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Comparison of Hourly and Daily Reference Evapotranspiration Values for GAP Project Area

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Abstract: In this study, hourly and daily reference plant water consumptions were calculated by Penman Monteith equations, using meteorological data of temperature, relative humidity, solar radiation and wind speed obtained in 12 min periods from an automatic metrological station in Koruklu Research Station which represents Harran plain and is located within GAP region borders. Daily reference plant water consumption values (ET_0_H) obtained by adding the calculated hourly plant water consumption values were compared with directly calculated daily reference plant water consumption values (ET_0_D) for 2001-2002 period between the dates May1 and September 30 and statistical analysis were carried out. As a result of the study, it was found that ET_0 values calculated by different approaches exhibited a linear relation and ET_0_D values exhibited non-coincidently higher values than ET_0_H for all periods investigated.

Key words: Reference evapotranspiration, penman monteith, southeastern anatolian project, agricultural meteorology

INTRODUCTION

Plant water consumption is the amount of water released to atmosphere from plant surfaces by transpiration and from soil surface by evaporation. This value is expressed as ET_{crop} and direct measurement of it is costly and time consuming process. That is why, initially reference plant water consumption values are calculated by using meteorological data and then plant water consumption is estimated by multiplying these values with a plant coefficient (k_c) ($ET_{crop} = ET_0 \times k_c$) (FAO24, FAO56).

Reference plant water consumption (ET_0) is value determined from the meteorological data for a selected reference plant. Several different methods are employed in different regions of the world to calculate this value[1]. The most commonly preferred ones among them are Blaney Criddle, Penman, Penman Monteith and Pan evaporation methods.

Blaney Criddle (SCS) method was used in design of irrigation systems in Turkey until the early 1950s[2]. Then in the following years, Penman method and recently Penman Monteith method was started to be used. The reason to choose this method is due to its better and more realistic estimates in Turkish conditions by using more number of meteorological parameters.

Reference plant water consumption values calculated by Penman Monteith method using hourly meteorological data give more reliable results than Reference plant water consumption values obtained by using daily data with the same method[3].

Number of automatic meteorological station has increased significantly nation-wide in Turkey with recently carried out projects. General Directorate of State Meteorological Works aims to have periodical data with for shorter intervals by increasing the number of this type station more. In addition, requests from local farmers toward local meteorological data to have necessary measures against the meteorological conditions also caused an increase in the number of this type of automatic stations.

Climate classification method or/and precipitation index applied in Turkey gives reliable results for Southeastern Anatolian Region. Based on Erinc and Thornthwaite precipitation effectiveness index, generally arid, semi-arid and humid climatically conditions are seen in south-north direction in Southeastern Anatolian Region. With a broader definition, arid climatical conditions are dominant in Akcakale-Ceylanpinar region, semi-arid in Gaziantep-Sanliurfa plate and Siverek-Diyarbakir-Cizre region, arid-semi humid and humid conditions are dominant in locations surrounding the previous one from north[4].

Considering the very arid and hot climatical conditions effective in the region, climate of the region was also evaluated about desertification. Based on the

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aridity Index defined in United Nations Convention to Combat Desertification Agreement, especially middle parts of the region has a significant annual water deficit. Semi-arid conditions are effective in Kilis-Sanliurfa-Ceylanpinar triangle. Arid - semi-humid climatical conditions are dominant from surrounding of this triangle to northern borders of the region. According to this index, semi humid climatical conditions are dominant in west and east of the arid- semi humid lands mainly seen in the middle of the region. Characteristic vegetation formations of the semi arid and arid- semi humid lands of the region are step, step with loose trees, step with trees and dry forest[5].

Southeastern Anatolian Region is located in Terrestrial Mediterranean precipitation regime region. Main difference between Terrestrial Mediterranean precipitation regime and real Mediterranean precipitation regime is related to contribution of spring precipitation to amount of annual average precipitation; this contribution comes second following the winter precipitations[6].

Arable agriculture is carried out in 170 000 ha land area in Harran plain located in the hottest and the most arid region of Turkey. Significant plant water needs during the months of July and August makes the irrigation time scheduling a must. A proper scheduling depends on continuous climatical data for shorter periods.

In this study, hourly and daily reference plant water consumptions were calculated by Penman Monteith equations, using meteorological data obtained in 12 min periods from May 1 to September 30 for the years 2001-2002. Daily ET_0 values obtained by adding the calculated hourly plant water consumption values were compared with directly calculated daily ET_0 values.

