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Manual on calculation and choosing the norms and elements of irrigation technique for cotton and winter wheat based on results of IWRM-Fergana project

IWMI
International
Water Management
Institute

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The present manual is developed in Scientific-Information Centre of Interstate Coordination Water Commission (SIC ICWC) under the project «Integrated water resources management in Fergana valley» (director of the project «IWRM - Fergana» - professor V.A. Dukhovny, regional manager of the project - V.I. Sokolov). Recommendations are developed by the head of activity «Introduction of advanced technologies below WUA level» Sh.Sh. Mukhamedjanov by results of the research.

The given recommendations are intended for a wide range of water users and, in particular, for the farmers seeking consultations and practical recommendations concerning effective and productive use of irrigation water.

On any questions you can address:

at local water organizations to regional executors of the project:
at Sogd region – Hodzhiev Halim Rifatovich (phone 6-34-93);
at Fergana region – Kabulov Kadir (phone 24-12-60);
at Osh region – Alybaev Sherbay Alybaevich (phone 5-79-49);
at Andijan region – Ergashev Shukhrat (phone 24-42-73).

at SIC ICWC:

to the head of activity Mukhamedjanov Shukhrat Shakirovich (phone 265-09-57);

Production of agricultural crops is accompanied by a complex of actions, each of which has own features and specifications for various soil-climatic conditions. For arid zones, the most important of actions is carrying out the irrigation. At planning and use of water, special attention should be paid to **crop, soil, meliorative and climatic conditions**.

At planning and rationing of irrigation water the most important indicator is combination of biases of district and water penetration of ground. Irrigation technique and water supply volume are chosen depending on a combination of these two indicators. N.T. Laktaev had studied under production conditions and offered irrigation technique elements for various combinations of biases and water penetration.

Using his approach as a basis, we defined combinations of district biases and water penetration for the irrigated lands linked to pilot canals of the project IWRM-Fergana in II phase (table 1).

Distinction in water requirements of various crops is insignificant and the minimum quantity of water that is required for the vegetation period for reception a top yield for the majority of cultures is in limits of **660-750 mm (6600-7500 m3/hectare) and only for a Lucerne reaches 990 mm (9900 m3/hectare).**

The notable factors causing deficiency of moisture are climatic ones. Intensity of evaporation from the surface of plants and soil surface is changed according to temperature of air and speed of wind.

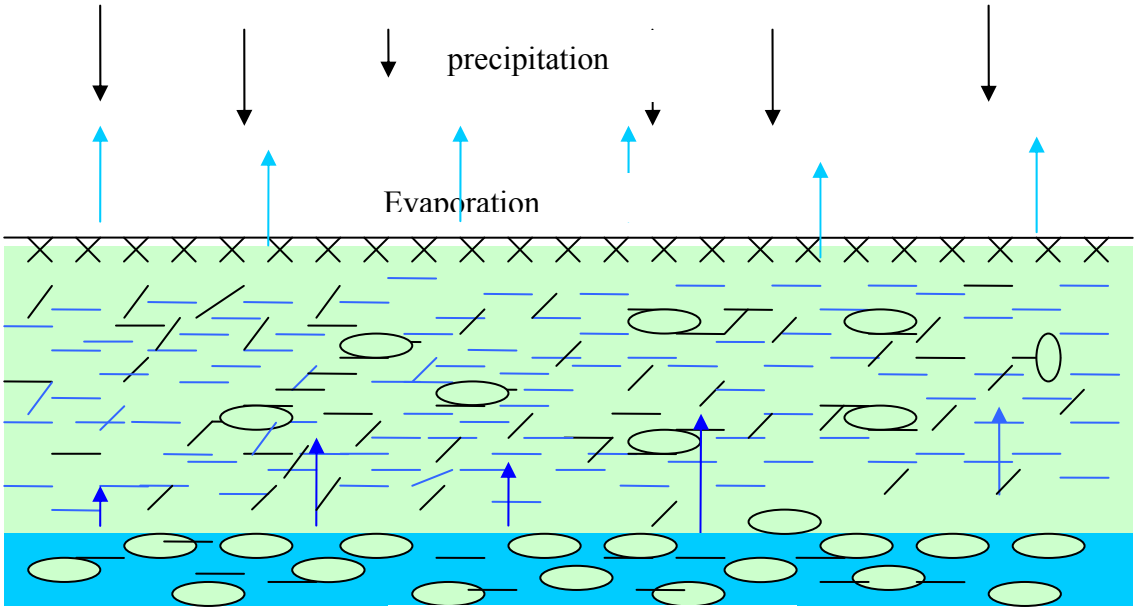
Combination of water penetration and biases on demonstration fields of states

