DATA ANALYSIS AND EVALUATION OF THE IMPACT OF METEOROLOGICAL PARAMETERS ON THE VALUES OF EVAPOTRANSPIRATION (ETO) CALCULATED BY FAO PENMAN-MONTEITH EQUATION

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Abstract

This study focuses on data analysis and assessment of the influence of meteorological parameters on Evapotranspiration (ETo) values calculated by the FAO Penman-Monteith Equation on the daily time interval. This equation is known as a reliable method for estimating ETo due to the study of meteorological parameters such as temperature, humidity, wind speed, solar radiation, sunshine hours. Data analysis was performed for the terms that influence the final ETo equation by FAO. Meteorological data were collected from the meteorological station installed in Prrenjas, Albania. Through data analysis and assessment, this study shows that there is a strong positive correlation between ETO and wind speed, sunshine hours, radiation, solar declination and sunset hour angle. A slightly positive correlation between ETO and temperature, solar radiation. A negative correlation was observed with humidity and daylight hours. Relative humidity showed a strong negative correlation with ETo, highlighting its role in reducing evapotranspiration under high humidity conditions. The highest ETo value (14.196 mm/day) was observed in March, while the lowest (1.0089 mm/day) was observed in February, reflecting seasonal variability. These findings highlight the importance of monitoring multiple meteorological parameters for accurate irrigation planning in regions with similar climatic conditions.

The findings of this study serve to clarify which factors directly affect and have the greatest impact, which we should have in monitoring the plant irrigation system in the study area.

Key words**:** *ETO calculation, data analysis, FAO, solar radiation, wind speed, humidity.*

Përmbledhje

Ky studim fokusohet në analizën e të dhënave dhe vlerësimin e ndikimit të parametrave meteorologjikë në vlerat e Evapotranspirimit (ETo) të llogaritura nga Ekuacioni Penman-Monteith FAO në intervalin ditor kohor. Ky ekuacion njihet si një metodë e besueshme për vlerësimin e ETo-s për shkak të studimit të parametrave meteorologjikë si temperatura, lagështia, shpejtësia e erës, rrezatimi diellor, orët e diellit. Analiza e të dhënave është kryer për termat që ndikojnë në ekuacionin përfundimtar të ETo nga FAO. Të dhënat meteorologjike janë mbledhur nga stacioni meteorologjik i instaluar në Prrenjas, Shqipëri. Nëpërmjet analizës dhe vlerësimit të të dhënave, ky studim tregon se ekziston një korrelacion i fortë pozitiv midis ETO dhe shpejtësisë së erës, orëve të diellit, rrezatimit, deklinimit diellor dhe këndit të orës së perëndimit të diellit. U vu re një korrelacion pak pozitiv midis ETO dhe temperaturës, rrezatimit diellor, gjithashtu vu re një korrelacion negativ me lagështinë dhe në orët e ditës. Lagështia relative tregoi një korrelacion të fortë negativ me ETo, duke theksuar rolin e saj në uljen e evapotranspirimit në kushte të larta lagështie. Vlera më e lartë e ETo (14.196 mm/ditë) u vu re në mars, ndërsa më e ulëta (1.0089 mm/ditë) në shkurt, duke reflektuar ndryshueshmërinë sezonale. Këto përfundime nënvizojnë rëndësinë e monitorimit të shumë parametrave meteorologjikë për planifikimin e saktë të ujitjes në rajonet me kushte klimatike të ngjashme. Përfundimet e këtij studimi shërbejnë për të bërë më të qartë se cilët janë faktorët që ndikojnë drejtpërdrejt dhe kanë ndikimin më të madh, që duhet të kemi në monitorimin e sistemit të ujitjes së bimëve në zonën e studimit.

Fjalë kyçe: *Llogaritja e ETO, analiza e të dhënave, FAO, rrezatimi diellor, shpejtësia e erës, lagështia.*

Introduction

For predicting the irrigation requirement, ETo can be used prior to scheduling, which is the major element to schedule water demand. Herrmann, E. (1964) Evapotranspiration covers water evaporation to the atmosphere from the soil surface, evaporation from the capillary fringe of the

groundwater table and evaporative losses from standing water on the land surface. Kiani S. (2017). According to certain earlier research, ETO is crucial in assessing and figuring out how much water the irrigation system needs Ali et al. (2009). Previous research relies on the FAO Penman-Monteith Equation's computation of ETO, which allows for the theoretical value to be determined depending on variables including temperature, wind speed, sun exposure, sunshine hours, and relative humidity.

