# AN APPROACH TO MAPPING EVAPOTRANSPIRATION BY METEOROLOGICAL ELEMENT WITH APPLICATION TO THE TERRITORY OF ALBANIA

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## ABSTRACT

Evapotranspiration is one of the major problems of soil water balance Evapotranspiration. Data and Information, as an important element in the context of Spatial data Infrastructure is a question of great interest to a wide community of specialists, such as meteorologists, agronomists, hydrologists, managers of irrigation etc. Many particular researches are carried out in Albania to evaluate evapotraspiration. This paper is an attempt to introduce a general evaluation of the evapotranspiration in the Albanian territory, including the evapotranspiration regionalization. Evaluation of evapotranspiration in the Albanian territory plays a major role because Albania is a complicated and complex natural area in Europe as a result of its specific physical-geographical conditions: a mountainous region, typical Mediterranean climate, a particular hydrographical system, etc.

There are various methods applied: direct measurement or observed method, indirect calculating method using empiric formulas, based on meteorological data, water balance method. It is evaluated by using multi-annual archival hydro-meteorological information of the Institute for Energy, Water and Environment, such as temperature, rainfall, solar radiation, vapor pressure, wind speed. Evotranspiration evaluation is based on the observed period of 20-30 years and 6 experimental stations GGJ with an observed period of about 10 years. Evaporation is evaluated by computing its principal components, such as: potential or reference evapotranspitarion – $E_0$, real evapotranspiration – $E_R$, evaporation deficit – $\Delta E$, pluviometric deficit – $\Delta x$. Evapotranspiration and territory altitude dependence subdues the vertical zonal law, having e typical regional character. Using these dependences, the evapotranspiration maps are compiled for the Albanian territory.

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The diverse meteorological elements and the evapotranspiration values, evaluated according to the various empirical methods have been updated and plotted on the 3D digital map, thereby creating the data spatial distribution by employing G.I.S system. The spatial distribution for the values of evapotranspiration in the Albanian territory has been performed in connection with other spatial values, such as altitude above sea level, longitude and latitude for each area, rainfall rate distribution, temperature, solar radiation, relative humidity and other strata as the variable elements of spatial data infrastructure to be processed and analyzed in the context of GIS program

**Key word**: Evapotranspiration, regionalization, empirical method, map, G.I.S, spatial

## 1. INTRODUCTION

This paper is an attempt to introduce a general evaluation of the evapotranspiration in Albanian territory. Evapotranspiration is one of the major problems of soil water balance. Knowing the amount of water directly evaporated from the soil or through transpiration of plants is a point of interest not only for the agronomists, but also for meteorologist, hydrologists, managers of irrigation etc. Evaluation of evapotranspiration in the Albanian territory plays a major role because Albania is a complicated and complex natural area in Europe as a result of its specific physical-geographical conditions: a mountainous region, typical Mediterranean climate, a particular hydrographical system, etc.

The principle of evapotranspiration estimation consists in the association of climatological data, which provide a way of determining the atmospheric demand of water, with both agronomic knowledge and estimates of soil water availability which, combined, indicate how the soil-crop system can meet this demand. There are various methods applied for its evaluation, respectively: direct method, indirect calculating method using empiric formulas, based on meteorological data, water balance method. It is evaluated by using multi-annual archival hydro-meteorological information of the Institute for Energy, Water and Environment, such as temperature, rainfall, solar radiation, vapor pressure, wind speed.

Albanian monitoring network consists of more than 125 meteorological stations located all over the country with an observed long period, 175 hydrometric stations, and experimental stations, especially in the Lushnja region with an observed period of about 10 years. Evapotranspiration evaluation is based on the observed period of 1961-1990. National topographical maps of 1:25000 scale are used to evaluate the morphometric characteristics

## 2. DESCRIPTION OF THE REGION

The Republic of Albania is situated in South east Europe, in the western part of the Balkan Peninsula facing the Adriatic Sea (sandy shore) and the Ionian Sea (rocky shore). Albania has a surface area of 28,745 $km^2$. Its terrain is mountainous, with the hilly and mountainous areas making up 77% of the country's territory, with an average altitude of 708 meters double that of Europe.

The general length of the state border is 1,093 km, out of which 657 km land border, 316 km sea border, 48 km river border and 72 km lake border. North and Northeast, Albania borders with the Republic of Montenegro, East bordering with Former Yugoslav Republic of Macedonia, while south and southeast with Greece.(Figure1)

A number of rivers flow into the sea such as Buna, Drini, Mati, Ishmi, Erzen, Shkumbin, Seman, Vjosa and Bistrica which constitute an important source of hydro power. The lakes are of varying origin: glacial lakes in the highlands, carstic lakes in the hilly areas, and tectonic lakes Shkodra, Ohri and Prespa.(Selenica A et Al 1984) Moreover they are very important for the fishermen, especially those of wetland type, which are large fishing reserves.

Albania belongs to the subtropical Mediterranean climate. It is characterized by mild winter with abundant precipitation and hot, dry summer. The annual mean air temperature has a wide variation over the territory. All the territory is characterized by the negative trend of annual mean temperature. The negative trend of annual mean temperature comes out as a result of the influence of negative trend of minimum temperatures. The mean annual precipitation total over the Albania is about 1,485 mm/year. The highest precipitation total (70%) is recorded during the cold months (October-March). The richest month in precipitation over the whole territory is November, while the poorest are July and August.


