**Original Research Article**

# Hydrological Studies of ArtalSub-Watershedof Belagavi District, Karnataka, India

**Abstract:**Watershed is also a hydrological response unit and a holistic ecosystem in terms of the materials, energy and information present. The Artal sub-watershed (4d5e3b) is located in the Athani taluk of Belagavi district. It lies between 16$^0$43'50" - 16$^0$45'40" North latitudes and 75$^0$17'30" - 75$^0$23'0" East longitudes and covers an area of about 4632.04 ha. The average annual rainfall (2016 - 2021) of Artal sub-watershedwas 536.0 mm. The maximum precipitationof 357.3 mm is received from June to September, 108.9 mm from October to early December and the remaining 99.8 mm is received during the rest of the year. The number of rainy days (>2.5 mm) varied from 14-24 days per year. On average, number of rainy-day events likely to produce runoff (20 to 30 mm) isabout 3 to 7 rainy days per year with moderate variation across the years. The Actual Evapotranspiration (AET) over the years 2016 - 2021 in the Artal sub-watershed varied from 297.0 to 558.1 mm. During 2016 - 2021, the average annual AET (421.0 mm) was less than the average rainfall (536.0 mm). The average AET/P ratio between 2016-2021 was about 0.74 which is less than the sustainable limit of about 0.80. During 2018 and 2020, the AET/P ratio were 1.14 and 1.06, respectively, which indicates receipt of less rainfall in these years and also a possibility of groundwater being augmented to maintain crop water requirements. A maximum area of about 875 ha (18.9 %) requires graded bunding and 3657 ha (78.96 %) area requires contour bunding.

***Keywords**: Watershed,Evapotranspiration, Groundwater, Kriging and Soil conservation measures*

## 1. INTRODUCTION

"The backbone of the Indian economy is agriculture and allied fields which mostly depend upon an abundance of natural resources like rainfall, water resources, soil and forest vegetation. As these resources are limited and depleted yearly, there is an utmost need to stabilize and conserve these resources. Watershed is the geographical area which is drained by the network of streams to the common outlet. A watershed is a complex and dynamic biophysical system which is identified as a planning and management unit. A watershed is also a hydrological response unit and a holistic ecosystem in terms of the materials, energy and information present. Land and water are the two main resources of the watershed. The watershed not only is a useful unit for physical analyses, it can also be an appropriate socio-economic-political component for the execution of management strategies. In essence, a watershed is a basic organizing unit to manage resources"[1].

"Unplanned and uncontrolled use of resources results in the deterioration of watershed which is further aggravated by human interventions. The population residing in the watershed is one of the most important assets of that watershed and the condition of a particular watershed depends heavily on its population. So, it is imperative to involve the people inconservational strategies actively involving proper management and execution of the watershed resources. The planning and management of the watershed aredone to accomplish the tasksrelated to the overall development of the watershed, which may be withrespect of water quality and quantity improvement, management of ecosystem, enrichment of the socio-economic status of the watershed inhabitants, enhancing the employment opportunity for the people and selection of most appropriate cropping pattern etc."[2].

“Watershed management is the balanced exploitation of terrestrial and aquatic resources for the acquisition of optimal production with petite vulnerability to natural assets. It adopts the rehearsal of soil and water conservational strategies in the watershed, for example, appropriate exploitation of the land, defensive measures of land against anthropogenic pressures, enhancement and management of soil fertility, water conservation for irrigational practices, proper supervision of local water supplies for drainage, protection against flash floods and reduction in runoff and soil erosion, and also escalating the production from all the existing land use patterns. Watershed-level hydrological studies are essential to soil and water resources evaluation, improvement and management. At the field scale, hydrologic studies are engaged indevising and designing of soil conservation practices”[3], management of irrigation water, water quality evaluation and water supply availability etc, [3]. Hydrological studies are important tools for comprehending the hydrological behaviour of the watersheds. Hence the hydrological studies have been taken up at the Artal sub-watershed (4d5e3b),which is located in the Athani taluk of Belagavi district, Karnataka.

## 2. METHODOLOGY

### 2.1 Location and Extent

The Artal sub-watershed is located in the south-eastern part of Karnataka in Athani taluk and Belagavi district (Fig 1.). It lies between 16043’50” – 16045’40” North latitudes and 75017’30” – 75023’0” East longitudes and covers an area of about 4632.04 ha. It is about 30 km from Athani town and is bounded by Halahalli on the east, Savalagi&Thungala on the south, Badagi&Aigali on the west and Thelasanga on the northern side of the subwatershed.

