ORIGINAL ARTICLE

MODULE DEFINITION FOR DRAINAGE RUNOFFS CONSIDERING CLIMATIC AND SOIL CONDITIONS OF THE KOLKHETI LOWLAND

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Abstract

The present article describes existing methods of calculating a drainage runoff module; their values are compared with those of the countries of Europe, USA and Russia. Parallels are drawn between the climatic and soil conditions of the Great Britain and the Kolkheti lowland. In view of the above and according to the experimental data the following conclusion was made implying that a value of the drainage runoff design module for the conditions of the Kolkheti lowland requires to be increased.

Keywords*: drainage, runoff module, excessive moisture, precipitation.*

1. INTRODUCTION

Drainage runoffs along with ground water levels regime and soil moisture represent a key indicator for drainage hydrological influence on which depends optimal values of drainage design parameters, operational condition of drainage network as well as the cost of its construction and payback period. In view of this, the issue of defining correctly a design rate of drainage runoffs is of key importance in draining melioration.

2. MATERIALS AND METHODS

Over the years since the middle period of the 19th century in the countries of Europe including Russia in order to define a design rate of drainage runoffs they used the so-called "Silesian norm" which was recommended by the well-known "Silesian instruction" according to which a numeric value of runoff module q = 0.65l/sec.ha [1,2]. This value was derived not according to the multi-year observation on drainage hydrological influence but as a result of processing the data of Silesian meteorological stations. It was implied that 50% of precipitation of the cold period (December-March) should be drained out in spring during the 14 days round the clock.

A principle accepted as a key point of the instruction implying that design drainage runoff should be defined by the necessary speed of ground water level lowering was later used by a number of researchers. For instance, it was accepted that 40% of precipitation with the intensity of 4mm/h and the duration of 24h, should be drained out over the 7 days round the clock, i.e., with an runoff rate of 0,63l/sec.ha [1,2]. This is the part of the atmospheric precipitations (5,41mm/a day) that should be drained out when it rains or directly after rain. Later on, in Europe, as a result of expansion of the construction area of drainage systems and gaining practical experience runoff design rate was defined by correlation of measured value of runoff with atmospheric precipitations for various climatic and soil zones.

3. RESULTS AND Discussion

For the time being runoff norm in the countries of Europe and USA is increased. For instance, in Germany, based on the amount of precipitation, it is recommended the design values of drainage runoffs as follows (Table 1) [3]:

Table 1: The table presents the module definition for drainage runoff considering climatic and soil conditions in Germany.

Average precipitation, mm	Runoff module, l/sec	Drainage runoff layer, mm/a day
<600	0.8	7
600-1000	1.0	9
>1000	2.0	17

According to USA drainage norms (Table 2) [1]:

Table 2: The table presents the design drainage runoff (l/sec.ha) in the United States of America

Soil	Crop rotation	
	Field	Vegetable
During the inner-soil runoff		
Mineral	1.09-1.45	1.45-2.19
Organic	1.45-2.19	2.19-4.40
During the inner soil and surface draining out process		
Mineral	1.45-2.95	2.19-4.40
Organic	2.19-4.40	4.40-11.80

Design module value for drainage runoff derived in Russia for various types of grounds is provided in Table 3:

Table 3: The table presents the design drainage runoff (l/sec.ha) in Russia.

Soil	Runoff module l/sec	Drainage runoff layer, mm/a day
Clay, heavy and average loamy soils	0.4-0.5	3.0-4.0
Light loamy soils, Sandy soils	0.6	5.0
sand, moor soil	0.7-0.8	6.0-7.0
Swamp	0.9-2.0	8.0-17.0

It should be noted that maximum value of design module for drainage runoff derived in Sweden during the drainage system designing is accepted up to 7.0l/sec.ha.

A different method of defining a drainage runoff module is used in Great Britain where climatic and soil conditions are similar to those in the Kolkheti lowland. Main reasons of excessive moisture of soils apart from atmospheric precipitations (900-1000mmm) are as follows: high level of ground waters (32% of lands), water-impermeable subsoil (56%), confined ground water (8%), unsatisfactory performance of old drainage system (4%). 53% of soils of excessive moisture is represented by clays and 32% - by heavy loamy soils. In view of this a melioration problem of the country is the drying up of heavy, low water-impermeable soils.

A design layer of drainage runoff (load on drain – mm/a day) is defined by the formula as follows:

$$q = (Rr + h_n)/S \, , \qquad (1)$$

Where,

R	is	a design intensity of precipitation - mm/a day;
r	-	Correcting coefficient of surface runoff;
h_n	-	Inflow of ground waters;
S	-	Reliability coefficient depended on the possibility of sedimentation of drainage pipelines.

Therefore, the total amount of precipitations is considered in calculation which decreases only on the value of surface runoff.

