Geo-ecological factor of water influence on the relief of steppe zones and semi-deserts of Kalmykia

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Abstract. The Republic of Kalmykia is the only region in Russia with up to 10% of deserts and semi-deserts. Geographically, it is located in the western part of the Caspian lowland. One of the problems of the residents is the lack of fresh water. The aim of the work is to show the influence of the geo-ecological factor on the relief and its connection with surface and groundwater, human health. To solve the problem, results of the expedition routes in Kalmykia were analyzed. Expeditionary and laboratory studies of water resources, express analysis of water, soil and plants was carried out. The decision-making hypothesis adopted a synergistic algorithm for the interconnection system of the water system, the steppe relief and human health. This approach identified that values of the environmental impact are interrelated. Changes in one or several parameters cause instability of the entropy of equilibrium in environmental management. The results can be used to assess the relationship between the relief, water quality, the ecological situation and human health.

1. Introduction
In Kalmykia, one of the areas with minimal rainfall and snowfall, there are its own peculiar desert-steppe relief. The aim of the work is to analyze changes in the local relief caused by the influence of water resources.

The northern and western parts of the Caspian lowland are represented by plains with a rugged ravine-girder system, some of which are located below the sea level (up to -28 m in Lagan) [1]. The northern part of the Republic of Kalmykia (RK) is represented by the Yergenin Upland. It was formed in the Proterozoic and served as a shore of the Caspian Sea. In the eastern part, due to the influence of the Caspian Sea, spits are formed. Their height reaches 60 m. The length of the spit is several kilometers (https://youtu.be/azj1O1noV54).

Ground and surface waters are fed by melting snow which accumulates in the ravine-gully system. Climatic conditions (rains, amounts of snow) are an influencing factor as well [2].

The horizon line of rainfall is not uniform in Ergeny and the Pre-Caspian region. This is due to the air flow, both in the lower part of the horizon and at the heights where the clouds are located.

One more important factor is wind influencing on the surface and altitudes of more than 50 meters. Frequent winds form sand tornades, especially in the second half of summer. Dust rising from the eastern and southeastern parts of the territory reaches Elista within a few hours (about 250 km). The same dust with dry and strong winds has a strong effect on ravines and beams. There is a pool-type
system; instead of water, a strong wind influences the relief (wind speeds is more than 10 m/s; at a height of more than 10-15 meters, it is 15 m/s and more). There are winds with a speed of 30 m/s (Figure 1).

![Figure 1. Dust storm in Kalmykia](image)

Wind and dust adversely affect the flora and fauna, the food chain and human health.

The relief is influenced by such factors as climate, drought, sand and dry winds. The role of the influence of tectonic factors is not great. But for the entire period of well operation and drilling in Chernozemel and Lagan district, probability of dig formation is high. This is due to the formation of voids in the lenses of water wells used mainly for technical needs. They form voids at different depths. The lithospheric composition is composed of a sedimentary cover with a depth of 2-2.5 km in the south-east of Kalmykia.

Due to tectonic phenomena, seismic waves with a force of 2-3 points reach Kalmykia. They can serve as an impetus for destruction in the hollows of the earth.

2. **Analysis of literary sources**

Scientific publications on climate changes were analyzed. The global warming is directly related to the economic potential of the regions. The climate has undergone several changes. As an example, one can analyze descriptions by Gumilev and other philosophers [2–4]. Employees of the Faculty of Engineering and Technology of the Kalmyk University published an article on climatic features of the region based on long-term observations and measurement data [5].

The influence of anthropogenic and natural factors on the formation and development of the ravine network is ambiguous. A positive aspect is accumulation of snow and rain. As a rule, small lakes are formed in the lower part of the ravines; they feed small rivers [6].

The influence of the human factor and regional sources on environmental management, ecology and subsoil management was described in “Peculiarities of subsoil management in the territory of the RK” [7].

The data on geological and geographical characteristics of the region were presented in [7, 8].

The interaction of ground and surface waters was studied by V.A. Onkaev, M.M. Sangadzhiev and others. [5]

Frequent dust storms, dry winds carry sand over long distances. The focus is deserts located in the Chernozemel, Yustin and Yashkul districts. They are formed due to the influence of man on the nature, violations of the soil cover by animals, the anthropogenic impact of man, and land reclamation.
In the republic, there are more than 40 small rivers which form a wide ravine-gully system and channels of a complex geometry. A network of meanders is directly related to the destruction of the coastline and steep formation [5].

