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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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© P.S. Dmitriyev[1], I.A. Fomin[1], S.A. Teslenok[2], Zh.G. Berdenov[3*], R.Z. Safarov[3], 2024
[1]Manash Kozybayev North Kazakhstan University, Petropavlovsk, Kazakhstan;
[2]Yugra State University, Khanty-Mansiysk, Russia;
[3]L.N. Gumilyov Eurasian National University, Astana, Kazakhstan.
E-mail berdenov-z@mail.ru

THE USE OF GEOINFORMATION SYSTEMS IN FORECASTING GULLY EROSION ON THE TERRITORY OF THE NORTH KAZAKHSTAN REGION

Dmitriyev P.S. — Candidate of Biological Sciences, Associate Professor. Professor of the Department of Geography and Ecology of Manash Kozybayev North Kazakhstan University, Petropavlovsk, Kazakhstan
E-mail: dmitriev_pavel@mail.ru, https://orcid.org/0000-0002-2712-3508;
Fomin I.A. — Master's degree, Senior Lecturer of the Department of Geography and Ecology of the North Kazakhstan University named after Manash Kozybayev, Petropavlovsk, Kazakhstan
E-mail: iafomin@mail.ru, https://orcid.org/0000-0001-9943-4914;
Teslenok S.A. — Candidate of Geographical Sciences, Associate Professor of the Higher Ecological School, Yugra State University, Khanty-Mansiysk, Russia
E-mail: teslserg@mail.ru, https://orcid.org/0000-0001-6691-3724;
Berdenov Zh.G. — PhD, Associate Professor of the Department of Physical and Economic Geography, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan
E-mail: berdenov-z@mail.ru, http://orcid.org/0000-0002-2898-8212;
Safarov R.Z. — Candidate of chemical sciences, Lecturer-researcher at the Department of Chemistry, Faculty of Natural Sciences, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan
E-mail: ruslanbox@yandex.ru, https://orcid.org/0000-0003-2158-6330.

Abstract. The materials of the publication reflect the importance of using geoinformation technologies for predicting ravines in the territory of the North Kazakhstan region. For the study, a section of the A16 Petropavlovsk-Zhezkazgan highway was chosen, where dozens of ravines with different growth rates are located. Satellite images for 2003, 2016, and 2019 were used for monitoring. A feature of the images is their detail and accuracy, which makes it possible to analyze the features of the structure and determine the dynamics of growth and the coordinates of the ravines. The calculations were made using the Google Earth program. To determine the dynamics and forecast of ravine erosion, the growth rate of the tops of ravines was determined according to the generally accepted method. Based on this technique, a model for predicting the growth rate of ravines in the Microsoft Excel program was developed. After entering the indicators in the Excel table, the model calculates the growth rate of the ravine and gives a forecast for

the next 30 years. The model was developed for natural ravines, the calculations present data typical for the North Kazakhstan region. The accuracy of the model depends on many factors. These are soil density, coefficient of erosion resistance of soils, amount of precipitation, and presence of vegetation cover. The result of the calculation obtained by the developed model is visualized as a sinusoid of the growth of ravines for the studied and predicted period. The used geoinformation technologies make it possible to carry out complex monitoring studies of ravines to predict their dynamics within the boundaries of the North Kazakhstan region.

Keywords: geoinformation systems, ravines, gully erosion, forest protection, North Kazakhstan region

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[1] Манаш Қозыбаев атындағы Солтүстік Қазақстан университеті, Петропавл, Қазақстан;

[2] Югра Мемлекеттік университет, Ханты-Мансийск, Ресей;

[3] Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан.

