HYDROLOGICAL AND HYDRAULIC RESEARCH FOR RE-EQUIPPING AN IRRIGATED PLOT WITH PRESSURIZED PIPELINES

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Abstract

Considering these factors we have decided that the following basic data are necessary for modernizing an irrigation plot: the climate studies for the last three decades regarding monthly precipitations and potential evaporation; the current crop planning; pedological studies on hydro-physical characteristics of the soil; phytotechnology studies; hydrogeological studies on the variation of the groundwater level; the types and functional characteristics of the irrigation systems in use now and/or in the future for each pipeline on the plot. Based on the aforementioned studies, there has been a recalculation of the maximum monthly norms of water application for the provisions of 50% and 80% on the rotating crops – norms which are indispensable in determining the maximum watering (hydro)module and the average weighted watering hydromodule, hydraulic variables used to determine the sizing flows of the plot pipeline network.

Key words: norm of water application, watering (hydro)module, medium-weighted watering hydromodule, sizing flow

Under today's conditions, many of the irrigated field plots with pressurized pipelines in use since the 70s in Romania have become worn-out and obsolete. We have identified the following important wear related factors: changes in the ownership of the land; lack of maintenance and repair funds; the realization that irrigation water transport through certain types of pipelines, like the asbestos ones, affects significantly the quality of the agricultural products ultimately affecting the consumers' health; the use in practice, besides the traditional devices for sprinkler irrigation, of other kinds of mobile irrigation systems like the ones with drums (drip irrigation) or ramps; climate changes over the last decades with significant implications on the precipitation regime and potential evaporation; changes in the ground water regime caused mainly by inadequate irrigation methods; continuous change of the prices of water and electric power.

Considering these factors, we have decided that the following research studies are necessary for modernizing an irrigation plot: 1°- the climate studies on Nc consecutive years from the latest three or four decades: monthly precipitations, Pp, [mm], and monthly potential evaporation EP, [mm]; 2°- the current crop rotation, with the number of crops, Nas, and the weight of each crop, $\pi\nu$, $\nu=1\div$ Nas; 3°- agricultural phytotechnology studies for each crop ν, $\nu=1\div$ Nas, and every month: the correction coefficients of the potential evaporation, d, the width of the active soil layer (of water storage and/or root growth), h, [m], exploitation coefficients of precipitations, r, and the coefficients of relative distribution of groundwater contribution, A.F., [%]; 4°- pedological studies on hydro-physical characteristics of the soil, average on the soil width h: water field capacity of the soil, CC, [%], the wither coefficient of the soil, CO, [%], the apparent soil density, DA, [g/cm3]; 5°- hydrogeological studies on the variation of the groundwater level and the global groundwater contribution in the vegetation period, A.F.G, [m3/ha].

The basic data can be taken from the databases of the institutes and organizations dealing with research in agriculture and land reclamation, from field literature or directly following experimental determinations.

Based on the aforementioned studies, there has been a recalculation of the maximum monthly norms of water application for the provisions of 50% and 80% on the rotating crops (in addition to the exceeding probabilities of 50% and respectively 20%) – norms which are indispensable in determining the maximum watering (hydro)module and the average weighted watering hydromodule, hydraulic variables used to

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determine the sizing flows of the plot pipeline network.

The modernization of an irrigation plot with pressurized pipelines also involves the following projective activities: the optimum technical-economical re-sizing of the pipeline network of the plot using high quality materials like PEHD PE 100; re-equipping the pressure station according to the variable flow and pressure needs of the plot network, including pumping devices with adjustable r.p.m. (rotative speed), as well as automating the station.

After re-equipping the plot, the following benefits have been achieved: water economy through reducing the maximum monthly watering norms and significant decrease of the volume losses in the pipeline network; the decrease of the specific power consumption through thorough adjustment of the functional parameters of the pumping station for the flow and pressure needs of the network; the decrease of the working force needed for moving the watering installations and operating the pumping station; significant improvement of the quality of the agricultural products through eliminating an important risk factor for the consumers' health.

