Using Remote sensing technique for estimation of real evapotranspiration

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Abstract— **Evapotranspiration is not easy to measure; Specific devices and accurate measurements are required to determine evapotranspiration. In this research, using the RS technique, the amount of real evapotranspiration will be determined in Chaviz sub-basin of Ilam dam catchment. n this study, there has been employed the image of ETM+ Landsat satellite dated June the 15th 2010. ENVI4.7 software was used to obtain the needed information from the image of ETM+ Landsat satellite. The daily information for estimation of evapotranspiration of reference crop was provided from Ilam weather forecast station. Finally, geometric calculations were done using ArcGIS9.3 software and there were obtained outputs from the prepared maps. In this work, real evapotranspiration has been estimated using bands 3&4 of ETM+ satellite and also vegetation fraction index. This is a new method for evaluating real evapotranspiration in the catchment and regional scale. The results show that real evapotranspiration with values of the 0-2.92 mm/day is dominant in Chaviz sub-basin. The most largest area in which evapotranspiration happens is the area of ranges (%63). Forest land use in the next rank. The maximum evapotranspiration happens in gardens (8.9 to 11.71 mm/day) but they cover only a little area of the basin (%10) and the minimum evapotranspiration happens in the land use of the ranges (0 to 2.92 mm/day) which covers a large area of the basin (%63). Base on the results of this study, it can be claimed that the rate of evapotranspiration is low in Chaviz sub basin (Ilam dam). Also, since this range of evapotranspiration coincides the area of ranges, it can be said that land use of the ranges enjoys less evapotranspiration comparing with other kinds of land uses and its water needs are accordingly lower than others.**

Index Terms— **Remote sensing, Real evapotranspiration, ETM+ satellite, Ilam dam.**

I. Introduction

Iran is among arid and semiarid countries of the world, so that its annual average rainfall is less than one third of the world's rainfall and the evaporation rate is three times greater than the evaporation rate of the world's lands [I]. Based on the studies in comprehensive project of the country's water, precipitation is the main origin of water resources in Iran which is estimated as 413 billion m3 per year. From this value, 25 billion m3 penetrates directly to alluvial basins and the remaining will be evapotranspirated and hence inaccessible [2].

Evapotranspiration is one of the main ways of consuming and wasting the water in a basin. Investigating the basin changes in the special periods of time, aside from determining the consumed water in each land use, can be helpful both in the management of water in the basin and determining the amount of water which be dedicated to each land use. The rate of Evapotranspiration can be estimated using geometrical data and evaporation equations. However, providing geometrical parameters in each point involves establishing weather forecast stations which will be expensive. On the other hand, considering the extent of natural resources and basins and also infeasibility of stationary inspection of Evapotranspiration in a basin, remote sensing can be a suitable technology in determining the real evapotranspiration in a basin [3].

“Reference [4] stated that the Evapotranspiration is the total of consumed body of water by the plants (transpiration) and also the amount of water evaporated from the earth. Evaporation and Transpiration (ET) are among the main elements of Hydrology circle the precise estimation of which is essential in most of the studies including water hydrologic balance, designing and managing irrigation systems, and also water resources management. One of the common methods of estimating evapotranspiration for plants is to measure the evapotranspiration of reference crop (grass or alfalfa) from a standard level and then using plant coefficients [5]. The schematic pattern of calculating Evapotranspiration using this method has been depicted in figure I. In this figure, ETC is the standard potential of Evapotranspiration of the atmosphere, KC is the product of plant coefficient of reference crop multiplying by the amount of Evapotranspiration in standard condition (ET0). For estimation of evapotranspiration for other plants with different growing qualities in agricultural conditions and also under environmental and managerial stresses which are effective factors on the amount of evapotranspiration, it is necessary that ETC be corrected. For this purpose, another coefficient (KS) will be considered for estimation of evapotranspiration. This method is prevalent mainly for agricultural plants.