E-mail berdenov-z@mail.ru

СОЛТҮСТІК ҚАЗАҚСТАН ОБЛЫСЫ АУМАҒЫНДА ЖЫРА ЭРОЗИЯСЫН БОЛЖАУДА ГЕОАҚПАРАТТЫҚ ЖҮЙЕЛЕРДІ ҚОЛДАНУ

Дмитриев П.С. — биология ғылымдарының кандидаты, доцент. Манаш Қозыбаев атындағы Солтүстік Қазақстан университеті География және экология кафедрасының профессоры, Петропавл қаласы, Қазақстан
E-mail: dmitriev_pavel@mail.ru, https://orcid.org/0000-0002-2712-3508;
Фомин И.А. — магистр, Манаш Қозыбаев атындағы Солтүстік Қазақстан университеті География және экология кафедрасының аға оқытушысы, Петропавл қаласы, Қазақстан
E-mail: iafomin@mail.ru, https://orcid.org/0000-0001-9943-4914;
Тесленок С.А. — география ғылымдарының кандидаты, Югра Мемлекеттік университетінің жоғары экологиялық мектебінің доценті, Ханты-Мансийск, Ресей
E-mail: teslserg@mail.ru, https://orcid.org/0000-0001-6691-3724;
Берденов Ж.Ғ. — PhD, Л.Н.Гумилев атындағы Еуразия ұлттық университеті физикалық және экономикалық география кафедрасының доценті, Астана, Қазақстан
E-mail: berdenov-z@mail.ru, http://orcid.org/0000-0002-2898-8212;
Сафаров Р.З. — химия ғылымдарының кандидаты, Л.Н.Гумилев атындағы Еуразия ұлттық университеті жаратылыстану ғылымдары факультеті химия кафедрасының оқытушы-зерттеуші, Астана, Қазақстан
E-mail: ruslanbox@yandex.ru, https://orcid.org/0000-0003-2158-6330.

Аннотация. Басылым материалдары Солтүстік Қазақстан облысының аумағындағы жыраларды болжау үшін геоақпараттық технологияларды пайдаланудың маңыздылығын көрсетеді. Зерттеу үшін Петропавл – Жезқазған А16 трассасының учаскесі таңдалды, онда өсу қарқыны әртүрлі ондаған жыралар орналасқан. Бақылау үшін 2003, 2016 және 2019 жылдардағы

ғарыштық суреттер қолданылды. Суреттердің ерекшелігі-құрылымның ерекшеліктерін талдауға, өсу динамикасы мен шатқалдардың координаттарын анықтауға мүмкіндік беретін егжей-тегжейлі және дәлдік. Есептеулер Google Earth бағдарламасы арқылы жүзеге асырылады. Жыра эрозиясының динамикасы мен болжамын анықтау үшін жалпы қабылданған әдістеме бойынша жыралар шыңының өсу қарқыны анықталды. Осы әдістеменің негізінде Microsoft Exel бағдарламасында жартастардың өсу қарқынын болжау моделі жасалды. Ecel кестесіне көрсеткіштер енгізілгеннен кейін модель шатқалдың өсу қарқынын есептейді және алдағы 30 жылға болжам жасайды. Модель табиғи жыраларға арналған, есептеулерде Солтүстік Қазақстан облысына тән деректер ұсынылған. Модельдің дәлдігі көптеген факторларға байланысты. Бұл топырақтың тығыздығы, топырақтың эрозияға төзімділік коэффициенті, жауын-шашын мөлшері, өсімдік жамылғысының болуы. Әзірленген модель арқылы алынған есептеу нәтижесі зерттелген және болжанған кезеңдегі шатқалдардың өсу синусоиды ретінде бейнеленген. Пайдаланылған геоақпараттық технологиялар Солтүстік Қазақстан облысының шекараларында олардың динамикасын болжау үшін жыраларды мониторингтік зерттеу кешенін жүзеге асыруға мүмкіндік береді.

Түйін сөздер: геоақпараттық жүйелер, жыралар, жыра эрозиясы, орманды қорғау, Солтүстік Қазақстан облысы

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[1]Северо-Казахстанский университет имени Манаша Козыбаева, Петропавловск, Казахстан;

[2] Югорский государственный университет, Ханты-Мансийск, Россия;

[3]Евразийский национальный университет им. Л.Н. Гумилёва, Астана, Казахстан.