***Figure 1 Geographical map of Albania***

## 3. METHODS AND ANALYSES

Evapotranspiration in Albania is determined by the correlation of different geographical factors, such as: climate, relief, territory lithological structure, vegetation, etc. As a result the influence of all these factors in the territory is different not only during the months, seasons and different periods of the year, but also in the multi-annual cycle.
The evaluation of potential evapotranspiration, otherwise recognized nowadays as the referential area evapotranspiration, has been performed with reference to diverse climatic zones in Albania. Therefore, to this end, the Albanian territory subjected has been classified into three areas:
I-Field areas situated on the Western Lowlands in Shkoder, Lezhe, Lushnje, Durres, Vlore;
II-Hilly areas in Peshkopi, Burrel, etc;
III-Mountainous areas in Korce, Erseke, etc;
In this paper it is evaluated by computing Potential Evapotranspiration (reference evapotranspiration) $ET_p$, Real Evapotranspiration – $ET_R$, Evaporation Deficit –$\Delta E$, Pluviometric Deficit – $\Delta X_0$. Reference (Potential) Evaporation – $ET_0$ is calculated by various methods such as: Turc, Penman, Thornthweit, Penman Monteith, Equation FAO56 Penman-Monteith.Penman Monteith ASCE. In 1990, the experts and researches of FAO in collaboration with the International Commission for Irrigation and Drainage of OBM chose the FAO Penman Monteith as the correct method for the evaluation of $ET_p$.

### 3.1 Evapotranspiration reference ( Potential)

Since Reference evapotranspiration ($ET_0$) was defined as atmospheric demand, there were a lot of attempts to establish the formulae giving its dependence on meteorological observation. These formulae can be classified into empirical formulae and formulae based on physics. In the empirical formulae we can find: the radiation methods and the temperature methods (Thornthwaite). The physics formulae are Penman formula original, Penman Monteith , Turc, Blaney Cridel, Penman Monteith ASCE, FAO56 Penman Monteith etc.
The values of $ET_{0,}$ calculated by different ways, result similar to be each-other. It is evidently seen in Figure 2, with relevance to the Distribution of months values of ETp by Turc, Penman original, Thornthwaite methods (Laska A 2007, 2008). These values are relatively similar, to the results of the direct experimental observed method (the Lushnja stations), the difference about – $\delta ET_0 = \pm 5 \div 10\%$.