Groundwater located in the lithospheric zone at depths of 100-150 m is mineralized. Surface water is not suitable for household and drinking supply as well [5]. The theoretical data on groundwater are presented in [9].

The geotechnical characteristics of the soil, its salt composition and changes during long-term water filtration are described in the work by KalmGU workers [8].

3. Research methods and area. Data on water bodies in Kalmykia

Small rivers and intermittent lakes create a peculiar flat terrain. It is carved with beams, ravines and river beds.

The university staff and researchers of the Geographical faculty of Moscow State University study the areas of Kalmykia. The purpose of their expeditions was to study channels of small rivers, their coastal part. Heights on the slopes of the Yergenin Upland were measured. Some data were presented as informative on the websites for students studying general and regional geology and geography of the republic. Data can be interesting for schoolchildren studying the nature of the RK.

During the expeditionary routes, water was taken from various sources: streams, rivers, lakes, springs and wells. The data were presented to the laboratory. In addition to water and soil, the vegetable layer was analyzed.

A one-time sampling of water and soil was used. The dynamics of water changes was not studied due to the fact that main indicators of the water composition do not change. We did not carry out a detailed analysis of water for chemical compounds and elements.

Before the expedition, cartographic materials of the expedition area, photo and video were studied. We used a Garmin navigator with a built-in map of the region. With the help of the navigator, geometric measurements of the shoreline of rivers and lakes, steep heights, slopes were made. Quadcopters were used. The areas are presented on the Internet sites (https://youtu.be/O_HbiROOpEM, https://youtu.be/aSKEqLrezwE).

4. Results and discussion

Kalmykia is cut up by a network of ravines and beams, especially at the foot of the Yergenin Upland. This is due to the fact that thawing and rainwater flowing from the surface of the hill wash the upper ground layer. This layer consists of loams, sandy loams, and clay.

Therefore, the influence of surface and underground waters on the lithospheric part of the earth forms a ravine-ravine system. This system violates the cover, changes the relief, reduces areas suitable for agriculture. The growth of ravines and beams is linear.

The economic damage is due to the loss of agricultural land areas, expansion of ravines and land plots and water reservoirs with ravines. To assess and determine the possible damage from ravines, the choice of anti-vegetation facilities and their rational placement, data on ravine growth rates are necessary.

Growth rates at different stages of ravine development vary considerably. In the initial stage of gully formation, the intensive linear growth is observed; the growth rate is more than 100-150 m/year. For the territory of the Republic of Kalmykia, the maximum linear growth rates vary from a few meters to 10 m/year. The average annual growth ranges from 0.7 to 10 m/year. Growth rates vary in individual years and seasons. Therefore, the use of short-term observations to estimate average growth rates can lead to erroneous conclusions. In addition, the ravines at different stages of their development are compared; the measured speed rates are atypical for evaluating the process as a whole. Cartographic materials that provide reliable data on the growth of ravines make it impossible to determine a seasonal increase and identify differences in speed rates at different stages of ravine development.

Various external factors influence the rate of changes in gullying conditions. But the growth of ravines changes under the influence of changes in the conditions of ravine formation produced by ravine
erosion and transformations of the channel bed. This process is directional and goes through a series of stages characterized by significant changes in trends (acceleration, deceleration) and growth intensity in different dimensions (linear, area, volume) and directions (depth, width, length). Growth rates can change. As a result, at the late stages of development with relatively favorable conditions for the ravine growth, the growth is slower than at the first stages with less favorable environmental conditions.

One of the most characteristic features of the dynamics of the ravine development is the uneven growth of all its morphometric parameters.

In the initial period of gullying, an increase in intensity of erosion during the formation of a channel stream is important. When small slope streams merge into the mainstream, a significant increase in flow velocity is observed. It is due to the decrease in energy losses spent on the movement of water masses within the channel compared with the movement of small stratified streams on the surface of the slope.

