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Estimation of Evapotranspiration for Onion Crop in Semi-Arid Region: Experimental Field Setup Using Lysimeter

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Abstract: In this work, Blaney-Criddle and Lysimeter method were applied to evaluate the actual evapotranspiration for onion crop in the semi-arid region of Chitradurga district. A reliable and accurate estimation of evapotranspiration are required for proper water balance and to define water-crop requirement. For this purpose, Lysimeter was set up in the field using three different soil layers of specific gravity 2.30. In this research work, an attempt is made to estimate daily evapotranspiration for onion crop, for which 1000ml of water was added on daily basis and corresponding percolation was observed to find the potential water balance deficit and surplus. Onion is a local crop of Chitradurga district having growth rate 90-120 days. For Blaney-Criddle equation, crop coefficient of 0.75 is adopted to estimate the actual evapotranspiration. This method was found to be simple and reliable to estimate the evapotranspiration in semi-arid region.

Keywords: Evapotranspiration, Lysimeter, Onion Crop, Blaney-Criddle Equation

1. Introduction

In the context of climatic change, water resources for agriculture are decreasing with respect to time and space in many parts of the world with more emphasis in the semi-arid and arid regions. Demand for water is increasing due to increase in anthropogenic activities, increase in population, rapid industrialization and increase in growing of crops under limited irrigation practices. Hence the necessity of judicious use of water is required for maximum agricultural production. Nearly, 85% of water is withdrawing from the earth's surface including ground water resource for agricultural activities. Normally in Semi-Arid regions, the scarce of water resources are stored as a ground water; whereas the demand for limited ground water is increasing. For better improvement of water management and to increase water use efficiency of various agricultural production, crop water use should be accurately evaluated.

The process of water released to the atmosphere by different ways includes solids, liquids, soil, and plants surfaces are difficult to distinguish. Hence, together it is termed as evapotranspiration (ET). Evapotranspiration was found to be more sensitive towards climatic variables such as relative humidity, temperature, wind speed, sunshine hours and other parameters. This sensitivity may decrease on different scale index due to variation of climatic variables. Evapotranspiration was found to be more important and integral component of hydrological cycle, which has significant and direct impact on hydrological aspects.

Transpiration is depends on growth rate of plant. The value of evapotranspiration is high in midday and less in morning, hence it is unaffected by air-temperature and humidity. This work presented a simple equation for estimating the actual evapotranspiration (ET_a) from climatic and soil parameter using Lysimeter in the semi-arid regions. Consumptive use of water includes water used in plant metabolism and direct evapotranspiration from soil and plant surfaces. Thus Consumptive use exceeds Evapotranspiration by the amount of water used for plant metabolism through photosynthesis, transport of minerals, growth of plant and other activities.

Many methods have been applied for the estimation of Evapotranspiration. Some of them are found to be useful for the analysis. The daily values of reference crop evapotranspiration (ETr) were estimated by Penman-Monteith method for 32 years [1]. The study of evaporation and transpiration components of evapotranspiration and to estimate their contributions in semi-arid regions characterized by shallow groundwater table [2]. Analyzing the evaporation and evapotranspiration measured on the caldarusani lake and their influences on the lakes water volume [3]. Numerical simulation of groundwater in this basin (Baoy-ang irrigation area) using FAO Penman-Monteith method under all circumstances [4]. Identifying the factors controlling the variability of Evapotranspiration (including associated atmospheric circulations) [5]. Relation between pan evaporation and actual evapotranspiration by using different types of pan evaporation apparatus [6]. Modified Penman-Monteith method to evaluate the reference evapotranspiration for effective planning and management [7]. Different Evapotranspiration equations were calibrated and used on river Delta region [8]. Approximately 1°C increase in temperature could increase ETo by 30 mm per year [9]. Estimation of reference evapotranspiration (ETo) using the Multivariate Empirical Mode Decomposition [10].

The present method was simple in construction and assessment, for this purpose soil test was done using core cutter apparatus and specific gravity of soil was found to be 2.30. Three different soil layers were prepared in the Lysimeter. Water was added on daily basis with a quantity of 1000ml and correspondingly percolated value was found to find the potential water balance (surplus or deficit). The Blaney-Criddle equation was used to estimate the actual evapotranspiration and method was found to be reliable for different crop in semi-arid regions.

2. Study Area

The present study area covers the Hosadurga located near the fast developing western section of Chitradurga, at 14°N to 76.5°E. The summer season starts from March with temperature ranging from 30^0-36^0. At the end of May, the monsoon season starts and lasts until the end of October. The physical features of Chitradurga District are such that, Precipitation is confined to the period between April to October with rainfall ranging from 700 to 900mm approximately. During summer the crops are invariably subjected to drought condition. Therefore, it becomes increasingly important to optimize the irrigation needs for the crop in semi-arid regions. Figure 1 shows the location of study area.

