The water availability days are 120 to 125 days in Gooty and Singanamala stations. In Anantapur, Atmakur, Garladinne and Rapthadu the water availability days are 154. In Narpala the water availability days are 153. In Kanaganapalli, Ramagiri, Tadipatri, Pamidi, Kudair and Uravakonda stations the water availability days during moderately dry period are 182.

Dry Period:

During Dry period the water availability days vary from 61 to 90 days. In Gooty, Kanaganapalli, Kudair, Pamidi, Ramagiri, Tadipatri and Uravakonda stations the water availability days are 61. In Anantapur, Atmakur, Dharmavaram, Garladinne, Ramagiri and Singanamala stations the water availability days are 89. In Narpala the water availability days are 90.

Water Availability Calendar:

The analysis of water availability months of the different periods of the Pandameru and Tadakaleru basin reveal that in Dharmavaram, Narpala, Pamidi and Rapthadu stations nil period. In Anantapur, Atmakur, Garladinne, Gooty, Kudair, Singanamala, Tadipatri and Uravakonda stations September is the only month present in Humid period. In Kanaganapalli and Ramagiri stations the water availability months found are September and October in Humid period.

Wet Period:

During Wet period October, November and December are noticed in Anantapur, Garladinne, Kudair, Singanamala, Tadipatri and Uravakonda stations. The January, August, October, November and December months are found in Wet period in Gooty station. The September, October, November and December months are found in Wet period in Dharmavaram, Narpala, Pamidi and Rapthadu stations. In Kanaganapalli and Ramagiri stations in Wet period there are two months, November and December.

Moderately Dry Period:

During Moderately Dry period in Anantapur, Atmakur, Dharmavaram, Garladinne, Narpala and Rapthadu stations there are five months, they are January, May, June, July and August months. In Gooty station Moderately Dry period in four months they are February, May, June and July months. The January, February, May, June, July and August months are found in Kanaganapalli, Kudair, Pamidi and Ramagiri stations. In Tadipatri and Uravakonda station Moderately Dry period in six months they are January, February, May, June, July and August. In Singanamala station Moderately Dry period found in four months they are January, May, June and July.

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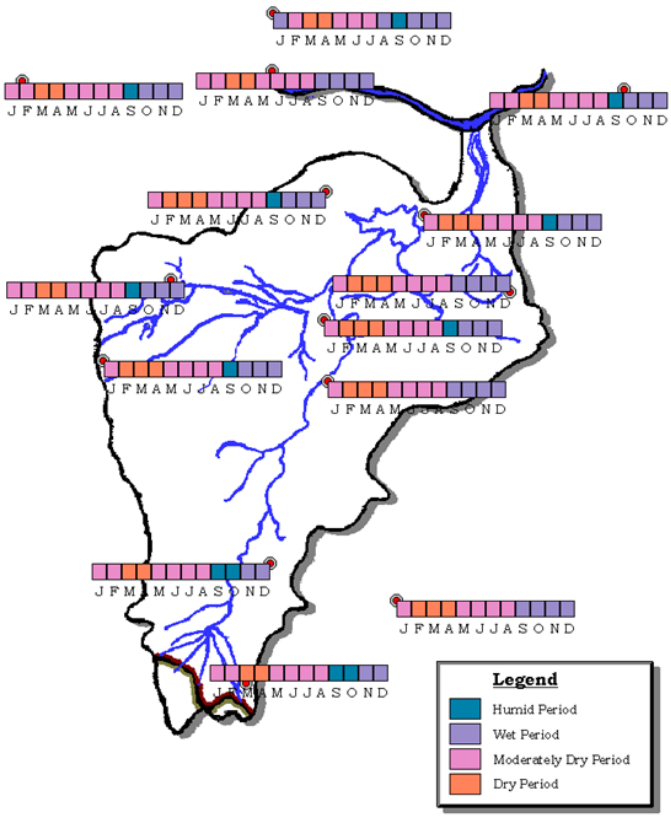

Fig 2: Water Availability Calendar of Pandameru and Tadakaleru River Basin

Dry Period:

In Anantapur, Atmakur, Dharmavaram, Garladinne, Narpala, Rapthadu, Singanamala stations there are three months dry period, they are February, March and April months. In Gooty, Kanaganapalli, Kudair, Pamidi, Ramagiri, Tadipatri and Uravakonda the dry period is only two months they are March and April months.