To identify the variables that directly have a beneficial impact, a thorough analysis of the data was conducted. The International Scientific Society has determined that FAO-PM is the best empirical model because, when compared to other techniques in various parts of the world, it yields results that are quite accurate. Jensen et al. (1997) confirm that this is the industry standard model used by global experts to define and calculate reference evapotranspiration. Accordingly, FAO-PM has been regarded as the industry standard technique that is applicable everywhere and doesn't require calibration (Willmott et al., 1985). The FAO-PM model was stated by Allen et al. (1998) as follows:

$$ET_o = \frac{0.408(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.034\, U_2)} \qquad (1)$$

Where, ET_o = estimated reference evapotranspiration (mm/day), T = average atmospheric temperature (^{o} C), U_2 = wind speed at 2 m height (m/s), R_n = surface radiation balance (MJ/m^2 /day), e_a = actual vapour pressure (kPa), Δ = slope of the water vapour saturation pressure curve (kPa/^{o} C), G = sensible heat flux in the soil (MJ/m^2 /day), e_s = saturation vapour pressure (kPa).

Data analysis for factors such as: humidity, temperature, solar radiation, sunhours, etc. that affect the ETO value based on the FAO-PM equation (FAO, Chapter 2) is important to determine which of the parameters will have the greatest impact. Ethnopharmacol., (2016). The current study is an evaluation in the period January-August in a small area where the planting of medicinal plants is applied. As in several studies conducted at regional levels to show the most important climatic variables that determine ETo, the goal here is the

same, but in a smaller area, which is located in the area of Rrajce, Perrenja, Albania. Collected datas for weather and impact of it has taken an important place in nowdays studies. Çaushaj (2024). Therefore, the objective of the

study is to determine the correlation that exists between the ETo values and the parameters that are included in the FAO-PM equation.

The analysis of these relationships is important of considering multiple meteorological parameters in ETo estimation. Accurate ETo calculation is crucial for effective irrigation planning and water resource management, particularly in regions with varying climatic conditions. By understanding the specific impacts of different weather parameters on ETo, agricultural practices can be better tailored to optimize water use efficiency and ensure sustainable crop production. In our study, we investigate the reliability of the FAO Penman-Monteith equation for ETo estimation and highlights the critical meteorological parameters that significantly influence ETo values.

These findings provide valuable insights for the development of precise irrigation schedules and the implementation of efficient water management strategies in the study area and other regions with similar climatic conditions. The relationship between each parameter and ETo showed an ascending trend, starting with minimum temperature, followed by maximum temperature, solar radiation maximum, vapor pressure deficit, and sunhours. This positive correlation indicates that as these parameters increase, ETo also increases Onwuegbunam et al. (2019). Additionally, the negative correlation between ETo and relative humidity suggests that areas with higher humidity levels may experience lower ETo values.

Materials and methods

Study location

The study area is Sutaji, a village in Rrajcë Administrative Unit, Prrenjas Municipality, Elbasan District, Albania, which lies on latitude 41°6'6"N and longitude 20°34'41"E. It is located in eastern Albania. The geographical position, the configuration of the relief, the absolute height above the sea level and the distance from the Adriatic Sea have enabled the continental nature of the climate, which appears in the cold and wet winter and in the short, hot and dry summer. Daily values of minimum temperature, maximum temperature, relative humidity, wind speed, sunshine hours were measured in the months of January to August during the 2023 at the meteorological station installed by

PiKt company in Sutaj, Prrenjas, Albania. The analysis of the data obtained from the PiKt company system was performed. Based on the simple linearity regression equation, the dependence that exists between the input (Weather parameters) and output parameters (ETO) was determined.