MATERIAL AND METHOD

The monthly norms of water application for each of the rotating crops have been determined using the soil water balance equation (Cazacu E. et al, 1989) for hydrological years. The hydrological year i includes the last three months (October – December) of the calendar year i-1, followed by the first nine months (January – September) of the calendar year i. Thus, having the climate data of Nc consecutive calendar years, we can make a string of Nh=Nc-1 consecutive hydrological years.

Following the processing of the basic data for each hydrological year i, i =1÷ Nh, and/or month j, j =1÷12, the following elements involved in the soil water balance have been determined:

- water contribution from precipitations,

$P_{i,j} = 10 \cdot r_j \cdot Pp_{i,j}$, [m^3/ha]; (1)

- real optimum evapotranspiration,

$ETRO_{i,j} = 10 \cdot d_j \cdot EP_{i,j}$, [m^3/ha]; (2)

- water contribution from groundwater,

$Af_{i,j} = 0.01 \cdot A.F_j \cdot A.F.G_i$, [m^3/ha]; (3)

- active moisture index,

$I.U.A. = CC - CO$, [%]; (4)

- minimum limit (of soil humidity), dependent on the crop and soil texture;

- for the field crops and average texture,

$P_{\min} = CO + \frac{1}{2} \cdot I.U.A.$, [%]; (5)

-for the field crops and light texture,

$P_{\min} = CO + \frac{1}{3} \cdot I.U.A.$, [%]; (6)

-soil water content corresponding to moisture weight percentage w,

$Rw_j = 100 \cdot w \cdot h_j \cdot DA_j$, [m^3/ha] (7)

- for $w = CC$, from equation (7) we get the maximum content, $R\max_j$;

- for $w = P_{\min}$, from equation (7) we get the minimum content, $R\min_j$;

- for $w = CO$, from equation (7) we get the inferior limit of water content, $R\inf_j$;

- soil water content at the beginning of the month *j* in hydrological year *i*, is determined in the following way:

$Rin_{1,1} = R\min_j + \xi \cdot \left(R\max_1 - R\min_1 \right)$, with $0 < \xi < 1$; usually $\xi = 1/2$, [m^3/ha] (8)

$Rin_{i,1} = Rfin_{i-1,12} \cdot \left(h_1 / h_{12} \right)$, with $1 < i \leq Nh$, [m^3/ha] (9)

$Rin_{i,j} = Rfin_{i,j-1} \cdot \left(h_j / h_{j-1} \right)$, with $1 \leq i \leq Nh$ and with $1 < j \leq 12$, [m^3/ha] (10)

- fictitious soil water content at the end of the month *j* of hydrological year *i*,

$Rfin0_{i,j} = Rin_{i,j} + P_{i,j} + Af_{i,j} - ETRO_{i,j}$

with $1 \leq i \leq Nh$ and $1 \leq j \leq 12$, [m^3/ha] (11)

Soil water content at the end of the month *j* of hydrological year *i*, $Rfin_{i,j}$, with $1 \leq i \leq Nh$, as well as the monthly norm of water application, $m_{i,j}$, or deep percolation, $S_{i,j}$, are determined using equations differentiated according to the order relations between the contents $Rfin0_{i,j}$, $R\max_j$ and $R\min_j$ (for the months within the vegetation period) or $R\inf_j$ (for the months not included in the vegetation period); thus, we differentiate the following situations:

- Situation 1, for $1 \leq j \leq 12$

$R\min_j \leq Rfin0_{i,j} \leq R\max_j$, (12)

$Rfin_{i,j} = Rfin0_{i,j}$, $m_{i,j} = 0$ and $S_{i,j} = 0$ (13)

- Situation 2, for $1 \leq j \leq 12$

$Rfin0_{i,j} > R\max_j$, (14)

$Rfin_{i,j} = R\max_j$, $m_{i,j} = 0$ and

$S_{i,j} = Rfin0_{i,j} - R\max_j$ (15)