Runoff coefficient depends on the condition of soil surface which determines the speed of water infiltration and is derived according to Table 4.

Table 4: The table presents the values of runoff correcting coefficient (r).

Water penetration of soil profile	Drying up method	Condition of surface layer	Plain		Lowering		Watersheds	
			Surface slope					
			<1%б	1...3%	<1%	1...3%	<1%	1...3%
High	Closed drainage	Regular ploughing	1	0.9	1	1.2	1	0.8
		Meadow or minimum processing	1	0.9	1	1.2	1	0.8
	Open drainage	Regular ploughing	0.8	0.7	1.3	1.5	0.7	0.5
		Meadow or minimum processing	0.7	0.6	1.4	1.6	0.6	0.4
Average	Closed drainage + Deep loosening	Regular ploughing	0.9	0.8	1.2	1.4	0.8	0.6
		Meadow or minimum processing	0.8	0.7	1.3	1.5	0.7	0.5
	Closed catchment areas + deep loosening	Regular ploughing	1	0.9	1	1.2	1	0.8
		Meadow or minimum processing	0.9	0.8	1.2	1.4	0.8	0.6
Low	Closed catchment areas + Deep loosening	Regular ploughing	0.9	0.8	1.2	1.4	0.8	0.6
		Meadow or minimum processing	0.8	0.6	1.3	1.5	0.7	0.5
	Closed catchment areas + Deep loosening	Regular ploughing	1	0.9	1	1.2	1	0.8
		Meadow or minimum processing	0.9	0.7	1.3	1.5	0.7	0.5

Ground waters inflow is determined based on the operation experience of drainage systems operating in similar conditions. If inflow of ground waters is low and it can be drained out by an usual closed drainage the amount of precipitations can be increased $h_n \leq 5$ mm.

While determining the diameter of drainage pipelines the possibility of their sedimentation should be taken into account. In view of deposition of sediments high threat is silt as well as minor fractions of sand. In this regard the coefficient S (Table 5) was put in the formula of drainage runoff that considers the existence of such fractions in the soils to be dried up.

Table 5: The table presents the reliability coefficient values S.

Soil-ground	Drain slope		
	<1%	1...3%	>3%
Sand	1	1	1
Fine sand	0.7	0.8	0.9
Extremely fine sand	0.5	0.6	0.8
Silt	0.7	0.8	0.9
Clay	1	1	1

In view of the above-mentioned, we will consider the condition created on the closed drainage systems arranged on the Kolkheti lowland. On the territory of the lowland the research of precipitation regime is of key importance in order to resolve the issues about carrying out melioration measures. The only obstacle for effective utilization of the Kolkheti lowland is land bogging the main reasons of which are excessive moisture caused by atmospheric precipitations (Table 6) and limited natural drainage of the territory.

Table 6: The table presents the inner annual distribution of precipitations on the Kolkheti lowland.

	Gali	Zugdidi	Anaklia	Poti	Senaki	Kheta	Lanchkhuti	Supsa	Abasha	Samtredia
I	130	148	130	128	149	134	184	188	148	140
II	122	133	106	106	141	127	151	149	138	130
111	128	137	109	91	133	119	139	141	107	101
1V	125	109	108	79	89	93	72	85	82	78
V	106	110	70	56	83	88	74	81	82	78
VI	158	148	99	122	131	131	113	131	70	66
VII	161	164	171	168	137	209	138	206	94	89
VIII	134	140	155	214	150	197	147	234	105	99
IX	141	161	173	236	177	209	223	314	102	96
X	135	154	160	166	158	160	232	250	138	130
XI	110	124	114	144	152	135	172	215	157	148
XII	112	129	137	137	139	125	177	195	156	147
Annual	1562	1657	1561	1647	1639	1727	1822	2189	1454	1372
Winter %	23	25	24	22	26	22	28	24	31	30
Spring %	23	22	19	14	19	17	16	14	17	18
Summer %	29	27	25	31	25	31	22	26	20	21
Autumn %	25	26	30	33	30	30	34	36	32	31

The analysis of the data of ten items provided in the table which are more or less equally disposed on the Kolkheti lowland allows making decisions as follows:

- The south part of the lowland including Lanchkhuti, Supsa is characterized by extremely excessive moisture – 1822 -2189mm;
- In the central part of the lowland including Poti, Senaki, Kheta, total multi-year amount of precipitation ranges between 1639 -1727mm;
- In the north part of the lowland including Gali, Anaklia, Zugdidi, the amount of precipitation reduces to 1562 – 1657mm;
- The minimum amount of precipitation is observed in the east part of the lowland including Abasha, Samtredia – 1372 -1454mm;
- In the seasonal distribution of precipitations the spring precipitations are the lowest – 18%, the amount of precipitations in summer and winter are equal – 26%, while the amount of autumn precipitations is the highest – 32%, i.e. the distribution of precipitations are more or less equal throughout the year;
- Precipitation regime in spring where the month of May is the driest helps to carry out field works (ploughing, sowing) while in summer (435mm) and in autumn (509mm) during the vegetation as well as harvesting periods of agricultural plants the situation is much more difficult.