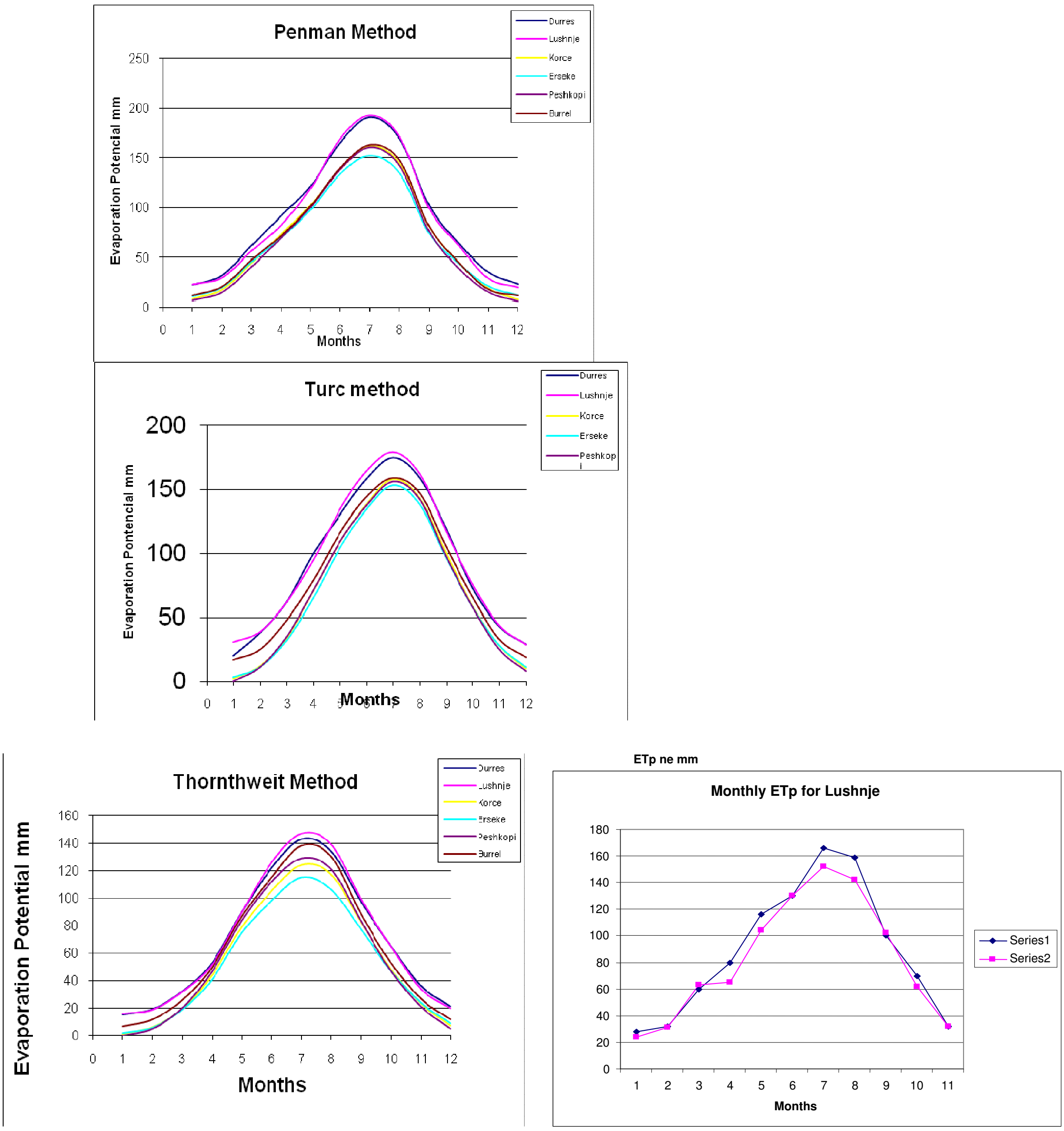



*Fig.2 Distribution of months values of $ET_0$ by diverse methods*

Currently there are several analytical-empirical methods for the evaluation of the reference evaporation $ET_0$, based on miscellaneous theoretical backgrounds. The evaluation of evapotranspiration in this research work has been performed by employing different methods as explained even in the above-mentioned instances. The formula of the Penman original equation combines the method of the energetic balance with that of the turbulent diffusion. Later, this equation was subjected to numerous modifications by various scholars and researchers. The most significant modification for this equation is recognized as Monteith, whose mathematical expression has been introduced as the Penman Monteith method. Later, various modifications have been carried out wherein the FAO56 Penman Monteith has been recently recognized as the most accurate and physically comprehensive method, since his formula involves the exploitation of numerous climatic elements.(FAO 2000) In addition, it should be emphasized that this formula is closer to reality, apart from few differences, as compared to the direct method (Lushnje Station in Lowland of Albania)

Therefore, the average monthly Reference Evapotranspiration on the Albanian territory differs from about $ET_0 = 10 \div 40$mm in January, the coldest month of the year, to about $ET_0 = 120 \div 170$mm in June, the hottest month, referring to FAO56 Pennman-Monteith and ASCE Penman Monteith. The average annual potential evaporation for the multi-annual period is about $ET_0 = 800 \div 1100$mm. The average annual (potential) reference evaporation in the plains varies from $ET_0 = 1000 \div 1100$mm and on the mountains about $ET_0 = 800 \div 850$mm. (referring to FAO56 Pennman-Monteith)

In the Figure 3 has been presented the distribution of reference (potencial) evapotranspiration (by GIS system) on the Albanian territory.

### 3.1.1. Employing GIS for the visualisation of Etp, Etr and ΔE

With a view to visually representing evapotranspiration, as well as representing it not only graphically, but also by employing other data as well, even the method of representing them through the GIS systems was utilized. It is common knowledge that the GIS systems constitute an extremely efficient method for the data collection, their digital processing, their linkage to a database, their graphical displaying and realizing QUERIES with a graphic interface.

Considering the entire range of the statistical data of evapotranspiration with various climatic elements, such as rainfalls, monthly average temperature, sun radiation, wind, relative humidity, etc., in this research employing the GIS systems was intended to enable the mapping through the evapotranspiration isolines and rainfalls, as well as the evapotranspiration with temperatures through the isolines, which themselves indicate the same size, or value, which permeates the entire country’s territory. The isolines were acquired analytically considering the statistical data collected throughout the years.

This representation permits and enables the scholars and researchers of various research areas to have a quick and logical perception of these phenomena, thereby enabling them to have a clear and simplified understanding in cases of decision-making or in the event of specialists in the various research areas are looking for information associated with this problem.

In the following maps it is evident that the data representation, both the evapotranspiration data and the data associated with the various climatic elements has been made in line with the logic familiar to every specialist and the public at large. As regards realizing the QUEIRES within the framework of GIS, there was established a Linkage between the graphical representation and the database for the data available to us (Gjata G 2009). In this case this linkage was modeled by utilizing a simple hierarchical ranking between evapotranspiration and rainfalls (or in cases, which have not been represented, based on the relationship between evapotanspiration and the various climatic elements), thereby realizing a topologic process for a dot, line, and polygon, hence enabling the linkage with the database.

The maps represented are a product of this system established for the research introduced and submitted in this conference.
These maps are formed by using different layers for each climatic element using their monthly and yearly data. The layers allow everyone see more clearly the spatial data and compare them easily. As regards QUERIES, their programming is continuing so as to enhancing the opportunities towards a comprehensive alphanumeric representation. Within the framework of the products received by GIS, even the regionalization hartograme of the evapotranspiration values for the entire country's territory was acquired, Figure 9
It is exactly by implementing the formula of FAO56 Penman Monteith that we have managed to obtain the results for monthly and annual $ET_0$ for the territory of Albania. The annual distribution of the $ET_0$ values, the annual rainfalls and mean temperature (January, July, annual) for the territory of Albania is represented through GIS in Figure 3 ,4,5