- Situation 3, for $Rfin0_{i,j} < R\min_j$,

$$m0_{i,j} = R\min_j - Rfin0_{i,j} \tag{16}$$

- Situation 3a, $m0_{i,j} \geq m_{\min}$

$$Rfin_{i,j} = R\min_j,\ m_{i,j} = m0_{i,j} \text{ and } S_{i,j} = 0 \tag{17}$$

-Situation 3b, $m0_{i,j} < m_{\min}$ $m_{i,j} = m_{\min}$,

$$Rfin_{i,j} = Rfin0_{i,j} + m_{\min} \text{ and } S_{i,j} = 0 \tag{18}$$

In order to calculate the maximum monthly watering norms with exceeding probabilities of 50% and 80% for each rotating crop, following, for each hydrological year *i*, $1 \leq i \leq Nh$, there have been considered only the monthly water application norms from the vegetation period corresponding to months *j*,

$$j \in J^*,\ J^* = \left\{ j_1^*, j_2^*, \ldots \right\} \tag{19}$$

where $j_1^*, j_2^*, \ldots$ are the indexes of the months in which actual watering is done.

Thus, for each rotating crop, we get the strings of statistical data:

$$m_{1,j}, m_{2,j}, \ldots, m_{Nh,j}, \text{ cu } j \in J^* \tag{20}$$

The secured monthly water application norms have been determined using the theoretical probability curve of Pearson III type (Giurma I., et. al., 2001; Hîncu S., et. al., 1991); to this end, the following characteristic variables have been determined:

- arithmetic mean,

$$m_{med} = m_j^{med} = \sum_{i=1}^{Nh} m_{j,i} \Big/ Nh \tag{21}$$

- module coefficients

$$K_{j,i} = m_{j,i} \Big/ m_j^{med} \tag{22}$$

- variation coefficient

$$C_v = C_j^v = \sqrt{\sum_{i=1}^{Nh} \left(K_{j,i} - 1 \right)^2 \Big/ Nh - 1} \tag{26}$$

- asymmetry coefficient

$$C_s = C_j^s = \alpha \cdot C_j^v \tag{23}$$

where the value of coefficient α is approximated according to the nature of the variable whose probabilistic values are calculated.

The theoretical probabilities curves show the dependency of module coefficients *K* on the exceeding probability *p*; the curves of Pearson III type can be grouped in a family of curves with two parameters: *α* and C_v; this family can be formally represented by the following general equation:

$$K = \mathrm{K}\left(p, C_v, \alpha \right) \tag{24}$$

Krîţkii and Menkel (Hîncu S. *et al*, 1971) gave the family (24) in a table for the following discrete values attributed to the exceeding probability *p*, in the role of independent variable,

$p \in$ {0.1,1,2,5,10,20,50,80,95,99,99.9}[%] (25)
and parameters C_v and *α*,
$C_v \in$ {0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2}and *α* $\in$ {1.0, 1.5, 3.0, 4.0} (26)

Foster and Rîbkin rewrote the equation (23) as $K = 1 + C_v \cdot \Psi\left(p, \alpha \cdot C_v, \alpha \right)$ or

$$K = 1 + C_v \cdot \Psi\left(p, C_s, \alpha \right) \tag{27}$$

And wrote the function $\Psi\left(p, C_s, \alpha \right)$ in a table (Giurma I. *et al*, 2001) for the values of *p* (29), α =2 and
$C_s \in$ {0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.60, 1.8, 2.0, 2.2, 2.4} (28)

Using equation (23) for the values of the parameter C_s selected adequately from the aggregate (28), the aggregate (26) was achieved for the values of the parameter C_v, which then helped in determining the corresponding module coefficients *K* using equation (27); thus the Foster-Rîbkin table could be rewritten in the form of Krîţkii and Menkel tables.

From Krîţkii and Menkel tables generalized in this way, we extracted the module coefficients *K* (*table 1*) only for the exceeding probabilities *p*=50% and *p*=20 % (which corresponded to the shares of 50% and respectively, 80 %), while for parameters C_v and *α* the values (26) and respectively, *α* $\in$ {1.5, 2.0, 3.0} were taken into consideration.

