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Results of the study of desert soil as a source of surface runoff formation

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Abstract. The Kyzyl Kum Desert in Uzbekistan has not been adequately studied, despite the fact that it occupies more than half (68.7%) of the country's territory. Even in ancient times, the lands of Kyzyl Kum were used as pasture and now these lands are a classic example of distant pasture animal husbandry, including karakul breeding. The industry is developing with guaranteed sales markets, whose products are export items. In the desert, the main factor in the cultivation of crops is the lack of water resources, and the resources of the rivers of Uzbekistan are almost completely depleted. The aim of the study is to scientifically substantiate the possible volumes of surface runoff in the desert, which could be used in the interests of agricultural production, as well as for the creation of local systems of domestic drinking water supply.

1. Introduction

The Kyzyl Kum Desert covers an area of 300 thousand square km, including within the Republic of Uzbekistan 279 thousand sq. km, and is bounded from the south by the Nuratau mountain range and the Zaravshan river valley, from the southwest by the Amu Darya river valley, from the northwest by the Aral Sea and the SyrDarya river valley. As you know, in any desert, the main limiting factor in the development of the national economy, including the cultivation of agricultural crops, is the lack of water resources. It is also known that the resources of the rivers of Uzbekistan, as well as the water resources entering the territory of Uzbekistan from neighboring states, are almost completely exhausted.

The own water resources of the region under study are composed of groundwater and surface water. The underground waters of the riverbed areas (the right bank of the AmuDarya River and the left bank of the SirDarya River) are closely related to the river runoff and, due to the return waters, are heavily polluted by residues of mineral fertilizers, phenols and other toxicants. Highly mineralized groundwater in the central regions of the Amudarya-Syrdarya interfluve is mainly used in sheep breeding. These waters are relatively well studied, monitoring of their operation is established.

2. Materials and methods

It is proposed to distinguish the following three physical and geographical zones within the Kyzyl Kum desert:

- Northern Kyzyl Kum - the territory lying above 42° north latitude
- Central Kyzyl Kum - the territory lying between 40.6 and 42° north latitude
- Southern Kyzyl Kum - the territory lying between 39 and 40.5^o north latitude.

The proposed classification can be considered as a technical device, as far as the conditional boundaries between latitudinal zones. On the territory of the Kyzyl Kum desert, the only surface capable of forming surface runoff is takyr.

Considering various variants of the classification of takyrs that exist in the literature, V.N. Kunin and G.T. Leshchinsky note that only "theoretically, it can be assumed that each type of takyr has its own, different from others, ability to form a runoff. But from the point of view of practical tasks, these differences are insignificant and do not go beyond the accuracy of our generalizations" [2]. A survey of a series of takyrs throughout the Kyzyl Kum Desert made it possible to micro classify takyrs by the nature of their crust. In total, the following six types of surfaces are distinguished:

- Heavy structural crust
- Heavy sedimentary crust
- Swollen crust
- Bark with sparse low shrub
- Shallow crust
- Bark partially covered with sand.

The main difference between our classification and those performed earlier by other authors is that each takyr crustal surface has its own water-physical properties inherent only to it, and, consequently, its own, inherent only in it, the ability to form a runoff with the same amount of precipitation.

The area of takyrs was determined by planimetry using a topographic base of scales 1: 100000 and 1: 200000, followed by monitoring of individual, most representative takyrs in a place using the modern satellite navigation system Global Position System (GPS). The main purpose of the system is to determine its location on the ground and find objects with known geographic coordinates. The results of determining the areas of takyrs with a slight correction by the GPS system show (table 1) that the total area is 8670 km, of which almost 40% correspond to the Northern latitudinal zone.

Table 1. Distribution of the takyr areas of the Kyzyl Kum desert by latitudinal zones.

Latitude zone	Takyrs area	
	km^2	%
South	2250	25.9
Center	2980	34.4
North	3440	39.7
Total:	8670	100

Source: Author's research.

