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# Integrated River Basin Plan for Achencoil River in Kerala State, India

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**Abstract:** Increasing human needs on the available fresh water resources suggest the need and scope for integrated water resources assessment and management. Achencoil River, an elongated river spread over 1484 Km2, situated in Kerala State, has been selected for the detailed hydrological studies. The main objective of the study is to estimate surface and groundwater availability, present utilization and future demand for various purposes and finally to suggest water conservation measures for meeting the water deficit. The river has a length of 128 km, originates from the Western Ghats at an altitude of 700 meters above MSL. The river basin receives an annual average rainfall of 2817.60 mm. Spatial and temporal variation of rainfall and runoff were analyzed to estimate the total water availability and utilizable water potential of the basin. The groundwater recharge, as estimated by Central Ground Water Board for different blocks was appropriated to the river basin. Isohyetal map and flow duration curves were drawn to understand the spatial and temporal availability of water. Domestic demand, irrigation demand and demand for other environmental purposes were estimated following the standard procedures. The investigations have brought to light that the Achencoil basin will have a deficit of fresh water of 692.36 MCM during non-monsoon season by 2050 AD and during monsoon season there has a surplus of 591.86 Mm3. Based on the studies, certain water resources development schemes have been recommended for the basin with a view to optimally make use of water resources for maximizing the agricultural production and meeting other important needs.

***Keywords:*** *Integrated river basin plan, utilizable water potential, water balance, water deficit*

## 1. Introduction

India has more than 18 % of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area [1]. There are further limits on utilizable quantities of water owing to uneven distribution over time and space. In addition, there are challenges of frequent floods and droughts in one or the other part of the country. There is wide temporal and spatial variation in availability of water, which may increase substantially due to a combination of climate change, causing deepening of water crisis and incidences of water related disasters, i.e., floods, increased erosion and increased frequency of droughts, etc. Characteristics of catchment areas of streams, rivers and recharge zones of aquifers are changing as a consequence of landuse and land cover changes, affecting water resource availability and quality.

Integrated River Basin Management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximize the economic and social benefits derived from water resources in an equitable manner.

The present study is an attempt to quantify the available water in the Achencoil river basin, in space and time, to assess the demand for water in different sectors and to suggest some approaches for optimal utilization of water resources in the basin. In quantifying the water resources, various hydrologic approaches have been resorted to. The demand for various purposes has been worked out considering the population, landuse, industrial potential and some environmental aspects.

### 1.2 Need for the Study

Most of the water resources development projects in the country, especially in Kerala, are planned and executed without giving due weightage to the overall development of the basins. Often, the development upstream creates water quality problems in the downstream. For example, the diversion of water to other river basins from the upstream of the Periyar River in Kerala has been the main cause for pollution and salinity intrusion in the downstream reach close to the industrial belt at Kochi.

The Achencoil river basin one of the forty one rivers flowing to the west in Kerala has been selected for the present study. Though the present attempt is only to impress upon the necessity for basin planning in the context of Kerala, future studies are expected to come forward with different phases of the integrated development and a management strategy.

The major objectives of the present study are the following:

- To assess the spatial and temporal water availability in Achencoil River basin,
- To estimate the future demand of water for various purposes in the Achencoil river basin,
- To derive the water balance for the river, and to suggest sustainable management strategies for the river basin.

## 2. Materials and Methods

The catchment or watershed is a natural integrator of all the hydrologic phenomena pertaining to its boundaries and, as such, it is a logical unit for planning optimum development of soils and water resources [2]. The entire area of a river basin, whose surface runoff due to storm drains into the river in the basin, is considered as a hydrologic unit and is called a drainage basin, watershed or catchment area of a river.