Table 1

Plots linked to the canal	Soil type	Capacity of surface melkozem	Grounds	Index - bias	Water penetration infiltration speed (m/h)
Tajikistan, Sogd region (Dzhabar Rasulov, B.Gafurov districts)					
Guljakandoz	Easy loam	0,5-1,5 m.	shingle	I-zone of big and very big biases 0,014- 0,03	АВ – strong, average water penetration 0,0138-0,0042
Uzbekistan, Fergana region (Kuva, Tashlak, Ahunbabaev districts)					
SFC	Light and medium loams, sandy grey soil	0,5-0,7 m. In some places -powerful	shingle	II – a zone of big and average biases 0,003-0,012	АБ –strong, higher water penetration 0,0102- 0,0198
Uzbekistan, Andijan region (Bulakbosh district)					
SFC	light and medium loams, sandy grey soil	0,5-0,7 m. in some-places-powerful	shingle	II – a zone of big and average biases 0,003-0,012	А Б –strong, higher water penetration 0,0102- 0,0198
Kyrgyzstan, Osh area (Karasu, Aravan districts)					
Aravan-Akbura	light and medium loams	0,5-0,7 m. in some-places-powerful	shingle	I – a zone of very big biases 0,042-0,06	А Б – strong and higher water penetration 0,006-0,0402

Therefore at planning and rationing of irrigation water the basic attention is given to change of humidity in soil and total evaporation (total evaporation is evaporation from a soil surface + evaporation of water from a plant).

The soil has the natural moisture generated as a result of loss of precipitation. The expenditure of moisture from soil occurs because of evaporation. The higher air temperature, the higher is evaporation and faster a process of expenditure of moisture from the soil.



For cultivation of plants and maintenance of its ability to grow the certain quantity of moisture in soil is necessary. The minimum limit of moisture content in soil below which the plant starts to feel deficiency of moisture is known. At reaching this limit, it is necessary to feed the soil with water until full saturation, i.e. to irrigate. It is studied, that the greatest yield at economical expenditure is provided at pre-irrigation humidity at level:

- for lucerne, vegetable and grain crops - 75 %-80 % of maximum soil water capacity;
- for cotton – from shoots till maturing - 70 % of maximum soil water capacity;
- during a phase of disclosing of bolls - 60-65 % of maximum soil water capacity;

Recommendations for choosing the irrigation technique elements for cotton and wheat for the plots linked to pilot canals of the project IWRM-Fergana