E-mail berdenov-z@mail.ru

ИСПОЛЬЗОВАНИЕ ГЕОИНФОРМАЦИОННЫХ СИСТЕМ В ПРОГНОЗИРОВАНИИ ОВРАЖНОЙ ЭРОЗИИ НА ТЕРРИТОРИИ СЕВЕРО-КАЗАХСТАНСКОЙ ОБЛАСТИ

Дмитриев П.С. — кандидат биологических наук, доцент. Профессор кафедры географии и экологии Северо-Казахстанского университета им. Манаша Козыбаева, г. Петропавловск, Казахстан

E-mail: dmitriev_pavel@mail.ru, https://orcid.org/0000-0002-2712-3508;

Фомин И.А. — магистр, старший преподаватель кафедры географии и экологии Северо-Казахстанского университета имени Манаша Козыбаева, г. Петропавловск, Казахстан

E-mail: iafomin@mail.ru, https://orcid.org/0000-0001-9943-4914;

Тесленок С.А. — кандидат географических наук, доцент Высшей экологической школы Югорского государственного университета, Ханты-Мансийск, Россия

E-mail: teslserg@mail.ru, https://orcid.org/0000-0001-6691-3724;

Берденов Ж.Г. — PhD, доцент кафедры физической и экономической географии Евразийского национального университета им. Л.Н. Гумилёва, Астана, Казахстан

E-mail: berdenov-z@mail.ru, http://orcid.org/0000-0002-2898-8212;

Сафаров Р.З. — кандидат химических наук, преподаватель-исследователь Кафедры химии Факультета естественных наук Евразийского национального университета им. Л.Н. Гумилева, Астана, Казахстан
E-mail: ruslanbox@yandex.ru, https://orcid.org/0000-0003-2158-6330.

Аннотация. Материалы публикации отражают значение использования геоинформационных технологий для прогнозирования оврагов на территории Северо-Казахстанской области. Для исследования был выбран участок трассы А16 Петропавловск – Жезказган, где располагаются десятки оврагов с разными темпами роста. Для мониторинга использовались космические снимки за 2003, 2016 и 2019 годы. Снимки являются детальными и точными, что позволяет анализировать особенности строения, определять динамику роста и координаты оврагов. Расчеты выполнены посредством программы Google Earth. Для определения динамики и прогноза овражной эрозии определены скорость роста вершины оврагов по общепринятой методике. На основании этой методики разработана модель прогнозирования скорости роста оврагов в программе Microsoft Excel. После внесения показателей в таблицу Excel, модель рассчитывает скорость роста оврага и дает прогноз на ближайшие 30 лет. Модель разработана для природных оврагов, в расчетах представлены данные характерные для Северо-Казахстанской области. Точность работы модели зависит от многих факторов, таких как: плотность почв, коэффициент эрозионной стойкости почв, количество осадков, наличие растительного покрова. Результат расчета, полученный посредством разработанной модели, визуализирован в виде синусоида роста оврагов за исследованный и прогнозируемый период. Использованные геоинформационные технологии позволяют осуществлять комплекс мониторинговых исследований оврагов, для прогнозирования их динамики в границах Северо-Казахстанской области.

Ключевые слова: геоинформационные системы, овраги, овражная эрозия, лесозащита, Северо-Казахстанская область

Introduction

Geographic information systems (GIS) in modern research are one of the main methods of modeling, as well as forecasting processes and phenomena. This complex of computer technologies is aimed at creating databases and data banks and working with them, for graphical visualization of information and geographical (spatial) analysis. Visualization of information stored in databases can be carried out in cartographic form, in the form of tables, graphs, and texts.

In modern geographical and geoecological studies, a direction has become widespread that allows modeling the influence of disruptive factors on the response, vulnerability and integrity of ecosystems, and plant communities (Huang et al., 2010; Kennedy et al., 2010).