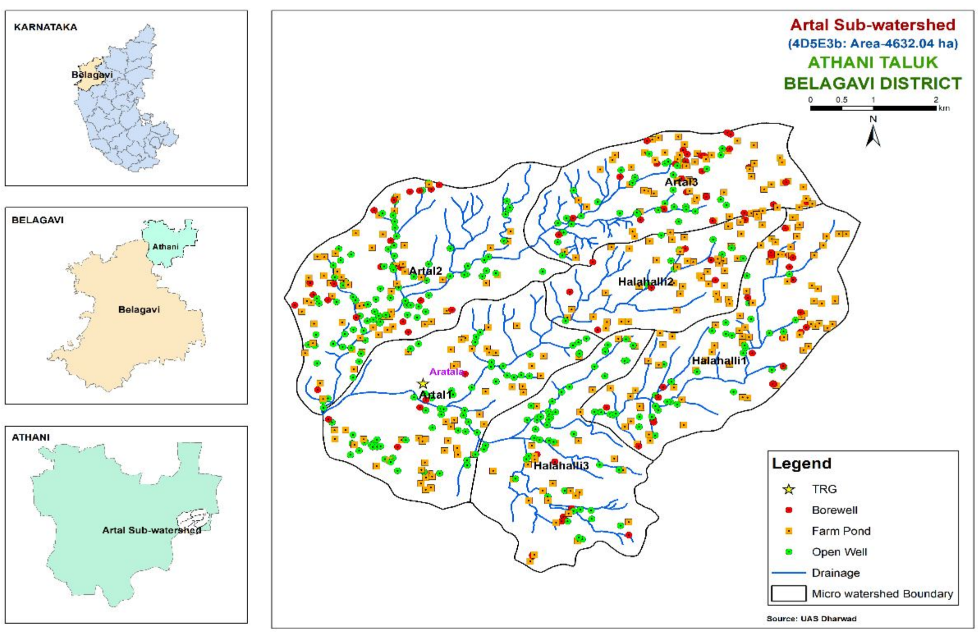


**Fig.1. Location map of Artal Sub-watershed**

### 2.2 Geology and Physiography of the Belagavi district

“Complex geological formations can be observed in theBelagavidistrict. The Schist and Banded ferruginous quartzite, the peninsular gneiss by granite and gneissic granites, the Kaladgi formations, sandstone, quartzite, shale and limestone and dolomite, basalt (Deccan Trap) and the laterite formations are observed in the district. The Deccan basalt occupieslarge extent in the Northern part, thinning out towards the South and it can be seen in Belagavi, Khanapur, Hukkeri, Chikkodi, Athani and Raibagtaluks.TheKhanapur taluk is enriched with a varietyof fire clay, clastic clay, china clay etc" [3].

The district is divided into three physiographical divisions namely asMalenaadu Tract (Western Ghat Region), Gadinaadu Tract (Border area Region) and Bayalunaadu Tract (Plain Land Region). The "Malenaadu" tract is the Western Ghat area, with lush green forests, sharply undulating topography, and heavy rainfall. Many 1st order streams traverse this area. There are many natural springs in this tract. The "Gadinaadu" (intermediary) tract shows medium range flat to gently rising hills, with shrubby greenery, receiving an average rainfall. The streams are of 3rd & 4th order. The "Bayalunaadu" tract shows vast, flat terrain, with flat-topped barren hills. The rainfall received is less than 650 mm. The streams are very gentle.

### 2.3Drainage, Rainfall and Ground Water Measurement

"The district falls under the influence of the Krishna River basin, and a small part of Khanapur taluka under the Kali River basin. The major tributary rivers of KrishnaRiver are Ghataprabha and Malaprabha, which are supported by sub-tributaries like Markandeya, Hiranyakeshi, Doodhaganga, Vedganga, Agrani etc. The Malaprabha and Mahadai River originating in the Western Ghat of Khanapur taluka having several perennial springs, all along their courses. The Pandhari and Mahadai rivers in the south join the Kaali River basin" [2].

"Groundwater recharge is an important and required necessary activity in managing and developing water resourcesof a watershed. Rainfall is the major source of groundwater recharge. The infiltration of water is mainly governed by lithology, land use practice and elevation of the terrain. Spatial maps were prepared using ArcGIS 10.8. Month-wise data of the water table was collected in the artal sub watershed. The seasonal water-level fluctuations in the Artal watershed have been analyzed. Rainfall data are one of the important datasets in the spatial domain, controlling the water resources budget of the region. Rainfall data forthe last 06 years were collected from Karnataka State Natural Disaster Monitoring Centre, Govt of Karnataka" [3].

### 2.4Point Interpolation: Kriging

"Kriging is a geostatistical method for estimating values in unknown areas by considering both the distance and variation between known data points. It involves creating an estimated surface from scattered points with z-values by fitting a mathematical function to nearby points. The process includes statistical analysis, variogram modelling, surface creation, and variance exploration. Predicted values are calculated using a weighted average technique based on the relationship between samples. The search radius can be fixed or variable and generated cell values may exceed the sample range"[4].

$$Z(S_0)^N = \sum_{i=1}^{N} \lambda Z(Si)$$

Where,

$Z(Si)$ = the measured value at the ith location

$\lambda_i$ = an unknown weight for the measured value at the ith location

$S_0$ = the prediction location

N = the number of measured values

"The Kriging method is an interpolation method based on principles of zero bias and minimum mean square error. It determines values for a process over an entire domain, finitevolume block or specific point using a linear combination of data values. The summation may be over an entire area or restricted region centred at the estimation point"[5].

## 3. RESULTS AND DISCUSSION

### 3.1 Rainfall Analysis and Distribution

To develop the rainfall indices of the Artal sub-watershed, data from the Artal rain gauge station in Athani taluk of Belagavi district was taken into account. During the year 2018, annual rainfall was deficient by 30 %. The district falls under the hot semiarid tract of the state and is categorized as drought -prone with an average annual rainfall of 565.9 mm received in the last 7 years (Table 1 and Fig 2). Amaximum of 357.3 mm of precipitation is received during south-west monsoon period from June to September, the north-east monsoon contributes about 108.9 mm and prevails from October to early December and the remaining 99.8 mm arereceived during the rest of the year. The winter season is from December to February. During April and May, the temperatures reach up to 38.8°C and in December and January, the temperatures will go down to 15.1°C. Rainfall distribution is shown in Figure 3. The average monthly Potential Evapotranspiration (PET) is 139.1 mm and varies from a low of 102.4 mm in December to 191.7 mm in March. The PET is higher than precipitation in all the months except September. Generally, the length of the growing period in the Artal sub-watershed ranged from 150 to 160 days. The length of the growing period begins at 21stweek (which is May 2nd week)) and ends at 43rd week (which is October 3rd week). Based on the observation, farmers can schedule sowing and other agronomic practices for short duration and long duration crops.