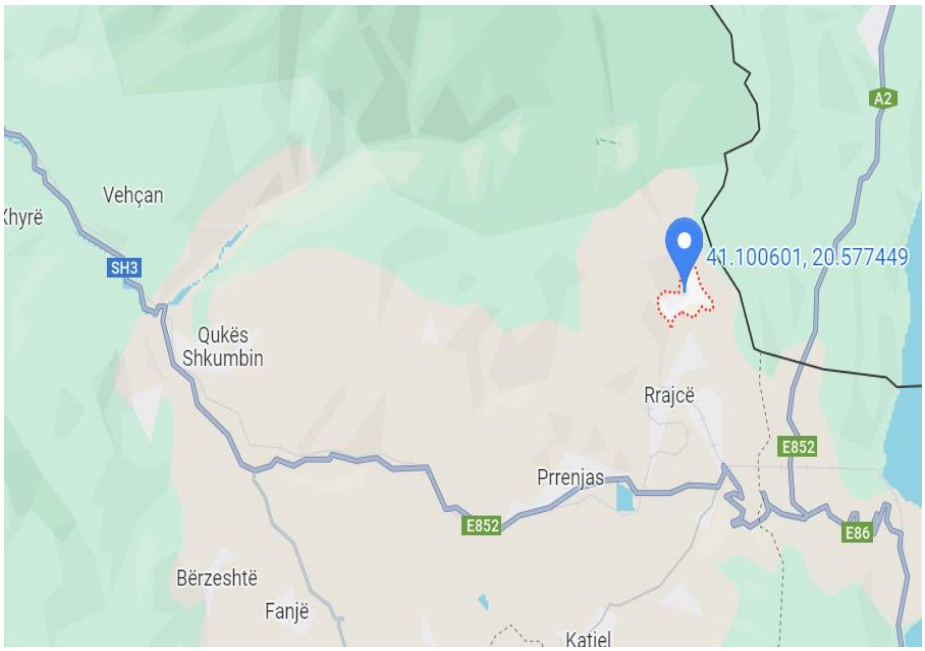

Figure 1. Location of Sutaj, Prrenjas, Albania

Figure 2. The study area, selected and sectioned in several parts.

Results and discussions

Table 1 below presents the average values of each parameter in the January-August 2023 period for the input values (weather parameters) and the ETO

output value. The relationship between the monthly reference evapotranspiration (ETo) and the varied maximum temperature is shown in the regression analysis presented in Figure 1. The coefficient of determination (R^2) is 0.8069 showing a strong positive linear correlation between ETo and varied maximum temperature.

The relationship between the monthly reference evapotranspiration (ETo) and the varied minimum temperature is shown in the regression analysis presented in figure 3 The coefficient of determination (R^2) is 0.726 showing a strong positive linear correlation between ETo and varied maximum temperature. The results of the relationship of reference evapotranspiration with each of the maximum solar radiation, wind speed, sunhours and vapour pressure defficit are presented in Figures 6, 4, 8 and 7.

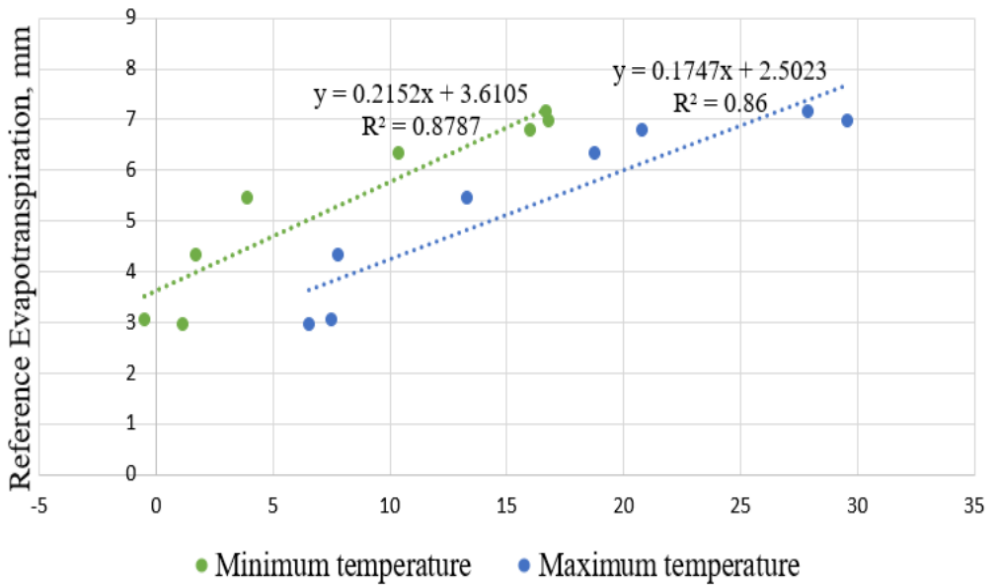

Figure 3. ETo at varied maximum and minimum temperature

These show similarities with that of minimum and maximum temperature, the relationships being positively linear with R^2 values of 0.7959, 0.5974, 0.7699 and 0.7939, for the the maximum solar radiation, wind speed, sunhours and vapour pressure defficit, respectively.