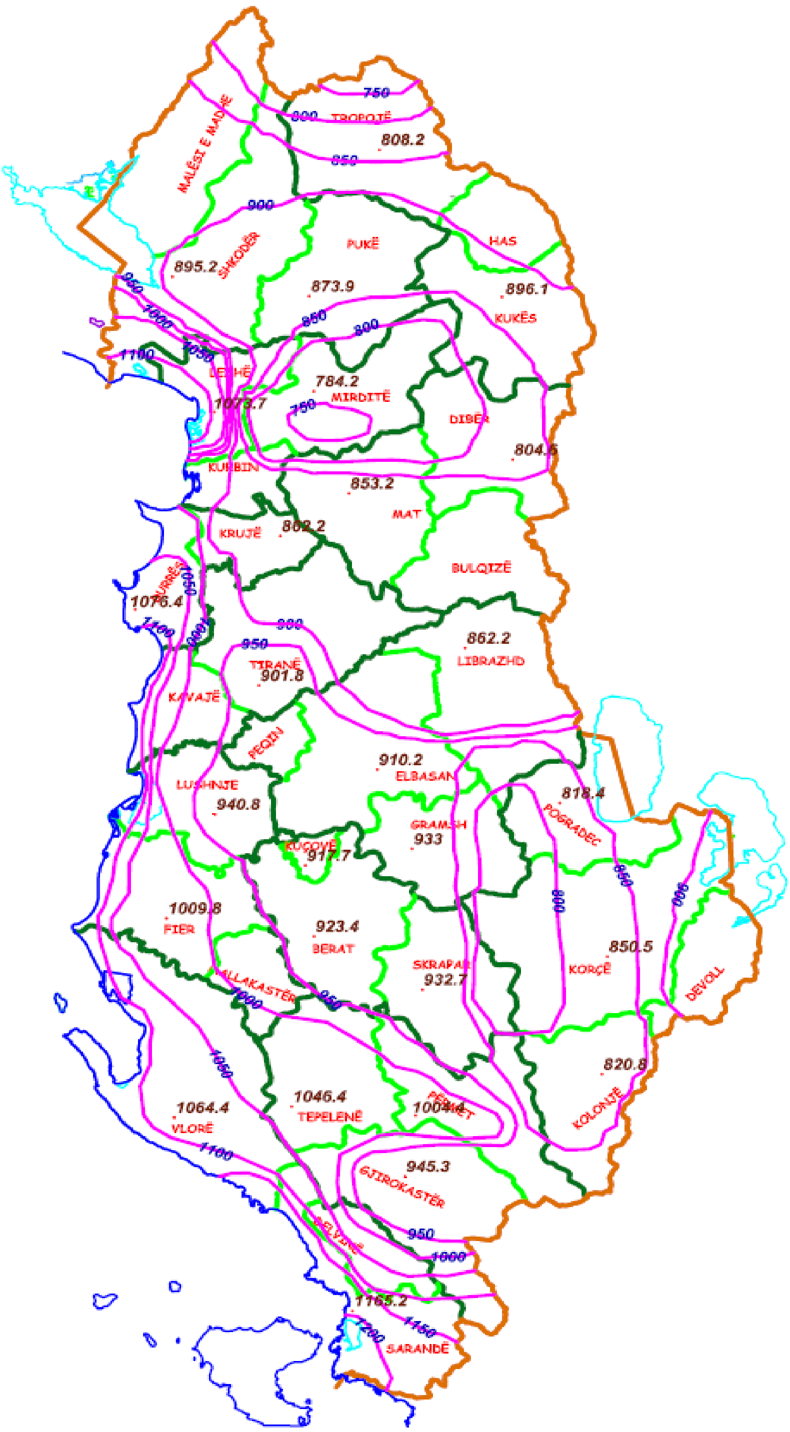


*Figure 3 The distribution of $ET_0$ on the Albanian territory*

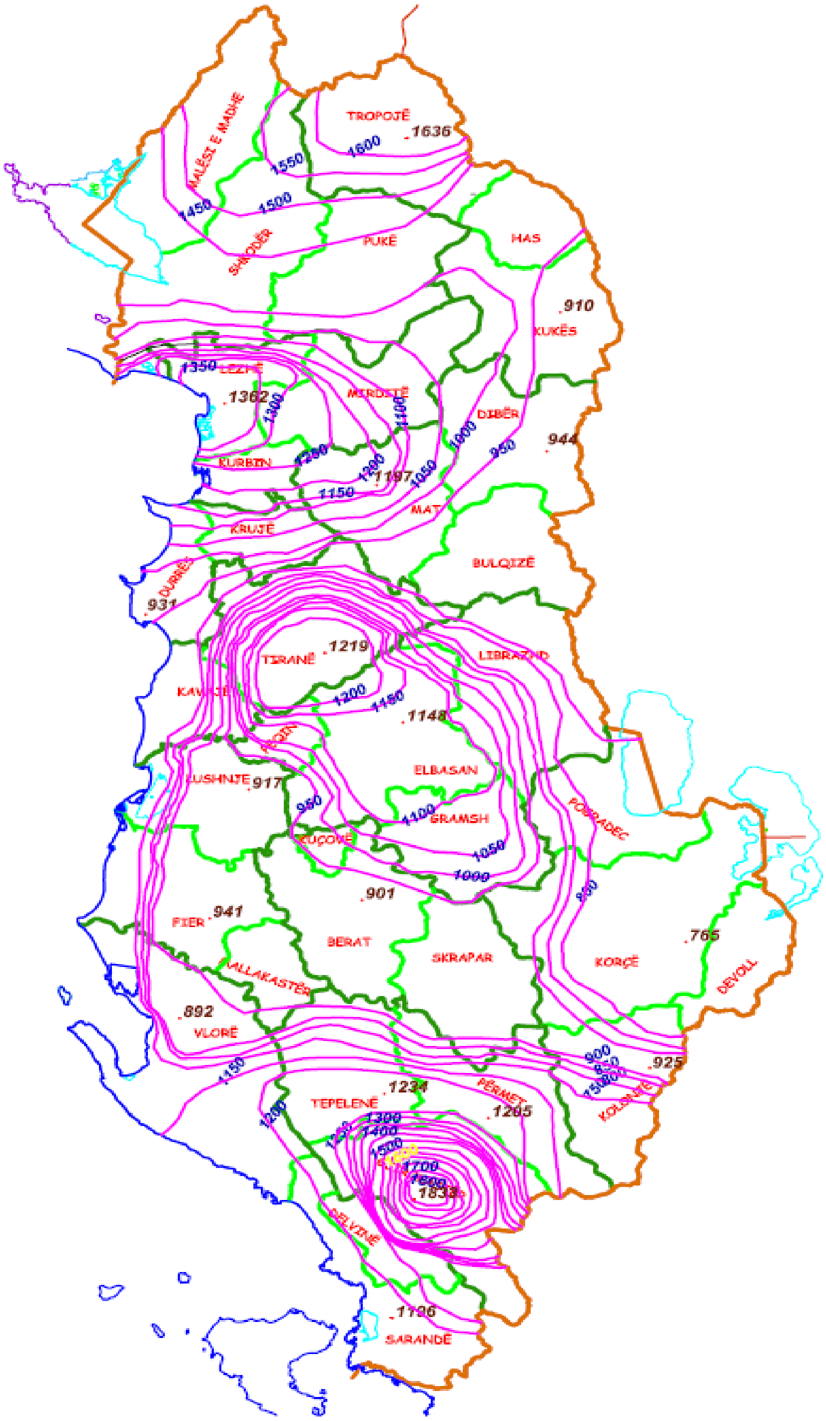
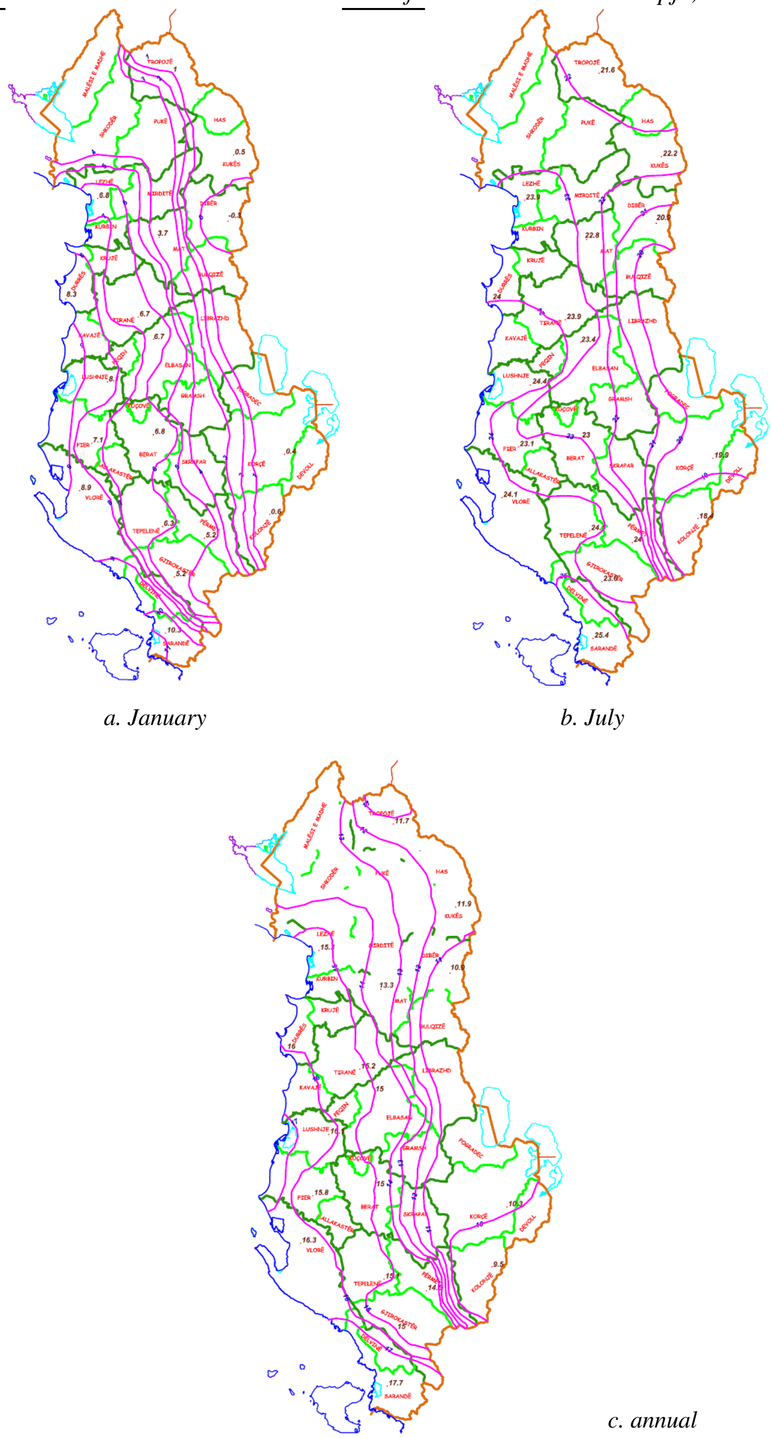



*Figure 4 The annual distribution of rainfall on the Albanian territory*



*a. January* *b. July*

*c. annual*

*Figure 5 The distribution of mean temperature on the Albanian territory*
*a. January, b. July, c. annual*

### 3.2 Real Evaporation

Another component of evapotranspiration is the Real Evapotranspiration $ET_r$ It is calculated by the methods: Thornthwait, Turc, water balance, Cotagne and Costandinov.(1986 Pano N) The values of $ET_r$, calculated by different methods, result relatively similar to each other. At the same time, these are relatively similar to the results of the deficit water flow-$Z_0$ calculated by the water balance method (difference about $-\delta$ ETr = ±5-10%). The monthly distribution of the real evapotranspiration values according to the Thornthwait method haven been graphically represented in Figure 6.