Thus, knowing the values for the probability *p*, *p* $\in$ {50, 20}, as well as for the parameters C_j^v, $C_j^v \in \left[0.1, 1.2 \right]$, and *α*, *α* $\in$ [1.5, 3.0], from the table above through two-dimensional interpolation C_{vnd} and *α*, using an adequate law (bilinear, bicubic, biharmonic etc.), we get the module coefficient K_j; in the end, the coefficient is used to calculate the water application norm with the exceeding probabilities *p*, $m_j^{p\%}$, using the following equation:

$$m_j^{p\%} = K_j \cdot m_j^{med} \tag{29}$$

The monthly norms of water application for *p*=50% are needed for technical-economical determinations, while those for *p*=20% (corresponding to the amount of 80%), $m_j^{20\%}$, $j \in J^*$,are used to calculate the maximum watering (hydro)module and the average weighted watering hydromodule, which determine the sizing flows of the pipeline network on the plot.

Table 1

Krîţkii-Menkel module coefficients for the exceeding probabilities $p \in \{50, 20\}$ and parameter $\alpha \in \{1.5, 2.0, 3.0\}$

p [%]	α [-]	C_v, [-] 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
50	1.5	1.00	0.99	0.99	0.97	0.96	0.93	0.89	0.83	0.76	0.67	0.628	0.56
	2.0	0.997	0.986	0.976	0.952	0.920	0.880	0.846	0.800	0.748	0.690	0.637	0.580
	3.0	0.99	0.98	0.95	0.92	0.89	0.85	0.82	0.76	0.75	0.71	0.67	0.53
20	1.5	1.08	1.17	1.25	1.34	1.42	1.51	1.59	1.89	1.78	1.88	1.694	1.709
	2.0	1.083	1.164	1.240	1.316	1.380	1.438	1.490	1.544	1.576	1.610	1.638	1.648
	3.0	1.08	1.15	1.21	1.26	1.31	1.34	1.37	1.40	1.41	1.42	1.43	1.43

RESULTS AND DISCUSSIONS

The mathematical model described in the above section was applied for re-equipping the pressurized pipelines irrigation plot *SRPA 21 Viziru, Brăila county*; for this purpose, we got and used the following basic data:

1°- climate studies on *Nc=30 years* consecutive calendar years from 1985 to 2014, consisting in: monthly precipitations, *Pp*, [mm] *(table 2)*, and monthly potential evaporation *EP*, [mm] *(table 3)*;

2°- the current crop rotation plan, with the number of crops, N_{as}=5 field crops *(table 4)*, having the weight of each crop, π_v, and the correction coefficients of potential evaporation, $d_{v,j}$, with v =1÷ 5 and j =1÷ 12;

3°- agricultural phytotechnology studies for each crop v, v=1÷ 5, and every calendar month j, j =1÷ 12: the width of the active soil layer, $h_{v,j}$, the coefficients of relative distribution of groundwater contribution, $A.F_{v,j}$, (*table 5*), as well as the values of the exploitation coefficient of precipitations, $r_{v,j}$=0.95;

4°- pedological studies on hydro-physical characteristics of the soil, average on the soil width $h_{v,j}$: water field capacity of the soil, *CC*=25% (out of the soil dry mass), the wither coefficient of the soil, *CO*=11%, and the apparent soil density, *DA*= g/cm^3, the soil having sandy-clay texture;

5°- hydrogeological studies: the groundwater level varies on the depths range 1.5÷2.0 m and the global groundwater contribution has the values *A.F.G*=3300 m^3/ha in dry years and *A.F.G*=2000 m^3/ha for the humid years.

From equations (4) and (5), we got the values for the active moisture, $I.U.A. = 25 - 11 = 14\,\%$ and the minimum limit, $P_{\min} = 11 + 14/2 = 18\,\%$.

Then, including in equation (7) the values *CC*=25%, *CO*=11% and $P_{\min} = 18\%$, we determined the values for the maximum content, $R\max_{v,j}$, minimum content, $R\min_{v,j}$ and the inferior limit of the water content, $R\inf_{v,j}$.

Applying algorithmically the equations (1)÷(3) and (8)÷(17), it resulted for all of the N_{as}=5 crops and for all *Nh*=29 hydrological years, the elements of the balance equations, centralized as examples for corn and for hydrological years 2003 and 2004 (*tables 6, 7*); so we generated $N_{as} \cdot Nh$ =5·29=145 tables similar to 6 and 7.