**Table 1. Mean monthly rainfall, PET, 0.5 PET at Athani Taluk, Belagavi District**

| Month | Rainfall (mm) | Temp-Max (°C) | Temp-Min (°C) | Max-RH (%) | Min-RH (%) | PET (mm) | 0.5 PET (mm) |
|---|---|---|---|---|---|---|---|
| Jan | 0.0 | 30.8 | 15.1 | 84.8 | 36.8 | 102.9 | 51.5 |
| Feb. | 0.0 | 33.1 | 16.6 | 75.1 | 28.0 | 121.3 | 60.7 |
| Mar | 8.9 | 36.7 | 19.9 | 72.6 | 22.1 | 191.7 | 95.9 |
| Apr | 29.8 | 38.8 | 22.5 | 80.7 | 22.7 | 171.5 | 85.8 |
| May | 61.2 | 37.9 | 23.6 | 88.1 | 30.7 | 177.1 | 88.6 |
| Jun | 76.9 | 33.1 | 22.8 | 94.5 | 54.5 | 146.9 | 73.5 |
| Jul | 93.8 | 30.0 | 22.2 | 95.4 | 65.7 | 151.8 | 75.9 |
| Aug | 56.9 | 29.3 | 21.7 | 96.9 | 66.8 | 146.7 | 73.4 |
| Sep | 129.7 | 30.3 | 21.3 | 97.2 | 60.9 | 114.1 | 57.1 |
| Oct | 93.9 | 31.2 | 20.6 | 93.8 | 51.0 | 139.1 | 69.6 |
| Nov | 11.2 | 31.1 | 18.5 | 87.5 | 44.2 | 103.9 | 52.0 |
| Dec | 3.8 | 30.2 | 16.3 | 87.9 | 43.1 | 102.4 | 51.2 |
| **Total** | **565.9** | | | | | **1669.4** | **834.7** |

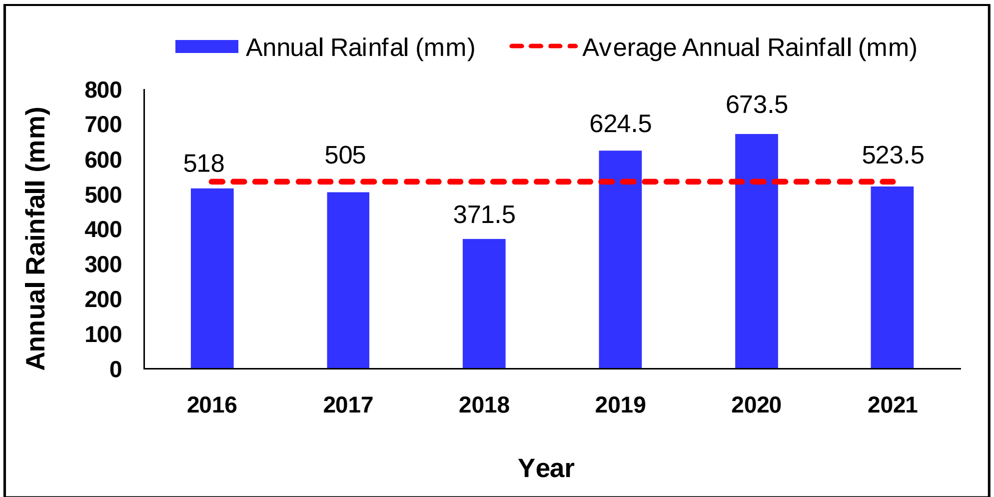


**Fig. 2. Average annual rainfall at Athani Taluk, Belagavi District**

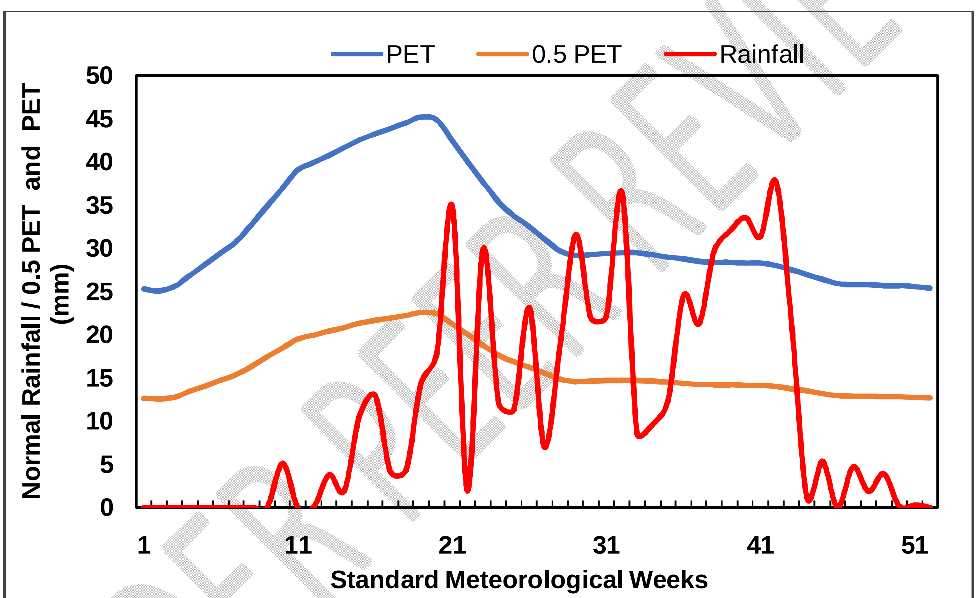


**Fig.3.Mean monthly rainfall, PET and 0.5 PET at Athani Taluk, Belagavi District**

### 3.2 Rainfall Distribution

The number of rainy days (>2.5 mm) varied from 14-24 days per year. On average the number of rainy-day events likely to produce runoff (20 to 30 mm) isabout 3 to 7 rainy days per year with moderate variation across the years (Fig. 4.). The extremely high rainfall peak event days (>30mm) 3 day per year observed in the year 2017. Which helps in designing conservation and harvesting structure in a watershed.