Table 2

The name of region, district	Soil conditions	Water penetration	Bias	Length of furrows L_b, m	Discharge in a furrow Q, l/s	Irrigation norm (gross) M_b m3/hectare	Irrigation norm (net) M_n m3/hectare	Number of waterings	Irrigation norm, m3/hectare	Row-spacing B_b
Osh region, Aravan and Karasu districts	Light and average loams with changable capacity of-melkozem, spread by shingle	А Б - strong and higher water penetration 0,006-0,0402	I - a zone of very big biases (0,042-0,06)	40-80	0,1	1100	600-700	Cotton-5-6 Wheat-4	Cotton – 6600-7700 Wheat - 4400	0,6
Sogd region, J. Rasulov district	Easy loams with integumentary melkozem 0,5-0,7м., spread by shingle	А В - strong, average water penetration 0,0138-0,0042	I-zone of big and very big biases (0,014 0,03)	80-100	0,75	900	600-700	Cotton – 8-9 Wheat-4	Cotton -7200-8100 Wheat - 3600-4000	0,6
Fergana region, Kuva district	Light and medium loams, in some places - sandy	А Б –strong, raised water penetration 0,0102- 0,0198	II - a zone of big and average biases (0,003-0,012)	80-100	0,25-0,75	900	600-700	Cotton – 7-8 Wheat-4	Cotton - 6300-7200 Wheat - 3600-4000	0,6
Andijan region, Bulak-bash district	Average loams sandy stony with powerful integumentary melkozem	А Б –strong, raised water penetration 0,0102- 0,0198	II - a zone of big and average biases (0,003-0,012)	80-100	0,25-0,75	900	600-700	Cotton -6-7 Wheat-4	Cotton -5400-6300 Wheat 3600-4000	0,6

It is necessary to have a mode of irrigation for each kind of crop and know its basic indicators for effective carrying out the irrigation:

- Time of irrigation;
- Norms of irrigation;
- Duration of irrigation;
- Quantity of irrigation.

Time of irrigation

Time of irrigation of any culture comes at achievement of such level of humidity in soil below which a plant feels deficiency of moisture and then process of wilting begins.

How to define the level of humidity? Definition of this value by sampling of a ground and its weighing is very difficult and impracticable in field conditions. There are traditional ways of definition the time of irrigation according to external signs – by a condition of leaves or by plasticity of ground. These ways are widely known to agricultural crops producers, having long-term experience:

- By the condition of leaves – at sufficient moisture cotton leaves are fragile and have a crackling sound, at insufficient moisture leaves are not broken and their slackness is visible;
- By plasticity of soil – the ground is selected from a depth of 10-20 sm and compressed in a fist. At sufficient moisture the selected soil is not scattered or rolled in a ball. At an insufficient moisture - the ground is scattered.

For the lands with deep level of subsoil water the way of definition the next irrigation is possible on the sum of daily evaporation from the date of previous irrigation taking into account its norm.

For example, cotton is sown on April, 25th, couching watering is carried out on April, 26th with water 800 m3/hectare. The account of daily evaporation is conducted since April, 26th. Evaporation forms 2-3 mm a day this month or 20-

30m^3/h. In 10 days from the soil surface evaporated 200-300 m3/hectare of the submitted water, in 20 days 400-600 m3/hectare and in 25 days 500-750 m3/hectare. If to accept, that evaporation on the average formed 3 mm then, taking into account a coefficient of efficient water use, we can do the first irrigation in 20 days when 800 m3/hectare of water have evaporated from the soil. Time of the second irrigation is defined with the account of volume of the first irrigation and the sum of daily evaporation for each next day after the first irrigation or on the basis of average daily evaporation for this month (tab. 4).

In practice each farmer should know in advance rough time of irrigation **(T_i)** in order to prepare the field for the irrigation. In that case, the farmer, knowing daily evaporation **E_{av}** for the time of irrigation can take this value as a basis (increasing it at expected heats) and to calculate when sum of daily evaporation will cover the submitted volume of water, i.e. inter-irrigation period **(N)**. The inter-irrigation period can be defined under the formula, knowing the volume of water submitted for the irrigation and daily evaporation for this period:

$$N = \frac{W_i}{E_{cp} * 10} * K_i, \qquad \textbf{(1)}$$

Where: **N** – the inter-irrigation period or time for which the irrigating water submitted in the field is spent at the certain sum of daily evaporation, days;

W_i – the volume of water submitted to the field, m3/hectare;

Eav - an average daily evaporation observed for the required period (month), mm;

10 - transition number from mm to m3/hectare;

К – coefficient of efficient water use in the field or coefficient of efficiency of a field equal to 0,75.

