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Azem BARDHI,
Aferdita LASKA MERKOCI, Mirela DVORANI[1]

ESTIMATING OF EVAPOTRANSPIRATION AND ITS COMPONENTS IN ALBANIA

SUMMARY

The process known as evapotranspiration (ET) is of great importance in many disciplines, including irrigation system design, irrigation scheduling and hydrologic and drainage studies. In a broad definition, the evapotranspiration is a combined process of both evaporation from soil and plant surfaces and transpiration through plant canopies.

There are various methods applied: direct measurement or observed method, indirect calculating method using empiric formulas, based on meteorological data (like temperature, wind, radiation, humidity, rainfall, etc.), water balance method.

Evapotranspiration is calculated by some methods such as: Turc, Penman, Thornthweit, Penman Monteith, FAO Penman Monteith, Standartized PM, FAO56 Penman-Monteith. In this investigation, is used to estimate ET_o, consisting of meteorological data FAO-56 Penman Monteith. Evapotranspiration values of obtained from FAO-56 PM are compared with values obtained by direct methods located in Lushnja station.

Methods such as Thornthweit, Konstandinov, Water Balance etc. were applied and the pluviometric deficit were estimated the evaluation of real evapotranspiration.

The aim of this paper is an attempt to introduce a general evaluation of the evapotranspiration in the Albanian territory, including Reference evapotranspiration (E_0), Real evapotranspiration, E_r, Deficit evaporation DE. For field, hilly and mountain area.

Keywords: evapotranspiration, meteorological data, water balance, FAO 56 PM, direct method

INTRODUCTION

Evapotranspiration process is the combination of two separate processes commonly known as Evaporation and Transpiration. In this process water is lost on the one hand from the top soil or water surface by evaporation and on the

[1] Azem BARDHI (corresponding author: bardhiazem@yahoo.com), Department of Climate and Environment, Institute of Geosciences, Energy, Water and Environment, Tirana, Albania; Aferdita LASKA MERKOCI, Department of Climate and Environment, Institute of Geosciences, Energy, Water and Environment, Tirana, Albania; Mirela DVORANI, Department of Water Economy, Institute of Geosciences, Energy, Water and Environment, Tirana, Albania

other hand from the crop plant tissues through transpiration by stomatal dynamics.

Evaporation and transpiration occur simultaneously therefore there is no easy way of distinguishing between the two processes. Instead of water quantity in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface (Monteith, 1965). When the crop is small, water is predominately lost by evaporation from the soil surface, but once the crop is well developed and completely covers the soil, transpiration becomes the main process (Allen et al, 1996).

Numerous methods have been devised to calculate the potential evapotranspiration. Until sometime are mention the methods of Thornthwait (1948), Blaney and Cridle (1950), Turc, Thornthwaite-Halzman, Energy Balance and combination methods, the most popular version of the latter being the Penman method (1948). All this methods are based on the dependence of free water evaporation (or the transpiration of e freely evaporating crop surface) on a number of meteorological parameters, mainly net radiation flux, wind speed and the relative humidity of the air.

From a practical point of view, the Penman method appears to be the most useful, the calculation involved being relatively simple and the accuracy is relatively high.

The Canadian Department of Agriculture has also published tables giving the potential evapotranspiration as a function of total solar radiation, minimum and maximum temperature.

Techniques have been devised to measure evaporation directly, i.e. by mean of evaporation pans the most commonly used being the U.S. Weather Bureau Class A Pan (Doorenbos and Pruitt, 1977). The Pan evaporation is very close to being the potential evapotranspiration, which is about that of a crop growing constantly at field capacity (Allen, 2001).

Many equations to model ET are available. One of the most common used ones is the Penman-Monteith (PM) formula. It is recommended by the FAO (Allen et al, 1996; FAO, 2000) as reference ET (adapted from grass ET when water is not limited). Nevertheless ET often has to be estimated under water stress conditions. Several studies investigated which method is most suitable for semi-arid areas Liu and Erda (2005) compared the Priestley-Taylor (PT) method with the reference crop PM equation for some weather stations on the Albanian territory.