MATERIALS AND METHODS

Materials: When the GAP project is completed, arable irrigation will be carries out in 1.7 million ha land area. 220 000 ha of this land area has already for irrigation and design and construction processes are still going on for the remaining part. 90% of the arable land area is located within Harran plain. Agricultural researches are being carried out at Koruklu Research Station which represents the plain. Automatic meteorological station was established in the plain in 2001 by GAP Regional Development Administration. Temperature, wind speed and direction, relative humidity and solar radiation data with 12 min intervals were gathered from this station. In this study, the measured data for the period between May 1 and September 30 in the years 2001 and 2002 were used to determine the hourly and daily reference plant water consumption values.

Methods: Daily reference plant water consumption values with Penman Monteith method was calculated by the equation 1 and hourly reference plant water consumption values were calculated by the equation 2[7]. For the determination of the parameters given in the equations, basic relations defined in Allen *et al.*[7] was used.

Penman Monteith reference plant water consumption equation for daily values is given below;

Equation 1;

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1+0.34u_2)}$$

Where;

ET_o : reference evapotranspiration [mm day^{-1}],
R_n : net radiation at the crop surface [MJ m^{-2} day^{-1}],
G : soil heat flux density [MJ m^{-2} day^{-1}],
T : mean daily air temperature at 2 m height [°C],
u_2 : wind speed at 2 m height [m s^{-1}],
e_s : saturation vapour pressure [kPa],
e_a : actual vapour pressure [kPa],
e_s - e_a : saturation vapour pressure deficit [kPa],
Δ_ : slope vapour pressure curve [kPa °C^{-1}],
γ_ : psychrometric constant [kPa °C^{-1}].

Penman Monteith reference plant water consumption equation for hourly values is given below;

Equation 2;

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{37}{T_h+273}u_2(e°(T_h) - e_a)}{\Delta + \gamma(1+0.34u_2)}$$

Where;

Et_o : reference evapotranspiration [mm h^{-1}],
R_n : net radiation at the grass surface [MJ m^{-2} h^{-1}],
G : soil heat flux density [MJ m^{-2} h^{-1}],
T_h : mean hourly air temperature [°C],
Δ : saturation slope vapour pressure curve at T_h [kPa °C^{-1}],
γ : psychrometric constant [kPa °C^{-1}],
$e°(T_h)$: saturation vapour pressure at air temperature T_h [kPa],
e_a : average hourly actual vapour pressure [kPa],
u_2 : average hourly wind speed [m s^{-1}].

Microsoft Excel software used to perform the calculations in equations for reference plant water consumption values.

Daily reference plant water consumption values obtained by adding the hourly reference plant water consumption values were expressed with ET_0_H and directly calculated daily reference plant water consumption values were expressed with ET_0_D.

Paired t-test was performed to evaluate the differences between ET_0_H and ET_0_D values and regression analysis were carried out for statistical evaluation of the results. MINITAB software was utilizes to perform both test Neter *et al.*[8].

RESULTS AND DISCUSSION

As seen in the Fig. 1 ET_0 values almost zero or close to zero belonging to night hours exhibits a fast increase between the h 6-12 and reaches about 0.8 mm, then the values show a fast decrease after 2.00 P.M. ET_0 values within a day varies according to changes in the climatical conditions within the day.

While ET_0_H values vary between 5-7 mm day^{-1} along the month, ET_0_D values vary between 7-9 mm day^{-1} (Fig. 2). Although the convex and concave points of the both values coincide at the same date, it shows a 2 mm day^{-1} excess value in ET_0_D values compared to ET_0_H values.

Statistical analyses were performed for ET_0_H and ET_0_D values obtained for the period between May 1-September 30. Paired t-test applied to the distribution of the above mentioned data for 2001-2002 years, monthly and daily periods and the results obtained were given in Table 1. Depending on the Paired t-test based on the difference between ET_0 _H and ET_0 _D values, it can be seen from the table that this value for 2001-2002 period was calculated as -1.47 and it started to increase in May and reached up to pick of -1.91 in June and gradually decreased during the following months and reached to -1.33 in September. When the results for ten day period were evaluated, it can be seen that t values for the period varied and greater t values were obtained for summer months. Based on t-test, ET_0_D values are grater than ET_0_H values that means the difference between ET_0_D and ET_0_H values is not coincidental.

Determination coefficient for 2001-2002 years for the distribution of these two values was found to be 97.9%, which was a significantly high value (Table 1).

Graphical representation of the above mentioned two parameter for the regression analysis results performed for the peak month August and 2001-2002 years were shown in Fig. 3 and 4. It can be seen from the figures that relationship between the values were linear and determination Coefficient for 2001-2002 was 97.9% and it was 92.8% for peak month August.