### 3.3 Evapotranspiration

The Actual Evapotranspiration (AET) over the years 2016-21 in the Artal sub-watershed varied from 297 to 558 mm (Fig. 5.) During 2016-21 the average annual AET (421 mm) was less than the average rainfall (536 mm). AET was higher than rainfall during the months of January, February, March, April, August, November and December, which forced groundwater withdrawal during those months to meet crop water needs.

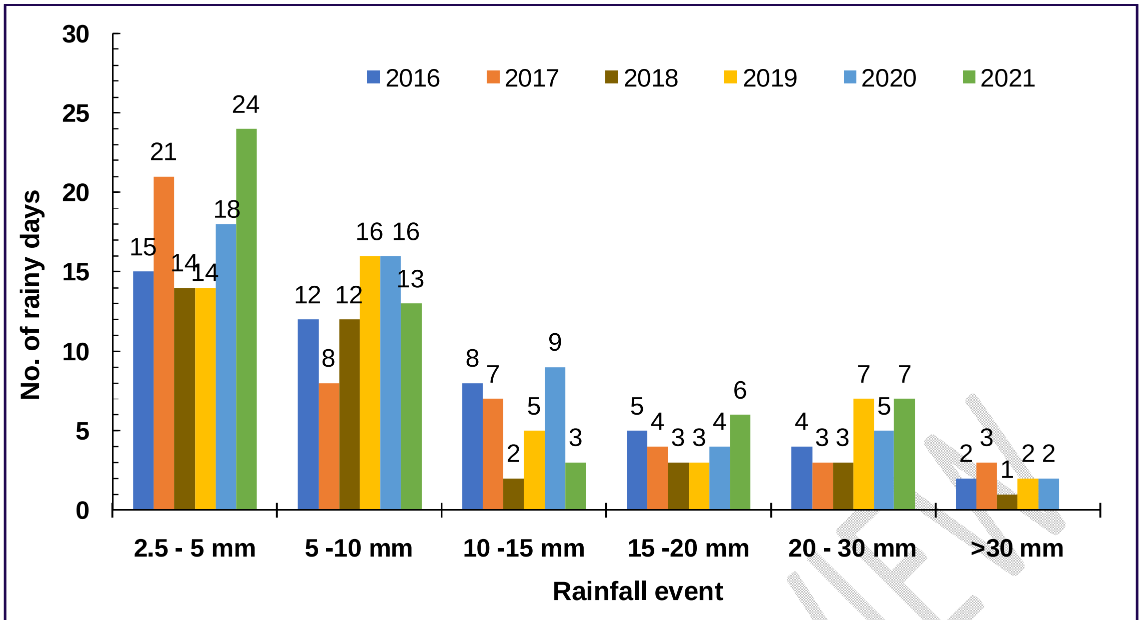


**Fig.4. Distribution of Rainfall in different rainfall events**

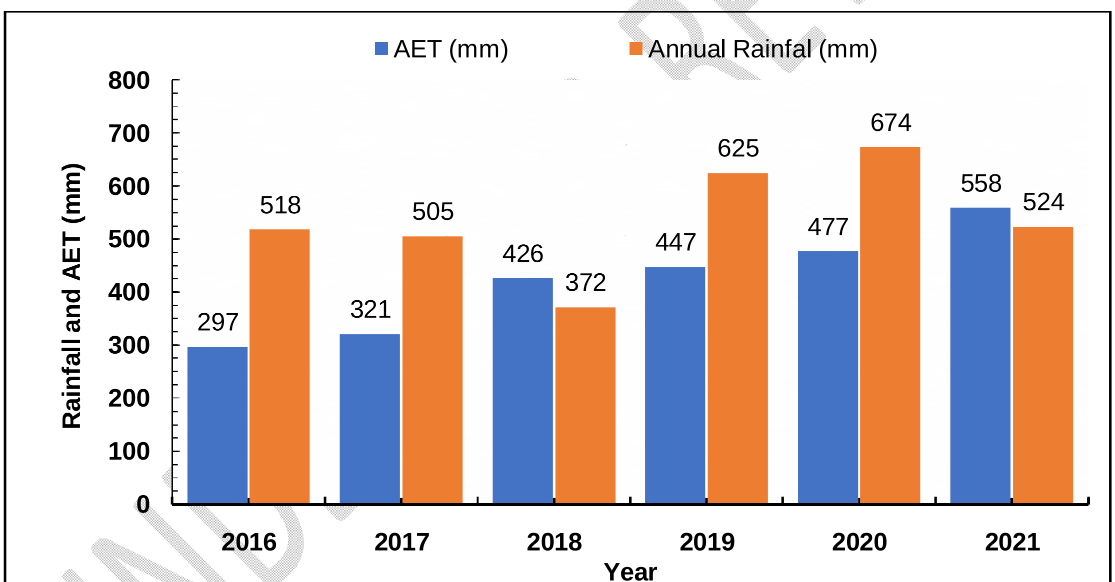


**Fig.5. Actual evapotranspiration (AET) and rainfall over different years**



## 3.4 Annual Actual Evapotranspiration

The spatial maps of reference and actual evapotranspirationdescribe that the difference between $ET_{ref}$ and $ET_a$ is lessover upper, middle and lower ridges of the watershed (Fig. 6.).“The ridge-wise analysis in annual actual evapotranspiration shows that the extremely low (348-366 mm) values observed over upper ridge of the watershed and high (499-510 mm) amount of ETa observed over lower ridge of the watershed. Spatial variability in of actual evapotranspiration was due to soil moisture, vegetation cover and cropping systemsadopted in the watershed”[6].“To understand the reason for the variability in ETa, the seasonal trends are calculated for the major evapotranspiration components including transpiration, bare soil evaporation, interception loss, and open water evaporation during the study period”[7]. The transpiration and interception loss from the vegetation hasshown a tremendous change in the evapotranspiration [8].