Further, knowing the inter-irrigation period **(N)** or quantity of days after which it is necessary to carry out the next irrigation, we count the date of the following irrigation **(T_{i+1}),** adding quantity of days to date of the carried out irrigation **(T_i)**.

$$T_{i+1} = T_i + N, \qquad \textbf{(2)}$$

If during the inter-irrigation period precipitation were observed it is necessary to enter the amendment for the date of irrigation defined by calculation (Table 3).

Example of calculation of rough date of the next irrigation

Table 3

Number of watering	Date of irrigation (T_i)	The inter-irrigation period (N) N = W / (Ei*10) *K	Date of the next irrigation (T_{i+1})	Precipitation	The amendment of the inter-irrigation period on size of the dropped precipitation	Date of the next irrigation adjusted for the dropped precipitation
Couching watering	April, 26th					
1 - irrigation		800 / (3*10 *0,75 = 20 days	26 Apr +20days = =On May, 16th	23 mm	230 / (3*10) = =8 days	
	On May, 24th					
2 - irrigation		800 / (4*10 *0,75 = 15days	24 May+15days = =8 June	12mm	120 / (4*10) = =3 days	8 June+3 days = =On June, 11th
	On June, 11th					
3 irrigation		800 / (5*10 *0,75 = 12 days	11June+12 days=23 June	5 mm	50 / (5*10 =1 day	23 June +1 day=24 June
	On June, 24th					

In table 3: 800 – water supply of the last irrigation in m3/hectare;
*(3,0*10) - the expected average value of daily evaporation (3) in mm, multiplied on 10, will be transformed to m3/hectare (that is 3,0 mm = 30m3/hectare);*
0,75 – value of efficiently- used water minus losses on runoff and a deep filtration.

Where is it possible to receive the information on daily evaporation and the dropped precipitation?

Such data are available on each meteorological station. As now there is no service giving such information, it is possible to use the average values of daily evaporation received by results of gauging on demonstration fields of the project IWRM-Fergana from 2002 till 2005 resulted in table 4.

Average values of evaporation

Table 4

The name of regions	Months								
	March	April	May	June	July	August	September	October	November
Fergana		3,1	6,5	7,9	7,7	5,9			
Osh		3,0	4,9	6,8	6,1	6,4	2,4		
Hodjent			5,7	7,5	7,1	5,9			

For a zone spanned by the project, data about daily evaporation and precipitation farmers can receive in WUA Japalak at Karasu district of the Osh region, in WUA Zeravshan at Sogd region, in WUA Akbarabad at Kuva district of the Fergana region, in farm Tolibjon **of** Bulakbash district of the Andijan region.

It is necessary to notice, that for a zone of Fergana valley most typical droughty months are March, April and May and for tilled crops, particularly for cotton, water retention and couching waterings are carried out. Carrying out the water retention irrigation and planting of cotton are the most effective to the natural moisture of soil. However, if year has appeared droughty it is often necessary to carry out the couching waterings after water retention irrigation. It is recommended to carry out the water retention irrigation in Fergana valley in March on loamy and medium loamy soils. It is not recommended to carry out the water retention irrigation on light, sabulous and sandy soils because of weak moisture-holding ability of these soils.

Calculation of irrigation norm

Norms of irrigation depend on moisture content in soil, soil type (mechanical structure), humidified layer, level of subsoil water and a kind of crop.

The size of irrigation norm can be defined from S.N. Ryzhov dependence:

$$W = (V_1*P - V_2*P) *h + K, (3)$$

Where W – norm of irrigation, m3/hectare;

$\mathbf{V_1}$ - The least moisture capacity of soil, % from weight of soil;

$\mathbf{V_2}$ - Preirrigation humidity of soil in the layer of soil, % from weight of soil;

P - volumetric weight of soil (average density of soil) in layer;

h – capacity of a layer, sm;

K – water losses on evaporation and deep filtration during irrigation, equal to 25 % from size of deficiency of a moisture in soil before the irrigation.