Next, we extracted from these tables, for all N_{as}=5 crops, the statistical strings (20) corresponding to the monthly norms of water application.

Doing all the mathematical processing required by equations (21)÷(27) and using for α=2, data from table 1, in the end we determined the values for the maximum monthly norms assured with the exceeding probabilities of 50% and 20 % (*table 8*)

Table 2

Monthly precipitations *Pp* between Jan. 1985 – Dec. 2014 (extract), at the weather station of influence (mm).

No.	year	I	II	III	IV	V	VI
1	1985	38.10	17.80	6.80	11.50	22.20	100.90
2	1986	29.20	41.30	8.90	18.00	10.80	66.40
...	...	...	...	...	...	...	...
18	2002	15.2	7.4	50.6	37.2	10.7	49.9
19	2003	46.5	28.6	24.4	47.7	30.2	10.4
20	2004	42.5	11	35	11	79	87
...	...	...	...	...	...	...	...
29	2013	100.00	23.00	14.00	18.00	42.00	79.00
30	2014	66.00	3.00	37.00	35.00	69.00	109.00

No.	VII	VIII	IX	X	XI	XII	Veget period
1	50.80	19.90	11.50	10.20	34.50	8.20	205.3
2	60.10	30.20	30.40	33.50	0.50	24.40	191.7
...	...	...	...	...	...	...	...
18	151.1	22.7	8.5	60.4	67.1	23.7	257.25
19	76.4	10.8	50.2	47.4	14.4	30.8	176.75
20	51.5	137.5	34	12	28	36	**377.5**
...	...	...	...	...	...	...	...
29	21.50	1.00	65.00	71.00	20.00	3.00	185
30	67.00	13.00	21.00	39.00	36.00	52.00	286

Table 3

Monthly potential evaporation EP calculated according to Penman–Monteith, between Jan. 1985 – Dec. 2014 (extract), at the weather station of influence (mm).

No	year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly
1	1985	12.64	16.29	22.12	95.63	154.95	135.46	142.27	140.97	98.45	56.34	20.32	11.71	907.2
2	1986	14.43	14.51	30.16	104.92	149.55	142.28	133.58	157.95	100.41	52.58	21.92	14.89	937.2
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	2002	7.40	30.00	69.78	69.63	135.83	152.42	155.48	125.66	85.35	49.02	30.69	16.00	927.3
19	2003	13.37	18.45	36.27	86.78	166.82	161.75	147.22	151.45	91.40	51.49	25.46	16.06	966.5
20	2004	12.35	22.50	52.36	101.28	122.15	128.98	142.13	132.74	91.15	55.37	26.01	16.89	903.9
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	2013	24.80	24.12	28.99	40.31	43.10	54.63	67.45	72.17	83.63	73.99	69.09	25.40	607.7
30	2014	37.66	38.55	78.55	64.53	58.00	38.82	39.18	52.33	66.50	68.92	37.54	31.83	612.4

Table 4

Crop rotation and correction coefficients of potential evaporation, d

No	Crop	Weight [%]	Monthly correction coefficients of potential evaporation											
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	Corn & grains	45,0	0,90	0,85	0,60	0,94	0,61	0,98	1,29	1,28	0,81	0,70	0,85	0,90
2	Wheat and barley	25,0	1,00	1,00	2,40	1,44	1,45	1,08	1,00	1,00	1,00	1,00	1,00	1,00
3	Rape	10,0	0,90	0,85	0,60	0,83	0,55	0,90	1,20	0,88	0,65	0,70	0,85	0,90
4	Soya	10,0	0,90	0,85	0,60	0,94	0,65	0,90	1,20	1,11	1,23	0,70	0,85	0,90
5	Sunflower	10,0	0,90	0,85	0,60	0,82	0,84	1,19	1,20	0,80	0,65	0,70	0,85	0,90

Table 5

Width variation of the (active) soil layer of storing water or growing roots, h, And the distribution of the groundwater contribution, A.F., on calendar months for the crops in the crop rotation.