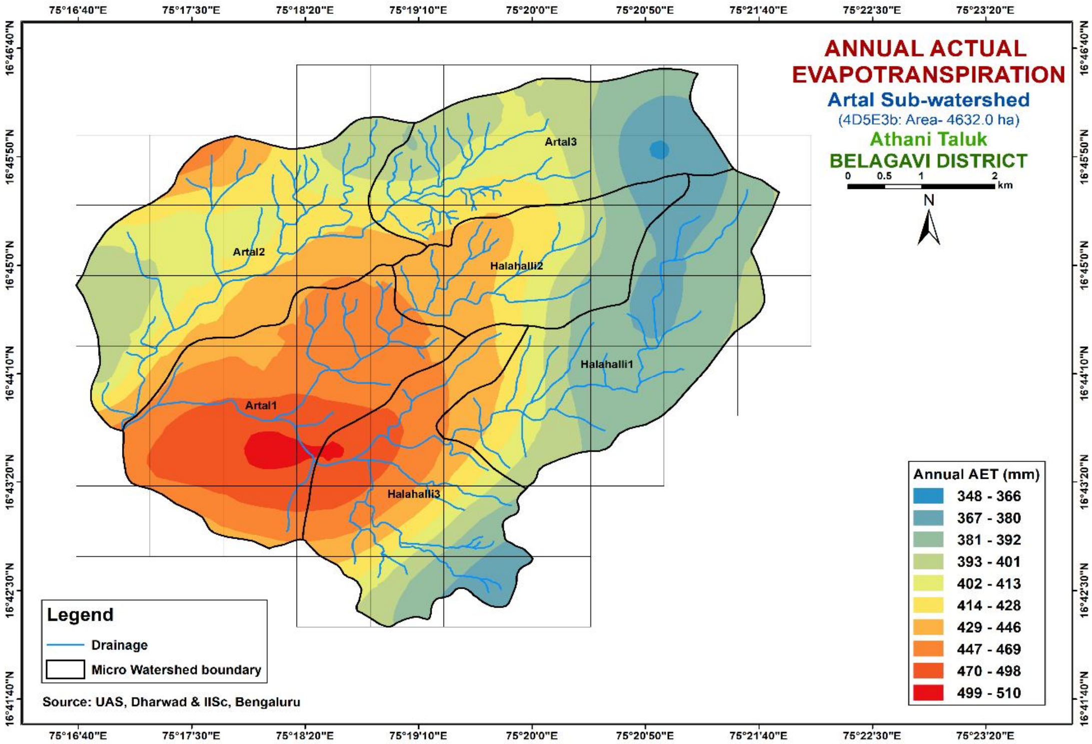


**Fig. 6. Map of the Annual Actual Evapotranspiration of Artal sub-watershed.**

### 3.5 Evapotranspiration Index

Budykocurve is the relationship between the ratio of the actual evaporation amount to the annual precipitation (AET/P) and the ratio of the potential evaporation amount to the annual precipitation (PET/P), called the dryness index or aridity index) based on data obtained from watersheds [9].The watershed water balance is in normal condition. For sustainability, the limit of AET/P should be below the Budyko curve for sustainable watersheds from hydrological considerations.This suggests that the cropping choices and irrigation choices have to be altered to reduce the total ET (Fig.7.). The average AET/P ratio between 2016-2021 was about 0.74 which is less than the sustainable limit of about 0.80. During 2018 and 2020 AET/P ratioswere 1.14 and 1.06 respectively, (Fig. 8.) which indicates receipt of less rainfall in the years and also the possibility of groundwater being augmented to maintain crop water requirement. To buildon this and linkthe Budyko's hypothesis to the complementary relationship between actual evaporation and potential evaporation[10]. The Budyko curve analytically by modelling total evaporation using simple models of interception and transpiration in combination with measurable parameters related to rainfall dynamics and storage availability obtained from remotely sensed data sources[11]. "The Budyko curve has also been interpreted at a higher physical level as a possible outcome of thermodynamic optimality through the invocation of the maximum entropy production principle"[12]."Budyko curve parameter could facilitate and easily utilized by policymakers for watershed quality assessment and hydrological system identification"[13].

### 3.6 Soil Texture and Infiltration Rate

Texture is an expression to indicate the coarseness or fineness of the soil as determined by the relative proportion of primary particles of sand, silt and clay. It has a direct bearing on the structure, porosity, water infiltration, adhesion and consistence. The textural classes used for LRI were used to classify and a surface soil texture map was generated. The area extent and their geographical distribution in the sub-watershed is shown in Fig 9.

An area of about 840 ha (18.13%) has a clay texture at the surface. The most productive lands concerning surface soil texture are clayey soils (93.19%) with an infiltration rate of 2mm/hr that have a high potential for retention and availability of water and nutrients but, have more problems withdrainage, infiltration, workability and other physical problems. The sandy loam (1182 ha), clay loam (307 ha), sandy clay (634 ha) and sandy clay loam (1570 ha) texture classes occupied the majority of the sub-watershed area. the soils of watershed viz., sandy clay loam (10 mm/hr), sandy clay (14 mm/hr) and sandy loam (28 mm/hr) resulted in more infiltration rate than clay (2 mm/hr) and clay loam soils (7 mm/hr). The surface soil textural class provides a guide to understanding soil-water retention and availability, nutrient holding capacity, infiltration, workability, drainage, physical and chemical behaviour, microbial activity and crop suitability [14][15][16].