As the left part of dependence 3 (without losses **K**) describes the volume of water necessary for fullfilment the deficiency and full saturation of a layer then we can count water losses regarding this volume.

At calculations, **K** can be accepted as:

$$\mathbf{K = (V_1*P - V_2*P) *h* 0,25, (4)}$$

It is difficult under production conditions to pick up all indicators of the given dependence and to calculate irrigation norm. Knowing that deficiency of moisture in soil is a result of total evaporation (evaporation from soil + evaporation from plants), all calculations can be brought to the only indicator, namely to size of total evaporation:

$$W_{2\text{-}n} = (\Sigma E_i *10) + K, (5)$$

where: $\mathbf{W_{2\text{-}n}}$– norm of irrigation, calculated for the first irrigation, conducted after couching irrigation, further for the second, etc. , m3/h;

$\mathbf{\Sigma E_i}$ – sum of daily evaporation equal to volume supplied by the previous irrigation, mm;

K – water losses on evaporation and deep infiltration during irrigation, equal to 25% of deficiency i.e. of evaporated volume for the whole inter-irrigation period:

$$K = (\Sigma E_i * 10) * 0,25, \qquad (6)$$

At definition and calculation the time and norm of irrigation for the lands with deep level of ground water, it is sufficient to know daily evaporation or its average values (table 4) for every decade for the given region, in a case if there is no daily information. The calculation principle is very simple and can be used not only by experts, but also by farmers. At use of the given method, it is necessary to have the water account in the field or in a farm. It is possible to define water supply to each field on water-measuring devices (Chipoletti, Thomson, Yartsev) with sufficient accuracy.

Sequence of calculation is the following:

1. After sowing the cotton (or other crop) couching watering is carried out. It is recommended to sow crops from April, 20 till April, 25th for the Fergana region, which means that couching watering is carried out on April, 21st or 26.
2. The norm of couching watering is defined proceeding from humidifying of a layer of earth of 50 sm and forms 700-950 m3/hectare gross. Since the day of termination the couching watering, the account of daily evaporation is conducted. At evaporation 3-4mm a day at the end of April and in the beginning of May every day 35-40 m3/hectare of a moisture supplied in the field by irrigation water is gone by evaporation from soil and plants, in 10 days– 350-400 m3/hectare, in 20 days– 700-800 m3/hectare accordingly. That means that the norm of the following irrigation should be equal to the norm of the spent moisture received by soil and plants in previous irrigation. If to irrigate after 20 days the norm will form 750-800 m3/hectare net or 950-1066 m3/hectares gross. As usually, there is no possibility to irrigate timely within days, we recommend to be prepared for the irrigation 3-5 days in advance before the full expenditure of

the submitted moisture. The procedure of calculating the norm of the following irrigation is resulted in the table 5.

The water discharge in a furrow and duration of irrigation

The important elements of irrigation actions besides term and norm are the water discharge in a furrow and duration of irrigation. These elements depend on several important indicators:

1. Water penetration of soil;
2. Bias of irrigation site;
3. Length of a furrow;
4. a kind of crop.

Duration of irrigation and discharge in a furrow are defined for each condition by experimental researches taking into account all indicators of irrigation. It is impossible to carry out such calculations under production conditions. For conditions of pilot objects of the project we recommend to use water discharges in a furrow, resulted in table 2.