The total area of takyrs in the Kyzyl Kum desert, indicated in table 1, does not differ too much from the data of other authors. Since there are very few reliable quantitative data on the properties of the takyr crust in Kyzyl Kum, a sequential sampling of soil samples was carried out in the central part of each of 24 experimental takyrs located in different latitudinal zones. The samples were processed in laboratory conditions by standard methods in order to determine the parameters of the mechanical composition of the takyr crust. At the same time, at each takyr, the values of the crust filtration coefficient were determined using a membrane infiltrometer. Below (table 2) there were given the average indicators for latitudinal zones, mechanical composition and filtration coefficients of the takyr crust.

Table 2. Average mechanical composition and filtration coefficient of takyr crust.

Latitude zone	Soil particle size (mm), % of soil weight					Physical clay (f), %	K_{Φ} sm/hour
	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	<0.005		
South	9	21	24	7	39	46	0.60
Center	8	19	20	10	43	53	0.30

North	12	18	12	5	53	58	0.20

Source: Author's research.

As can be seen in the structure of the takyr crust, particles of small size (silt fraction) undoubtedly prevail. Physical clay, i.e. the sum of particles less than 0.01 mm in size, 81-91% is composed of particles less than 0.005 mm in size, and the values of the filtration coefficient vary across latitudinal zones, following the dynamics of physical clay.

At takyr №5 (young zone), takyr №12 (center) and takyr №21 (northern zone), which are representative of their latitudinal zones, frequent measurements of the mechanical composition and filtration coefficient of the takyr crust were carried out on each of the identified surface types in order to avoid the influence of the spatial variability of the determined elements.

3. Results and discussion
Based on the performed studies, it seems possible to conclude the following:

- Over the entire area of the takyr, regardless of the type of its surface, soil particles of less than 0.005 mm in size undoubtedly prevail.
- The content of particles of all sizes is different in the takyr area and corresponds to the selected types of surfaces.
- Within the boundaries of each type of surface, the variability of the parameters of the mechanical composition of the crust is so small that it is within the limits of the probable measurement error.

The above data indicate, first of all, a progressive increase in the content of physical clay in the takyr crust as it moves from the southern latitudinal zone to the northern one. This distribution is primarily due to the different contribution of each specific takyr surface to the formation of its total area, which will be confirmed below.

Now it seems possible to obtain the dependence of the filtration coefficient of the takyr crust on the content of physical clay in it, using the entire volume of collected information during the period of field research.

It is characterized by a correlation ratio (correlation coefficient for nonlinear relationships) of -0.911, which means that the variability of the filtration coefficient by 83% (the square of the correlation ratio) depends on fluctuations in the content of physical clay in the takyr crust. The remaining 17% are unaccounted for factors and errors of field and laboratory measurements.

It is important to note that factual data relating to takyrs located in different latitudinal zones fit relatively well into the studied dependence, which gives grounds to assert that the dependence is territorially common for the entire area of the Kyzyl Kum desert. It obeys the equation:

$$K_{\phi} = 6{,}26 \bullet e^{-0{,}058f} \tag{1}$$

where: e - base of natural logarithms, other designations are the same.

With the help of formula (1), the values of the filtration coefficient of takyrs, which are very difficult to determine in field conditions, can be estimated from the data on the parameters of the mechanical composition of the soil, which are relatively easily accessible.

Based on the performed studies, it is possible to objectively approach the issue of the main parameters of surface runoff from takyrs, namely, the initial rain losses (x_o) and the runoff coefficient. The initial loss of rain is a layer of rain that fell before the start of runoff. In other words, x_o can be defined as the amount of water required to reach the moisture content of the daytime soil horizon of the lowest moisture capacity (LMC). Thus, the total losses are made up of losses for saturation of the soil before LMC, for filtration into its deeper horizons, for evaporation during rain and for filling negative forms of micro relief.

In the literature there is information about $x_o = 7$ mm and even 8 mm [2], in relation to the Central Kyzyl Kum in two cases it was obtained that $x_o = 6$ mm [3]. Despite the differences in the quantitative

assessment of the initial rain loss layer, researchers agree that x_o reflects and depends on the previous soil moisture. The runoff ratio shows the proportion of precipitation that has fallen into runoff. In this sense, the runoff coefficient and the initial rain loss are inversely related. As you can see, the values x_o and η depend on a large number of factors, the role and significance of which changes over time. For this reason, their calculation is accompanied by very significant errors [4] and preference is given to experimental estimates.