In this study two different models of Penman Monteith method (FAO-56 Penman Monteith and standardized ASCE Penman Monteith) are used to estimate ET_o over a range of climate at a six regions in Albania based on daily weather data time period (Allen et al, 1998)

In May 1990, FAO organized a consultation of high level experts and researchers in collaboration with the International Commission for Irrigation and Drainage and with World Meteorological Organization, on review the FAO methodologies on crop water requirements and to advice on the revision and update of procedures. The panel of experts recommended FAO-56 Penman Monteith method (Allen et al, 1998) as a new standard for reference evapotranspiration and as a sole method for determining ET_0. The method has been selected because it physically based and explicitly incorporates both physiological and aerodynamic parameters (Grazhdani, 2002). Moreover, procedures have been developed for estimating missing climatic parameters. The FAO Penman Monteith method requires radiation, air temperature, air humidity and wind speed data.

The American Society of Civil Engineering (ASCE) established a Task Committee on "Standardization of Reference Evapotranspiration Calculation" which recommended the use of the standardized ASCE Penman Monteith method as the basis for "standardized" ET_0 computation (ASCE-EWRI, 2004).

Indirect calculating method using empiric formulas, based in this data, water balance method. It is evaluated by using multi-annual archival hydrological and meteorological information of the Institute for Energy, Water and Environment, such as temperature, rainfall, solar radiation, vapor pressure, wind speed.

MATERIAL AND METHODS

Geographical and Climate regime - 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. 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). Moreover they are very important for the fishermen, especially those of wetland type, which are large fishing reserves (Jaho et al, 1984).

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.

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.

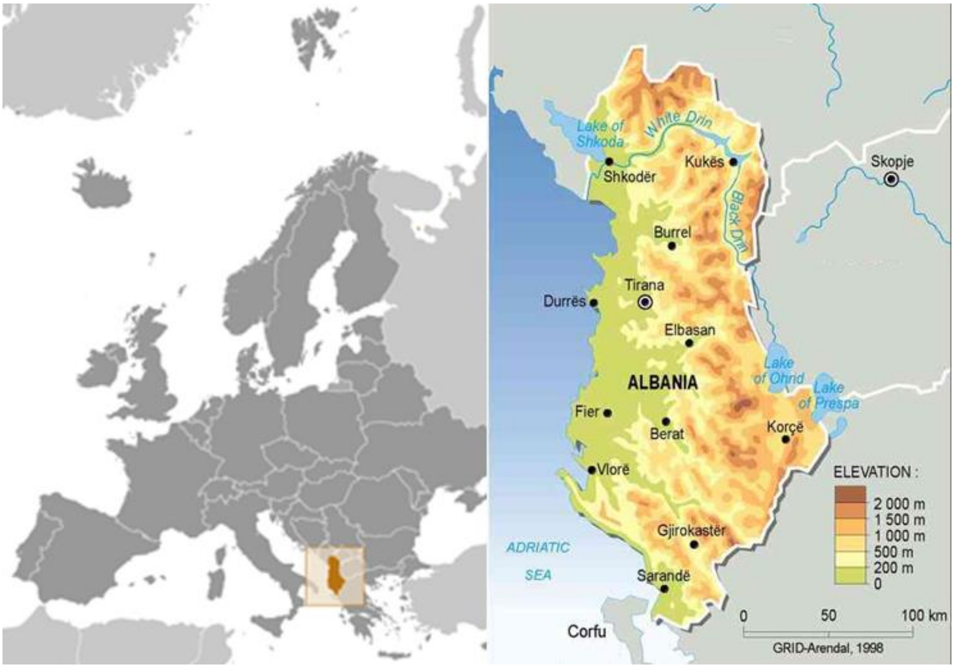

Figure 1: Map of Albania

The Evapotranspiration Process - Evapotranspiration in Albania is determined by the correlation of different geographical factors like: climate, relief, territory litological structure, vegetation, etc. As a result the influence of all these factors in territory is different not only during the months, seasons and different periods of the years, but also in the multi-annual cycle.