Based on the results of this study, daily water consumptions calculated by adding the hourly estimates are statistically different from directly estimated daily water consumption values. Evett *et al.*[3] explained that reference plant water consumption values obtained with Penman Monteith method by using hourly climatical data provided healthier results than the values obtained with the same method by using daily data. In this case, if there is an automatic meteorological station available in project areas, utilization of hourly climatical data to calculate plant water consumptions will result in more reliable water consumption values. In project areas without an

Table 1: Statistical analysis results for ET_0_H and ET_0_D values over 2001-2002 years, monthly and daily periods

Period	Paired t-test results	Determination coefficient (%)	Regression equation
2001-2002 period			
All data	-1.47	97.9	ET_0_H = 0.8244ET_0_D - 0.1631
Monthly results			
May	-1.19	98.8	ET_0_H = 0.8572ET_0_D - 0.205
June	-1.91	93.1	ET_0_H = 0.8127ET_0_D - 0.0478
July	-1.85	94.3	ET_0_H = 0.818ET_0_D - 0.1974
August	-1.61	92.9	ET_0_H = 0.7414ET_0_D + 0.4315
September	-1.33	88.1	ET_0_H = 0.8384ET_0_D - 0.3014
Decade results			
May 1	-0.95	98.7	ET_0_H = 0.9099ET_0_D - 0.4808
May 2	-1.08	98.2	ET_0_H = 0.8377ET_0_D - 0.0594
May 3	-1.49	91.6	ET_0_H = 0.803ET_0_D + 0.258
June 1	-1.75	96.5	ET_0_H = 0.7868ET_0_D + 0.2673
June 2	-2.00	93.2	ET_0_H = 0.8881ET_0_D - 0.8642
June 3	-2.10	83.9	ET_0_H = 0.7998ET_0_D + 0.032
July 1	-2.06	91.7	ET_0_H = 0.904ET_0_D - 1.0928
July 2	-1.96	99.2	ET_0_H = 0.8551ET_0_D - 0.662
July 3	-1.68	90.4	ET_0_H = 0.8201ET_0_D - 0.1435
August 1	-1.63	96.0	ET_0_H = 0.7695ET_0_D + 0.2481
August 2	-1.73	86.6	ET_0_H = 0.6647ET_0_D + 1.0294
August 3	-1.49	92.4	ET_0_H = 0.7969ET_0_D + 0.0103
September 1	-1.36	83.8	ET_0_H = 0.577ET_0_D + 1.5833
September 2	-1.26	82.9	ET_0_H = 0.8121ET_0_D - 0.0704
September 3	-1.39	85.2	ET_0_H = 0.8134ET_0_D - 0.2825

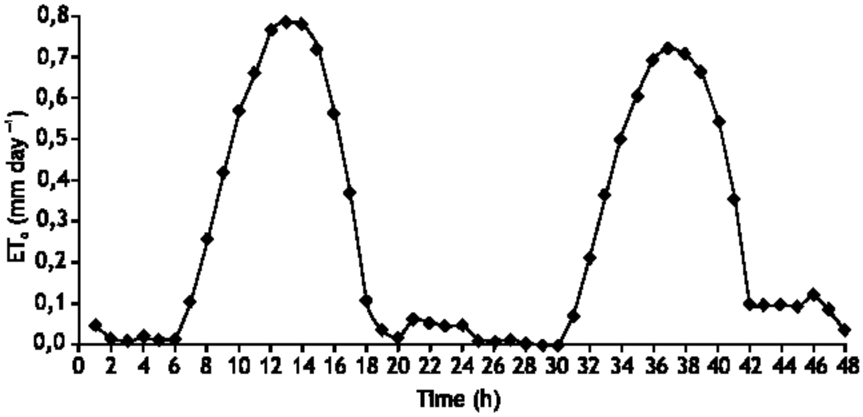

Fig. 1: Distribution of hourly reference plant water consumption between 14-15 August 2001