The results of determinations (table 3) show not only the probable values of the initial rain losses and runoff coefficients, but also confirm the validity of the micro classification of the takyr crust.

Table 3. Initial rain loss (X mm) and runoff coefficient (η) from various types of surfaces.

Surface number	X_o		η	
	Oscillation limits	Average	Oscillation limits	Average
I	2.4-3.1	2.7	0.41-0.52	0.46
II	2.9-3.6	3.1	0.32-0.39	0.36
III	3.8-4.5	4.2	0.23-0.32	0.29
IV	4.3-5.4	5.0	0.24-0.33	0.29
V	6.7-7.9	7.2	0.16-0.23	0.19
VI	7.8-8.9	8.4	0.06-0.12	0.09

Source: Author's research.

Indeed, the studied runoff parameters are inversely proportional to each other and vary in accordance with the above water-physical properties of the takyr crust. Based on the calculated amounts of atmospheric precipitation (table 4), the water resources of the Kyzyl Kum desert within the Republic of Uzbekistan can be objectively calculated.

For the calculation, we use the formula:

$$Y = x \cdot \eta_P \text{ mm} \tag{2}$$

where: Y - the volume of runoff of a given provision, x is the monthly amount of precipitation of the same provision.

η_P - calculated runoff coefficient.

The latter is called calculated, because it differs from the data in table 4 in that it is calculated as a weighted average by fractions of the area occupied by each type of surface in each latitudinal zone. In turn, the proportions of the area under the individual types of the surface of the takyr crust (table 4) were determined by eye surveys of the takyrs.

Table 4. Distribution of areas on different types of takyr surface by latitudinal zones.

Surface type number	Its distribution by latitudinal zones, %		
	South	Center	North
I	10	25	65
II	15	15	10
III	10	15	10
IV	5	5	5
V	45	15	5
VI	15	25	5
Total	100	100	100

Source: Author's research.

The weighted average calculations of the calculated runoff coefficient showed that for the southern, central and northern latitudinal zones η_P is 0.24, respectively; 0.28 and 0.40.

4. Conclusion

Based on the obtained results, it can be concluded that with the same rainfall, its other parameters, and other things being equal, the flow-forming capacity of the takyr crust increases from south to north, reaching a maximum in the northern latitudinal zone. The water resources of the Kyzyl Kum desert, calculated by the formula (2), are equal (table 5) 52.3 mm (in an average water content year).

Table 5. Water resources (with provision P = 50%) and calculated surface runoff (mm layer) in the Kyzyl Kum desert.

Month	Zone	The availability, %							
		1	5	0	5	0	5	0	5
March	South	2.8	8.2	2.5	0.2	0.8	0.9	0	0.2
	Center	22.1	17.9	13.7	7.6	6.2	2.0	0.8	0.3
	North	40.4	31.6	22.0	13.6	10.4	3.6	2.0	0.8
	Total	85.3	67.7	48.2	28.4	22.4	7.5	3.8	1.3
April	South	21.4	16.3	11.3	6.7	5.3	1.4	0.7	0
	Center	21.3	16.8	13.2	7.3	5.9	1.7	0.6	0
	North	36.4	28.0	20.4	11.6	8.4	3.2	1.4	0.4
	Total	79.1	61.1	44.9	25.6	19.6	6.3	2.7	0.4
May	South	9.6	7.2	5.3	3.4	2.4	0.2	0	0
	Center	10.6	8.1	5.6	3.6	3.1	0.3	0	0
	North	17.2	12.8	10.8	7.6	4.8	0.8	0.4	0
	Total	37.4	28.1	21.7	14.6	10.3	1.3	0.4	0
Total		202	157	115	68.6	52.3	15.1	6.9	1.7

Source: Author's research.

In years with rare (1%) precipitation, the runoff layer can exceed 200 mm. To recalculate it into volumetric values, it is necessary to multiply the runoff layer by the area of takyrs, but it should be borne in mind that the runoff volume decreases adequately to the growth of the runoff-forming surface area due to the increase in the initial rain losses. The reduction in the runoff volume can be minimized by optimizing the layout of the closing sections.

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