The analysis of water availability months in different periods of Pandameru and Tadakaleru basin depict that in Anantapur, Atmakur, Garladinne, Kanaganapalli, Singanamala, Tadipatri and Uravakonda stations there are four months with wet and humid periods in a year. In Gooty station there are six months wet and humid periods. In these stations crop cultivation is highly favorable during September, October, November, December and January months. In Dharmavaram, Narpala, Pamidi and Rapthadu stations there are four months with wet and dry period they are September, October, November and December months. In this stations only one crop can be cultivated under normal climatic conditions. The studies showed that in the South, Southeastern parts of the basin two crops could be cultivated during Kharif and Rabi seasons. In Central and Northern parts of the basin only one crop could be cultivated in Kharif season under normal climatic conditions.

Crop Suitability of the Pandameru and Tadakaleru Basin:

Based on water availability days and months in different periods of Pandameru and Tadakaleru basin it is found that the Southern parts of the basin covering Paragonda of Karnataka state, Ramagiri, Kanaganapalli, Anantapur, Dharmavaram, Kudair, Tadipatri, Uravakonda stations, there are four months in wet and humid periods. In Gooty station there are five months in wet and humid periods. In these stations crop cultivation is highly favorable during September, October, November, December and January months. One crop could be cultivated in Kharif season. The crops that could be cultivated are paddy, groundnut, redgram, fruits and vegetables plantation crops (mango, citrus, lemon etc.) oil seeds and dry food crops.

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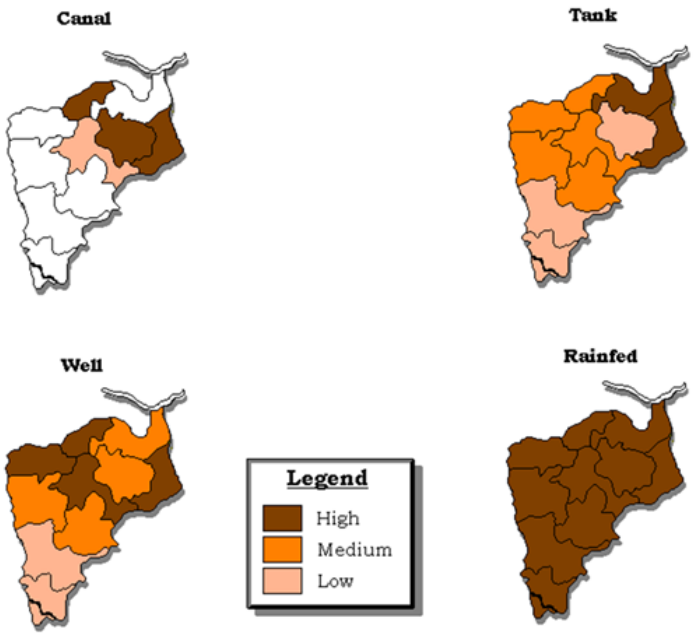