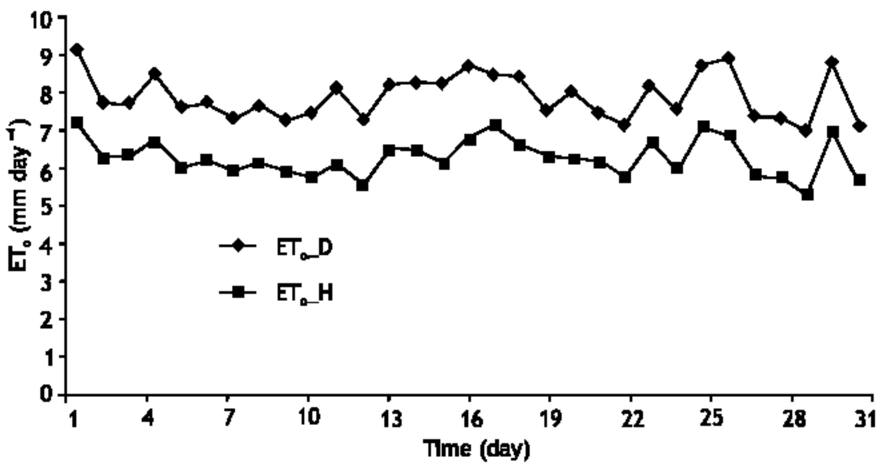

Fig. 2: Distribution of ET_0_H and ET_0_D values for the pick month August

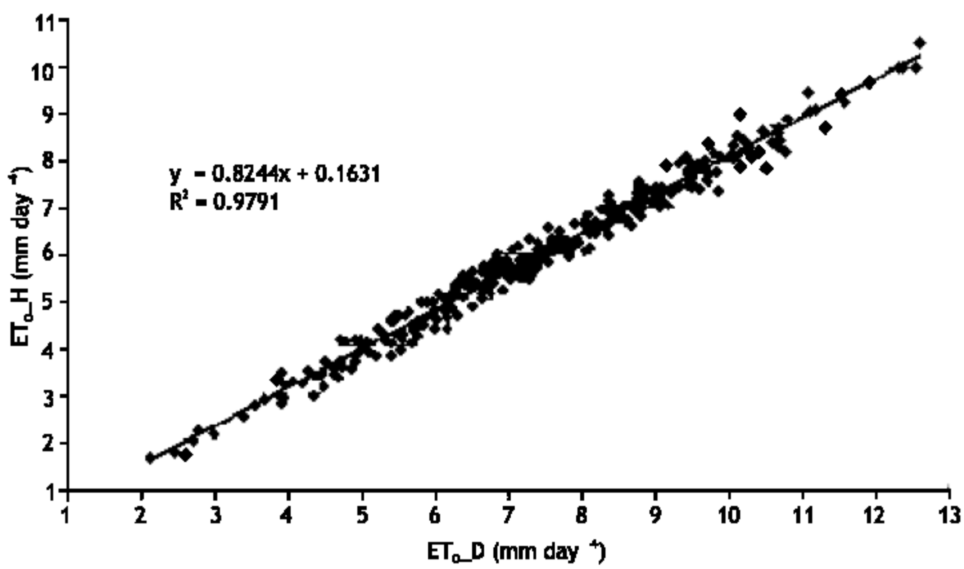

Fig. 3: Relationship between ET_0_H and ET_0_D values over 2001-2002 years

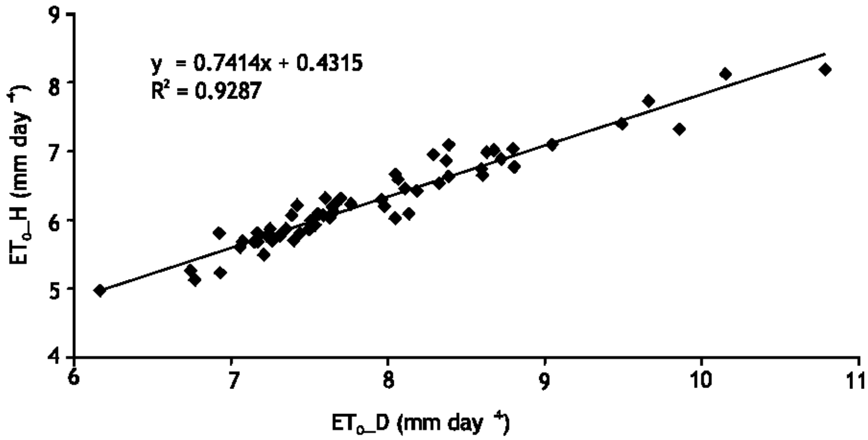

Fig. 4: Relationship between ET_0_H and ET_0_D values for August

automatic meteorological station, reliable results can be obtained by initially calculating the plant water consumptions by using daily data and revising them according to regression equations developed in this study.

In longer term, especially in the regions in which water has a significant importance such as Harran plain, deciding about whether to use hourly climatical data or to use daily data to calculate the reference plant water consumption (ET_0) is an issue to be investigated by lizimeter tests which was a determinating criteria in irrigation system design. If decided to use the hourly plant water consumption estimates (ET_0_H) based on the lizimeter test results, cost of construction will decrease since the system capacity will decrease. It will be possible to irrigate more land area with the water saved in this way. Also less water will be needed to irrigate same land area in already running projects.

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