The relationship between the reference evapotranspiration and the minimum relative humidity (Figure 5) is however different, being negatively linear but with excellent correlation (R^2 = 0.9111). The relationship between the reference evapotranspiration and the average relative humidity is shown in Figure 5

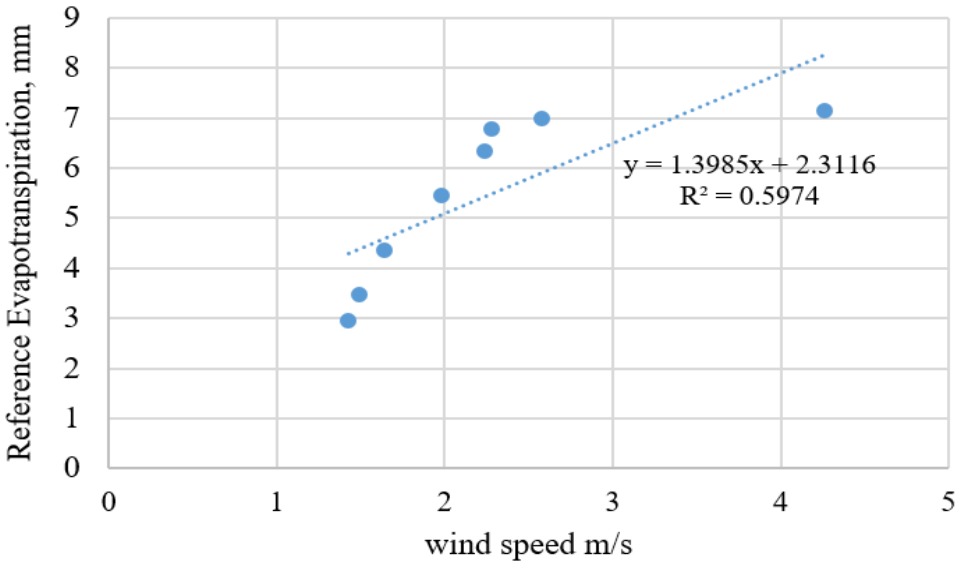

Figure 4. ETo at varied wind speed

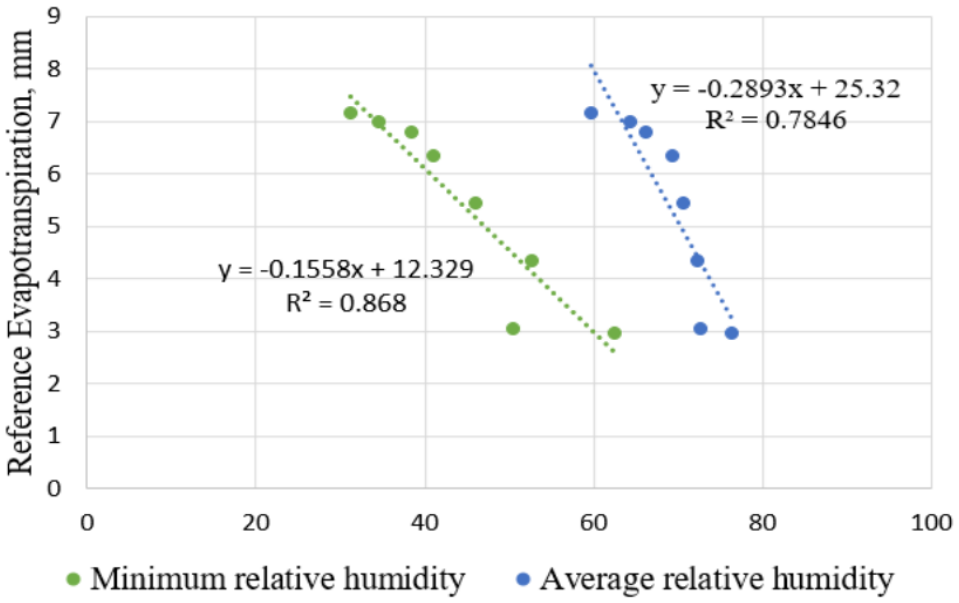

Figure 5. ETo at varied minimum and average relative humidity

The coefficient of determination (R^2) is 0.7846 showing a strong negative linear correlation between ETo and varied average relative humidity.