Geoinformation methods are widely used to predict exogenous processes caused by the humidification factor (Chupina et al., 2017; Zolnikov et al., 2016). In addition, GIS is successfully used for environmental assessment with industry impact. This makes timely resettlement and evacuation of the population in flood situations of varying intensity, mudflow and ravine-forming processes.

One of the directions of modern geoinformation research is monitoring and forecasting the growth of ravines caused by changes in climatic and hydrological phenomena (Zaitseva, Rysin, 2019). Ravine formation is a process that at the present stage of relief formation has a fairly high rate in conditions of anthropogenic activity (Chalov et al., 2019). The use of the capabilities of modern geoinformation systems and elementary mathematical modeling tools in predicting gully erosion is of great importance. Their results will make it possible to create timely protection of territories, preserve natural and man-made landscapes (Slepnev, 2019).

In conditions of deforestation, as a result of the destruction of vegetation and trees, erosion increases. Irrational use of land is one of the factors in the formation of ravines, which leads to their rapid growth. Plowing the slopes of the beams in the longitudinal direction leads to the destruction of the grass cover, another cause of erosion may be the incorrect organization of strengthening roadside ditches and pits (Leonova et al., 2016; Rasyid et al., 2016). The studies of the causes of the development of the gully network, assessment and forecast, and mapping of territories subject to suffusion and erosion processes are noted in the works of foreign scientists (Gudiyangada Nachappa et al., 2019; Zhang et al., 2020).

A distinctive feature of the formation of gully erosion is the concentration of small water flows into powerful watercourses. Under these conditions, the flow of water from the catchment area into a natural or artificial hollow occurs in a concentrated manner (Lee et al., 2005; Guzzetti et al., 2006; Gudiyangada Nachappa et al., 2020). The annual process of water flow activity forms ravines representing a negative form of relief. The structural elements of the ravine are the top, the mouth, the cone of the outflow, the bottom, the edge, and the slopes. There is an independent change in the parameters of ravines, under the action of seasonal watercourses (Chupina et al., 2017; Zaitseva, Rysin 2019).

In modern conditions of development of geoinformation technologies, the application of an integrated approach to the development of a mathematical model for the forecast of gully erosion is promising. In particular, when designing anti-theft technologies and technical means on slope and ravine-girder lands (Barabanov, 2019). A feature of the territorial location of the city of Petropavlovsk, a number of rural settlements and development, highways is their location in the valley of the Ishim River (Beletskaya, 2019; Taizhanova,1991). The increase in the building area is associated with the development of new territories. This happens, including within the boundaries of floodplain terraces, on the slopes of the river valley. Without taking into account the dynamics of the possible consequences of natural and man-made processes of the spread of gully erosion, it is impossible to develop territories qualitatively. It is necessary to assess the intensity of the development of gully erosion, as well as to predict the probability of its manifestation using GIS technologies. The capabilities of these technologies make it possible to process and analyze multidimensional data about the geological environment of the studied territory (Leonova, Strokova, 2021).

As evidence of the growth of gullies, elementary geoinformation systems that are in the public domain are used, namely the modern functions of the Google Earth satellite image retrospective and the possibilities of their morphometric analysis. In combination with geoinformation systems, mathematical estimation methods are used to build predictive models of ravine growth (Dmitriyev et al., 2022).

Materials and research methods

The possibilities of geoinformation systems are clearly illustrated by traditional statistical data characterizing the process of ravine formation in dynamics for monitoring and forecasting. There are four stages of ravine growth, and growth can be carried out in three directions length, width, and depth. The first stage is the formation of a washout, the second is the formation of a vertex cliff, and the third stage is the development of an equilibrium profile. The fourth stage is the damping of the ravine growth, characterized by the equilibrium of the formed structure. The growth rate of the ravine in depth depends on the power of the water flow and the resistance of the soil, and when these forces are balanced, the growth of the ravine stops (Taizhanova, 1991; Chupina et al., 2017). Modern technical means make it possible to stop the growth of the ravine at any stage, by fixing the bottom and top, as well as when changing the direction of the water flow. Water flows can change the profile of the ravine, with simultaneous rupture and deposition of soils. As a result, a beam is formed, and the ravine fades (Taizhanova, 1991). In the historical past, ravines were formed due to the hydrographic network. A secondary factor in the increase in surface runoff is probably the irrational use of land and forest lands, expressed in plowing the land and deforestation. This leads to a deterioration of the hydrological regime and physical properties of soils.

