UTILIZATION OF REMOTE SENSING TECHNIQUES FOR EVAPOTRANSPIRATION ESTIMATES OF AGRICULTURAL CROPS

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Abstract

Investigating usage possibilities of remote - sensing techniques to estimate evapotranspiration of pepper (Capsicum Annum L.) was aimed in this study, which was carried out at Ankara Köy Hizmetleri Research Institute during 1987 plant growing season.

Evapotranspiration rates measured by soil moisture balance model were compared to those predicted by using a model utilized remotely - sensed data.

Research results displayed that some insignificant deviations were encountered between mean values of measured and estimated cumulative evapotranspiration groups. Consequently, it has been deduced that remote - sensing techniques may be used for predicting evapotranspiration rates of pepper crop.

1 Introduction

The availability of soil water, which is dependent upon the water holding capacity of the soil, effective precipitation and evapotranspiration, is an important factor influencing plant growth. Evapotranspiration estimates can be used in ecological, hydrological, and agricultural studies such as erosion and flood control, crop management, irrigation scheduling and crop yield prediction (1). The rate of the transfer of water from soil, through plants, to the atmosphere in a developing row crop may be limited by soil, plant and atmospheric factors. When annual row crop plants are in an early growth stage with little vegetative cover, the evaporation rate from the entire field surface is dominated by the soil evaporation rate. Evaporation from bare wet soil surfaces is primarily influenced by the energy available for evaporation. As surface drying proceeds, evaporation becomes more dependent on the hydraulic properties of the soil near the surface. As the plant cover increases the evaporation rate becomes more dependent on the leaf area and the potential evaporation so long as the soil water available to the plant roots is not limited (2).

Leaf area index (LAI), the ratio of leaf plan area to a given land area, is a useful measurement to estimate evapotranspiration and yield, plant vigor, disease, soil salinity and moisture stress. LAI is used to characterize crops for interception and penetration of photosynthetically active radiation (PAR) as needed for photosynthesis or crop growth models and to partition energy between soil water evaporation and transpiration from plants (3). However, LAI is a tedious measurement and proper analysis requires large number of samples and much labor. Sampling errors can be quite large, especialy when non- uniform crop stands are sampled. For this purpose, utilizing remote - sensing techniques have given the possibilities to acquire reliable data over large areas in short time periods and to predict evapotranspiration rates of crops by using this data (4).

Green Pepper (variety 11 - B - 14) was used in this study as research material. This crop was intentially chosen for its importance of human nutrition. In addition to this it also includes " Capsicin ", which is an imperative element as a disinfectant for human digestion system (5).

The purpose of this investigation was to estimate evapotranspiration rates for Green Pepper crop by utilizing remote - sensing techniques for certain time period of plant growing season.

2 Material and Method

The research was carried out at Ankara Köy Hizmetleri Research Institute during 1987 plant growing season.

Irrigation water for the trial plots was obtained from the hydrants located over main pipe - line in the experimental fields of the Institute. Water was applied to the parcels with a gated - pipe system which is defined by (6).

Trial was designed according to randomized parcel system with three replications. Parcel sizes were planned 3m x 6m = 18 m^2 . All sides of the parcels were backfilled by compacted earth in order to ensure the prevention of water loss out from the parcel.

Soil water content values were determined by gravimetric method. Effective root zone depth was assumed 90 cm for pepper crop. For this reason, the crop was irrigated when 40 percent of the available water was consumed in the plant root zone.

Consumptive - use of water for pepper crop in the trial was measured by using water - balanced method given by (7) ;

$$Et = Ss + Yf \mp \Delta t_s \tag{1}$$

In this equation;

Et = Evapotranspiration (mm)
Ss = Amount of Irrigation water (mm)
Yf = Effective rainfall (mm)
Δt_s = Amount of soil water used by plant (mm)

Since the soil samples were collected by three days intervals, evapotranspiration values were also calculated in accordance to these intervals.

By using remote - sensing techniques, evapotranspiration rate for pepper was predicted with a model explained by (8). In respect to the model, evapotranspiration is the sum of evaporation from soil and transpiration from plant.