The linear regression analyses result of the relationship between ETo and each of the climatic parameters is summarized in Table 2.

The performance of each varied parameter with respect to ETo, other parameters remaining constant, increased in the order: wind speed, followed by sunshine hour, maximum temperature and then minimum temperature, for the positive relationship. A negative correlation exists between ETo and humidity. Based on previous research like Allen et. Al. (1998). Crop evapotranspiration: Guidelines for figuring crop water needs.

FAO Irrigation and Drainage Paper 56. Food and Agriculture Organization of the United Nations. and Sensitivity of Reference Evapotranspiration Computed with FAO CropWat 8.0 Model to Weather Input Variables During Two Irrigation Seasons in Kaduna, Nigeria N.E. Onwuegbunam, the relation between Evapotranspiration (ETO) and weather parameters has been widely studied.

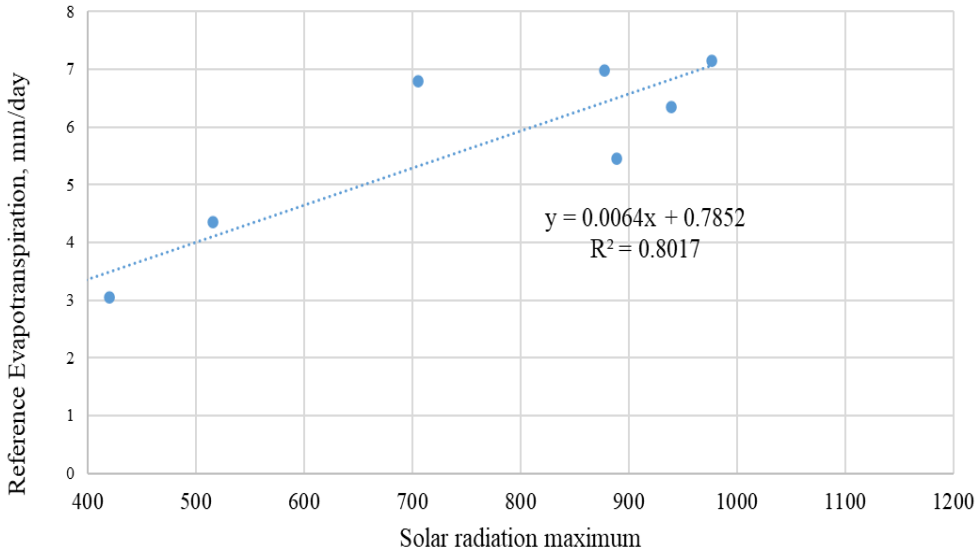

Figure 6. ETo at varied solar radiation maximum

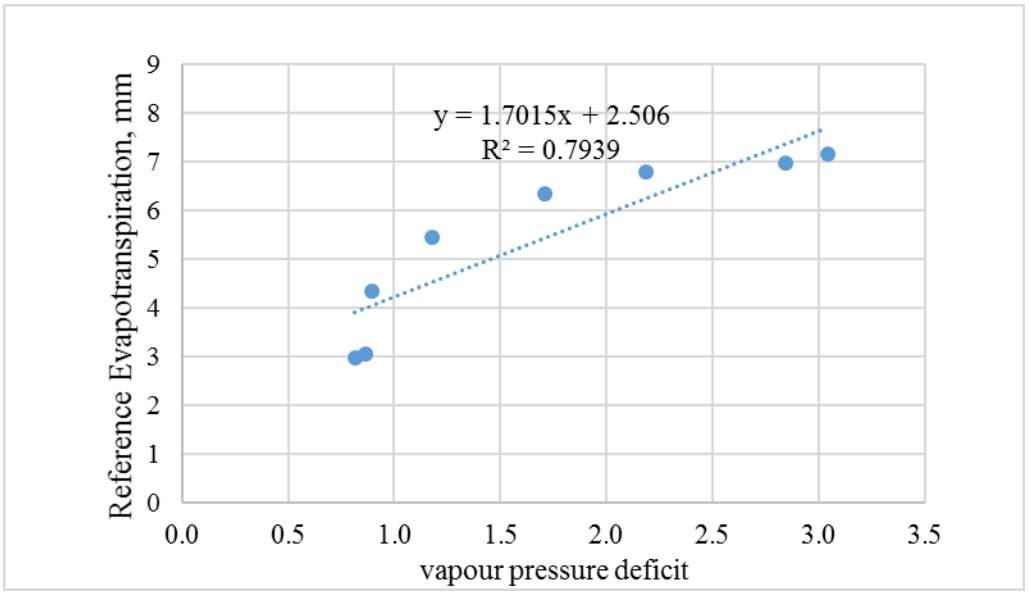

Figure 7. ETo at varied vapour pressure defficit

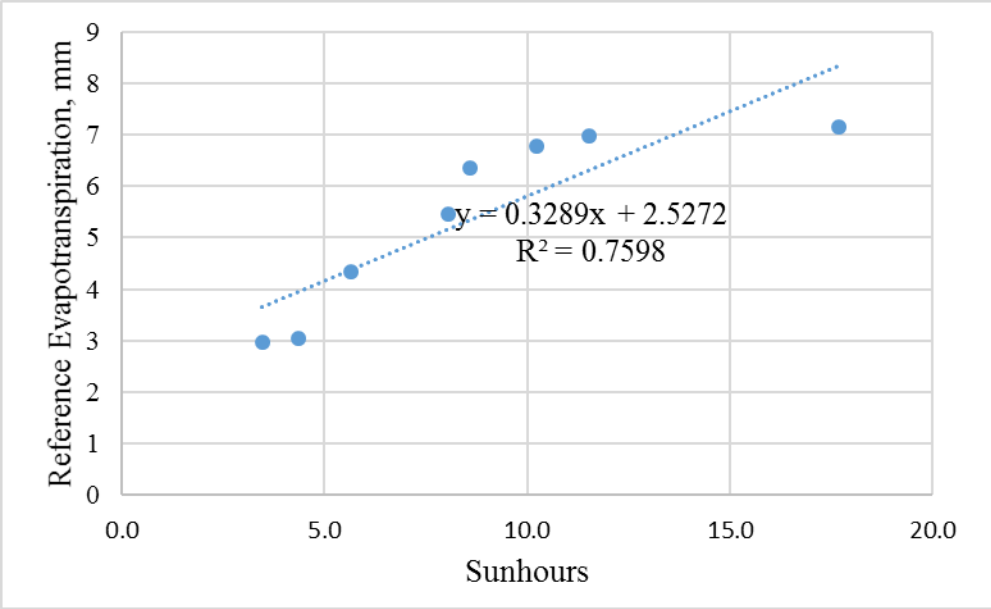

Figure 8. ETo at varied sunhours

Previous studies have explored the link between ETO and different weather factors, like temperature, humidity, wind speed, sunhours, maximum solar radiation. In the study titled "Sensitivity of Reference Evapotranspiration Computed with FAO CropWat 8.0 Model to Weather Input Variables During Two Irrigation Seasons in Kaduna, Nigeria" an analysis was conducted to study how different weather factors impact reference evapotranspiration (ETO). The results showed some clear patterns. The research found a strong positive connection between ETO and both minimum and maximum temperatures.