Evapotranspiration Reference ET_0 - 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 month's values of ETp by Turc, Penman original, Thornthwaite methods (Laska et al, 2011). These values are relatively similar, to the results of the direct experimental observed method (the Lushnja stations), the difference about – $\delta ET_0 = \pm 5 \div 10\%$.

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 evaluation of potential evapotranspiration, otherwise recognised 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 to our research has been classified into three areas.

I - Field areas situated on the Western Lowlands in Lushnje, Durres;

II - Hilly areas Peshkopi, Burrel and

III - Mountainous areas Korce, Erseke.

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 original Penman 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 Standardized ASCE-PM and FAO56 Penman Monteith (Allen et al, 1998) 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) in the Figure2.

Equation 1 presents the form of the standardized ASCE-PM equation for all hourly and daily calculation time steps.

$$ET_0 = \frac{0,408\Delta\left(R_0 - G\right) + \gamma \dfrac{C_n}{T+273} u_2\left(e_s - e_a\right)}{\left[\Delta + \gamma\left(1 + C_d u_2\right)\right]} \qquad (1)$$

Where: ET_0 = standardized grass-reference ET (mm d^{-1} or mm h^{-1});Δ = slope of saturation vapor pressure versus air temperature curve (kPa $^0C^{-1}$);R_n = calculated net radiation at the crop surface (MJ m^{-2} d^{-1} for 24 h time step, or MJ m^{-2} h^{-1} for hourly time steps);G = heat flux density at the soil surface (MJ m-^{2} d-^{1} for 24 h time step, or MJ m^{-2} h^{-1} for hourly time steps);T = mean daily or hourly air temperature at 1.5 to 2.5 m (^{0}C);u_2 = mean daily or hourly wind speed at 2 m height (m s^{-1});e_s = saturation vapor pressure (kPa);e_a = actual vapor pressure (kPa);$e_s - e_a$ = vapor pressure deficit (kP_a);γ = psychrometric constant (kPa $^0C^{-1}$);C_n = numerator constant that changes with reference surface and calculation time step (900 ^{0}Cmm s^3 Mg^{-1} d^{-1} for 24 h time step and 37 ^{0}C mm s^3 Mg^{-1} d^{-1} for hourly time steps for the grass reference surface);C_d = denominator constant that changes with reference surface and calculation time step (0.34 sm^{-1} for 24 h time step, 0.24 s m^{-1} for hourly time steps during daytime, and 0.96 s m^{-1} for hourly nighttime for the grass-reference surface).

The 24 h form and coefficients for the FAO56-PM method are the same as for the ASCE standardized equation (eq. 2), where C_n = 900 and C_d = 0.34. The form of the FAO56-PM equation for hourly time step (Allen et al, 1998) is:

$$ET_0 = \frac{0,408\Delta\left(R_n - G\right) + \gamma \frac{37}{T+273} u_2\left(e_s - e_a\right)}{\left[\Delta + \gamma\left(1 + 0,34u_2\right)\right]} \qquad (2)$$

R_n and G are in MJ m^{-2} h^{-1}.

The ASCE-PM and FAO56-PM equations use essentially the same procedure for computing hourly and 24 h values of G, R_n, and other parameters.

Blaney and Criddle Formula. Blaney-Criddle equation (1950) involves the calculation of the consumptive use factor (f) from mean daily temperature (T) and percentage (P) of total annual daylight hours occurring during the period being considered. The recommended relationship representing mean value over the given month, is expressed as:

$$ET_0 = c[p\ (0.4T + 8.13)]$$

Where: *ETo* reference crop evapotranspiration (mm/day) for the month considered; *T* mean daily temperature (°C) over the month considered; *p* mean daily percentage of total annual daytime hours; *c* sunshine hours and daytime wind estimates.