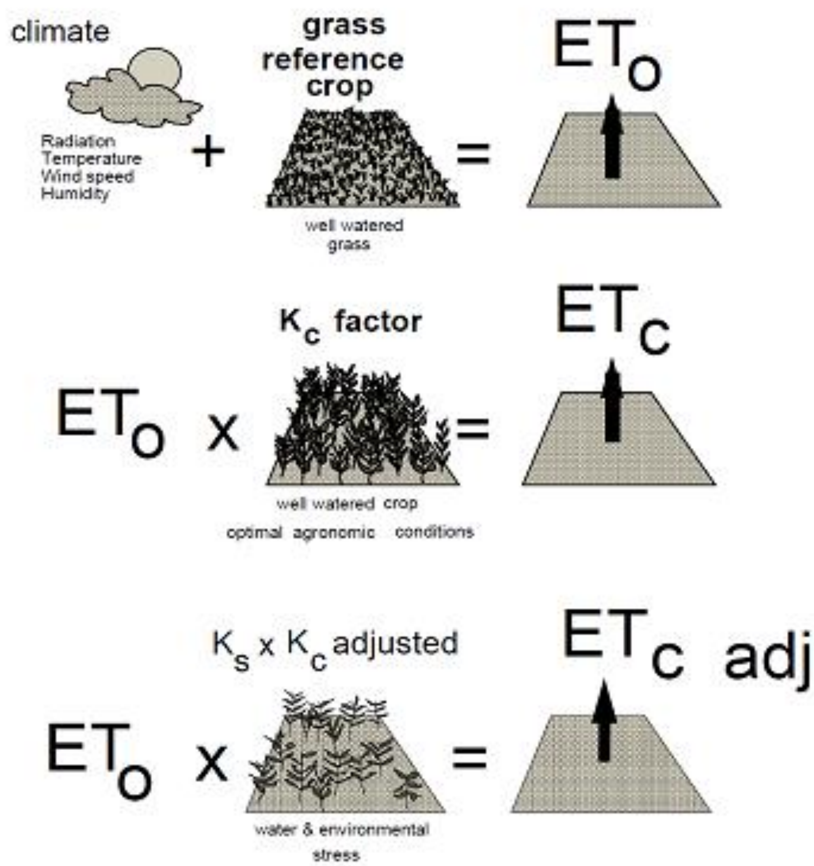

Figure I. The way of calculating Evapotranspiration using the method of Evapotranspiration of reference crop

Growing developments of remote sensing technology has made it possible to estimate real Evapotranspiration widely. The estimation of real Evapotranspiration and its spatial distribution are among the operations that can be accomplished using remote sensing technology. It is much significant than point methods and is employed in macro decision makings too. Although regarding time intervals, there are limitations in using remote sensing, its use at extended levels enjoys acceptable accuracy and it has been accepted as a practical method [6].

Akbari et al (2012), using the information of NOAA-AVHRR satellite, determined the real transpiration of plants via remote sensing and considered it as the consumed water by the plants. “Reference [7] showed that there is a good relationship between NDVI and Kcr in plants of Soya, sorghum and corn. The main purpose of this study is to estimate real Evapotranspiration via RS and GIS technique as a modern and economic method of estimating evapotranspiration in sub basin of Chviz (Ilam dam).

II. MATERIALS AND METHODS

a. Description of the area of study

The area of study is one of the sub basins of Ilam dam called Chaviz (Fig II). Chaviz sub basin has been located between eastern longitudes of 46˚ 21′ 29″ to 46˚ 31′ 51″ and northern latitudes of 33˚ 36′ 21″ to 33˚ 39′ 19″. With minimum and maximum altitudes of 1030 m and 2170 m and also area approximately about 116 km2, Chaviz sub basin has a moderate mountaineer climate. The average annual precipitation is 850mm and the average absolute temperature ranges from -13.6 to 42 ˚C in this area and it has been located in the south west of Ilam.