### 2.1 Study Area

The Achencoil River with a length of 128 Km originates from the western Ghats at an altitude of 700 meters above MSL has been taken for the present study. It flows through Alappuzha, Kollam, and Pathanamthitta districts of Kerala and finally joins the Vembanad backwater after splitting up in to numerous interconnected water courses. The drainage area of the river basin is 1484 Sq.Km [3]. The basin lies between $76^0$26' and $77^0$15' East longitudes and $9^0$18' and $9^0$8' North latitudes. Fig. 1 shows the location map of the study area. About 50% of area of the river basin falls in Alappuzha District, 43 % in Pathanamthitta and remaining 7 % in Kollam District [5]. Kallar is the main tributary of Achencoil river basin.

## 3. Databases

Secondary data on hydrological and meteorological parameters of Achencoil river basin have been collected form Water Resources Department (WRD), Indian Meteorological Department (IMD) and Central Water Commission (CWC) [6].


***Figure 1*** *Location map of Achencoil river basin*

The Achencoil river basin is covered by a network of seventeen raingauge stations. On an average, 20 years of data are available from these stations. There are five river gauging stations maintained by Water Resources Department and one station by Central Water Commission. Fig 2 shows the locations of raingauge and river gauging sites of Achencoil river basin. The groundwater recharge, as estimated by Central Ground Water Board (CGWB), for different blocks of the river basin, was appropriated to the river basin. The Indian Remote Sensing data published by National Remote Sensing Centre has been made use of for deriving the present landuse.

## 4. Preparation of Base Maps

The drainage map of Achencoil river basin has been digitized in Arc GIS 9.3 software, making use of GTS maps of Survey of India, scale 1:50,000. An attempt was made to derive a Digital Elevation Model (DEM) for Achencoil river basin with high undulating and steep topography. The contour map was digitized from GTS maps at 20 m contour interval to generate the line feature class in ArcGIS, which was further processed using the spatial analyst module to generate the Digital Elevation Model (DEM) representing the watershed terrain topology. Slope, aspect and Triangulated Irregular Network (TIN) maps have been derived using digitised contour map. Slope, aspect, DEM and TIN map of Acencoil river basin were shown in Figs 3 to 6. These maps will be useful for the planners and decision makers in the field of water resources.