Maximum evapotranspiration (ETmax) is the energy - limited ET occuring from a well - watered surface during non - advective conditions:

$$ETmax = \alpha [s / (s + \gamma)] Rn \quad (2)$$

where;

ETmax = Maximum evapotranspiration (mm / day)
α = Proportionality constant for a paticular crop and climate (α = 1.26 (1))
s = Slope of saturated vapor pressure curve for the mean air temperature (mbar / ^{0}C)
γ = Psychrometer constant (mbar / ^{0}C)
Rn = Net radiation (mm / day)

Net radiation;

$$Rn = 0.725 (Rs / 58.5) - 0.860 \quad (3)$$

Where;

Rs = Solar radiation (cal / cm^2 / day)

When the soil surface is wet, the amount of energy at the surface is limiting evaporation (2); thus,

$$Eo = (\tau / \alpha) ETmax \quad (4)$$

Where Eo is daily rate of the evaporation from the soil surface during stage 1 *evaporation (constant rate phase).*

$$\tau = \exp (- 0.398 LAI) \quad (5)$$

In this formula;

LAI = Leaf area index

Evaporation continues until $\sum$ Eo = U where U is the upper limit of stage 1 evaporation. Evaporation, when limited by the transmitting properties of the soil (stage 2), is given as;

$$E = c t^{0.5} - c (t - 1)^{0.5} \quad (6)$$

Where c (mm / day $^{0.5}$) is dependent upon the hydraulic properties of the soil and t is time (days) after stage 1 evaporation. Values for U and c were reported for several soils (2) . In our research U and c were taken as 10mm and 3.5 mm / day $^{0.5}$ respectively.

Transpiration from plant was evaluated in according to the principles given by (8).

$$T = \alpha_v (1- \tau) ETmax / \alpha \qquad \text{for LAI} < 1.5 \qquad (7)$$

$$T = (\alpha - \tau) ETmax / \alpha \qquad \text{for LAI} \geqslant 1.5 \qquad (8)$$

Where; T = Transpiration (mm / day)

$$\alpha v = (\alpha -0.5) / 0.5 \qquad (9)$$

When the daily maximum temperatures (Tmax) exceeded a critical temperature, Advection has to be taken into considiration ;

$$A = 0.25\ T \qquad \text{for Tmax} > 31^{0}C \qquad (10)$$

Where A = Advection effect (mm / day)

Leaf area index for this model was estimated by a equation;

$$LAI = [(MSS\ 7 / MSS\ 5) - 1.717] / 1.431 \qquad (11)$$

In this equation ;

MSS 7 = Spectral reflectance measured at the near - infrared band (0.8 - 1.1 μm)

MSS 5 = Spectral reflectance measured at the red band (0.6 - 0.7 μm)

Spectral reflectance values were measured by a hand - held spectroradiometer (Exotech Model 100 A) . The spectral measurements were taken in respect to the principles given by (9, 10).

3 Research results and discussion

Evapotranspiration values estimated by using previously explained model which utilized Leaf Area Index values predicted with remote - sensing techniques and evapotranspiration values measured by water - balance model were drawn in relation to a certain time period (from 29 June 1987 to 18 August 1987) of the plant growing season in Figure 1. In addition to cumulative evapotranspiration rates, cumulative evaporation and transpiration values were also given in the same figure.

Numerical values of evapotranspiration rates for two different methods were also tabulated in Table 1.

As seen in Table 1, estimated and measured evapotranspiration values are very close to each other. Maximum difference within the above - mentioned values is 3.52 mm. Statistical analysis was performed in order to determine the significance level of difference between mean group values related to estimated and measured evapotranspiration rates. The analysis have shown that the difference between

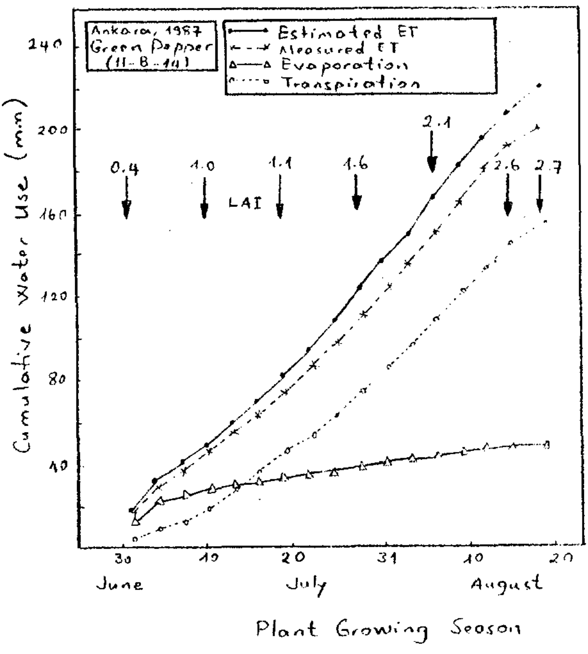

Figure 1: Estimated and measured evapotranspiration values for a certain time period of 1987 pepper growing season

mean group values was smaller than 1 % . This result has revealed that the prediction model can be used within statistical confidence levels where evapotranspiration measurement possibilities are restricted or at the planning stages of irrigation projects. Meanwhile, predicted consumptive use of water for pepper is 220.14mm and measured one is 201.84mm for the investigated growing period. Similarity between these values verifies the above - mentioned explanations.