At known indicators of irrigation (defined with use of table 2 or on hydromodule districting), duration of irrigation for one furrow or group of simultaneously watered furrows can be defined. Duration of irrigation is defined at known values of irrigation norm ($\mathbf{M_{br}}$), length ($\mathbf{L_b}$) and width ($\mathbf{B_b}$) of a furrow and the water discharge in a furrow (**q**) as follows:

At the given irrigation norm in m3/hectare it is defined, how much water to submit to one furrow. For this purpose we define the furrow area – F, hectares:

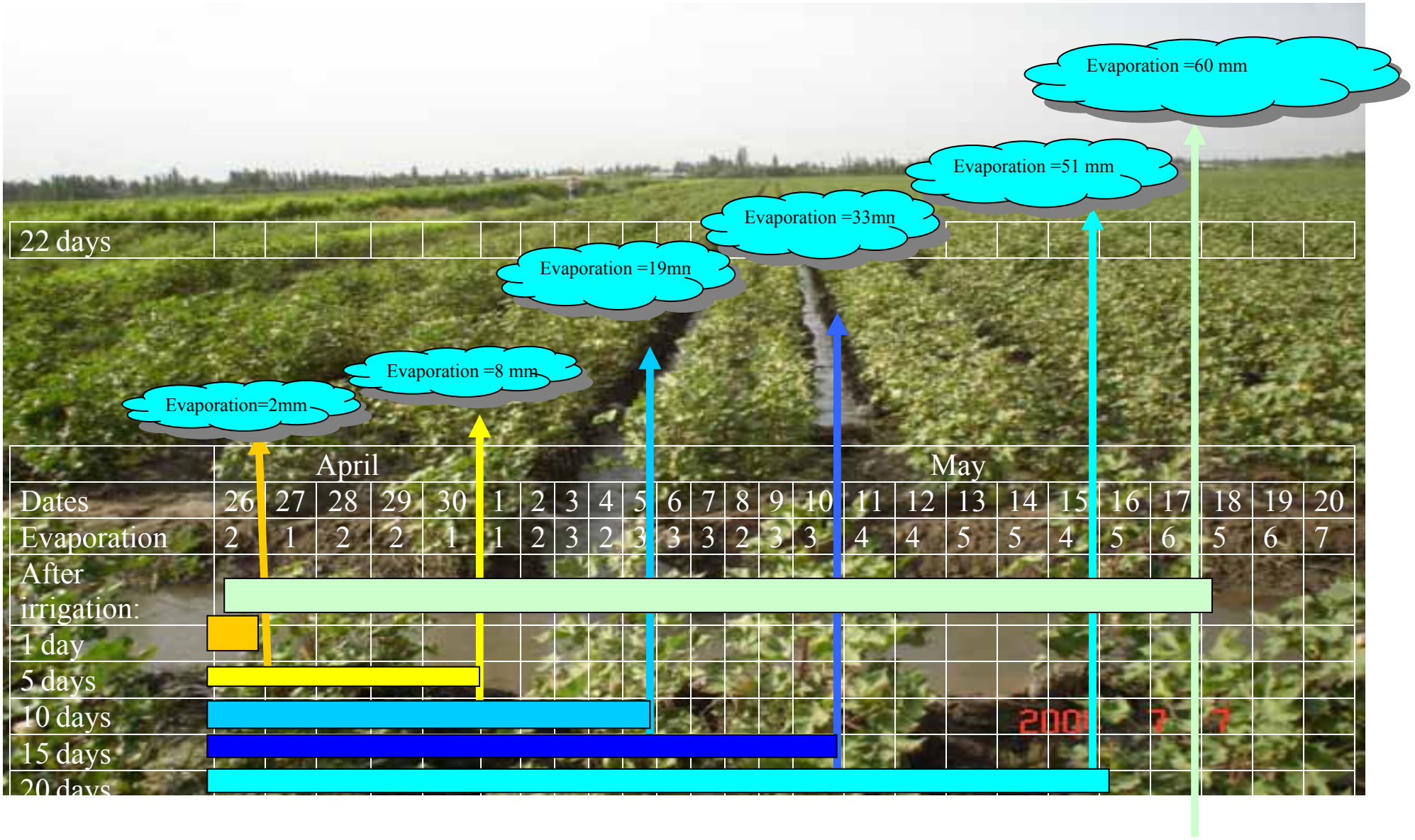
$$F = \frac{L_b * B_b}{10000}, \qquad \textbf{(7)}$$