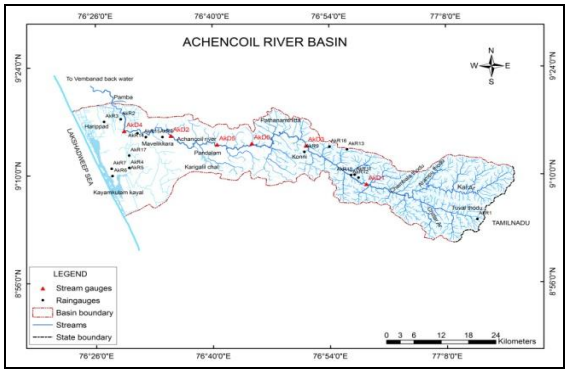


***Figure 2*** *Locations of rain gauge stations and discharge stations in Achencoil river basin*

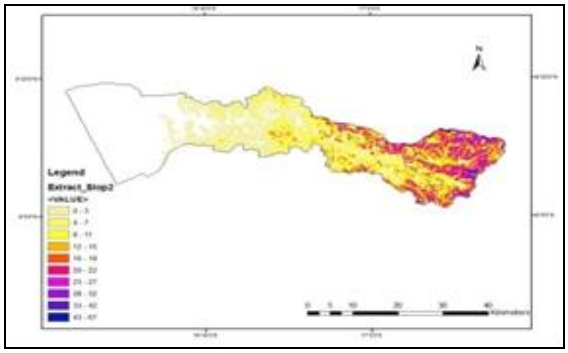

***Figure 3*** *Slope map of Achencoil river basin*

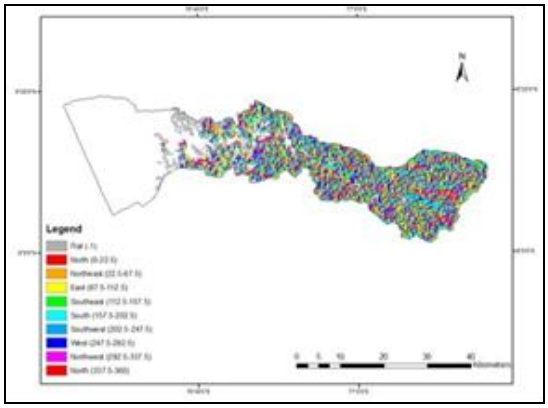


***Figure 4*** *Aspect map of Achencoil river basin*

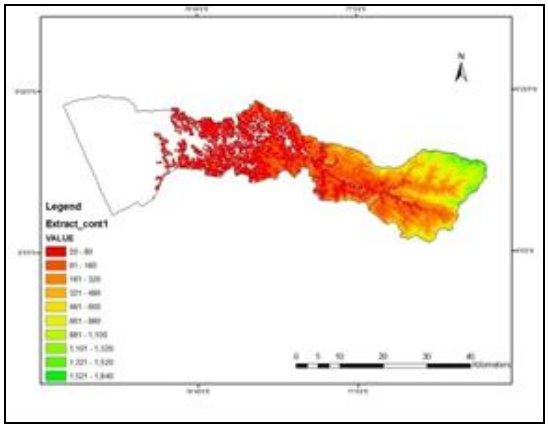


***Figure 5*** *DEM of Achencoil river basin*

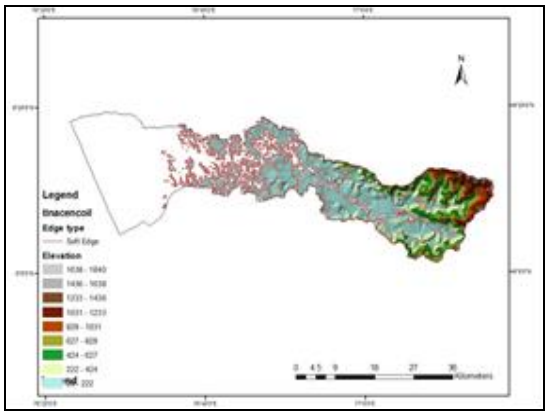


***Figure 6*** *TIN map of Achencoil river basin*

## 5. Hydrological Analysis

### 5.1 Analysis of Rainfall Data

As a part of this study, the spatial and temporal variation of rainfall in Achencoil river basin has been studied. The annual rainfall is varying from1786 mm to 3081 mm. The hilly area shows the highest rainfall than the coastal area. The spatial variation of rainfall shows a decreasing trend towards the coastal land (low land).

Using spatial analysis tool, an isohyetal map has been derived. Fig 7 shows the isohyetal map of Achencoil river basin.