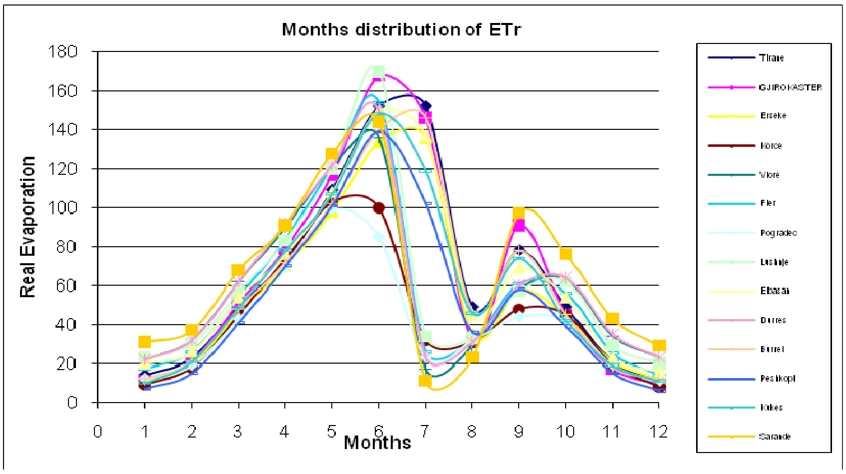



*Figure 6 The monthly distribution of Etr according to Thornthweit method on the Albanian territory*

$ET_r$ in Albania varies from about 650 ÷ 700mm in the coastal area to 300 ÷ 400mm in the mountains, having an average of $ET_R$ = 500 ÷ 600mm all over the Albanian territory. Real Evaporation $ET_R$ is presented with water balance method on Figure 8 by the GIS system.

### 3.3. Deficit evaporation

Deficit evaporation ΔE is computed as the difference $\Delta E = \left(ET_0 - ET_R\right)$. ΔE in Albanian varies about ΔE = 425 ÷ 450mm on the coastal area to ΔE = 150 ÷ 200mm in the mountains. Having already recognised the $ET_p$ values, it is possible to determine the pluviometric deficit ΔE referring to every period of the year, as a difference of potential evapotranspiration with the respective rainfalls corresponding to this period. It is in this way that the water balance-sheet for every month of the year is calculated, likewise the pluviometric deficit is later determined during the dry months, whereas the superfluous water-supply is determined during the wet months.

In Figure 7 there has been represented the annual distribution of pluviometric deficit ΔE in Albania, wherein it is evident that during the June-September period $Et_p$ is greater than the rainfalls, consequently there is shortage of water-supply. The opposite happens during the October-May period when the rainfalls are greater than evapotranspiration, consequently there are excessive rainfalls.

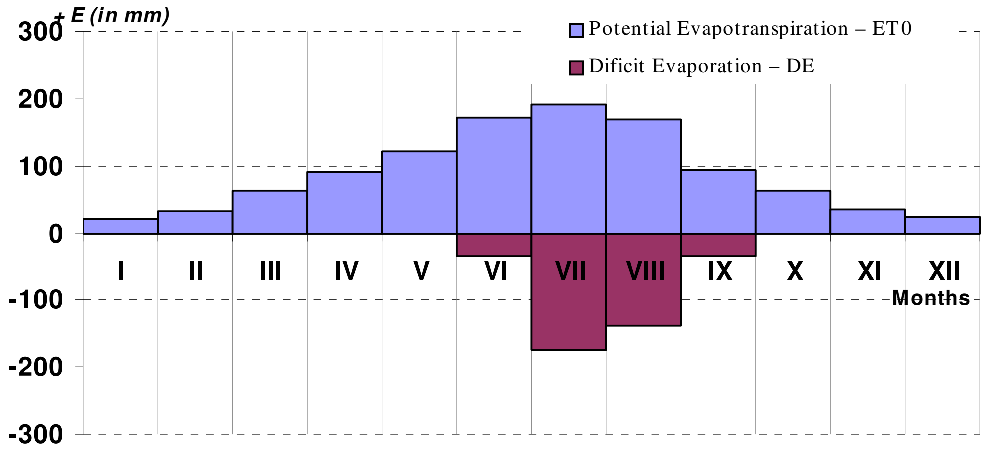



*Figure 7. Annual distribution of $ET_P$; $ET_R$ and deficit evaporation - $\Delta E$ in Albania*

