CHAPTER I
Introduction

Water balance is a comparative study of water input in the form of rainfall and water losses in the form of 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. It plays an important role in development of agriculture, hydrology and especially for water resources management. It is well established that water supply to 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 resource. Water balance plays a crucial role in the optimum utilization and conservation of water resources.
Land is an important natural resource. It embraces the atmosphere, the soil and the underlying geology, the hydrology and plants above and below a specific area of earth surface. It is a result of past and present human activities. River basins form convenient and appropriate units for study of natural resources like land and water. The planning of development land and readjustment is usually carried out in a number of successive phases namely land evaluation, socio-economic analysis, land classification and land development programmes effectuation. Land evaluation includes both qualitative and quantitative classification.

Water is an important liquid gold. The surface water resources of a region has to be carefully evaluated by a systematic study of the distribution of rainfall based on rainfall data collected from the available raingauge stations over a period of time.

Land use of any region is the interaction of operation of the whole range of environmental factors modified by socio-economic and historical elements. It is a complex diversified and dynamic concept. It is a functional concept because transformation of land cover is always meant for specific purposes like agriculture, pasture, forest, settlement, industry and communication. Land
uses are distributed in interactive mixtures. The concept of land use is considered as a relatively stable subject, related mainly to the use to which the land in certain season is put use at a certain period of time.

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 evapotranspiration 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.

Watershed is a geohydrological unit draining at a common point by a system of streams. It is a land and water area, which contributes runoff to a common point. It is a land area that captures rainfall and conveys the overland flow and runoff to an outlet in the main flow channel. The watershed has a third height.
The depth of the watershed may extend from the top of the vegetation to the confining geological strata beneath. The watershed may be nearly flat or may include hillocks, hills or mountains. Each and every land and water area is a part of one watershed or other. The peoples and animals are part of watershed community. The size of the watershed varies from a few square meters to thousands of square kilometers. The size becomes important depending upon the objective of watershed. The larger watershed could be selected in the plains or where afforestation and grassland development is a main objective. In the hilly area of watershed, where agriculture development is the main objective, smaller watersheds are chosen. On an average 5000 hectares of milli-watershed is an effective unit for watershed management and 500 hectares of micro-watershed is a functional watershed development unit. Watershed is a biological, physical, economic and social system. It is a land mass bounded vertically by the area influenced by human activities and horizontally by water that drains into a point in the channel. Soil, water and vegetation are the most vital natural resources of the watershed. Judicious and effective management of soil, water and vegetation in the watershed can ensure the sustained productivity of food, fuel, fodder, forage, fiber, fruit and small timber. In the present study an attempt is made to describe the land and water resources,
water balance, land use irrigation and cropping pattern and watershed development for a sustained land use of Pandameru and Tadakaleru river sub 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 km². It is located in the part of Anantapur and a part of Tumkur district of Karnataka state. It is located between \(14^\circ 15'\) to \(14^\circ 57' 30''\) North latitude, \(77^\circ 19'\) to \(77^\circ 54'\) East Longitude (Fig 1.1).

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 1.3).
Location Map of the Pandameru and Tadakaleru River Basin

Figure: 1.1
Mandal Location of the Pandameru and Tadakaluru River Basins

Legend
- Anantapur
- Athmakur
- B. K. Samudram
- Garadinne
- Kanaganapalli
- Kudair
- Narpala
- Ramagiri
- Raphadu
- Singanamala
- Tumkur

Figure: 1.3
Climate:

The Pandameru and Tadakaleru basin lying off 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 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:

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>6.070 mm</th>
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<tbody>
<tr>
<td>1</td>
<td>(Jan - Feb)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Summer</td>
<td>77.142 mm</td>
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<tr>
<td></td>
<td>(Mar - May)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>3</td>
<td>South-West Monsoon</td>
<td>312.357 mm</td>
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<tr>
<td></td>
<td>(June - Sept)</td>
<td></td>
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<td></td>
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<tr>
<td>4</td>
<td>North-East Monsoon</td>
<td>141.286 mm</td>
</tr>
<tr>
<td></td>
<td>(Oct - Dec)</td>
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<td></td>
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<td>536.855 mm</td>
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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° to 42°c. The coolest part of the year is November, December, January and February months. During the summer the temperatures raises up to 42°c. 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.

**Objectives:**

The main objectives of the study are:

1. to study the water balance elements on monthly, seasonal and annual basis,
2. to study the water resources of Pandameru and Tadakaleru basins,
3. to study the land resources of the Pandameru and Tadakaleru basins,
4. to study the existing land use, irrigation and cropping pattern of the Pandameru and Tadakaleru basins,
5. to work out the water availability days, water availability calendar and suggest crop suitability of the basin,
6. to delineate the micro watersheds of the basin and study in detail two micro watersheds of the basin and suggest watershed development programmes to be undertaken in these two watersheds, and

7. to suggest the appropriate land use depending upon the available land and water resources of the Pandamru and Tadakaleru basins.