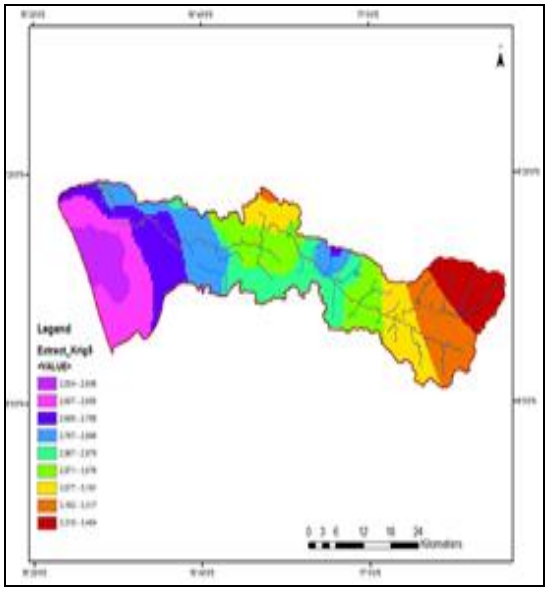


***Figure 7*** *Isohyetal map of Achencoil river basin*

### 5.2 Analysis of Stream Flow Data

The spatial and temporal availability of water have been computed with the help of historical data. From the actual values of stream flows, the total surface water availability has been estimated as 1145.81 MCM, in which 1055.22 MCM during monsoon period and remaining 90.29 MCM during non-monsoon period. The utilisable yields were estimated for the river basin, following the criteria recommended by Kerala PWD [2] and are found to be 729.87 MCM. in which 672.37 MCM during monsoon season and remaining 57.5 MCM during non-monsoon season. The actual utilizable yields would be much less than that estimated, due to various constraints, especially the restrictions on storage or diversion works causing deforestation in the highland and the problems associated with rehabilitation of people in the midland with high density of population. In order to understand the percentage time of availability of flows, monthly flow duration curves have been constructed for all sub basins. It is observed that most of the sub basins are dry during February to April.

It can be observed that summer flows are considerably less in comparison to monsoon flows, as expected in this humid tropic region. The irrigation requirements as well as scarcity for drinking water and water for other purposes are more mainly during summer season during which period the flows are comparatively very low. Fig 8 shows the flow duration curves of Thumbamon station for the summer months.

### 5.3 Estimation of Water Potential

#### *5.3.1 Surface water*

The spatial and temporal availability of water was computed with the help of historical data.

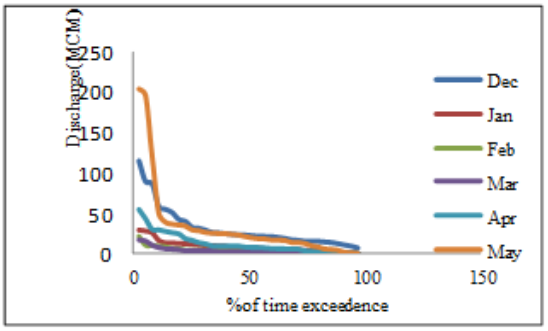


***Figure 8*** *flow duration curves for Thumbamon*

For estimating the surface water potential of the basin the CWC river gauging station data have been made use of From the actual values of streamflows, the total surface water availability has been estimated as 1145.81 MCM, in which 1055.22 MCM during monsoon period and remaining 90.29 MCM during non-monsoon period. The utilizable yields were estimated for the river basin, following the criteria recommended by Kerala PWD [2] and are found to be 729.87 MCM in which 672.37 MCM during monsoon season and remaining 57.5 MCM during non-monsoon season. The actual utilisable yields would be much less than that estimated, due to various constraints, especially the restrictions on storage or diversion works causing deforestation in the highland and the problems associated with rehabilitation of people in the midland with high density of population[3].

#### *5.3.2 Groundwater*

For estimating the groundwater availability, the District wise reports published by Central Groundwater Board have been made use of [4]. The block wise data of groundwater recharge, potential and stage of development were appropriated to the river basin. It is estimated the annual groundwater potential is 241.1 MCM in which 96.44 MCM is available during non-monsoon period.

### 5.4 Estimation of Water Demand

#### *5.4.1 Domestic Demand*

The domestic water needs were estimated the river basin as a whole based on present population and projected population. It is estimated that at present, for the rural population, domestic demand is 60.3 MCM and for urban 61.6 MCM. For future population it is estimated that total demand for domestic purposes is found to be 138.68 MCM.

#### *5.4.2 Irrigation Demand*

In order to have a correct assessment of the present landuse, Indian Remote Sensing (IRS) data of 2013 were made use of from National Remote Sensing Centre (NRSC) site (BHUVAN); ground truth verification added to the reliability of the landuse estimate. The irrigation requirements for sustaining the existing cropping system have been worked out by making use of the values of evapotranspiration (computed using CROPWAT Software, Penman Monteith) and crop coefficients recommended by F AO and CWRDM.