Real evapotranspiraton - Relying on the interdependence and interrelation existing between the climatic factors and ET_r, the Thornthwait, Turc, water balance, Cotagne and Costandinov methods were applied to calculate real evapotranspiration ET_r, an important component of evapotranspiration (Pano, 1986).

Turc formula:

$$E_{Tr} = \frac{P}{\sqrt{0.9 + \frac{P^2}{L^2}}} \qquad (2)$$

where: P = precipitation, L parameter = $300+25T+0.05T^3$.

Pluviometric deficit - In the present situation, the pluviometric deficit is of a high interest as it estimates the quantity of the water required for the normal development of vegetation and plants. It is necessary to emphasise that the relevant precipitation is partly removed in the form of ground flow and streams, is partly infiltrated into the ground, while the rest evaporates back into the atmosphere. Out of the portion of precipitation penetrating the ground, part is absorbed by plant roots, with the rest penetrating deep into underground waters.

Having already recognized the ET_p values, it is possible to determine the pluviometric deficit DE referring to every period of the year, as a difference of potential evapotranspiration from the respective rainfalls corresponding to this period.

$$DP = P - ET_0 \qquad (3)$$

where: ET_o = reference evapotranspiration, P = precipitation.

Another component is the deficit evaporation ΔE. Deficit evaporation is computed as a difference, $\Delta E = \left(ET_0 - ET_R\right)$.

RESULTS AND DISCUSSION

By implementing the formula of FAO 56-Penman Monteith results for monthly and annual ET_o for some regions of Albania were obtained. The monthly distribution of reference evapotranspiration for Lushnja is shown in Figure 2, where ET_o distribution is determined by the FAO 56-PM method and the direct method. It is evident that the results from these two methods are almost equal during the periods January–May and September–December, while from June–September the difference is slightly, about ten per cent, larger.

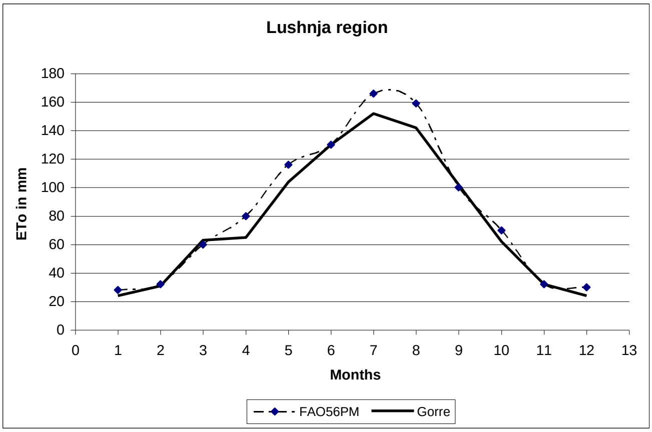

Figure 2: The distribution of ET_o by FAO 56-PM and direct methods in the Lushnja region

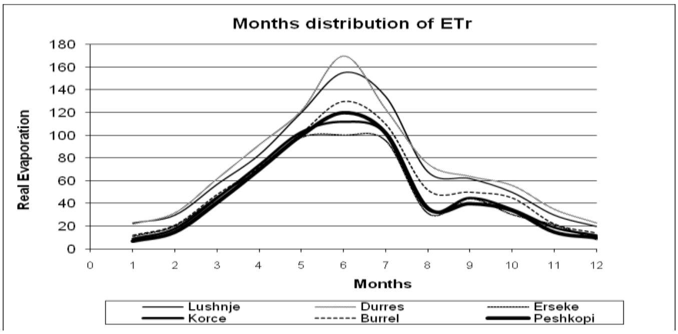

Figure 4: Annual distribution of ET_r by different methods at three study sites

Figure 3 presents the Map of Albania the annual distribution of ET_o values for some regions studied. The average monthly reference evapotranspiration in these areas differs by about ET_o = 10–40mm in January, the coldest month of the year, to about ET_o = 120–170mm in June, the hottest month. The average annual reference evaporation for the multi-annual period is about ET_o = 800–1100mm. The average annual (potential) reference evaporation in the plains varies from ET_o = 950–1100mm and on the hilly and mountains areas ET_o = 800–850mm (Table 1).

