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REVIEW OF CALCULATION METHODS FOR DETERMINING THE TOTAL EVAPORATION OF IRRIGATED AGRICULTURAL FIELDS.

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Abstract:
Determining the optimal rates and timing of irrigation is one of the most difficult tasks of irrigated agriculture. When solving it, it is necessary to take into account all the natural and climatic conditions of the region. The main task before us is to determine the total evaporation from cotton fields with the calculation-empirical methods of Penman-Monteith, Blaine-Criddle, N.I. Ivanov, S.M. Alpatev. Field studies to determine the total evaporation were carried out in the farm "Jalilbobo" of the Shafirkan district of the Bukhara region. To solve the desired problem, two experimental plots were organized - one on a field irrigated by furrow irrigation, the other - on a drip irrigation site. The soils of the study area are semi-hydromorphic, slightly saline, light loamy in terms of mechanical composition.

Keywords: Reference evapotranspiration, evapotranspiration, crop water consumption, calculation methods, evapotranspiration models.

1. INTRODUCTION

The most important characteristic in hydromelioration is the amount of total evaporation. Some researchers in their works call it water consumption, and abroad - evapotranspiration. Evapotranspiration has a serious impact on the technology of irrigation regimes, and through them on crop yields, planning of water resources and managing the water balances of agricultural landscapes. Its value, together with precipitation, is the input information for most hydrological and water balance models.

The water consumption of a field occupied by agricultural crops is spent on transpiration (Et) and soil evaporation (Ep):

E = Et + Ep

Transpiration is the evaporation of water from the vascular system of plants into the atmosphere as a result of the process of photosynthesis. It is limited by thermal energy, water availability, humidity, temperature, ambient CO2 concentration and wind speed. Plant species affect transpiration differently through effects on leaf conductance and plant adaptation to water availability. Evapotranspiration is the total amount of water evaporated from the soil, plant body and leaves. The evaporation of water from the soil after irrigation is affected by air temperature, humidity, solar radiation activity and wind strength. In addition, the shade from plants on the soil surface also affects the evaporation of soil moisture. When the soil surface dries out (within a few days), the level of radiation exposure decreases sharply [1-2].

As plants grow, more of the soil surface is covered, evaporation over the soil decreases, but the amount of transpiration increases.

Due to the hot and dry climate in most of the territory of the Republic of Uzbekistan, the value of evapotranspiration is high. To determine the amount of evapotranspiration of various crops, it is necessary to determine the value of "reference evapotranspiration".

"Reference evopotranspiration" is the volume of water evaporated per unit time from a normally grown, not waterlogged green plant, completely covered with vegetation and not very tall (up to 20 cm) in size. This number is accepted throughout the world as a guideline for plants. Over the past 50 years, leading scientists and experts in the world have developed numerous methods for calculating the reference (potential) evapotranspiration ETo using various climatic parameters. These methods are regional in nature and require additional labor and time to be applied in other parts of the world. On the other hand, time requires fast detection of ETo indicators [5-6].

2. RESEARCH METHODS

Penman-Monteith method: FAO recommended the Penman-Monteith method as the only and standard method for determining the reference (potential) evapotranspiration ETo. According to some experts, the disadvantage of this method is that not all weather stations have all the climatic parameters required in formula (1). Non-existent climate indicators can also be determined using theoretical formulas, which is time consuming. However, FAO has developed an automated computer program that quickly determines the standard evopotranspiration even in the absence of all climate indicators. This program is used both in Uzbekistan and abroad.

Reference crop evapotranspiration is calculated from ETo, crop coefficient (Kc), crop characteristics and evapotranspiration (ETc), calculation of total water demand for cotton based on the adapted Penman-Monteith method, and data on air temperature, humidity, wind speed and sunshine duration.

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}; \text{ мм} \quad (1)$$

Reference evapotranspiration ETo is calculated from climate and weather data and represents the evaporative capacity of the atmosphere in a particular region and season and is independent of crop type or soil.