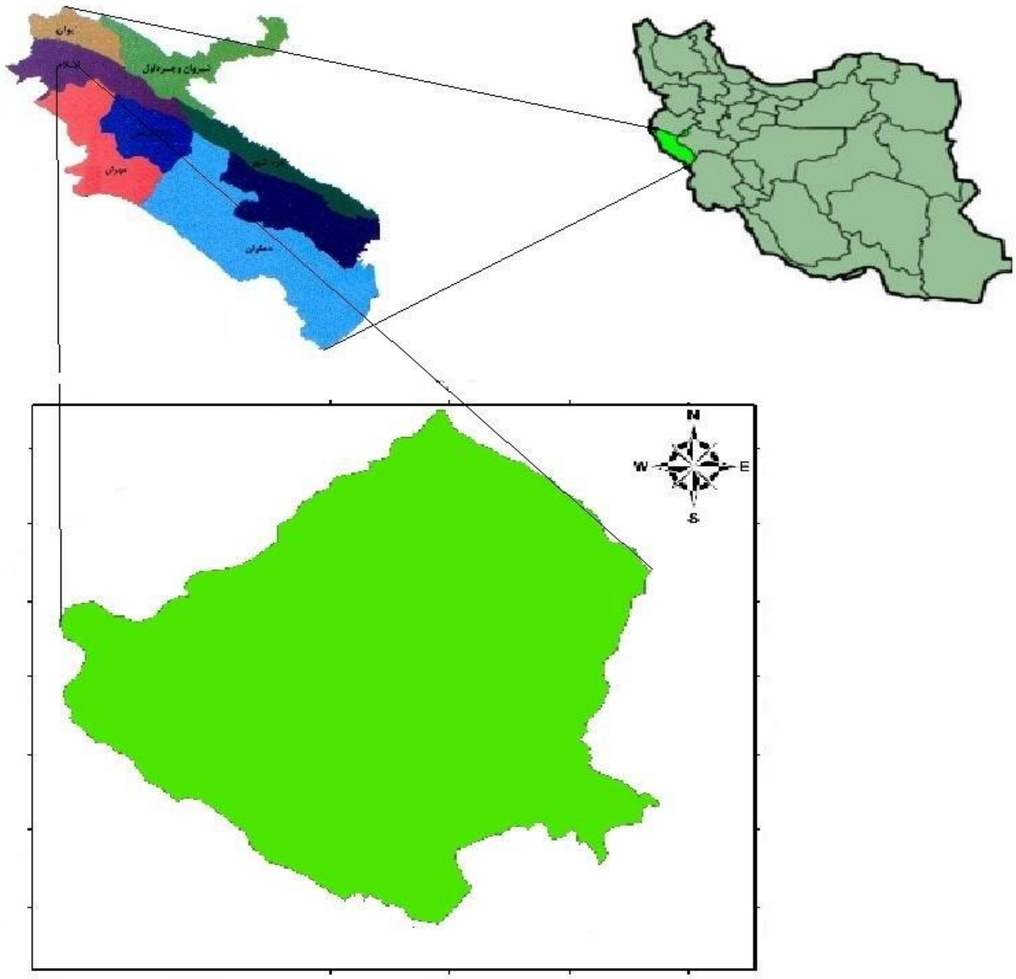

Fig II. The location of the sub basin under study

b. Methodology

In this study, there has been employed the image of ETM+ Landsat satellite dated June the 15th 2010. ENVI4.7 software was used to obtain the needed information from the image of ETM+ Landsat satellite. The daily information for estimation of evapotranspiration of reference crop was provided from Ilam weather forecast station. Finally, geometric calculations were done using ArcGIS9.3 software and there were obtained outputs from the prepared maps. The steps of estimating evapotranspiration are as follows:

c. Preparing the index map of normalized vegetation cover

Index is Normalized Difference Vegetation Index (NDVI) that obtained by Remote Sensing technology. NDVI is one of the most popular vegetation indices that is defined by infrared and near-infrared bands as equation (1) [8].

$$NDVI= (NIR+ IR)/ (NIR- IR) \quad (1)$$

This index is introducing solar energy reflection from the earth surface which represents the types of vegetation. The NDVI values have fluctuation between 0 and 1. When the measured spectral response from the earth surface is very similar, NDVI values are close to zero. The normal vegetation (with photosynthesis activity) in near-infrared wavelength (NIR) (Landsat Band 4) has more reflection in comparison with visible spectrum (Red, Landsat Band 3); therefore, the NDVI values for green vegetation will be positive. The regions with little or no vegetation such as urban areas and arid lands usually show NDVI values between clouds and water resources show negative or zero values. The Normalized Difference Vegetation Index (NDVI) used for calculation of the ground spectral data and its results showed that this index has the high correlation with ground biomass [9].