The values of ET_r obtained from different methods approximate to each other. Also, they are similar to the results of the deficit water flow, Z_0, calculated by the water balance method (difference about ±5–10%). The annual distribution of ET_r by different methods is represented in Figure 4.

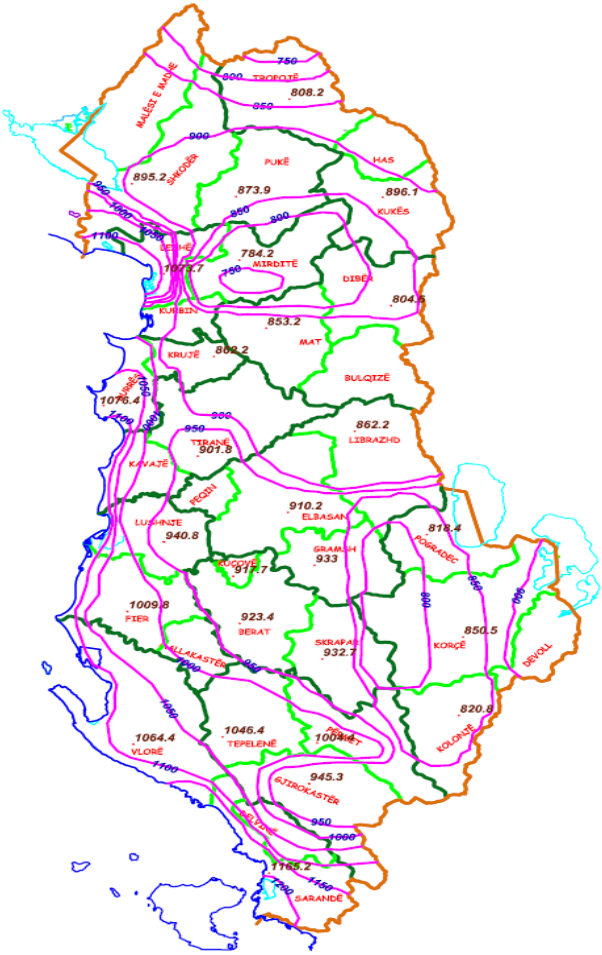

Figure 3: The distribution of ET_0 on the Albanian territory

Table 1 reports a summary of the evapotranspiration results with its constituent components, respectively ET_r and DE for the three regions involved in our research, the lowland area, mountain area and hilly area, respectively.

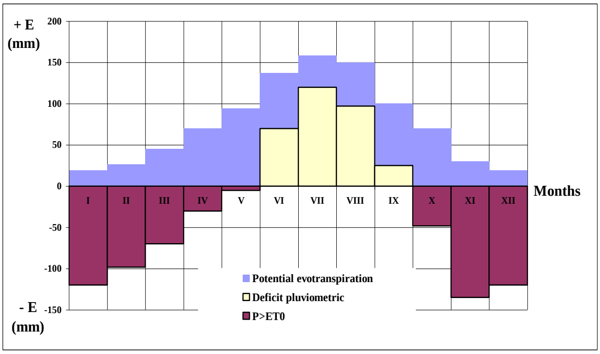

Figure 5: Annual distribution of DE in Durres region

Thus, in our study area, ET_r varied from about 700mm in the coastal area to 500mm in the mountains, with an average of 500–600mm across Albanian territory.

Figure 5 shows the pluviometric deficit for Lowlands (Durres region) of Albania. It is evident that during the June–September period Et_p is greater than the rainfall, while the opposite happens during October–May when the rainfall is greater than evapotranspiration, i.e. there are excessive rainfalls.