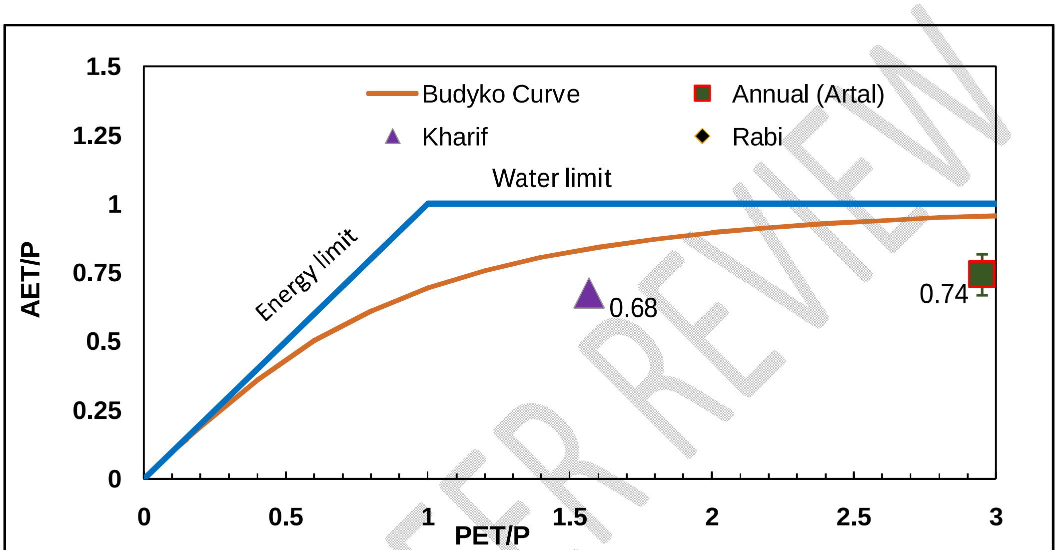


**Fig. 7. Seasonal Budyko curve of Artal subwatershed of Karanatka (2016-2021)**

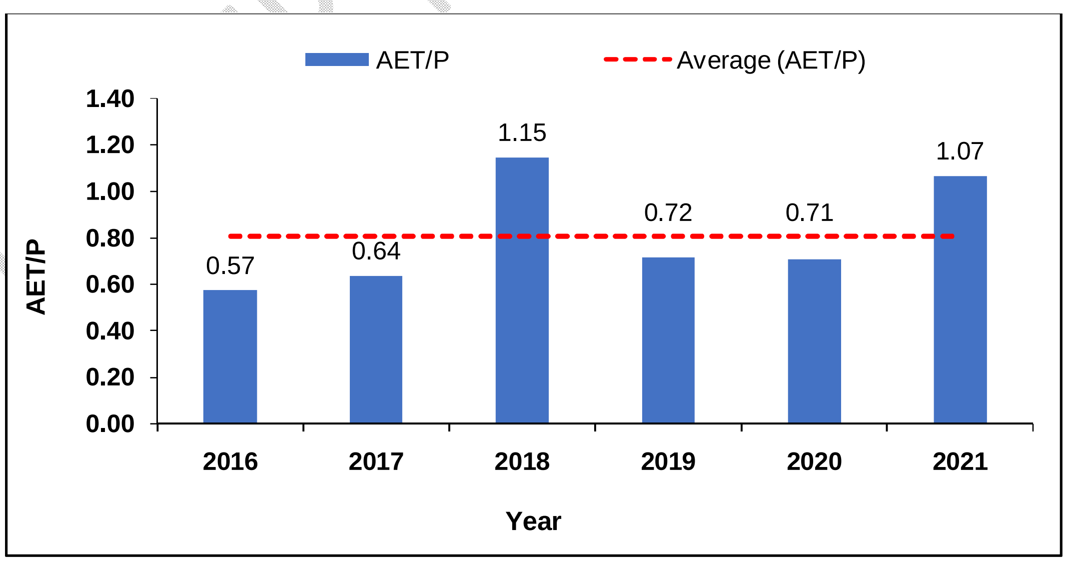


**Fig .8. AET/P Ratio of Artal subwatershed of Karanatka**

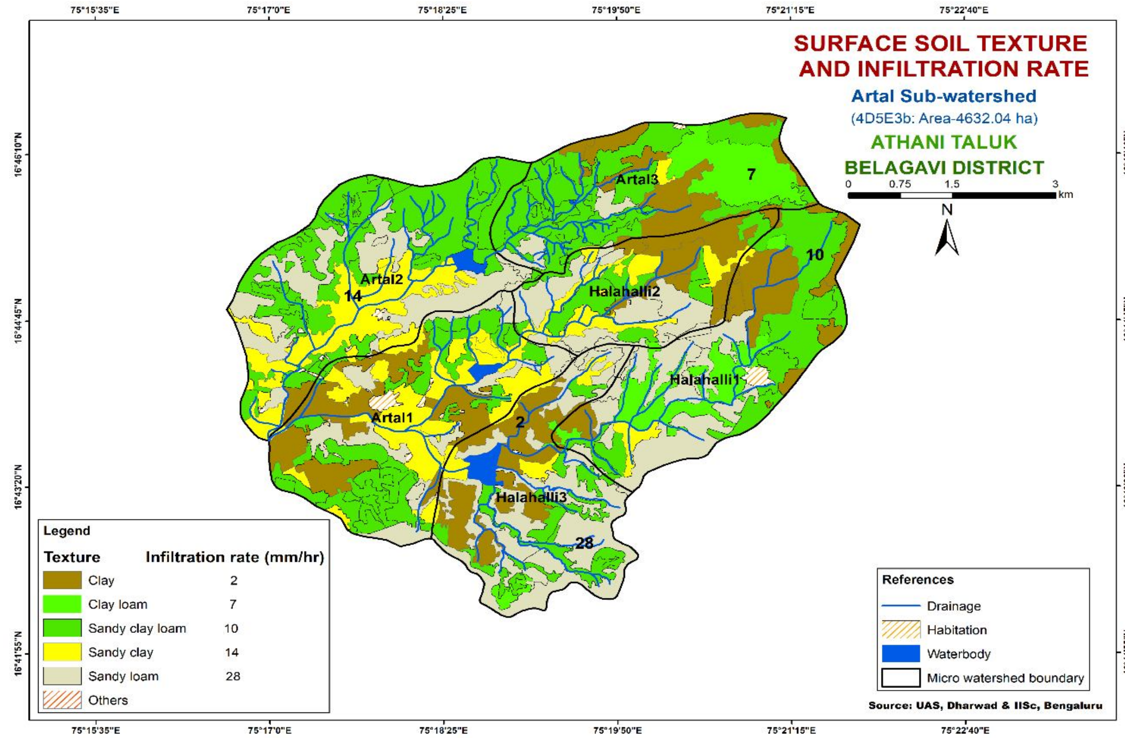


**Fig. 9. Surface soil texture and infiltration rate map of Artal sub-watershed of Karnataka**

### 3.7 Ground Water Depth Measurementand Kriging

Groundwater levels fluctuate naturally in response to a sequence of climatic events and to constraints imposed by hydrogeologic and topographic characteristics. The groundwater level is influenced by borewell recharge, discharge, topography of land, soil texture etc. Trend analysis of water table depths indicates marked spatial variations of groundwater levels in the Artal sub-watershed of the study area. The mean depth of groundwater observed from ground level during pre and post-monsoon. During pre and monsoon the average ground water depth highest of 46-50 mbgland lowest of 5-10mbgl. These data indicate marked spatial variability in the distribution of wells with distinct rates of change across the different geomorphic units visible[17].The groundwaterresource of a region is one of the building blocks for the balanced economic development of the area. The water table represents the groundwater reservoir, and changes in its level represent the changes in groundwater storage [18].

The map of groundwater elevation determined by this method ispresented in Fig.10 and 11**.** It shows that the highest groundwater elevation occurred in the west to the western part of the study area and the lowest groundwater elevation was obtained in the northeastern part of the study area. The groundwater elevation gradients are higher in the northern part and gradually decrease towards the southern parts and the general flow occurs from north to south [19]. "The groundwater table is deep on the upstream side and shallow on the mid and valley sides. This is possibly due to the flux that the water drains downslope to bring the soil moisture to the field capacity"[20]. "In addition, the soil depth on the upslope is shallow, which means it dries out faster than the deep soils due to evaporation; therefore, the quantity of water flowing toward the well is declining faster as compared with the well in the deep soil"[21].