In recommending the irrigation requirements, the policies of the Government and the aspirations of the farmers were taken into cognizance. Fig 9 shows the landuse map and Table 1 furnishes the landuse classification

***Table 1*** *Landuse classification*

| Landuse classification | Area in Sq Km |
|---|---|
| Built Up Area | 212.16 |
| Deciduous forest | 146.51 |
| Evergreen forest | 222.00 |
| Forest Plantation | 109.85 |
| Paddy | 201.20 |
| Scrub Forest | 56.13 |
| Waste Land | 39.15 |
| water body | 24.28 |
| Wet Land | 74.26 |
| Plantations | 398.46 |

Table 2 shows the monthly irrigation demand for paddy and plantation crops. Estimation of monthly irrigation requirement of each crop is found to be important for planning purpose. From the analysis total annual irrigation demand in Achencoil river basin is found to be 817.11 MCM. Maximum monthly irrigation demand 189.96 MCM is obtained in the month of January. No irrigation water is needed in June, July August and October.

#### *5.4.4 Industrial Demand*

The future requirement of water for industries was estimated, based on the report published by CWRDM, 1999[5]. It is found that 66.5 MCM water required for industrial purposes in future.

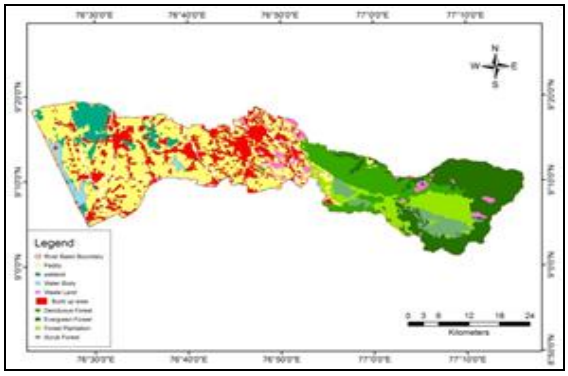


***Figure 9*** *Landuse map of Achencoil river basin*

***Table 2*** *Monthly volume of water required for paddy and plantation*

| Month | Total irrigation demand, MCM | | |
|---|---|---|---|
| | Paddy | Plantation crop | Total |
| Jan | 117.93 | 72.03 | 189.96 |
| Feb | 70.09 | 72.7 | 142.79 |

| | | | |
|---|---|---|---|
| Mar | 85.21 | 84.81 | 170.02 |
| Apr | 0 | 77.9 | 77.9 |
| May | 81.83 | 12.99 | 94.82 |
| Jun | 0 | 0 | 0 |
| Jul | 0 | 0 | 0 |
| Aug | 0 | 0 | 0 |
| Sep | 76.48 | 0 | 76.48 |
| Oct | 0 | 0 | 0 |
| Nov | 46.4 | 0 | 46.4 |
| Dec | 18.74 | 0 | 18.74 |
| Total | 496.68 | 320.43 | 817.11 |

#### *5.4.5 Water for other environmental purposes*

The water required for environmental purposes including salinity exclusion is taken from the published reports [5] due to lack of time. It is estimated that 49.7 MCM water is required for this purposes .This will take care of the flora and fauna of the river basin.

### 5.5 Water Balance

The consolidated water balance of the Achencoil river basin namely, utilizable potential, future water demand and status is given in Table 3. It is observed that during non-monsoon season, the basin become deficit in water for meeting the increasing demand in future. During monsoon season, the utilizable water potential is more and demand is less, and hence there is a water surplus.

***Table 3*** *Utilizable potential Future demand and status*

| **Description (*All units in MCM*)** | **Monsoon** | **Non monsoon** | **Total** |
|---|---|---|---|
| Surface water potential | 672.37 | 57.5 | 729.87 |
| Groundwater potential | 144.66 | 96.44 | 241.10 |
| Future water demand Domestic | 69.12 | 69.12 | 138.24 |
| Irrigation | 122.88 | 694.23 | 817.11 |
| Industrial | 33.25 | 33.25 | 66.50 |
| Environmental | 0 | 49.7 | 49.70 |
| Surplus/Deficit | 591.78 | - 692.36 | |

### 5.6 Strategies for Water Resources Utilization

#### *5.6.1 Mass curve*

An attempt has been done to derive mass curve for the river basin as a whole considering the monthly inflows and demand. Fig 10 shows the mass curve of the river basin.