To link with reference evapotranspiration (ETo) and crop evapotranspiration (ETc), crop factors (Kc) are introduced and water consumption at the cotton development stages is taken into account. The value of the crop factor (Kc) at full efficiency in plant growth is the evapotranspiration (ETc) according to equation 2, taking into account the cultivation of plants in large fields with pain-free, optimal soil conditions, optimal soil fertility and irrigation conditions.

$$ETc = Kc \cdot ETo; \quad \text{mm.} \quad (2)$$

Wherein: ETc – plant evapotranspiration, (irrigation rate) mm;
Kc - stages of development to the plant and the coefficient of the plant, taking into account water consumption; ETo- reference evopotranspiration, mm.

The value of the plant coefficient (Kc) depends on factors such as sowing time, stage of development, duration of the growing season, method and technique of irrigation (furrow and drip irrigation), climatic conditions. Plant coefficient (Kc) is determined [table. 2] on the basis of many years of field experimental research on the irrigation of agricultural crops.

Table 1 shows the values of the reference evapotranspiration according to the long-term average monthly (the last 35 years) climatic data of the Bukhara weather station in a computer program automated by the Penman-Monteith method [1-3].

Table 2

Values of coefficients (Kc) of the stages of development of cotton according to the mechanical composition of soils (according to the FAO method)

Stages of development	The mechanical composition of the soil		
	Light	Average	Heavy
1	0,39	0,36	0,37
2	0,72	0,70	0,71
3	1,11	1,09	1,10
4	0,70	0,69	0,70

Table 3

Monthly cotton evapotranspiration (ETc) according to the Penman-Monteith method.

Months	April	May	June	July	August
ETo (mm/ мonths)	118	193	237	282	219
Kc	0,35	0,35	0,7	1,1	0,7
ETc- every month, mm	41,3	67,5	166	277	153

Blaine-Criddle Method: In the Blaine-Criddle method, the value of the reference evapotranspiration ETo is determined by the following formula:

ETo = P · (0,46 · Tsrednaya. +8) mm. (3)

where: P - is the average percentage of annual periods of time of day (hours) per day;

Tsrednaya.- the average air temperature in the daytime, at ^{0}C;

Tsrednaya.=(Tmax + Tmin) / 2 (3.1)

Tmax – the sum of the highest temperatures in a month;

Tmax = (∑Tmax within a month) / Nday (3.2)

Nday- number of days in 1 month;

Tmin = (∑Tmin within a month) **/** Nday (3.3)

To determine P, it is necessary to know at what latitude (at what degree north or south of the equator) the area where the experimental field is located is located. To determine the value of P, use the following table [table. 4] [5-7].

Table 1

Long-term average monthly climatic data of the weather station Bukhara.

№ weather station	weather station / zone	coordinates nl/el	heights, м	Month	day T ^{0}C	Max average T ^{0}C	Absol Max T ^{0}C	Min average T ^{0}C	Absol Min T ^{0}C	Precipitation mm	Relative Humidity, %	Wind speed м/sec	sunshine hour	Solar radiation Mj/m2/ day	ETo Penman mm
20	35,36 Bukhara	39:40 64:20	230	January	0	6	25	-5	-23	18	74	2,9	4,1	7,1	22
				February	3	9	28	-2	-25	21	70	3,2	4.7	9,7	33
				March	8	16	33	3	-18	28	63	3,5	5,2	13,1	67
				April	16	24	38	10	-6	26	54	3,6	7,3	18,5	118
				May	22	30	42	14	2	10	39	3,8	10,1	24,2	193
				June	26	35	43	17	7	3	31	4	12,3	27,9	237
				July	28	36	45	19	12	1	32	4	12,8	28,1	252
				August	25	34	43	17	8	0	34	4,1	12	25,3	219
				September	20	29	39	11	-2	0	40	3.3	10,2	19,9	139
				October	13	23	36	5	-7	5	51	2,6	7,6	13,3	75
				November	6	15	30	0	-17	13	62	2,5	5,6	8,7	36
				December	2	8	24	-2	-25	18	74	2,5	4	6,4	21