**Methodology:**

1. The water balance elements of the Pandameru and Tadakaleru basin are studied using Thronthwaite and Mathur (1955) method on monthly, seasonal and annual basis taking mean monthly temperature and mean monthly rainfall over a period of 100 years for fourteen stations. The water balance of the Pandameru and Tadakaleru basins are delineated using mean rainfall, water stored in ponds, tanks and reservoirs, evaporation and evapotranspiration, runoff 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 Thronthwaite and Mathur (1955) book keeping procedure for fourteen stations in the basin on monthly,
seasonal and annual basis taking the monthly and seasonal variations of actual evapotranspiration and potential evapotranspiration.

2. The water resources of the basin are studied by analyzing rainfall data on monthly, seasonal and annual basis. About fourteen stations are selected in and around the Pandameru and Tadakaleru basins to analyze the rainfall data. The rainfall recharge is worked out. Based on rainfall recharge and specific yield data the ground water resources of the basin are worked out. The surface water resources of the basin are also worked out based on mean annual rainfall and geographical area of the basin.

3. The land resources of the basin are studied using IRS – IB Geo-coded data on 1:50,000 and Survey of India topography sheets on scale 1:50,000. The landforms, soils, land use, geological units; hydrogeomorphic units and intensity of erosion are mapped. Based on the relief, slope and above said physical elements the land capability of the basin is evaluated.

4. Using Survey of India toposheets 1:50,000 scale traces out the drainage of the basins are traced. These maps are in Analog form are converted into the Digital format using automatic digitization including Scanning. The scanned
data are vectorized using AutoCAD software and this Digital data is transformed into a data compatible to ARC/INFO GIS software environment. After editing, detecting and correcting the errors caused during the process of raster to vector conversion of data, spatial database information system is created for further analysis.

5. The land use of the Pandameru and Tadakaleru river basins are studied from IRS – 1B Geo-coded data for both rabi and kharif season. The land use, irrigation and cropping pattern data at mandal level is collected from Chief Planning Officer to study concentration, diversification and intensity of cropping pattern and crop combination adopting different statistical methods.

6. The water availability days calendar are worked out using monthly actual evapotranspiration and potential evapotranspiration values for each station. The water availability periods are categorized into dry, moderately dry, wet and humid periods. Based on water availability days and water availability calendar the crop suitability of the Pandameru and Tadakaleru basins are suggested.

7. The watersheds of the Pandameru and Tadakaleru basin are delineated at micro-level using the relief and drainage
using SOI topographic sheets and IRS – IB Geo-coded data. Erosion prone areas are those areas in which the rate of soil loss or soil removal exceeds the tolerance limit of soil erosion. For the classification of watershed area into various erosion susceptible classes; criterion given by Zacher (1982) is adopted. Soil conservation practices such as contour stonewall, contour terracing on barren slope hills for steep slopes, diversion channels, contour and graded bunding in agriculture land, gully protection by construction of rock fill dams, check dams, stream bank erosion, pasture development, road side stabilization, control of land slides, insitu moisture conservation and vegetative barriers along contours are suggested. Depending upon intensity of soil erosion and amount of soil removal the number of rock fill dams, check dams, percolation ponds and water harvesting structures to be constructed in the selected two micro level watersheds are suggested for conservation of land and water resources of the Pandameru and Tadakaleru basins.

8. Finally based on land systems, landforms, soils, land capability and groundwater availability appropriately land use for the development of the selected two micro
watersheds are suggested for Pandameru and Tadakaluru basins.

**Review of Literature**

The water balance studies are applied in various fields like hydrology, agriculture, ecology and earth sciences. 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. Thronthwaite (1946, 1947 & 1948), Thronthwaite and Mathur (1955), Penman (1956), Van Bavel (1966), Ojo (1969) and Hargreaves (1977) have developed formulae for estimation of potential evapotranspiration. In India, the water balance methodology given by Thronthwaite and Mathur (1955) had been widely used by (late) Prof. V. P. Subramanyam. He was a pioneer worker in the field of water balance studies in India adopting Thronthwaite and Mathur (1955) method. He has published a monograph in 1982, on application of water balance technique in India. Subramanyam (1956) has studied the water balance in India adopting Thronthwaite concept of potential evapotranspiration. Subramanyam (1957) has given a
good account of thermal efficiency as an index of continentality.
The climate of India has been studied by Subramanyam (1959) in relation to distribution of natural vegetation. Subramanyam (1963) has studied to the continentality trends over India and its neighborhood. The problem of incidents and spread of continental droughts have been well documented by Subramanyam (1967). Subramanyam (1982) has published a monograph of about water balance and its application with special reference to India. Subramanyam (1983) carried out study on some aspects of hydroclimatolology and water balance of Chandrapalem basin. Subramanyam (1983) has organized a National Symposium on Water Balance and National Development in the Department of Meteorology and Oceanography on 19th, 20th and 21st December 1983 in Andhra University, Visakhatnam. The symposium covered various aspects of water balance in application of agriculture, hydrology, river basin and environmental studies. The Indian Journal of Agriculture Meteorology has published 35 papers presented in the symposium in 1984. A review of papers indicate that the papers mainly deal with application of water balance studies in hydrology, agriculture, droughts, climate classification and environmental studies. The other pioneers who have worked in the field of water balance are Shastri (1969), Rama Shastri (1973), Sharma (1974), Bora (1976), Ram Mohan (1978), Hemamalini