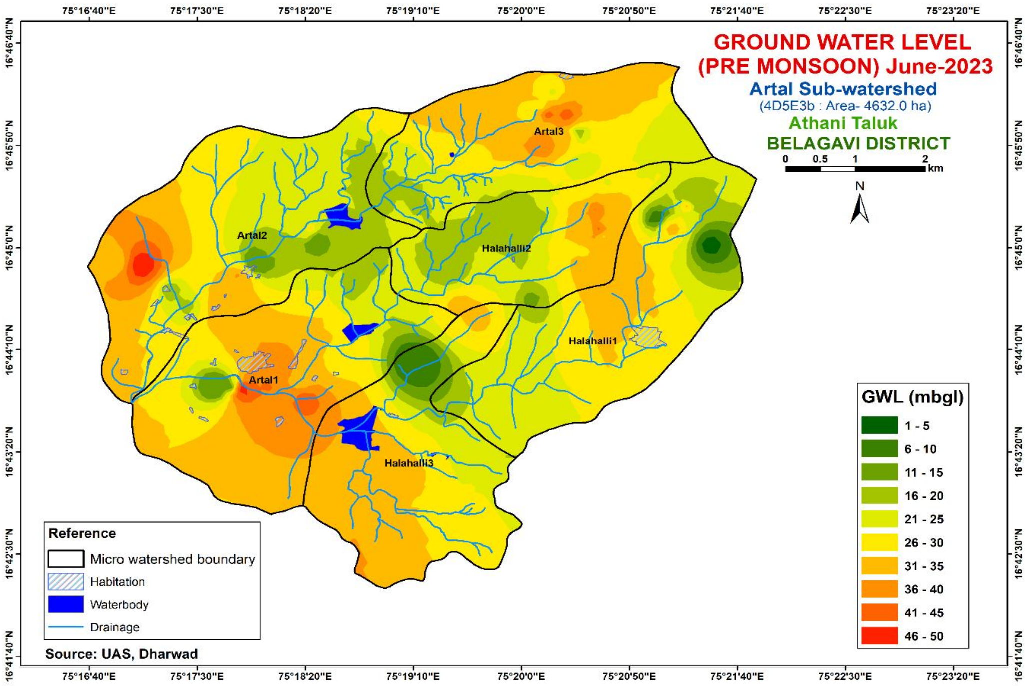


**Fig. 10. Pre- monsoon Ground water depth of Artal sub-watershed of Karnataka**

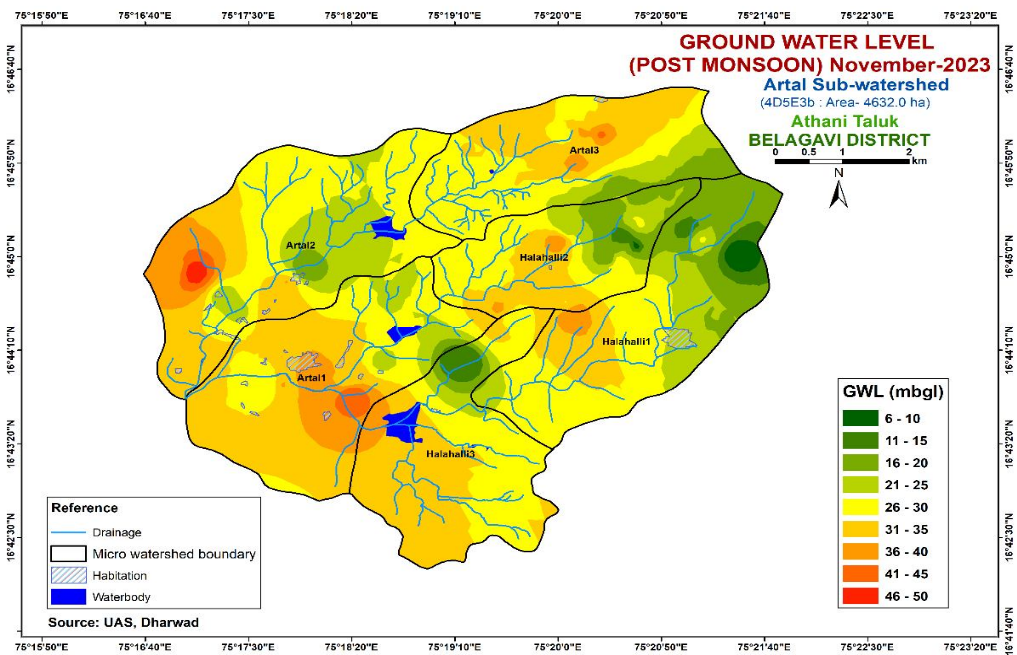


**Fig. 11.Post-monsoon Groundwater depth of Artal sub-watershed of Karnataka**

## 3.8 Soil and water conservation treatment plan

For preparing the soil and water conservation treatment plan for the Artal sub-watershed, the land resource inventory database was generated and transformed as information through a series of interpretative (Thematic) maps using a soil phase map as a base. A map showing soil and water conservation plan with different kinds of structures recommended has been generated which shows the spatial distribution and extent of area. A maximum area of about 875 ha (18.9%) requires graded bunding and a 3657 ha (78.96%) area requires contour bunding (Fig.12.)

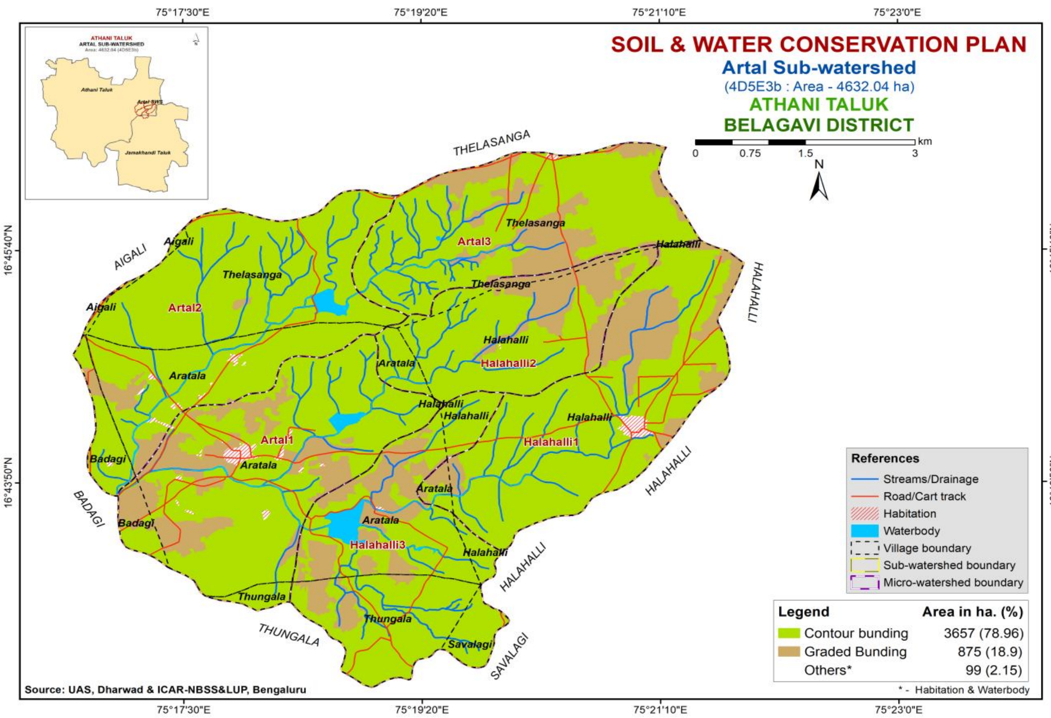


**Fig.12. Soil and Water Conservation Plan map of Artal sub-watershed**

## 4. CONCLUSION

The total geographical area of the Artal sub-watershed is 4632.04 ha and the sub-watershed is primarily composed of loamy sand followed by sandy clay loam, sandy loam and clay.The infiltration rates within the sub-watershed varied based on the type of soil and ranged from 3 to 28 mm/hr. In sub-watershedthe mean annual ET is lower than the mean annual rainfall. This means that inthe annual time scale of the water budget demand side is lower than the supply side. The focus in this sub-watershed should be to develop an improved water use efficiency (WUE) in agriculture and hence efforts should focus on the demand side of water use. The groundwater map shows the natural topography and prevailing conditions in the watershed are favourablefor declining water table. The point recharge and farm ponds may be constructed in the lowermost corner of the agricultural fields to increase the natural recharge of rainwater during the monsoon period.

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