Calculation of irrigation norm

Table 5

Number of watering	Date of irrigation	Inter-irrigation period (T)	Time of watering under forecast	Precipitation	Amendment of the inter-irrigation period on quantity of the dropped out precipitation	Time of irrigation upon adjusted for the dropped out precipitation	Irrigation norm of the next irrigation	Gross irrigation norm including all losses
		Days	Days	mm	Days	Days	m3/hectare	m3/hectare
Couching	26 apr.							800 m3/hectare
		800 / (3*10 *0,75 = = 20 days	26 apr+20days = = On May, 16th	23	230 / (3*10) = = 8 days	16 May+8 days = On May, 24th	20 * (3*10 =600 m3/hectare	600/0,75 = 800 m3/hectare
1	On May, 24th							
		800 / (4*10) *0,75=15days	24 may+15days = On June, 8th	12	120 / (4*10) = = 3 days	8 june+3days = = On June, 11th	15* (4*10) =600 m3/hectares	600/0,75 = 800 m3/hectare
2	On June, 11th							
		800 / (5*10) *0,75=12days	11june+12days = = On June, 23rd	5	50 / (5*10 =1 day	23 June+1day = = 24 June	12* (5*10) =600 m3/hectare	600/0,75=800 m3/hectare
3	On June, 24th							

Moisture evaporation from soil and plants for the various periods after irrigation



Recommended irrigation norms for the various soils, received on the basis of work of the project IWRM-Fergana

Table 6

		irrigation								Irrigation norm,
The characteristic of soils and grounds	Water table	Couching	1	2	3	4	5	6	7	m3/hectare
		Irrigation norms, net m3/hectare								
		Wheat, Osh region								
Light and medium loams stony, spread by shingle, with the big biases.	> 5m	1000	1050	1000	950					4000
		Cotton, Fergana valley								
Medium and easy loams with variable capacity of integumentary melkozem, spread by shingle, with the big biases.	> 5m	980	950	950	950	800	800			5430
Medium loams sandy stony with powerful integumentary melkozem.	> 5m	600	733	890	965	960	560	602		5300
Easy loams with integumentary melkozem - 1,0-1,2 m spread by shingle	0,5-1,0m	605	609	526						1740
Medium and heavy loams with powerful integumentary melkozem.	1,0-1,5m	800	600	600	600	600	600	600		4400
Light and medium loams with integumentary melkozem 0,5-0,7m., spread by shingle	> 5m	1100	1192	1063	1053	1220	1160	1232	902	8922
Easy loams with powerful integumentary melkozem.	> 5m	1100	1080	950	1200	1165	1176	955		7626
Easy loams with integumentary melkozem 0,5-0,7м., spread by shingle.	> 5m	489	711	840	850	863	709	637	559	5657,5

Further the volume of water necessary for one furrow W_b, m/hectare is defined:

$$W_b = M_{br} * F = M_{br} * F = M_{br} * \frac{L_b * B_b}{10000}, \qquad \textbf{(8)}$$

Then it is possible to calculate duration of irrigation of one furrow at known or defined water discharge in a furrow:

$$D_{irr} = \frac{W_b}{3600q} * 1000 \ , \qquad \textbf{(9)}$$

Duration of irrigation is defined in hours from the equation 9. Multiplying the received value on 60, it is received duration of irrigation in minutes.

