ANNOTATION

Dissertation for the degree of Doctor of Philosophy (PhD) in the specialty 6D060800 – «Ecology»

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Gully erosion in the western part of Zhetysu Alatau and its development trend

The dissertation is devoted to studying the process of gully erosion in the western part of Zhetysu Alatau for the purpose of creating scientifically based recommendations for the management of gullying, taking into account regional characteristics.

Research object – gully landforms in the foothills, low-mountain and flat areas of western Zhetysu Alatau and ongoing erosion processes.

 $\label{eq:Research} \textbf{Research subject} - \texttt{gully erosion and natural-anthropogenic processes affecting gully landforms.}$

Research purpose – to conduct monitoring, study the dynamics, assess the occurance of gully erosion, determine the degree of influence of natural and anthropogenic factors on gully formation and develop scientifically based recommendations for managing gully processes in the western part of Zhetysu Alatau, taking into account regional characteristics.

To achieve this goal, the following tasks were identified:

- to make review and analyze available local and international scientific materials about the process of gully erosion and its distribution in the studied region;

- to substantiate the classification of gullies;

- to identify the dominating natural and anthropogenic factors causing the development of gully erosion in the region;

- to analyze existing methods for studying gully erosion and select the most effective ones for the study area;

 to identify key areas for detailed study of the morphometric characteristics of gullies and dynamics of gully erosion development;

- to collect qualitative and quantitative data at the key sites to assess the development of gully erosion;

- to create map of gully erosion density, identify the areal distribution of the gully network in the limits of the western part of Zhetysu Alatau;

- to develop scientifically based recommendations, taking into account regional characteristics for the management of gullying processes in the western part of Zhetysu Alatau.

Research methodology. The theoretical and methodological basis of the dissertation research are comparative geographical, cartographic, GIS-technological, route and semistationary field approaches, field observations, interpretation of remote sensing data, statistical processing of the geographical research results, geoecological and geomorphological research. Исследование носит междисциплинарный характер. The cartographic method was the leading method of the study; it helped to identify natural and anthropogenic factors influencing gully formation and to assess the development of gully erosion. Field observations of the typical gullies helped to identify the dynamics of their development, morphological and morphometric properties. Morphometric analysis and cartometric methods made it possible to obtain the characteristics of gullies and calculate the area and volume of the gully network. To calculate the volume of washed away soil, linear changes, transverse and longitudinal profiles of gullies, the terrestrial laser scanning method was used. Terrestrial laser scanning method was carried out using terrestrial 3D laser scanner RIEGL VZ-4000 to obtain a detailed digital terrain model in the form of point clouds. By the processing satellite images and creating maps, ArcGIS 10.8, Google Earth Pro, RiscanPro software was used.

Sources of research materials – archival cartographic and literary materials, including geological map of the Kazakh SSR, scale 1:500000. South Kazakhstan series; geological map of

the Kazakh SSR, scale 1: 200,000. L-43-XXXVI; geological map of the USSR, scale 1:200,000. L-43-XXXVI (Dzungarian series) (author: Mairin S.Ye., Sterkin V.D.); geomorphological map of Kazakhstan, scale 1:1,500,000 (author: Visloguzova A.V., Medeu A.R. et al.); soil map of Semirechye, scale 1:500,000 (authors: Pachikin K.M., Yerokhina O.G., Kusainova M.M., Sokolov A.A.); "Vegetation" map, scale 1:5,000,000 (authors: Volkova Ye.A., Ogar N.P., Rachkovskaya Ye.I., Sadvokasov R.Ye., Khramtsov V.N.); archival materials of JSC "Institute of Geography and Water Security" of the Ministry of Science and Higher Education of the Republic of Kazakhstan; factual material obtained by the author during the field research (2013-2018). Remote sensing data, including multispectral satellite images from Landsat, Sentinel-2, GeoEye-1, etc.

Relevance of the research topic. The relevance of the study of gully erosion within the western part of Zhetysu Alatau is determined by the needs for planning permissible loads on the natural environment, environmentally safe functioning of agricultural lands and infrastructure of the dynamically developing region. Recently, due to the increase of agricultural areas and the development of the agrarian-industrial complex, the study area has become intensively developed. The region's economic indicators are developing dynamically, especially in such industries as agriculture, farming, construction and mining. The region is characterized by favorable soil and climatic conditions, good water availability and high economic productivity for agriculture. The problem of protecting soil cover and land resources from gully erosion is one of the important problems for the western part of Zhetysu Alatau, where washout and erosion are most active in well-developed areas and cause significant damage.

One of the active and destructive modern relief-forming processes in the Zhetysu region is gully erosion. Gully erosion is most developed in the low-mountain and foothill areas of the west of Zhetysu Alatau near populated areas. Currently, the areas of eroded lands are increasing; their fertility and productivity are decreasing. The ecological result of gully erosion is a decrease in land fertility and in the efficiency of agricultural production.