In this study, band3 (red) and band4 (close infrared) were selected as ETM+ sensors and the related model was created in the environment of ENVI 4.7 software. The image of NDVI in the area of study, dated back to June 2010, has been given in Fig III.

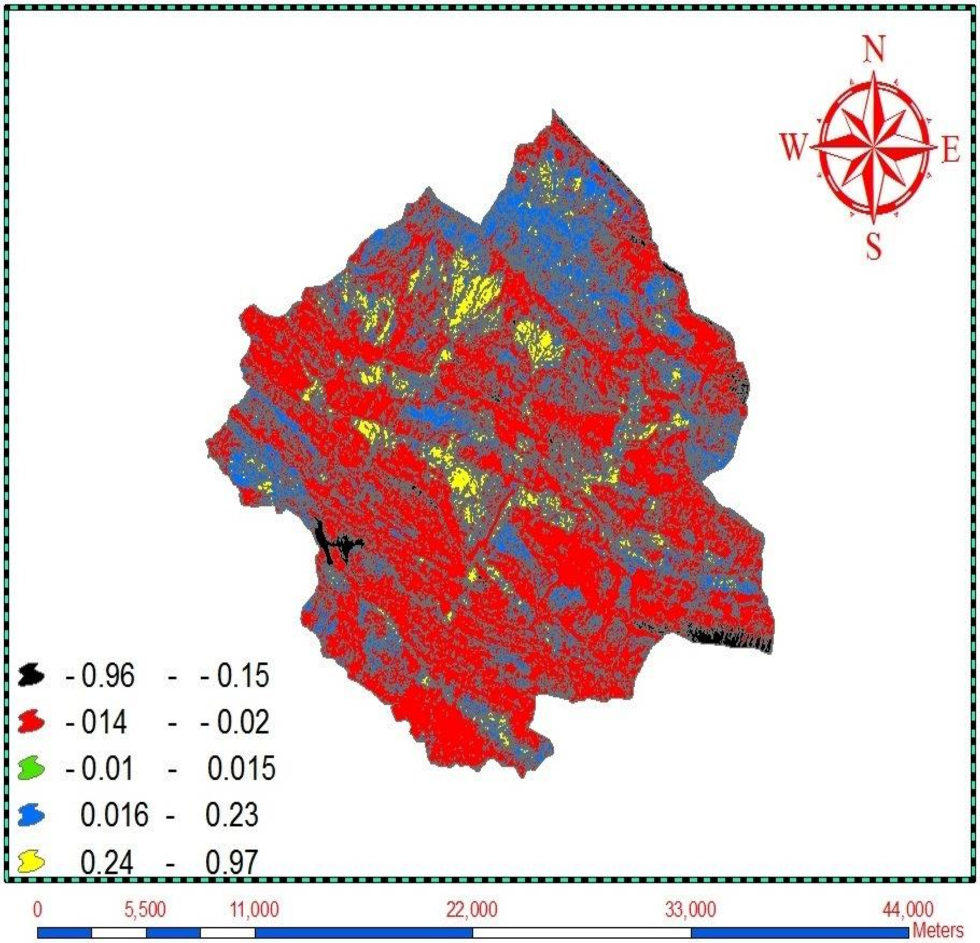

Fig III. The map of NDVI in sub basin of Chaviz (Ilam dam-2010)

d. Preparing the fraction map of vegetation cover

This map implies the ratio of the vegetated surface to the bare land. For preparing this map, Brunsell and Gillies method has been used. In this method in which NDVI values are used in calculation of vegetation cover fraction, the ratio of bare land emitting to the dense vegetation cover is measured and will be calculated via equation2 [10].

$$Fr = \frac{[(NDVI - NDVI0)]}{[(NDVImax - NDVI0)]^2} \quad (2)$$

In this equation, NDVI0 and NDVI max are the values of this index for bare land and dense vegetation cover respectively. In this equation, it is hypothesized that the evapotranspiration value in a completely dry pixel is zero and this value in a pixel located in a proper vegetated point which is irrigated well, is around 1.2. In Fig IV, there has been depicted the map related to the fraction of vegetation cover in June 2010 in the area of study.