Table 1. Evapotranspiration components, ETr and DE

Real Evaporation ETr- UNIT	Deficit Pluviometrik DE-UNIT
Region I_2 – **Low** ET_R (in mm) $\begin{cases} A_2 = 300 \div 400mm \\ B_2 = 401 \div 500mm \end{cases}$	Region I_3 – **Low** ΔX_0 (in mm) $\begin{cases} A_3 = -200 \div 000mm \\ B_3 = 001 \div 200mm \end{cases}$
Region II_2 – **Mean** ET_R (in mm) $\begin{cases} C_2 = 501 \div 550mm \\ D_2 = 551 \div 600mm \end{cases}$	Region II_3 – **Mean** ΔX_0 (in mm) $\begin{cases} C_3 = 201 \div 400mm \\ D_3 = 401 \div 1000mm \end{cases}$
Region III_2 – **High** ET_R (in mm) $\begin{cases} E_2 = 601 \div 700mm \\ F_2 = 701 \div 800mm \end{cases}$	Region III_3 – **High** ΔX_0 (in mm) $\begin{cases} E_3 = 1001 \div 1500mm \\ F_3 = 1501 \div 3000mm \end{cases}$

CONCLUSIONS

The content of essential oils, the amount of carvone and limonene in the oil and In this paper evaluation of the evapotranspiration process was undertaken through analysis of Reference Evapotranspiration (ET_o), Real Evapotranspiration (ET_r) and Pluviometric Deficit (DE) based on the FAO 56-PM formula. The results indicate the levels of evapotranspiration are convenient and adequate for the conditions of Albania. The values resulting from the analysis, compared to the logging from the evaporation meter installed in the Lushnje Station are very similar, with a difference of only 5–10 per cent.

Potential Evapotranspiration values vary from 890–1080mm in the lowlands, 850mm in the hilly areas and 800–850 mm in the mountain areas.

Real Evapotranspiration values for the lowlands are about 700 mm, 650 mm for the hilly areas and 500–540 mm for the mountain areas.

The Pluviometric Deficit in Albania varies from about 200mm on the coastal area to 2500–3000mm in the mountains.

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Azem BARDHI,
Aferdita LASKA MERKOCI, Mirela DVORANI

PROCJENA EVAPOTRANSPIRACIJE I NJENIH KOMPONENTI U ALBANIJI

SAŽETAK

Proces poznat kao evapotranspiracija (ET) je od velikog značaja u mnogim disciplinama, uključujući sistem za navodnjavanje, planiranje navodnjavanja, hidrološka istraživanja i istraživanja odvodnjavanja poljoprivrednog zemljišta. U širokoj definiciji, evapotranspiracija je kombinovani proces isparavanja putem vegetacije i zemljišta i transpiracije preko listova biljaka.

Primjenjene su različite metode: direktno mjerenje ili metoda posmatranja, indirektna metoda proračuna pomoću empirijskih formula, na osnovu meteoroloških podataka (kao što su temperatura, vjetar, zračenje, vlaga, kiša, itd.) i metoda bilansa vode.

Evapotranspiracija se izračunava metodama kao što su: Turc, Penman, Thornthveit, Penman Monteith, FAO Penman Monteith, Standardizovani PM, FAO56 Penman-Monteith. U ovom istraživanju, za izračunavanje ETo korišćena je FAO-56 Penman Monteith metoda koji se zasniva na meteorološkim podacima. Vrijednosti evapotranspiracija dobijene metodom FAO-56 PM upoređene su sa vrijednostima dobijenim direktnim metodama na stanici Lushnja.

Primjenjene se i metode kao što je Thornthweit, Konstandinov, bilans vode itd. i proračunom pluviometrijskog deficita dobijena je procjena stvarne evapotranspiracije.

Cilj ovog rada je pokušaj da predstavimo opštu procjenu evapotranspiracije na teritoriji Albanije, uključujući referentnu evapotranspiraciju (E0), stvarnu evapotranspiraciju, Er i deficit isparavanja DE u ravničarskom, brdskom i planinskom području.

Ključne riječi: evapotranspiracija, meteorološki podaci, bilans vode, FAO 56 PM, direktna metoda