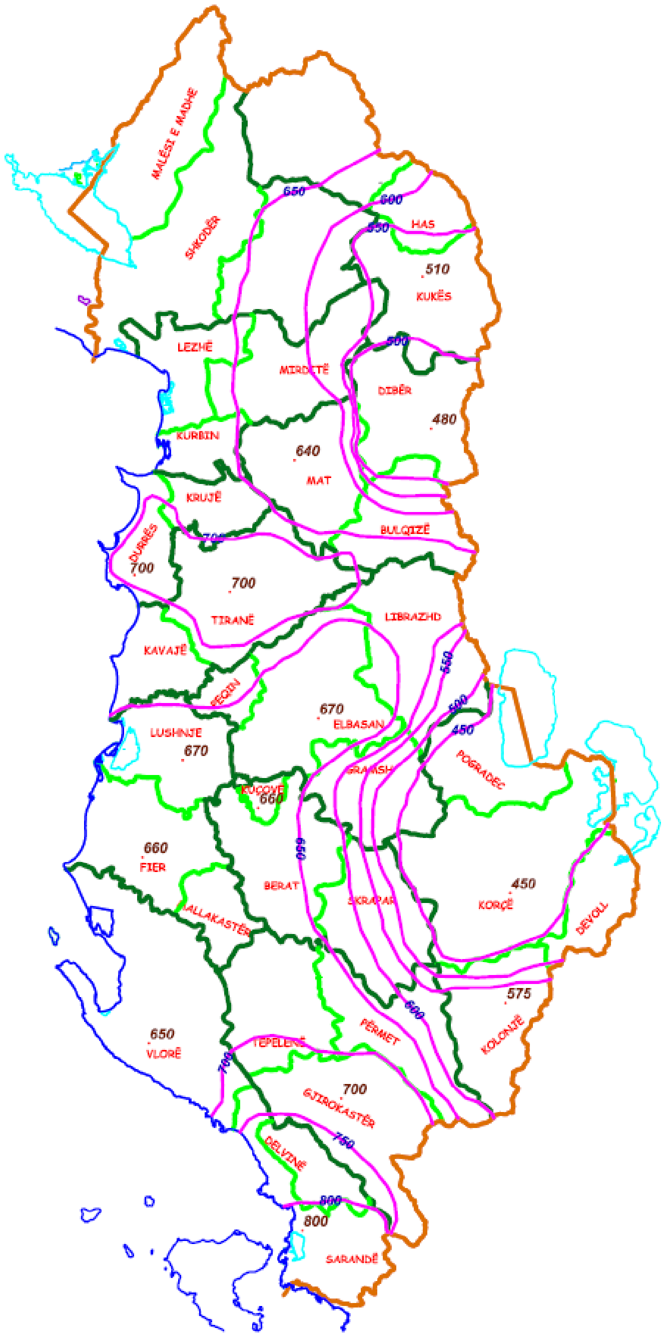



*Figure 8 The distribution of real evaporation on the Albanian territory*

# 4. RESULTS AND CONCLUSIONS

Evapotranspiration is an important phenomena and representative element of the water balance of the Albanian territory. The principal results of the evapotranspiration evaluation for the Albanian territory are:

Annual Evapotranspiration distribution is generally characterized by a typical Mediterranean nature.

The scheme of classification and division into homogenous sectors is based on evaluation and determination of the natural factors participating in the evapotranspiration process.

Albanian territory division scheme in homogeneous regions, based on evaluation and determination of the natural factors, influencing the intensity of the evapotranspiration process, is presented in this paper.

Territory morphometric parameters. Morphometric factors are determined by the topographical characteristics of the Albanian territory. The main parameters considered are: (h) – territory average altitude, and (l) – distance from the Sea.

Territory climatic parameters. Climatic parameters are: Sun radiation (J), Air temperature ($t_a$), precipitation ($X_0$), Air humidity ($l_0$), wind (v), etc.

Many important indicators to evaluate the integral impact of the natural conditions of the territory on the evapotranspiration process are respectively: Reference Evapotranspiration $ET_0$, Real Evapotranspiration $ET_R$ and Deficit Evaporation $\Delta E$. Table 1

In the general scheme of evapotranspiration intensity process, the natural conditions of the Albanian territory are grouped as in the following:

Computation principal parameters of the water balance of the territory. Water balance parameters are: pluviometric deficit ($\Delta X_0$) $\Delta X_0$ in Albania varies about 200mm on the coastal area to 2500 ÷ 3000mm on the mountain

Analyzing and dividing the Albanian territory in homogeneous areas, region is accepted as the smallest tecsinometric unit.

Classification is made for the following evapotranspiration categories: high, low and mean.

For the natural specific conditions of the Albanian territory, particularly, for mountainous areas, values of both evapotranspiration components were computed based on their vertical gradients and their altitude above sea level.

Composition methodology of the distribution for annual evapotranspiration components ($ET_0$, $ET_R$, $\Delta E$, $\Delta X_0$ and $Z_0$) used in the paper consists in the classification of the Albanian territory by the respective gradient $P_M = X_0/h$. Which were taken into consideration by the GIS System.

Evapotranspiration components and territory altitude subdues the vertical zone low, having a typical regional character. Using these dependences, in the table 2 are made their components for the Albanian territory.

As a conclusion, in the following we are representing the values of the respective Evapotranspiration components ($ET_0$, $ET_R$ and $\Delta X_0$) according to the various climatic regions and various altitudes of the Albanian territory.

Utilising GIS as a means of visual representation of the numerous ETp statistical data constitutes an innovatory approach for our article since it increases the community for the users of the relevant data. GIS enables the monthly representation of various data, both those associated with Etp, as well as the climatic elements.

Within the framework of the products received by GIS, even the regionalization hartograme of the evapotranspiration values for the entire country's territory was acquired, Figure 9