From the Table 3, it can be seen that even after considering the utilizable surface and ground water sources, in non-monsoon season, there will be 692.36 $Mm^3$ deficit and during monsoon season there has a surplus of 591.78 $Mm^3$. From the mass curve, it is clear that 73.82 MCM can be stored and utilized in future for meeting the increasing water demand. Hence following water management strategies have suggested for meeting the water scarcity.

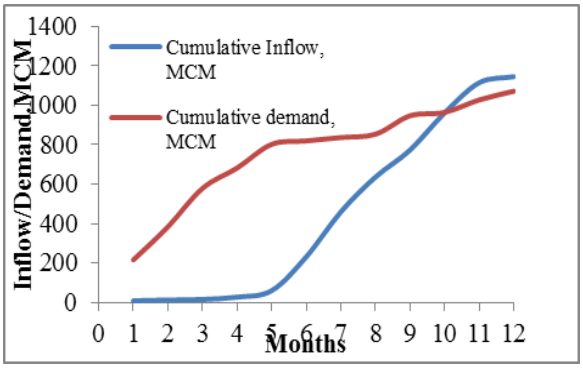


***Figure 10*** *Mass curve for Achencoil river basin*

#### *5.6.2 Water for hydel power generation*

The Kerala State Electricity Board has already proposed a hydel power project in their annual plan with installed capacity of 60 MW [2]. A dam across Kallar, a tributary of Achencoil river is proposed.

#### *5.6.3 Water for irrigation*

The Publics Works Department report recommended a storage reservoir across the river during 1974. The suitable site for the dam is near the Naduvathumuzhi forest rest house at Konni Salient features of the Konni dam are given below:

| | |
|---|---|
| Location | : Across the main river near Naduvathumuzhi forest rest house |
| Catchment | : 402 sq.km |
| Water spread area | : 19 sq. km |
| Capacity of the reservoir at F R L | : 142 MCM |
| Length of the dam | : 330 m |
| Height of the dam | : 31 m |

After detailed hydrologic investigations, especially reducing the capacity to 73 MCM, the scheme can be thought of for meeting the future water requirement. In order to meet location specific requirements for irrigation, it is suggested to go for check dams, tanks/ponds and groundwater based irrigation [6].

#### *5.6.4 Water for drinking and industries*

The water demand for future domestic purposes is estimated based on projected population. It is suggested that the groundwater available should be used as far as possible to meet the requirement of drinking water. The ground water potential of the basin is estimated as 321.46 $Mm^{3,}$ of which utilizable is 151 MCM .Over exploitation may be avoided by using this source mainly for drinking and for irrigation in pockets where other sources are not at all available. More emphasis should be given for renovating the existing tanks and ponds for utilizing the spring source for meeting the water requirements in addition to the utilization of existing open wells.

The water requirement for industries and livestock also may be met from similar sources as recommended for drinking water purposes. The future water requirement for industries is estimated as 66.5 MCM.

### *5.6.5 Water for environmental purposes*

It is estimated; using empirical relationships recommended by Kerala Engineering Research Institute that 295 MCM of fresh water is required to flush out the salinity propagating up from the Vembanad wetland system [7]. When the Thanneermukkom barrage is closed, there is no threat of salinity intrusion from the backwater. However, due to certain environmental reasons, this barrage was kept open during even summer months. This will lead to propagation of salinity in upstreams. Therefore it is worthwhile to ensure proper flushing by even storage of water upstream [8]. However, in the present study, the requirements of freshwater to maintain the eco-system of Vembanad wetland has not been considered due to limitations in time.