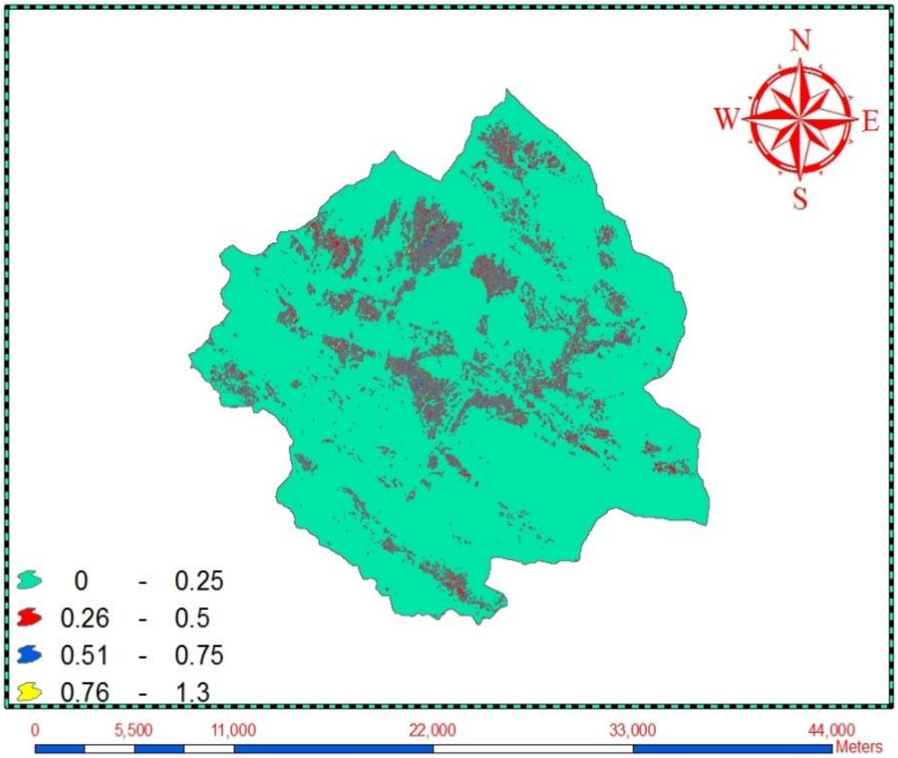

Fig IV. The map related to the fraction of vegetation cover in Chaviz sub basin (Ilam dam-2010)

e. Measurement of evapotranspiration of reference crop

In this study, the values of evapotranspiration for Ilam synoptic weather forecast station during 20 years-statistic period were measured using Blanney-Criddle method. The reason of using this method for measuring ETr is for the purpose of proving its accuracy and conformity with the obtained results of these calculations in the area of study. Based on these relations, the value of evapotranspiration for reference crop was calculated via equation3:

$$ET0 = a + b[p(0.64\, T\, mean + 8.13)] \qquad (3)$$

ETo: the amount of evapotranspiration in reference crop in mm/day.

T mean: the mean of temperature in Centigrade degree (˚C).

P: the coefficient related to day length or the annual percentage of sunshine obtained from the respective tabled.

a and b are climatic coefficients calculated from equations 4 and 5

a = 0.0043RHmin – (n/N)-1.41

b = 0.82-0.0041RHmin+1.07 (n/N) + 0.066 (U day) - 0.006 (RH min) (n/N)-0.0006 (RHmin) (U day)

Rh min: the minimum relative humidity in percentage

n: the real hours of the sun

N: the maximum feasible hours of sunshine

U day: the speed of wind during in the altitude of 2m in m/s

f. Extracting the map of real evapotranspiration

Real evapotranspiration was estimated via equation 6 [11]. The map of real evapotranspiration which is the product of vegetation fraction multiplying by the evapotranspiration of reference crop was prepared using [11] method for June 2010 in Chaviz sub basin (Ilam dam).

$$ETa = Fr(ETr) \qquad (4)$$

III. RESILTS

After determining the threshold for NDVI in ETM+ image, NDVI index was categorized into five categories.