This highlights how temperature influences evapotranspiration. Wind speed also had a positive correlation with ETO, indicating that atmospheric movement can increase evapotranspiration rates. On the other hand, relative humidity was the only factor that showed a negative relationship with ETO across previous studies and the current data analysis. This inverse relationship suggests that higher humidity levels tend to reduce evapotranspiration.

Table 1. Base values of input weather parameters (January to August 2023)

Period	Temp. Maximu	temp Minimum	Av. rel humidity	Minimum	wind speed in m/s	solar radiation	Sunhours	vapour pressure	ETO
January	6.5	1.1	76.4	62.4	1.43	393	3.5	0.8	3
February	7.5	-0.5	72.6	50.3	1.92	420	4.3	0.9	3
March	7.8	1.7	72.2	52.7	4.26	516	5.7	0.9	4
April	13.3	3.9	70.6	45.9	1.49	889	8.1	1.2	5
May	18.8	10.3	69.4	41.0	1.98	939	8.6	1.7	6
June	20.8	16.0	66.2	38.4	2.24	705	10.2	2.2	7
July	29.6	16.8	64.3	34.5	1.43	877	11.5	2.8	7
August	27.8	16.7	59.7	31.2	1.64	976	17.7	3.0	7

The relationship between each parameter and Eto showed an ascending trend, starting with minimum temperature, followed by maximum temperature, solar radiation maximum, vapour pressure defficit and sonhours. This positive correlation indicates that as these parameters increase, ETo also increases. Also there is a negative correlation between ETo and relative humidit. Interpreting the key results for the display of descriptive statistics for ETO values involves analyzing various statistical measures to gain insights into the distribution, central tendency, and variability of the data. In the study, 219 ETO values were taken from January 15 to August 2023.