The study on water resources planning and development has been developed for the river basins. Several National and International Seminars were organized to coordinate the water resources studies. In India a few geographers who have carried out studies in water resources are Dakshina Murthi (1964), Bhargava (1977), Dixit (1979), Subramanyam and Viswanatham (1979) and Sambasiva Rao (1984, 1996, 1997 & 2002). Narendra Kumar (1999) has carried out studies on an integrated land and water resources development for sustainable land use of Chitravathi river basin with special reference to Guttur watershed.


The studies on irrigation are carried out by Gulhati (1951), Chaturvedi and Reddy (1964), Chaturvedi (1968), Ahmad (1971),


The concept of watershed development in India has been proposed by Sri (Late) Y. P. Bali in 1974, when the Ministry of Agriculture, Government of India has proposed a programme of soil and water conservation adopting watershed as a planning unit. Various studies are carried out on concepts and methodology of watershed management. Bagachi and Philip (1993) have described the untapped potential of watersheds in India. All India Soil and
Land Use Survey (1990) has prepared an Atlas of watersheds of India on 1:1 million scale. Anil (1994) has suggested a few measures for development of watershed in drought prone areas. Bali (1987) has proposed the steps for priority delineation surveys and priority identification in watershed management. Dhruva Narayan et al. (1983) has suggested the measures for minimum erosion and maximum benefits of soil conservation. Dhruva Narayan (1985) has suggested measures for soil and water conservation and watershed development. Das et al. (1967) has suggested the measures for soil and watershed management of Nilgiris. Dhruva Narayan et al. (1990) described the watershed management practices. Dhruva Narayan Shastry and Patnaik (1990) have proposed watershed management programmes. Das Gupta (1992) has described strategies for integrated watershed development. FAO (1960) has described the measures to control soil erosion by wind in agriculture lands. FAO (1976) suggested the measures for soil conservation and management in developing countries. FAO (1985) has published a manual on watershed development with special reference to soil and water conservation. FAO (1988) has published a field manual of watershed management and slope treatment measures and practices. FAO (1990) has given guidelines for watershed survey, planning and conservation. Ghumare (1962) has carried out studies on
Government of India (2001) has given a good account of rain water-harvesting structures for the collection of rainfall and runoff in rural areas. Patnaik et al. (1982) has carried out studies on water harvesting structures in farm ponds in deep black soil plains. Purendare and Srivastava (1995) described the challenges in watershed development. Rajora Rajesh (1996) has carried out studies on integrated watershed development of Jhabua watershed. Rajora Rajesh (1998) has published a field manual for equitable, productive and sustainable development of watersheds in India. Subramaniam et al. (1987) has published a series of articles on soil survey and land use planning for watershed management. Singh et al. (1990) has proposed the watershed management practices to be undertaken for conservation of land and water resources of Aravalli foothills. Tejwani et al. (1960) described the measures to control gully erosion in the ravine lands of Gujarat. Tideman (1996) has proposed the guidelines for watershed management for Indian conditions. Vijayalakshmi and Vittal (1981) has described the importance of rainwater harvesting structures and recycling in semi-arid regions.

**Organization of Thesis:**

The whole thesis has been divided into 10 chapters. The first chapter deals with the introduction, study area, objectives,
methodology, source of data and review of literature. The second chapter contains a detailed description of water balance elements on monthly, seasonal and annual basis. In the third chapter an attempt is made to describe the geology and geomorphology of the sub-basins. The fourth chapter deals with the land resources of the sub-basins on the basis of physical characteristics. The morphometric studies of the sub-basins are described in the fifth chapter. The sixth chapter contains the water resources and water quality of the sub basin. In the seventh chapter the land use, irrigation, cropping pattern, water availability days, water availability calendar and crop suitability are dealt with. In the eighth chapter an attempt is made to delineate and describe the micro-watersheds of the sub basin. A detailed study of natural resources of the Tumpera and Kanaganapalli watersheds are described. In the ninth chapter an attempt is made to bring out the relationship between water balance elements, land resources and water resources for a sustainable land use development of the Pandameru and Tadakaleru sub-basins. The tenth chapter contains the summary and conclusions drawn out of study of Pandameru and Tadakaleru sub-basins.