### *5.6.5 Inland navigation*

There are a number of cris-cross channels in the basin, which serve as inland waterways. Some of the stretches of the waterways require widening, deepening and provision of certain infrastructure facilities. This may have to be done after detailed environmental impact studies.

### *5.6.6 Need for integrated river basin plan*

The recommended strategies for future water resources development and management call for detailed discussion at all levels before implementation. After arriving at a consensus by the user agencies, detailed project formulation has to be undertaken based on location specific investigations. Different alternatives may be worked out and the optimal plan adopted for execution. The development and management programmes can be successfully executed only if there is proper coordination among all concerned. This can be achieved only through a coordinating agency in the form of a River Basin Authority.

## 6. Summary and Conclusions

Detailed hydrological investigations were carried out to understand the water balance of Achencoil river basin, a typical river basin of Kerala. As a part of the project, meteorology, hydrology, landuse, and other related aspects have been collected from different agencies and the field as such.

The annual surface water potential of Achencoil river basin is estimated as 1145.81 $Mm^3$ based on the gauged data for about 30 years. The utilizable yield of surface water is 729.88 $Mm^3$. The groundwater recharge, as estimated by Central Ground Water Board (CGWB), for different blocks of the river basin, was appropriated to the river basin. It is found that out of 321.46 MCM recharge available the present groundwater draft was estimated as 241 MCM.

Spatial and temporal analysis of rainfall of Achencoil river basin has been carried out and an isohyetal map has been prepared using the spatial analyst tool in ARC GIS software. Mean annual rainfall of Achencoil river basin is 2817 mm. The annual rainfall is varying from1786 mm to 3081 mm. The hilly area shows the highest rainfall than the coastal area. The spatial variation of rainfall shows a decreasing trend towards the low land.

In order to understand the percentage time of availability of flows, monthly flow duration curves have been constructed for all sub basins. It is observed that most of the sub basins are dry during February to April.

The requirements of water for domestic, irrigation, industrial purposes, and other environmental purposes have been estimated following the standard procedures, modern tools like geographical information system, global positioning system and remote sensing techniques were employed wherever applicable.

In order to have a correct assessment of the present landuse, Indian Remote Sensing data (BHUVAN) for 2013 were made use of; ground truth verification added to the reliability of the landuse estimate. The irrigation requirements for sustaining the existing cropping system have been worked out by making use of the values of evapotranspiration (computed using CROPWAT software) and crop coefficients recommended by F AO and CWRDM. In recommending the irrigation requirements, the policies of the Government and the aspirations of the farmers were taken into cognisance. Though hydel power generation is a non-consumptive use of water, the projects recommended by KSEB have been considered. Water requirements for flushing out the pollutants and salinity from the lower reaches of Achencoil river basin have also been realized. The river is navigable round the year in the lower reaches and the need for maintaining necessary draft has been highlighted. The environmental considerations from the point of view of tourism and balancing the ecology also have been discussed.

Considering the utilizable yield, present and future demand, water balance was worked out for monsoon and non-monsoon season separately. The investigations have brought to light that the Achencoil basin will have a deficit of fresh water of 692.36 MCM. by 2050 AD . [11]

Based on the studies, certain water resources development schemes have been recommended for the basin with a view to optimally make use of water resources for maximising the agricultural production and meeting other important needs.

A necessity for integrated basin planning for achieving coordinated action by different user agencies has been highlighted.

## 7. Acknowledgements

This study is part of the project entitled 'Integrated river basin management plan for the rivers draining into Vembanad wetland system' funded by KSCSTE Plan fund. Dr. N B Narasimha Prasad, Executive Director, CWRDM has provided all technical support for the study. The Water Resources Department, Government of Kerala, Central Water Commission, Indian Meteorological Department and National Remote Sensing Centre, Government of India provided all data for conducting the study. All these are duly acknowledged.

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