*Table 1 The evapotranspiration components ($ET_0$, $ET_r$ and $\Delta X_0$) in the Albanian territory*

| Nr | ELEMENTS | Region $I_1$ – Low $ET_0$ (in mm) | Region $II_1$ – Mean $ET_0$ (in mm) |
|---|---|---|---|
| I | Potential Evapotranspiration ($ET_0$) | $\begin{cases} A_1 = 500 \div 700mm \\ B_1 = 701 \div 800mm \end{cases}$ | $\begin{cases} C_1 = 801 \div 900mm \\ D_1 = 901 \div 1000mm \end{cases}$ |
| II | Real Evapotranspiration ($ET_R$) | $\begin{cases} A_2 = 300 \div 400mm \\ B_2 = 401 \div 500mm \end{cases}$ | $\begin{cases} C_2 = 501 \div 550mm \\ D_2 = 551 \div 600mm \end{cases}$ |
| III | Deficit Pluviometric $\Delta X_0 = (ET_0 - X_0)$ | $\begin{cases} A_3 = -200 \div 000mm \\ B_3 = 001 \div 200mm \end{cases}$ | $\begin{cases} C_3 = 201 \div 400mm \\ D_3 = 401 \div 1000mm \end{cases}$ |

| Nr | ELEMENTS | Region $III_1$ – High $ET_0$ (in mm) |
|---|---|---|
| I | Potential Evapotranspiration ($ET_0$) | $\begin{cases} E_1 = 1001 \div 1100mm \\ F_1 = 1101 \div 1200mm \end{cases}$ |
| II | Real Evapotranspiration ($ET_R$) | $\begin{cases} E_2 = 601 \div 700mm \\ F_2 = 701 \div 800mm \end{cases}$ |
| III | Deficit Pluviometric $\Delta X_0 = (ET_0 - X_0)$ | $\begin{cases} E_3 = 1001 \div 1500mm \\ F_3 = 1501 \div 3000mm \end{cases}$ |

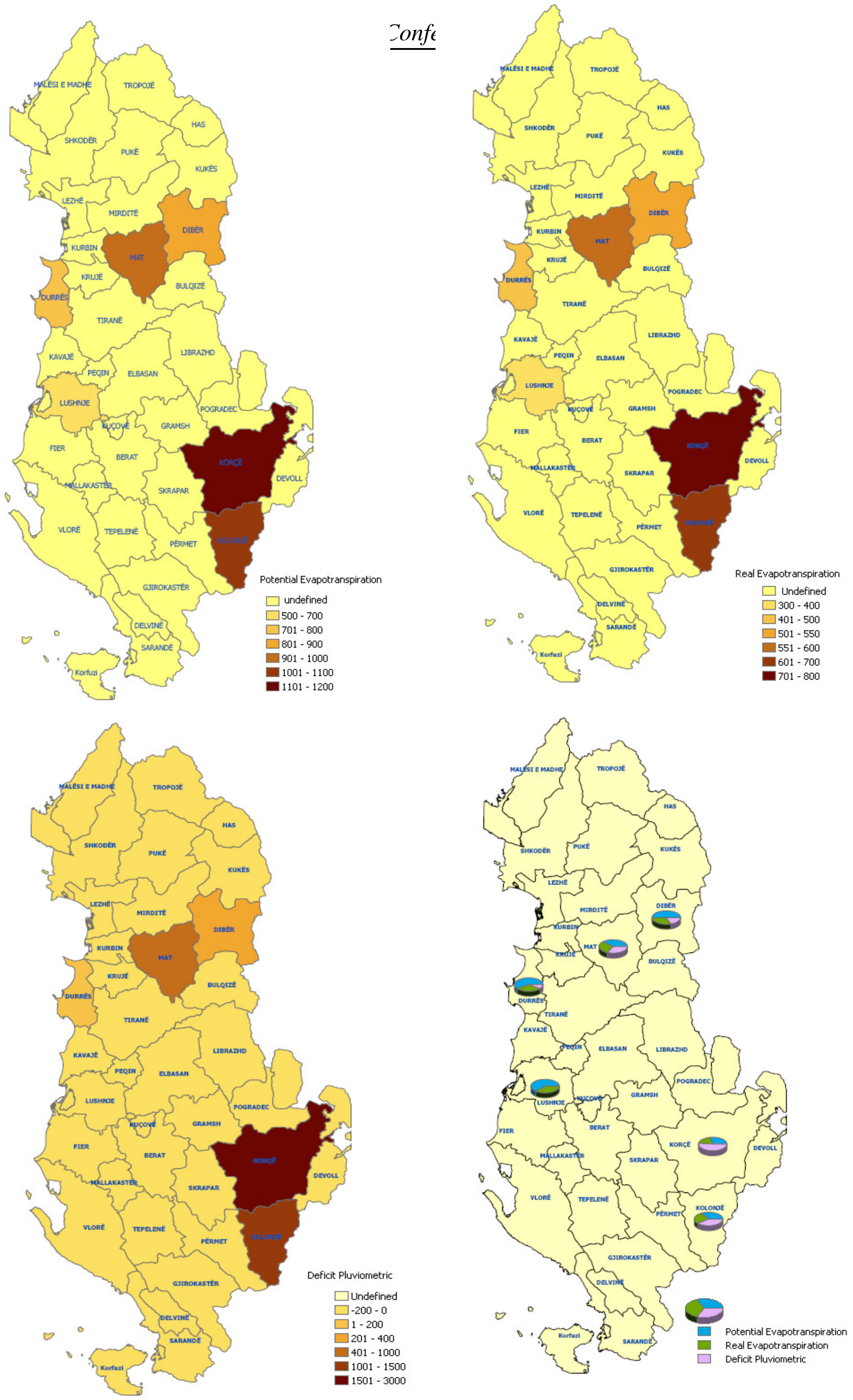



***Figure 9 The evapotranspiration components ($ET_0$, $ET_r$ and $\Delta X_0$) in the Albanian territory***

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The statistical model in agriculture

Programmer/Developer in GIS Systems like:
GIS Analysis and Statistics in Police System,
GIS application that manages the network of Medium and Low voltage distribution,
GIS application for Rates of Tirana municipality,
GIS application that manages the distribution of companies' products through a map.