The study of the development features of gully erosion in modern conditions of the western part of Zhetysu Alatau is very relevant and requires monitoring, assessment, forecasting of its development and development of acceptable methods for combating gullying. Intensive gully formation increases the ecological tension of the natural-anthropogenic environment of the region, decrease areas of agricultural lands and deteriorates their quality, creates a threat to road and residential infrastructure and causes damage to populated areas. The possibility of further development of the western part of Zhetysu Alatau, maintaining the environmental sustainability of the components of natural systems requires a comprehensive analysis and development of measures to mitigate gully erosion.

Based on the obtained results, the following conclusions were made:

1. The dominating natural and anthropogenic factors determining the development of gully erosion have been identified. The development of gully erosion in the western part of Zhetysu Alatau is influenced by a complex of factors, both natural conditions (geological-geomorphological, climatic, soils-vegetation) and anthropogenic (improper economic use of slope lands). The combination of these factors determines the possibility of occurrence and intensity of the process of gully erosion in the territory of western Zhetysu Alatau.

2. Field research and cartographic analysis made it possible to obtain morphometric data for 1896 gullies in the west of Zhetysu Alatau. The obtained morphometric characteristics include the length, width, depth and steepness of the slopes of ravines and gully systems.

3. During the last 20 years the development of gully erosion in the western part of Zhetysu Alatau has tended to increase. The dynamics of gullying in the studied region is following:

- the growth of gullies tops averages 0.77-1.38 m/year;

- the average value of the areal development of gullies is $73.34 \text{ m}^2/\text{year}$;

- based on the washed away volume of soil at the top part of the gullies, it averages 9.36 $\rm m^{3}/year;$

- the volume of washed away soil from the certain gullies has an average of 180.31 m³.

4. For the first time, the maps of the gullies distribution and maps of the gullies density in the western part of Zhetysu Alatau were created. The created maps allow to determine the intensity of gully erosion, the number of gullies in a certain territory and to make analysis of the gully erosion development, characterize the actual value of gully dissection and to estimate the degree of land degradation.

5. For the first time, the quantitative data on the areal distribution of the gullies network in the western part of Zhetysu Alatau has been obtained. The following results were for the study areas were received: site N_{01} (773,30 km²) - 10,75% (83,13 km²), site N_{02} (1500,87 km²) - 3,46% (51,93 km²), site N_{03} (2005,88 km²) - 0,51% (10,23 km²), site N_{04} (125,98 km²) - 7,12% (8,97 km²).

6. Gullies and ravines, changing over the time, depend on the relief environment associated with them and at the same time influence it. Ill-considered impact on ravines and gully systems and erosion processes leads to a response expressed in the activation of gully erosion. Gully erosion causes damage to many sectors of economic activity related to land use. The most representative are agricultural areas, where the occurence of gully erosion leads to the loss of arable areas and dissection of slopes.

7. Scientifically based recommendations have been developed for the management of gullying processes in the western part of Zhetysu Alatau, taking into account regional characteristics. The following set of recommended measures for managing gullying processes in the western part of Zhetysu Alatau is presented - phytomeliorative measures, measures to preserve soil cover, the use of engineering structures, complex measures. The integration of traditional methods and innovative technologies provides effective measures to protect land resources in the conditions of gully erosion. The proposed recommendations are aimed at reducing the eroded areas, rate and intensity of development of gully erosion, ecological restoration of the territory and conservation of land resources.

The scientific novelty of the research is determined by the following positions:

- For the first time, the role of natural and anthropogenic factors determining the development of gully erosion in the study area has been identified and assessed;

- a map of the rock formation erosion in the western part of Zhetysu Alatau has been created;

- for the first time, extensive interpretation of satellite images was carried out with verification based on the data obtained from field studies of gullies and gully network of the western part of Zhetysu Alatau;

- for the first time, detailed data on the morphometric characteristics of gully relief forms in the western part of Zhetysu Alatau was obtained;

- for the first time, data on the annual long-term dynamics of gully erosion including schematic maps was obtained;

- for the first time, gullies network distribution maps have been created for the study area;

– for the first time, gullies density maps have been created for the study area;

- for the first time, quantitative data on the areal distribution of the ravine network in the western part of Zhetysu Alatau was obtained;

- for the first time, was made assessment of the extent of gully erosion in western Zhetysu Alatau, characterizing the dissection of the territory by gullies and rate of their development;

- for the first time, scientifically based recommendations have been developed for the management of gullying processes in the western part of Zhetysu Alatau, taking into account regional characteristics.

Main statements submitted for defense:

1. The possibility and intensity of occurrence of the process of gully erosion in the western part of Zhetysu Alatau depends on the combination of natural and anthropogenic factors.