The results indicate that NDVI index has been included in the ranges of (-0.14 to -0.02) and (0.016 to 0.23) in the vast area of the basin and ranges of (-0.96 to -0.15) and (-0.01 to 0.015) in the narrower part (Fig IV), so that %64 of the basin has been located inside NDVI range of -0.14 to -0.02 and %25 in the range of 0.016 to 0.23 (Fig V).

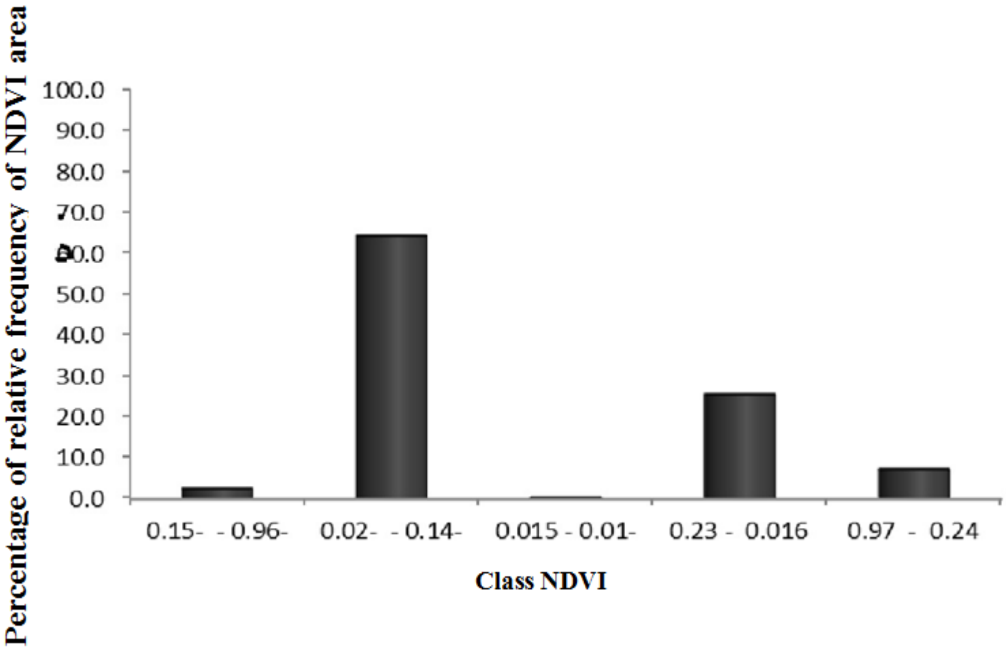

Fig V. The percentage of relative frequency of NDVI area in the basin-2010

Via equation6 in the environment of ENVI4.2 software, the evapotranspiration of reference crop was multiplied by the fraction map of vegetation cover and there were determined the value of evapotranspiration for each category (Fig VI). The minimum and maximum estimated evapotranspiration of the basin were 0-2.92 and 8.9-11.71 respectively (Fig VI). But in the majority parts of the basin, evapotranspiration rate was 0-2.92 mm/day (Fig VII). This parts are actually the land use of range in Chaviz sub basin.