Figure 1. *Location of the study area (Hosadurga: Google source).*

3. Methodology

3.1. Lysimeter

Lysimeter is a special type of cylindrical water tight tank which contains soil and was installed in a field with onion crops. The crops grown in lysimeter are same as that of crops in surrounding adjacent crops. Evapotranspiration was measured in terms of the amount of water necessary to maintain adequate and constant moisture conditions. The average value of water required over the crop period in mm/day will give the value of actual ET in mm/day under the specified field condition. Lysimeters was designed to accurately replicate the soil conditions, moisture content and type of vegetation around it. It was placed in the soil at the same level of ground. Lysimeter observations are usually combined with rainfall observations.

Figure 2 shows the lysimeter set up in the field. Figure 3 shows the different layers of the soil sample with different size. The figure 4 shows the onion plant in the lysimeter set up.

Figure 2. *Lysimeter setup in the field.*

Evapotranspiration is controlled by the climatic variables and is largely independent of the amount of vegetation present. If the soil and vegetation is confined within a small tank, then the measurements are made using inputs, such as rainfall(R), water added(W) and output (percolated water P) collected in the receiver. Henceforth the Evapotranspiration can be estimated from the equation.

$$PET = [R + W - P] \quad (1)$$

where, R-Rainfall

W-Water added (ml)
P-Water percolated (ml)

(If PET is positive, it is potential water surplus or else it is potential water deficit).

3.2. Construction

1. *Tank:* The tank was made up of Plastic which is cylindrical in shape and having a diameter of 30cm and depth of 30cm from surface of soil. A small outlet (opening) is provided near the base to collect the percolated water into a closed container.
2. *Installation:* Lysimeter was taken to the field, filled with gravel. Local soil which is lateritic is used in the lysimeter up to the desired level, then onion plant was grouted into the soil.
3. *Daily procedure:* Each day a known quantity of water was added to the crop in the lysimeter. Measurement of the water percolated "P" in mm was taken every day.

Figure 3. *Soil sample used.*

Figure 4. *Sample of onion crop.*

3.3. Results

1. Weight of empty pycnometer (W1) gm = 605
2. Weight of pycnometer + soil (W2) gm =900
3. Weight of pycnometer + soil + Water (W3) gm =1680
4. Weight of pycnometer + Water (W4) gm =1513

3.3.1. Calculation

$$G = (W2 - W1) / ((W2 - W1) - (W3 - W4)) \quad (2)$$

G = 2.3046

Table 1. *Details of water added and percolated.*

Date	Water added W (ml)	Percolation P (ml)	Rainfall (ml)	PET (ml)	PET (mm)	Potential water surplus PWS (mm)	Potential water Deficit PWD (mm)	Potential Water Balance PWB (mm)
15/3/2017	1000	220	0	780	11.035	11.035	0	11.035
16/3/2017	1000	260	0	740	10.469	10.469	0	10.469
17/3/2017	1000	295	0	705	9.974	9.974	0	9.974
18/3/2017	1000	355	0	645	9.125	9.125	0	9.125
19/3/2017	1000	410	0	590	8.347	8.347	0	8.347
20/3/2017	1000	650	162	512	7.243	7.243	0	7.243
21/3/2017	1000	510	0	490	6.932	6.932	0	6.932
22/3/2017	1000	530	0	470	6.649	6.649	0	6.649
23/3/2017	1000	520	0	480	6.791	6.791	0	6.791
24/3/2017	1000	515	0	485	6.861	6.861	0	6.861
25/3/2017	1500	790	0	710	10.045	10.045	0	10.045
26/3/2017	1500	826	0	674	9.535	9.535	0	9.535
27/3/2017	1500	820	0	620	8.771	8.771	0	8.771
28/3/2017	1500	920	0	580	8.205	8.205	0	8.205
29/3/2017	1500	960	0	540	7.640	7.640	0	7.640
30/3/2017	1500	970	0	530	7.49	7.49	0	7.49
31/3/2017	1500	1000	0	500	7.074	7.074	0	7.074
1/4/2017	1500	1050	0	450	6.366	6.366	0	6.366
2/4/2017	1500	1040	0	460	6.508	6.508	0	6.508
3/4/2017	1500	1045	0	455	6.437	6.437	0	6.437
4/4/2017	1500	1043	0	457	6.465	6.465	0	6.465
5/4/2017	2000	1220	0	780	11.035	11.035	0	11.035
6/4/2017	2000	1640	356	716	10.129	10.129	0	10.129
7/4/2017	2000	1385	0	618	8.701	8.701	0	8.701
8/4/2017	2000	1400	0	600	8.488	8.488	0	8.488
9/4/2017	2000	1460	0	540	7.640	7.640	0	7.640

Date	Water added W (ml)	Percolation P (ml)	Rainfall (ml)	PET (ml)	PET (mm)	Potential water surplus PWS (mm)	Potential water Deficit PWD (mm)	Potential Water Balance PWB (mm)
10/4/2017	2000	1495	0	505	7.144	7.144	0	7.144
11/4/2017	2000	1538	0	462	6.536	6.536	0	6.536
12/4/2017	2000	1560	0	440	6.225	6.225	0	6.225
13/4/2017	2000	1555	0	445	6.296	6.296	0	6.296
14/4/2017	2000	1540	0	460	6.508	6.508	0	6.508
15/4/2017	2000	1545	0	455	6.437	6.437	0	6.437

Average PET obtained is 7.909.