The mean ETO value 5.9199 provides an estimate of the average evapotranspiration rate in the dataset taken from program. The standard deviation measures the spread or dispersion of ETO values around the mean. Based on literature a value of standard deviation above or equal to 2 can be considered high so the value of 2.7172 shows a high standard deviation.

The minimum and maximum ETO values 1 and 14.196 respectively represent the lowest and highest observed evapotranspiration rates in the dataset.

The highest value has resulted in 26th March 2023 and the lowest value of ETO in 4th February 2023.

Table 2. Descriptive statistics for ETO val

ETO	
Mean	**5.9199**
Standard Error	0.1836
Median	5.8353
Standard Deviation	**2.7172**
Sample Variance	7.3832
Kurtosis	-0.1930
Skewness	0.4751
Range	13.187
Minimum	**1.0089**
Maximum	**14.196**
Sum	1296.4
Count	219
Largest(1)	14.196
Smallest(1)	1.0089
Confidence Level(95.0%)	0.3618

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Conclusions

The reference evapotranspiration (ETo) of Prrenjas, Albania, was found to be sensitive to changes in various climatic variables such as temperature, humidity, wind speed, solar radiation, sunshine hours, and vapor pressure deficit. Data collected from January 2023 to August 2023 showed that the relationship between ETo and each climatic parameter revealed several key insights. First, a strong relationship was observed between ETo and humidity, maximum temperature, and minimum temperature. Specifically, the mean ETo value of 5.9199 mm/day provided an estimate of the average evapotranspiration rate.

The highest ETo value recorded was 14.196 mm/day on March 26th, 2023, while the lowest was 1.0089 mm/day on February 4th, 2023. The positive correlation between ETo and temperatures indicates that as temperatures increase, ETo also increases significantly, which is crucial for understanding water demand in the region. Furthermore, a good relationship was observed between ETo and sunshine hours, wind speed, solar radiation, and vapor pressure deficit. For instance, the R^2 value of 0.7959 for maximum solar radiation and ETo indicates a strong positive linear correlation, suggesting that higher solar radiation leads to higher ETo values. Similarly, wind speed exhibited an R^2 value of 0.5974 with ETo, showing a positive correlation that highlights the importance of atmospheric movement in enhancing

evapotranspiration rates. Interestingly, the study also found a negative correlation between ETo and humidity.

This was evident from the R^2 value of 0.9111 for the relationship between minimum relative humidity and ETo, indicating a strong inverse relationship. As relative humidity increases, ETo decreases, which aligns with the concept that higher humidity reduces the evaporative demand from the atmosphere. This inverse relationship is critical for regions where humidity levels are high, as it suggests lower water loss through evapotranspiration. The study's findings are significant for the study area and can be adapted to other regions with similar climate conditions. The results emphasize the importance of considering multiple meteorological parameters in ETo estimation.

Accurate ETo calculation is crucial for effective irrigation planning and water resource management, particularly in regions with varying climatic conditions. For example, the standard deviation of 2.7172 indicates a high variability in ETo values, which must be accounted for in irrigation scheduling. Moreover, the research provides a theoretical basis for future studies on the response of ETo to climatic changes. Understanding how ETo reacts to different weather parameters can help in developing more precise irrigation schedules and implementing efficient water management strategies. This is particularly relevant as climate change continues to alter weather patterns, potentially impacting agricultural productivity.

The reference evapotranspiration in Prrenjas, Albania, is highly influenced by changes in climatic variables, with temperature, solar radiation, wind speed, and vapor pressure deficit positively correlated with ETo, while humidity is negatively correlated. These findings underscore the need for comprehensive data analysis and continuous monitoring of meteorological parameters to optimize water use efficiency and ensure sustainable crop production. The study provides valuable insights for the development of precise irrigation schedules, which are essential for maintaining agricultural productivity in the based on of climatic variability.

Acknowledgements

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