Development of suffusion and gravitational processes predetermines the occurrence of a primary differential stimulating a sharp increase in flow energy. The latter causes a rapid increase in the drop height and speed of its regressive movement (the linear growth of the ravine), as well as the rate of deepening of the channel below the drop (deep growth). At the same time, an increase in the relative height of the slopes under the influence of deep erosion intensifies gravity processes. A decrease in the speed of ravine growth which marks the transition from the first phase to the second one is caused by two factors. The linear growth slows down as a result of a gradual reduction in the mass of water entering the top of the ravine due to the linear growth of the ravine caused by a decrease in the apex of the catchment area. Deepening and lateral growth of the ravine slow down due to a drop in the flow energy caused by a decrease in its speed due to a decrease in the average slope. Figure 2 shows a photo taken by D. Badmaeva in the vicinity of Sadovoe (Sarpin District, Republic of Kalmykia).

![Figure 2. A ravine near Sadovoe (Republic of Kalmykia)](image)

The deformation of slopes and the ravine top is not always associated with the flood. Gravitational processes are regulated by the critical height and steepness of the slopes which can reach significant values at any runoff value. Filtering water filling side cracks plays a crucial role. This process is delayed. Dry periods contribute to the formation of slope debris; accumulation of slope destruction products at the bottom of the ravine is completely unrelated to the runoff.
The second feature of the dynamics of ravine growth is changes in the parameters of the ravine over time. The maximum frequency of oscillation of rates of all parameters of the ravine is observed during the first 10-20% of the period of its existence.

When assessing the growth rate, growth trends are of great importance, since at different stages of development at the same average speed, the ravine growth can be characterized by general acceleration and deceleration.

5. Influence of the water collection morphology on the ravine morphometry

The relief accelerates or slows down the transition of ravines from one stage to another one or ceases their growth at different stages. The main changes in the development of the ravine parameters under the influence of geomorphological factors (depth of the erosion basis, length and steepness of the slope, shape and area of the water collection area) are as follows: 1) frequencies and amplitudes of fluctuations in growth rates and ravine parameters; 2) limiting sizes and time.

Large morphological parameters of the water collection are in compliance with large maximum and average growth rates of the ravine in its different dimensions, as well as the frequency and amplitude of their oscillations. The size of the gully watershed has a major effect on the volume growth and intensity of the linear growth. The volume of the ravine and its growth rate at all are higher with large values of the water collection. The exception is a more active volume growth at the first stage of development on short steep slopes in comparison with more gentle long ones. At all the stages, the ratio changes and remains in this form until a longitudinal profile is developed by the ravine.

Changes in the morphology change absolute values of dimensions of the gully forms and the time of their development. In all cases, large sizes of the ravines correspond to the large morphological parameters of the water collection. However, maximum dimensions of any parameter depending on the morphological characteristics can reach different values causing a different width and area in the watershed zone of the "undetected" gully erosion, a different percentage of gully lands destruction, etc.

At large depths of the erosion basis when the length of the ravine is 40% of the maximum one, its volume does not exceed 5% of the final one. On a slope with a ledge, the ravine develops much earlier, and its volume (with the same length of 10-15%) exceeds the volume of the ravine developing on a straight slope.

With a large steepness and a base depth of the erosion basis, tops of the ravine can be so close to the line of the watershed and the width of the zone of "non-emerging" erosion becomes small.

The different shape of a slope affects the flow speed and its eroding ability at the early stages of development determining intensity of linear and volumetric growth of the ravine. The shape of the slope affects the marginal volume of the ravine: on a convex slope (ceteris paribus), it is significantly higher than on a straight one. At the same time, it was revealed that the shape of the slope has no effect on the shape of the “developed” longitudinal profile and the maximum length of the ravine.

6. Conclusion

Geological activity and other factors influencing the relief in the desert and semi-desert territories of the Republic of Kalmykia change the landscape. The main geological unit that changes the relief of Kalmykia is the Yergenin Upland with its numerous ravines and beams. The waters flowing from the summits of the hills in the Western and North-Western part of the Caspian lowland form a network of small rivers. They collect water for numerous lakes and ponds used for land reclamation, household and drinking purposes (for livestock).

Water is not used rationally. In the Soviet era, reservoirs, dams and other water-accumulating facilities were built. Currently, they are not used due to the collapse of the republic’s economy; settlements that used water from reservoirs and rivers ceased to exist or became very small (the number of inhabitants is 300 people per village). The lack of funding, reduction of the car and tractor fleet do not allow them to repair dams and monitor their performance.

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