Simplifying the equation (9), we will receive:

$$D_{irr} = \frac{M_{br} * L_b * B_b}{36000 * q}, \textbf{ in hours (10)}$$

$$D_{irr} = \frac{M_{br} * L_b * B_b}{600 * q}, \textbf{ in minutes (11)}$$

Where:

D_{irr} - duration of irrigation

M_{br}- gross irrigation norm, m3/hectare;

L_b - length of a furrow, m;

B_b - width of row-spacings, m;

q - the water discharge in a furrow, l/s;

<u>Calculation example:</u>

*Width of furrow **B_b** = 0,6 meters*

*Length of furrow **L_b** = 80 meters*

The furrow area along its length will be:

F = 0,6 * 80 = 48 м2 or 48/10000 = 0,0048 hectares

We define how many water it is necessary to supply to one furrow at known norm of irrigation 900 m3/hectare:

$W_б$ = 900 m3/hectare * 0,0048 hectares = 4,32 m^3;

Knowing necessary norm for one furrow ***($W_б$ = 4,32 m)*** *and the expense in a furrow* ***(q = 0,5 l/sek),*** *we define duration of irrigation for one furrow:*

At first we convert m^3 into liters, that is ***4,32 m^3 * 1000 = 4320 l;***

Further:

4320 l / 0,5 l/sek = 8640 sek, or 8640сек/60 = 144 minutes or 2 hours 24 minutes.

Duration of irrigation for group of simultaneously watered furrows will be the same, as for one furrow. Duration of irrigation the whole field will depend on the technological scheme of irrigation where the quantity and sequence of groups of simultaneously irrigated furrows depend on the water discharge at the head of the field.

Values of irrigation duration for various combinations of indicators are resulted in tables 7, 8, 9, 10.

Table 7

Width of row-spacings	**The discharge in a furrow**	**Length of furrows**	**Gross irrigation norm, m3/hectare**		
			600-700	**800-900**	**1000-1200**
Meter	**Litr/sec**	**Meter**	**Duration of irrigation, in minutes**		
0,6	1	40	28	36	48
0,6	1	50	35	45	60
0,6	1	60	42	54	72
0,6	1	70	49	63	84
0,6	1	80	56	72	96
0,6	1	90	63	81	108
0,6	1	100	70	90	120
0,6	1	150	105	135	180
0,6	1	200	140	180	240

Table 8

Width of row-spacings	The discharge in a furrow	Length of furrows	Irrigation norm gross, m3/hectare		
			600-700	800-900	1000-1200
Meter	Liter/sec	Meter	Duration of irrigation, in minutes		
0,6	0,5	40	56	72	96
0,6	0,5	50	70	90	120
0,6	0,5	60	84	108	144
0,6	0,5	70	98	126	168
0,6	0,5	80	112	144	192
0,6	0,5	90	126	162	216
0,6	0,5	100	140	180	240
0,6	0,5	150	210	270	360
0,6	0,5	200	280	360	480

Table 9

Width of row-spacings	The discharge in a furrow	Length of furrows	Gross irrigation norm, m3/hectare		
			600-700	800-900	1000-1200
Meter	Litr/sec	Meter	Duration of irrigation, in minutes		
0,6	0,25	40	112,0	144,0	192
0,6	0,25	50	140,0	180,0	240
0,6	0,25	60	168,0	216,0	288
0,6	0,25	70	196,0	252,0	336
0,6	0,25	80	224,0	288,0	384
0,6	0,25	90	252,0	324,0	432
0,6	0,25	100	280,0	360,0	480
0,6	0,25	150	420,0	540,0	720
0,6	0,25	200	560,0	720,0	960

Table 10

Width of row-spacings	The discharge in a furrow	Length of furrows	Gross irrigation norm, m3/hectare		
			600-700	800-900	1000-1200
Meter	Litr/sec	Meter	Duration of irrigation, in minutes		
0,6	0,1	40	5	6	8
0,6	0,1	50	6	8	10
0,6	0,1	60	7	9	12
0,6	0,1	70	8	11	14
0,6	0,1	80	9	12	16
0,6	0,1	90	11	14	18
0,6	0,1	100	12	15	20
0,6	0,1	150	18	23	30
0,6	0,1	200	23	30	40

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