No.	Crop	Element	month											
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	Corn & grains	*h*, [m]	1.50	1.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.50
		A.F., [%]	0.00	0.00	0.00	0.05	0.13	0.22	0.28	0.23	0.09	0.00	0.00	0.00
2	Wheat and barley	*h*, [m]	1.50	1.50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.50	1.50	1.50
		A.F., [%]	0.00	0.00	0.10	0.10	0.22	0.25	0.10	0.07	0.10	0.06	0.00	0.00
3	Rape	*h*, [m]	1.50	1.50	1.50	0.75	0.75	0.75	0.75	0.75	0.75	1.50	1.50	1.50
		A.F., [%]	0.00	0.00	0.05	0.06	0.17	0.24	0.26	0.11	0.06	0.05	0.00	0.00
4	Soya	*h*, [m]	1.50	1.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.50
		A.F., [%]	0.00	0.00	0.00	0.05	0.13	0.22	0.28	0.23	0.00	0.00	0.00	0.00
5	Sunflower	*h*, [m]	1.50	1.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.50
		A.F., [%]	0.00	0.00	0.05	0.06	0.17	0.24	0.26	0.11	0.06	0.05	0.00	0.00

Table 6

Example of balance for corn in 2003 hydrological year (dry year).

Balance element [m^3/ha]	month											
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
Useful precipitations	574	637	225	442	272	232	453	287	99	726	103	477
Evapotranspiration	343	261	144	120	157	218	816	1018	1585	1899	1939	740
Groundwater contribution	0	0	0	0	0	0	165	429	726	924	759	297
Initial content	3402	3633	4009	4090	4412	4527	3027	2830	2528	2268	2268	2268
Final content	3633	4009	4090	4412	4527	4541	2830	2528	2268	2268	2268	2302
Norm of water application	0	0	0	0	0	0	0	0	500	249	1077	0
Percolation	0	0	0	0	0	0	0	0	0	0	0	0

Table 7

Example of balance for corn in 2004 hydrological year (humid year).

Balance element [m^3/ha]	month											
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
Useful precipitations	450	137	293	404	105	333	105	751	827	489	1306	323
Evapotranspiration	360	216	145	111	191	314	952	745	1264	1833	1699	738
Groundwater contribution	0	0	0	0	0	0	100	260	440	560	460	180
Initial content	3452	3542	3463	3611	3903	3817	2557	2268	2533	2536	2268	2335
Final content	3542	3463	3611	3903	3817	3835	2268	2533	2536	2268	2335	2268
Norm of water application	0	0	0	0	0	0	459	0	0	516	0	168
Percolation	0	0	0	0	0	0	0	0	0	0	0	0

Table 8

Maximum water application norms assured with the exceeding probabilities of 50% and 80 %, [m3/ha], for the rotating crops.

No.	crop	p [%]	month					
			IV	V	VI	VII	VIII	IX
1	Corn	80	645	270	622	**1428**	**1428**	477
						*)**1450**		
		50	0	270	105	260	920	1021
2	Wheat and barley	80	**1545**	1370	787	-	-	-
			*)**1550**					
		50	0	1135	931	431	0	0
3	Rape	80	576	-	441	**1276**	1007	-
						*)**1300**		
		50	0	329	142	213	756	0
4	Soya	80	706	324	529	**1245**	1152	1098
						*)**1250**		
		50	**0**	329	142	213	756	793
5	sunflower	80	-	476	949	**1339**	876	-
						*)**1350**		
		50	0	240	528	860	578	0

*) Maximum water application norms assured with the exceeding probability of 80 % rounded, projected.

CONCLUSIONS

The Foster-Rîbkin table was rewritten as the Krîţkii table and the Menkel table for α =2; thus, the data in Table 1. Can be used to determine the water application norms for the shares of 50% and 80% with greater accuracy.

The updated water application norms with 80% share will be used to determine the maximum watering (hydro)module and the average weighted watering hydromodule for the rotating crops – important elements in determining the re-sizing flows for the pipeline network on the plot.

The mathematical modelling designed in this paper, implemented in a suitable computer programs package, was used on a concrete study case of re-equipping an irrigation plot with pressurized pipelines.

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