2. The morphometric characteristics of gullies well reflect gully formation, mapping gully forms, identifying certain patterns in the morphology and dynamics of gully erosion.

3. Determining the dynamics of gully erosion is one of the indicators of changes in relief

and relief-forming processes; it is of great importance for determining the rate of land degradation, for informed planning and implementation of anti-erosion measures, for the design of infrastructure facilities, for assessing the potential damage from erosion caused to agriculture and residential areas, solving scientific problems of geology, geomorphology and other sciences.

4. Gully erosion is one of the active and destructive modern relief-forming processes; its assessment of the damage to the territory of western Zhetysu Alatau allows us to identify the most dangerous areas for the further rational use and protection of land resources.

5. Integration of traditional methods and innovative technologies, taking into account the geographical features of the region for managing gullying processes in the western part of Zhetysu Alatau, ensures the rational use of residential and agricultural lands, reducing negative environmental consequences and improving measures to protect land resources.

Theoretical and practical significance of the work.

The theoretical significance of the research results is to obtain new scientific knowledge in the field of studying water erosion to ensure the rational use of land resources in Zhetysu region. The obtained materials can be used in geomorphological zoning to assess the erosional dissection of the region. The revealed patterns of gully erosion development can be applicable to similar territories. Considering the insufficient knowledge of the development of gully erosion in Kazakhstan, the results of this study will contribute to the development of geomorphology and geoecology on the creation of methodological bases for the management of gullying processes (using the example of the western part of Zhetysu Alatau).

Practical value and significance of the work is in solving problems of preservation of land resources and rational use of agricultural areas by providing scientifically based recommendations, taking into account regional characteristics for gully erosion management. The obtained data from the assessment of natural and anthropogenic factors on the development of gully erosion can be used by the planning of new developed lands in the region. The use of the obtained data on the morphology and patterns of development of gully erosion will reduce risks by the designing various constructions and infrastructure networks. Cartographic materials, especially maps of rock formations erosion, distribution and density of gully erosion can be used when developing the territory of settlements, by the planning of general scheme of complex measures to combat erosion in mountainous, low-mountain and plain areas. The obtained results of the areal distribution of the gullies network, together with data on the intensity of gully growth, can be applied in the development of integrated plans for the development of agricultural lands in the context of protecting land resources, as one of the main priority areas for sustainable development of the Republic of Kazakhstan.

The author's personal contribution to solving the objectives of the dissertation research include:

- organizing and conducting field observations at monitoring sites in the western part of Zhetysu Alatau: installing benchmarks to identify the intensity of gully erosion, conducting ground-based laser scanning together with researchers from JSC "Institute of Geography and Water Security" of the Ministry of Science and Higher Education of the Republic of Kazakhstan;

- conducting field surveys of the territory of the western part of Zhetysu Alatau to obtain morphological and morphometric data and studies of the geological and geomorphological structure of ravines and gully network together with researchers from JSC "Institute of Geography and Water Security" of the Ministry of Science and Higher Education of the Republic of Kazakhstan;

- analysis of natural and anthropogenic factors determining the development of gully erosion in the western part of Zhetysu Alatau;

- development and creation of a series of assessment thematic maps of rock formations erosion, density of the gully network, density of ravines, as well as series of map diagrams on the dynamics of gully erosion of the western part of Zhetysu Alatau;

- analyzing of the morphometric characteristics of gullies and dynamics of gully erosion in the western part of Zhetysu Alatau;

- conducting qualitative and quantitative assessment of the extent of gully erosion in western Zhetysu Alatau;

- development of scientifically based adapted recommendations for the management of gullying processes in the western part of Zhetysu Alatau;

- processing the obtained field data and remote sensing materials for the different survey years, preparing and publishing the obtained scientific results on the topic of the research in international scientific journals. The main provisions of scientific articles are reflected in the sections of the dissertation for PhD degree.

Approbation of work. The main results and provisions of this dissertation research were reported and discussed:

- at the International Conference "Geoinformation support for sustainable development of territories. InterCarto/InterGIS" (2018, Petrozavodsk-Russia, Bonn-Germany, Anchorage-USA);

- at the III International Scientific and Practical Conference "Anthropogenic transformation of geospace: history and modernity" (2016, Volgograd, Russian Federation);

- at the International Conference "Ecosystems of Central Asia in modern conditions of social-economic development" (2015, Ulaanbaatar, Mongolia).

Based on the dissertation research materials were published 8 printed works, including 2 articles in journals included in the Scopus database, 3 articles in republican scientific journals from the list of the Committee for Control in Education and Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 3 articles in materials of international conferences.

Dissertation structure. The dissertation is presented on 200 pages and consists of normative references, definitions, symbols and abbreviations, introduction, 5 sections, conclusion and a list of sources used from 205 titles, of which 104 are in a foreign languages; contains 4 tables, 45 figures and 19 appendices.