Average percentage of annual daytime. Table 4

Latitude	North - South	Jan Var Jul	February August	March September	April October	May November	JunDecember	Jul January	August February	September March	October April	November May	December Jun
60^0		15	20	26	32	38	41	40	34	28	22	17	13
55^0		17	21	26	32	36	39	38	33	28	23	18	16
50^0		19	23	27	31	34	36	35	32	28	24	20	18
45^0		20	23	27	30	34	35	34	32	28	24	21	20
40^0		22	24	27	30	32	34	33	31	28	25	22	21
35^0		23	25	27	29	31	32	32	30	28	25	23	22
30^0		24	25	27	29	31	32	31	30	28	26	24	23
25^0		24	26	27	29	30	31	31	29	28	26	25	24
20^0		25	26	27	28	29	30	30	29	28	26	25	25
15^0		26	26	27	28	29	29	29	28	28	27	26	25
10^0		26	27	27	28	28	29	29	28	28	27	26	26
5^0		27	27	27	28	28	28	28	28	28	27	27	27
0^0		27	27	27	27	27	27	27	27	27	27	27	27

The experimental field is located on the territory of Bukhara, i.e. at 39/40 degrees north latitude. According to the Bukhara weather station (Table 1), the average July temperature was +28 ^{0}C.

Tmax = (∑Tmax within a month) / Nday = 1116 / 31 = 36 ^{0}C

Tmin = (∑Tmin within a month) **/** Nday = 589 / 31 = 19 ^{0}C

Taverage.=(Tmax + Tmin) / 2 = (36 + 19) / 2 = 28 ^{0}C.

ETo = P · (0,46 · Taverage. +8) = 0,329 · (0,46 · 28 +8) =6,87 mm/day.

ETo = 6,87 mm/day · 31 day = 213 mm/ month. (ETo – for the month of July.) The remaining months were counted in the same order [tab. 5] [8-10].

Table 5

Cotton Monthly Evapotranspiration (ETc) Blaine-Criddle Method.

Months	April	May	June	July	August
ETo (mm/ day)	5,05	5,96	6,57	6,87	6,41
Kc	0,35	0,35	0,7	1,1	0,7
ETc (mm/ day)	1,77	2,09	4,6	7,6	4,5
ETc- every month, mm	53,1	64,8	138	235,6	139,5

N. I. Ivanov's method: We determine the amount of physical evaporation and transpiration (evapotranspiration-irrigation rate) in the experimental field where cotton is grown, according to the formula of N. I. Ivanov:

ETo = 0,0018 · 0,8 · $(25 + T)^2$ · (100 - a) (4)

where, ETo is the reference evapotranspiration.

T - average monthly air temperature, ^{0}C;

a- average monthly relative humidity, %.

According to the Bukhara weather station [Table. 1], the average July temperature was +28^{0}C, relative humidity 32%.

July: ETo =0,0018· 0,8· $(25+28)^2$ · (100-32) =275 mm. The remaining months were counted in the same order [1-2].

Table 6

Monthly cotton evapotranspiration (ETc) according to N.I. Ivanov.

Months	April	May	June	July	August
ETo (mm/ мonths)	111	193	258	275	237
Kc	0,35	0,35	0,7	1,1	0,7
ETc- every month, mm	38,8	67,5	180,6	302	166

Method S.M. Alpatev: Many design institutes carry out general evaporation based on the recommendations developed by research institutions or the bioclimatic method of the Ukrainian scientist S.M. Alpatev. According to the Alpatev formula, total evaporation-evapotranspiration is a function of air humidity deficit:

ETc = Kb ·Σd (5)

Σd - average daily amount of moisture deficit for the reporting period, kPa (accepted from the nearest weather station).

Kb – bioclimatic coefficient (determined on the basis of long-term field experimental studies).

Therefore, we need to define E and e in (6) to determine Σd - air humidity deficit.

d = E-e or d = Pт - P (6)

To find the pressure E of saturated water vapor at dew point air temperature (Td), you need to find the air temperature (Td) at the dew point. This information can be obtained from the data of the Bukhara weather station [tab. 1].

According to the table, the air temperature is +28 ^{0}C and F = 32% is the dew point air temperature corresponding to relative humidity Td = +10^{0}C and absolute humidity P = 9.4 g/m3.

To clarify this information, we can refer to [tab. 7].

At Td = + 10 ^{0}C, the density of saturated steam is P = 9.4 g/m3.