The growth of ravines also depends on the features of the geological structure of the terrain. The geological structure influences the erosion processes, the morphology of the ravine, and its structural elements. The formation of a gully network is especially fast on loose soils and loess deposits of the Ishim River (Beletskaya, 2019; Taizhanova, 1991). The development of the ravine network and the number of ravines depends on the degree of anthropogenic development of territories, development, and area of agricultural areas. With an increase in the area of ravines, a lot of lands is withdrawn from economic use. In addition, the development of a gully network reduces the groundwater level, thereby drying up the territories. Ravines can divide arable land into small plots, due to this, the integrity of the fields is lost, which affects the time and quality of processing. The growth of the gully network causes economic and environmental damage to natural and man-made ecosystems. The listed consequences of ravine erosion emphasize the need for scientific research on the dynamics of the growth of ravines to develop a complex of measures to protect territories from destruction (Barabanov, 2019).

To calculate the growth rate of the top of the ravine, the formula is used (1),

$$\vartheta\text{ов} = \frac{2Q\rho\text{в}\times\text{g}}{\Psi\rho\text{п}\beta\text{з}\left(1+\frac{\beta\text{в}}{\beta\text{д}}\right)\left(1-\frac{\text{Hp}}{\text{H}}\right)} \tag{1}$$

where Q - the amount of precipitation, the flow rate of water flowing down the cliff wall m/year; ρв-water density; ρп - the density of the soil horizon; g - acceleration of free fall (g = 9,81м/s^2); Ψ-coefficient of erosion resistance of soils (for backfill soil without vegetation - 0,025, in the presence of annual grass cover - 0,04); βв, βд, Hр, H - geometric dimensions of the ravine (Maksimov, 2004).

To verify the proposed formula, we compared the calculated data of the growth rate of the top of the ravine with the data of observations made by GIS studies. The use of elementary geoinformation systems makes it possible to predict the growth of ravines without preliminary observations on the ground. One of the sources of scientific information is retrospective satellite images, the analysis of which clearly shows the dynamics of erosion processes. They allow mapping and monitoring of the growth of the gully network. All the necessary observations and calculations can be performed by the Google Earth program.

Results and discussion

The task of monitoring the growth of ravines is one of the most urgent in the planning of economic activities, logistics development, and the formation of transport networks (Dmitriyev, et al., 2021). This is due to the serious negative impact of gully erosion on the roadbed, which can eventually lead to catastrophic consequences, up to the threat to people's lives.

In the North Kazakhstan region, in particular along the section of the A16 Petropavlovsk - Zhezkazgan highway, there are dozens of ravines with different growth rates, which sooner or later will have a negative impact. The A16 highway has a length of 940 km and is one of the main highways of Kazakhstan. In 2011, it was renamed from the A 342 road to the A16 highway. The road connects the Central and Northern parts of Kazakhstan and stretches from Zhezkazgan to Petropavlovsk. The highway is strategically important for the country, crossing the A 17 highway on its way. The logistics of the route passes through the hilly steppe, and desert landscapes, along the valley of the Ishim River (Dmitriyev et al., 2021, 2022). Within the borders of the North Kazakhstan region, west of the village of Ruzaevka, the A16 highway intersects the M36 road. It ends with the A1 highway in the territorial boundaries of the city of Petropavlovsk.

GIS widely available were used to predict the growth of ravines without preliminary observations on the ground. Modern computer technologies include means of processing satellite images. These technologies, along with digital cartographic material and terrain models, provide the basis for mapping, monitoring, and forecasting the growth of the gully network.