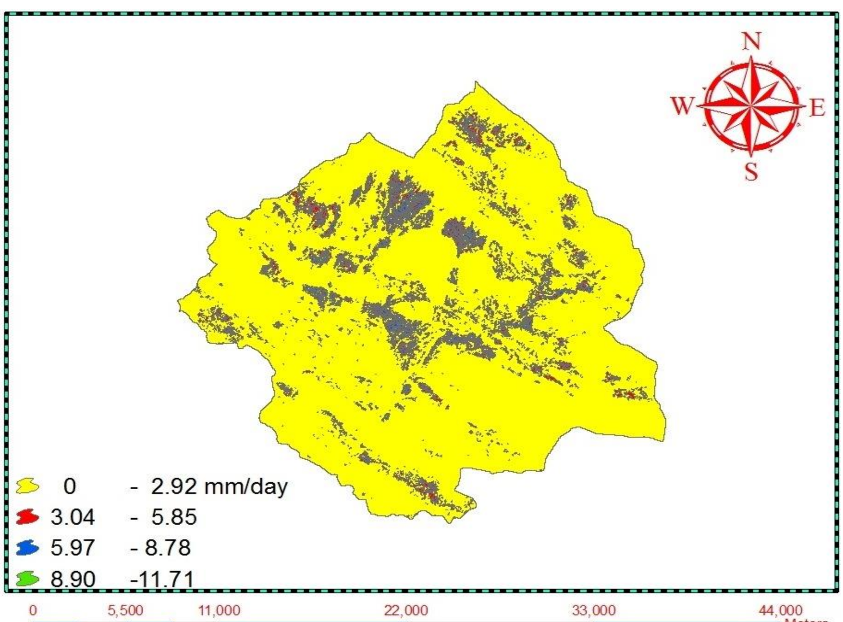

Fig VI. The map of evapotranspiration in Chaviz sub basin (Ilam – 2010)

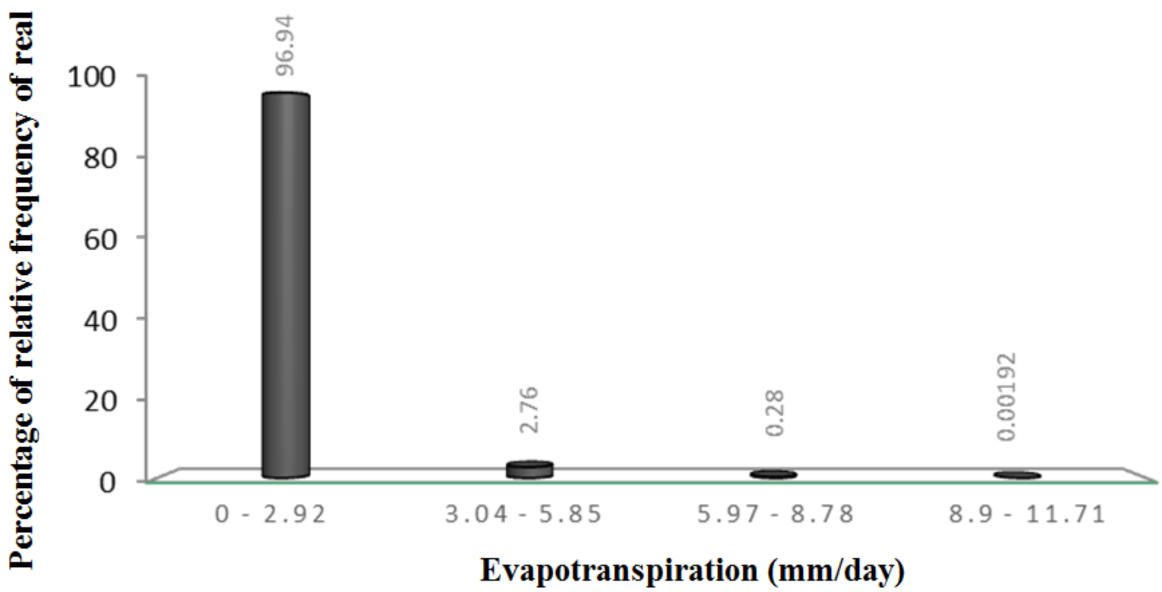

Fig VII. The percentage of relative frequency of real evapotranspiration area in Chaviz sub basin in 2010

IV. DISCUSSION

The most largest area in which evapotranspiration happens is the area of ranges (%63). Forest land use in the next rank. The maximum evapotranspiratio happens in gardens (8.9 to 11.71 mm/day) but they cover only a little area of the basin (%10) and the minimum evapotranspiration happens in the land use of the ranges (0 to 2.92 mm/day) which covers a large area of the basin (%63). Base on the results of this study, it can be claimed that the rate of evapotranspiration is low in Chaviz sub basin (Ilam dam). Also, since this range of evapotranspiration coincides the area of ranges, it can be said that land use of the ranges enjoys less evapotranspiration comparing with other kinds of land uses and its water needs are accordingly lower than others.

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