Table 7

Pressure and density of saturated water vapor at different temperatures.

t, °C	p, кПа	p, мм рт. ст.	ρ, г/м³	t, °C	p, кПа	p, мм рт. ст.	ρ, г/м³
0	0,611	4,58	4,84	17	1,94	14,53	14,5
1	0,656	4,92	5,22	18	2,06	15,48	15,4
2	0,705	5,29	5,60	19	2,19	16,48	16,3
3	0,757	5,68	5,98	20	2,34	17,54	17,3
4	0,813	6,10	6,40	21	2,48	18,6	18,3
5	0,872	6,54	6,84	22	2,64	19,8	19,4
6	0,934	7,01	7,3	23	2,81	21,1	20,6
7	1,01	7,57	7,8	24	2,99	22,4	21,8
8	1,07	8,05	8,3	25	3,17	23,8	23,0
9	1,15	8,61	8,8	30	4,24	31,8	30,3
10	1,23	9,21	9,4	40	7,37	55,3	51,2
11	1,31	9,84	10,0	50	12,3	92,5	83,0
12	1,40	10,52	10,7	60	19,9	149,4	130
13	1,50	11,23	11,4	70	31,0	233,7	198
14	1,59	11,99	12,1	80	47,3	355,1	293
15	1,70	12,79	12,8	90	70,1	525,8	424
16	1,81	13,63	13,6	100	101,3	760,0	598

Relative humidity is determined by formula (7).

F= (P / Pт) · 100% (7)

If we set the climate indicators to (7), we get the following representation:

32%= (P / 9,4 г/м3) · 100% ; where, P = (32 · 9,4) / 100= 3 г/м3

d = E-e or d = Pт - P (8)

From (8) the moisture deficit is as follows:

d = 9,4 г/м3 - 3 г/м3 = 6,4 г/м3.

The same is true for the rest of the months [11-14].

Table 8

Monthly evapotranspiration of cotton according to the bioclimatic method S.M. Alpatev.

Months	April	May	June	July	August
Σd — deficit of air humidity.	102	148	162	198,4	158
Kb	0,35	0,35	0,7	1,1	0,7
ETc- months, mm	36	52	113,4	218,2	110,6

3. RESULTS

As a result of the analysis of studies of calculation methods for determining total evaporation, conducted in various regions of the world, it was found that the development of models of total evaporation is widespread in most developed countries. For most regions, different research organizations have developed their own methods for determining the total evaporation. Methods of K. Lgov, P. Nevsky and D. A. Shtoiko, V. S. Mezentsev, N. Ivanov with Molchanov's correction and M. Alpatiev's bioclimatic method. The Penman-Monteith method is widely used abroad. FAO recommended it as a standard. Almost all calculation methods are based on climatic indicators. The main ones are the radiation balance for the vegetation period of the phytocenosis, the sum of the average daily deficits of air humidity and air temperature for the same period, wind speed. Such calculation methods have simple models and can be easily and timely used in both operational and predictive calculations. Calculation errors will be within acceptable limits when methods are used under conditions identical to those for which they were developed

Table 9

Evapotranspiration (ETo) reference values for cotton, determined by various methods.

Months	Penman Monteith(FAO)mm	Blaney Criddle mm	N.I. Ivanov mm	CM. Alpatiev mm
April	118	151	111	102
May	193	185	193	148

June	237	197	258	162
July	252	213	275	198
August	219	199	237	158
Total:	1019	945	1074	768

Table 10

Evapotranspiration (ETc) of cotton, determined by various methods.

Months	Penman Monteith(FAO) mm	Blaney Criddle mm	N.I. Ivanov mm	CM. Alpatiev mm
April	41,3	53,1	38,8	36
May	67,5	64,8	67,5	52
June	166	138	180,6	113,4
July	277	235,6	302	218,2
August	153	139,5	166	110,6
Total:	704,8	631	755	530,2

4. CONCLUSIONS

A review of even a small number of different evapotranspiration methods shows continued interest from researchers. The widely used empirical methods for calculating total water consumption are based on a high correlation with meteorological parameters. Accounting for the vegetative surface of the field increases the accuracy of calculations of the total water consumption. In the practical application of calculation methods for any area, one should choose from among the possible empirical methods based on meteorological parameters that most significantly correlate with evapotranspiration under given conditions and are easy to measure.

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