Satellite images were used in the study, which made it possible to carry out complex measurements of ravines, and determine the dynamics of growth and geographical coordinates, using the decryption of satellite images. All the necessary observations and calculations were made possible by the Google Earth program.

A ravine was identified on the Petropavlovsk – Zhezkazgan highway, between the villages of Krasnaya Gorka and Priishimka (with coordinates 54°34'57.34"n.l., 68°50'8.48"e.l.) posing a danger to the road (Fig. 1). Selection of images in the years presented (2003, 2016, and 2019). It is based on photographs of this territory by Google Earth satellites. At the time of the study, the images of recent years are not presented in the Google Earth program.

05.07.2003 year 23.05.2016 year

07.10.2019 year

Figure 1. Example of monitoring the growth of a ravine on the Petropavlovsk – Zhezkazgan highway, between the villages of Krasnaya Gorka and Priishimka

Based on retrospective images of this territory by year, it is possible to fix the main nodal points and observe the development and growth of the ravines. Comparing the 2003 snapshot with the 2016 snapshot, it is clear that the ravine has significantly increased. Moreover, an increase is observed not only in lateral erosion but also in the growth of the top of the ravine towards the road is noted, approaching it at a dangerously close distance (from the top of the ravine, in the 2016 picture, there are exactly 10 meters left to the road). Visually it can be seen that the ravine has stretched almost 20 meters, and over the past 5 years, the ravine has not only increased in length but has also become much wider. However, in the 2019 image, we observe that the ravine changed direction to the south and continued its growth along the roadway. This may be because when laying the roadway, the filling and compaction of the underlying surface were carried out. Nevertheless, there is a direct threat of destruction of the roadway, since the ravine has come close to the roadway and with spring floods, the most active leaching of the soils that make up the support for the road occurs.

The technique of using different time satellite images made it possible to effectively study the parameters of gully erosion, to identify the dynamics of the growth of the ravine. The images allow you to visualize changes in the ravine on an area and linear scale, with monitoring studies at minimal cost, and to make a forecast. These studies are important to prevent threats from the ravine network.

Thus, the development of effective ways to combat ravine formation requires knowledge of the methodology of quantitative prediction of the development of ravines under known soil, hydrological and geological conditions. The solution to this problem, even very approximate, requires some schematization since the process of ravine formation depends on many interrelated factors. To calculate the growth rate of the top of the ravine, the formula (1) is applied, (Maksimov, 2004). To verify the proposed formula, we compared the calculated data of the growth rate of the top of the ravine with the data of observations made by GIS researchers. Based on the above methodology, a model for predicting the growth rate of ravines in the Microsoft Excel program was developed.

To predict the growth of the ravine, the main indicators were obtained: the year of the first measurement, the length of the ravine from the mouth to the top, the height of the top of the ravine, and the height of the mouth of the ravine. All this is possible with the help of the Google Earth program. After entering the main indicators into the Excel spreadsheet, the model itself calculates the growth rate of the ravine and gives a forecast for the next 30 years (Table 1).

Table 1. Ravine growth forecast model

INTRODUCTION OF THE MAIN INDICATORS	
Year 1 of measurement	2003
The length of the ravine at 1 measurement	300
Acceleration of free fall	9,8
The amount of precipitation typical for this territory, mm per year	350
Water density	1
Soil horizon density	1,4

FORECAST OF RAVINE GROWTH BY YEAR			
Years	Length from the mouth to the top of the ravine	The growth rate of the ravine meters per year	The slope of the slope
2003	300,0	1,52	0,11
2004	301,5	1,52	0,11
2005	303,0	1,51	0,11
2006	304,5	1,50	0,11
2007	306,0	1,49	0,10
2008	307,5	1,49	0,10
2009	309,0	1,48	0,10
2010	310,5	1,48	0,10
2011	312,0	1,47	0,10
2012	313,5	1,46	0,10
2013	314,9	1,46	0,10