Fig 3: Irrigation Concentration of the Pandameru and Tadakaleru River Basin

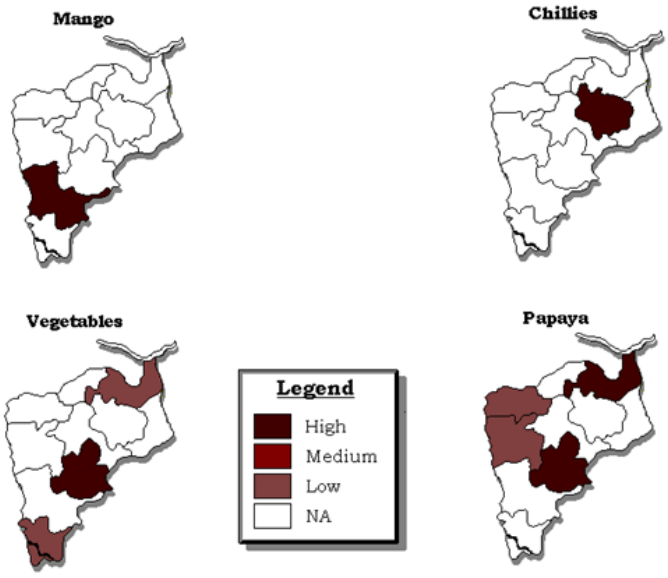

Fig 4: Cropping Concentration of the Pandameru and Tadakaleru River Basin

The total irrigated area under various sources of irrigation is 29233 hectares of land. It amounts 14.238% of the total geographical area of the basin. Out of this 6287 hectares area is under canal irrigation, 5026 hectares under tank irrigation and 17920 hectares under well irrigation. The intensity of irrigation is high in 7 mandals of the basin. The major crops cultivated are groundnut with intercropping of red gram. The total cropped area of the basin is 185377 hectares of the land. The water availability calendar shows September, October, November and December months fall under humid, wet period. They are highly favorable for crop cultivation. The water availability days in humid and wet period varies from 122 to 184 days, in moderately wet period 120 to 184 days and dry period ranges from 61 to 90 days. The January, May, June, July and August months fall under moderately dry period. Crop cultivation is favorable by providing irrigation facilities. The dry period of the basin is February, March and April months.

The total surface water resources of the basin are 1107927800 m^3. The total sub-surface water resources of the basin are 127189255 m^3. It accounts 11.47% of the total surface water resources. The average annual recharge of the basin is 54 mm. It amounts to 10.05% of the annual rainfall. The groundwater is found in weathered, jointed, fissures and fracture zones of Achaean

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rocks. The groundwater in Proterozoic formations is found in weathered, fissure, jointed caverns, bedding plains and fracture zones. The groundwater yield is high in alluvium and varies from 27,000 to 1,00,000 lph. About 1991.53 sq. km. of the basin consisting of Archaean rocks, the groundwater is highly restricted to weathered, fissures, jointed, fractured and faulted zones. The recharge is low. The specific yield is low and permeability is also low. The quality of groundwater of the basin is suitable for crop cultivation.

CONCLUSIONS:

1. Limited Rainfall and High Temperature Variability:

The Pandameru and Tadakaleru basins experience low average annual rainfall (~537 mm) and high temperatures (up to 42°C), making the region drought-prone and heavily reliant on precise water management strategies.

2. Uneven Water Availability:

The analysis using Evapo-transpiration-based classification reveals spatial and temporal variability in water availability. Only certain months (mainly September to December) fall under wet or humid periods those are conducive to crop cultivation without supplemental irrigation.

3. Crop Suitability Is Seasonally Constrained:

Favourable conditions for cropping are limited to 4–6 months per year in most stations, indicating that **only one crop** can be safely grown in most areas under natural rainfall. However, **two crops** are possible in southern parts of the basin with irrigation support.

4. Irrigation Dependence Is High:

With only 14.2% of the total area currently irrigated, groundwater and surface water resources are vital. Groundwater is mostly stored in fractured Achaean and Proterozoic rocks, with low recharge and yield in many areas, requiring careful management.

5. Need for Adaptive Agricultural Planning:

The study highlights the importance of a **water availability calendar** to guide crop calendars and selection. Crop types such as **groundnut, red gram, and dry land horticulture** are suitable for this climate, with the best cultivation period between **September and January**.

6. Groundwater Resource Constraints:

The basin has limited groundwater potential due to geological conditions. The specific yield and recharge are low, demanding sustainable extraction practices to avoid overuse and future scarcity.

7. Policy and Planning Implication:

The research emphasizes the need for **integrated watershed development**, **rainwater harvesting**, and **micro-irrigation** systems to enhance water use efficiency and agricultural productivity in semi-arid river basins.

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