3.3.2. Sample Calculation

Water added = 1000ml

Water percolated = 650ml

PET = R+W-P

= 162+1000-650

=512ml (+ve Hence PET = PWS)

3.3.3. Blanley - Criddle Method

It was observed that the amount of water consumptively used by crops during their growing seasons was closely co-related with mean monthly temperatures and daylight hours. The relationship developed by Blaney - Criddle in FPS units is stated as follows:

$$U = E_T = [2.54 \text{ x } K \text{ x } F] \quad (3)$$

Where,

1. U=Seasonal consumptive use of water by the crop for a given period.
2. E_T=PET in a crop season in cm
3. $F=\Sigma P_H T_f / 100$
4. K=An empirical co-efficient depends on type of crop
5. T_f=Mean monthly temp in Fahrenheit
6. P_h=Monthly percent of annual daytime hours.

Consumptive use of water by crop is give by the equation:

$$U = [\sum kf] \quad (4)$$

where, k = Empirical consumptive use crop coefficient

$$f = P\ (0.46t + 8.13)\ [t \text{ in } °C] \quad (5)$$

t = Mean of daily maximum and minimum temperatures in °C over the month considered.

P = Mean daily percentage of annual day time hours for a given month and latitude.

Table 2. *Results of Evapotranspiration estimated using Blanley-Criddle method.*

Date	Daily temperature (t)	Daytime hours (p)	F	U=kf (mm/day)
15/3/2017	26.5	12.3	249.93	6.24
16/3/2017	27.85	12.3	257.57	6.43
17/3/2017	27.8	12.4	259.38	6.48
18/3/2017	27.7	12.4	264.51	6.61
19/3/2017	29.5	12.5	271.25	6.78
20/3/2017	27.95	12.6	264.43	6.61
21/3/2017	28.3	12.7	268.57	6.71
22/3/2017	27	12.8	263.04	6.576
23/3/2017	26.75	12.9	263.65	6.59
24/3/2017	27.2	12.1	249.76	6.24
25/3/2017	29	12.1	259.75	6.49
26/3/2017	28.5	12.11	257.21	6.42
27/3/2017	28.5	12.12	257.42	6.435
28/3/2017	28.5	12.12	257.42	6.435
29/3/2017	28.75	12.13	259.036	6.475
30/3/2017	28	12.14	255.06	6.3765
31/3/2017	30.5	12.14	269.02	6.72
1/4/2017	28.25	12.15	256.66	6.41
2/4/2017	28.75	12.15	259.24	6.481
3/4/2017	29.5	12.14	263.43	6.58
4/4/2017	29	12.16	261.075	6.52
5/4/2017	30	12.19	261.719	6.54
6/4/2017	29	12.19	261.719	6.54
7/4/2017	29	12.20	261.934	6.54
8/4/2017	28.5	12.20	259.128	6.47
9/4/2017	28.45	12.21	259.06	6.47
10/4/2017	30.5	12.22	270.79	6.76
11/4/2017	30	12.23	268.20	6.705
12/4/2017	30.5	12.23	271.01	6.77
13/4/2017	29.5	12.25	265.82	6.64
14/4/2017	30	12.25	298.64	6.71
15/4/2017	31	12.25	274.27	6.85

Average consumptive use of water by Blanley-Criddle method is 6.491.

3.3.4. Sample Calculation

f = 12.30 (0.46x26.5 + 8.13)

= 242.67

U = K*f

= 0.75x246.67

= 185.0025 mm/month

= 185.0025/31

= 6.24 mm/day

4. Discussions

From the table 1, it is observed that, the value of potential evapotranspiration obtained on the first day was found to be 11.03mm/day and from the table 2, the value of evapotranspiration was found to be 6.24mm/day for Blanley-Criddle equation. The difference in values signifies the growth rate of the crop, but the values obtained in the later stages compensate to the value of beginning stages of crop. Henceforth, the average value of 7.90 and 6.49 are considered. Therefore, the average value of 7.90 and 6.49 is considered from table 1 and table 2.

5. Conclusions

The average value of evapotranspiration for onion crop is found to be 7.90mm/day from Lysimeter and 6.49 mm/day from Blaney-Criddle equation method. Lysimeter found to be simple in operation. Henceforth, it can be used effectively to estimate the evapotranspiration for different regions and for different crops.

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