It should be noted that on the Kolkheti lowland in winter the rain is constant while summer is characterized by pouring rains. Besides, pouring rains can be observed in all months, however, mostly in the second half of the year, particularly, in July-November. Rains with the duration of two days or more are not observed in the summer period. This period is more characterized by brief rains with the duration of from less than an hour up to six hours. During the rainy period the rains of this duration can last for several days or two-three weeks. On the territory of the lowland there are days when the amount of precipitation can be more than 50mm, 75mm or 100mm. The number of days with the precipitation amount of more than 50mm on the coast and in the central part achieves 6-8 days, in the north part – 2-4 days, in the south part – 13-17 days; while the number of days with the precipitation amount of more than 75mm and 100mm are mostly observed in the months of August-October.

During the draining hydrotechnical melioration (closed drain) on the territory of the Kolkheti lowland the data about average daily maximum amount of precipitations are of key importance. Their value in the south part of the lowland can amount to 50-60mm. The same amount of daily precipitations is observed in the area of Kheta as well. In the central part of the lowland this figure achieves 41-45mm, in the north part it is 35-40mm, while in the east areas it is 31-35mm. The distribution of average daily maximum precipitations is mainly similar to average annual distribution showing that there is some connection between them. The average value of the average daily maximum precipitation layer for the Kolkheti lowland amounts to 43mm. These are special characteristics of the climatic conditions that cannot be neglected while resolving melioration issues, in particular, while designing a closed piped drainage system.

Based on the above, we will consider hydrological effects of the piped drainage through the example of the experiment carried out on the Khorga experimental segment located in the central part of the Kolkheti lowland (Table 7). According to the author as well as following the results of the experiment, draining changes filtration properties of soil for the better.

Table 7: The table presents the drainage runoffs module, l/sec.ha through the example of the Khorga segment.

Piped drainage	At the beginning of the experiment		At the end of the experiment	
	Minimum	Maximum	Minimum	Maximum
Distance between the drains 5m	0.06	1.52	0.007	2.05
bed + drainage 5m	0.13	2.04	0.009	3.91
bed + drainage 10m	0.03	1.14	0.02	1.70

Runoff maximum module while the distance between the drains is 5m was q =2.05 l/sec.ha, i.e. past precipitation will be drained out 17.7mm/a day. In the event of compatibility of a bed and a drainage located in the distance of 5m runoff maximum module increases up to q =3.91 l/sec.ha (33.8 mm/a day), while in the event of compatibility of a bed and a drainage located in the distance of 10m, runoff maximum module amounts to 1.7l/sec.ha (14.7mm/sec). If we take into account that the rain with the intensity of 50mm is observed several times annually during the various seasons then we can make a conclusion that hydrological activity of the drainage is unsatisfactory to create an efficient water-air regime in the soil. This is proved by the operation of the meliorated lands in the central part of the lowland where alluvial-hydromorphic and hydromorphic heavy loamy grounds are prevailing. In the Great Britain considering two-centuries experience of ground draining of heavy mechanical consistence (see the formula), in the conditions of the Kolkheti lowland soil properties and the intensity of rains – 40-50mm/a day, we have to achieve a runoff module value – 5-6l/sec.ha. This is quite reasonable as during the atmospheric precipitations it is important to remove impounded sediment from the ground surface as soon as possible (in the heavy soils it is possible to do only by drainage). The sooner the sediment water is removed from the ground surface, the sooner the draining process starts in the ploughing and deeper layers of the soil mostly at the expense of evaporation and transpiration.

4. CONCLUSION

The Kolkheti lowland is characterized by permanent rains with the significant intensity, mostly pouring rains. Taking into account the above-mentioned, a piped drainage should be designed so that it can flow through the precipitation with the amount of 40-50mm/a day and, relatively, the design value of drainage module should be equal to 5-6l/sec.ha. In view of this the use of a piped drainage should be limited by the indicator of ground water permeability ($K_{ფ} \geq 0.1$ m/a day), while the areas of its utilization – by the lands located in the strip of the deltas of average and large rivers as well as floodplains, the soils of which are represented by light and average loamy soils. As for the amelioration of the soils of heavy mechanical consistence, during the rehabilitation of drainage systems in order to ensure a drainage design module instead of matching a piped drainage and a bed, draining trenches should be used.

5. REFERENCES

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