On table 1, it is obvious that predicted and measured values were somewhat diverted. The reason for this circumstance was due to advection effect as a result of increasing daily maximum temperatures.

However as it can be seen on table 1 daily maximum temperatures created some advection effect in a parallel way to increasing temperatures. Additionally if the changing procedure of evaporation and transpiration is analyzed (Figure 1), it was deduced that an important part of total water consumption of plant was because of evaporation over early growing stages where Leaf Area Values were smaller than 1.1. Increasing LAI values lead to an increase of transpiration and evapotranspiration has become mainly dependent upon transpiration rather than evaporation.

Table 1: Estimated and Measured Evapotranspiration Values for Pepper

Date	LAI	Evaporation E or Eo (mm / day)	Transpiration T (mm / day)	Advection A (mm / day)	Evapotranspiration ET (mm / day)	Cumulative ET (mm)	Three days ETu (mm)	Measured ET (mm)	ETu - ET	Cumulative Measured ET (mm)
29.6.87		4.55	1.23		5.78					
30.6	0.4	4.46	1.20		5.66	11.45				
1.7.87		4.40	1.19		5.59	17.03	17.03	15.50	1.53	15.50
2.7		5.08	1.81		6.89	23.92				
3.7	0.6	2.11	1.77		3.88	27.80				
4.7		1.61	1.79		3.40	31.20	14.17	13.65	0.52	29.15
5.7		1.36	1.07		2.43	31.63				
6.7	0.9	1.20	2.25		3.45	37.08				
7.7		1.08	0.25		1.33	38.41	7.21	8.00	0.79	37.15
8.7		1.00	1.81		2.81	41.22				
9.7	1.0	0.93	2.49		3.42	44.64				
10.7		0.87	2.82		3.69	48.33	9.92	8.90	1.02	46.05
11.7		0.82	2.62		3.44	51.77				
12.7	1.0	0.78	2.57		3.33	55.12				
13.7		0.75	2.58		3.33	58.45	10.12	9.13	0.99	55.18
14.7		0.72	2.68		3.40	61.85				
15.7	1.1	0.69	2.65		3.34	65.19				
16.7		0.67	2.68		3.35	68.54	10.09	8.09	2.00	63.27
17.7		0.65	2.72		3.37	71.91				
18.7	1.1	0.63	3.14	0.79	4.56	76.47				
19.7		0.61	2.75	0.69	4.05	80.52	11.98	10.00	1.98	73.27
20.7		0.59	3.00	0.75	4.34	84.86				
21.7	1.2	0.58	2.98	0.75	4.31	89.17				
22.7		0.56	2.90	0.72	4.18	93.35	12.83	11.24	1.59	84.51
23.7		0.55	2.96	0.74	4.25	97.60				
24.7	1.4	0.54	3.42	0.86	4.82	102.42				
25.7		0.53	3.45	0.86	4.84	107.26	13.91	11.55	2.36	96.06
26.7		0.51	3.96	0.99	5.46	112.72				
27.7	1.6	0.50	3.72	0.94	5.16	117.88				
28.7		0.49	3.53	0.08	4.90	122.78	15.52	12.00	3.52	109.06
29.7		0.48	3.47	0.87	4.82	127.60				
30.7	1.8	0.47	3.25	0.87	4.59	132.19				
31.7.87		0.47	3.47	0.87	4.81	137.00	14.22	14.38	0.16	122.44
1.8.87		0.46	4.04		4.50	141.50				
2.8	1.9	0.45	3.31		3.76	140.26				
3.8		0.45	3.94		4.39	149.65	12.65	13.10	0.45	135.54
4.8		0.44	4.11		4.55	154.20				
5.8	2.1	0.43	4.19	1.05	5.67	159.87				
6.8.		0.43	4.34	1.09	5.86	165.73	16.08	15.16	0.92	150.70
7.8		0.42	4.54	1.13	6.09	171.82				
8.8	2.2	0.41	4.21	1.05	5.67	177.49				
9.8		0.41	4.11	1.03	5.55	183.04	17.31	15.00	2.31	165.70
10.8		0.40	4.36		4.76	187.80				
11.8	2.4	0.40	4.25		4.65	192.45				
12.8		0.39	3.98		4.37	196.82	13.78	14.98	-1.20	180.68
13.8		0.39	3.64		4.03	200.85				
14.8	2.6	0.39	3.74		4.13	204.98				
15.8		0.38	3.51		3.89	208.87	12.05	11.00	1.05	191.68
16.8		0.38	4.23		4.61	213.48				
17.8	2.7	0.38	2.16		2.84	216.32				
18.8.87		0.37	3.45		3.82	220.14	11.27	10.16	1.11	201.84

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