2014	316,4	1,45	0,10
2015	317,8	1,44	0,10
2016	319,3	1,44	0,10
2017	320,7	1,43	0,10
2018	322,1	1,43	0,10
2019	323,6	1,42	0,10
2020	325,0	1,42	0,10
2021	326,4	1,41	0,10
2022	327,8	1,40	0,10
2023	329,2	1,40	0,10
2024	330,6	1,39	0,10
2025	332,0	1,39	0,10
2026	333,4	1,38	0,10
2027	334,8	1,38	0,10
2028	336,2	1,37	0,10
2029	337,5	1,37	0,09
2030	338,9	1,36	0,09

As a result of entering ravine data into the model (with coordinates 54°34'57.34"n.l., 68°50'8.48"e.l.) from the Google Earth program for 2003, the program makes a forecast for the years of such indicators as slope, ravine growth rate, length from the mouth to the top of the ravine (Fig. 2). To verify the reliability of the calculations, we compare the indicators obtained for 2016 and 2019 in the model with measurements from the image from the Google Earth program for 2016 and 2019 of the same ravine. In this case, the results coincided. This allows us to speak, first of all, about the reliability of calculations.

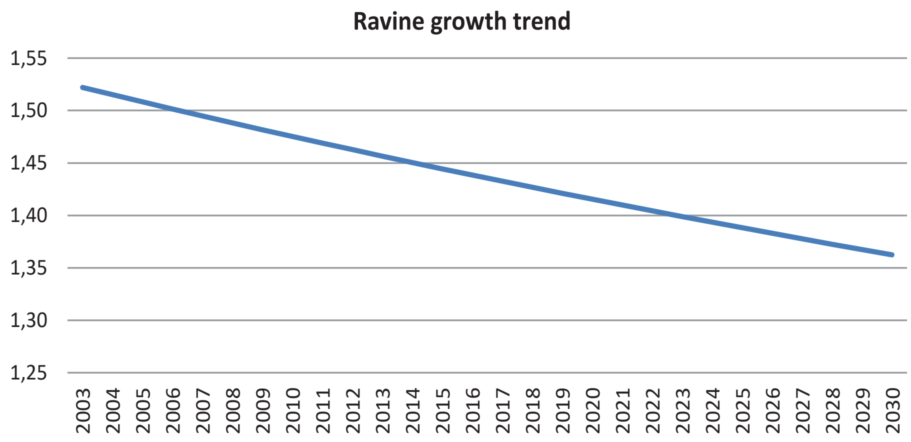

Figure 2. Trends in the growth of the ravine of the studied area, based on the results of the model calculation

The proposed model is designed for natural ravines. The calculations present data typical for the North Kazakhstan region. The accuracy of the model depends on many factors. First of all, this is the amount of precipitation. In our case, the climate of the studied territory is moderately continental and the amount of precipitation is 350 mm per year, however, this value is not constant and may vary in different years. Secondly, it is the density of the soil cover (a value equal to 1.4 g/ cm^3 is taken), which may vary depending on the structure of the ravine soil (sand, sandy loam, loam, clay). Thirdly, this is the coefficient of erosion resistance of soils, it depends on the presence or absence of vegetation, in our case, it is 0.04.

The model will give false information about the growth rate of the ravine during technological measures aimed at stopping the erosion processes of the ravine network. And also, in case of an increase in anthropogenic load on the ravine territory (plowing in the immediate vicinity, selection of exposed rocks for construction needs, and other negative influences). At the same time, the growth rate of the ravine can significantly increase. It is assumed that there is a small error in the model, the value of which is dictated by the variability of humidity in different years. However, when analyzing the data obtained based on the model, for 2016 and 2019, an absolute accuracy of 100% is noted.

Also, the model has developed a function for plotting the growth trend of the ravine and the sinusoid of the growth of the ravine. In the case of the studied ravine, there is a tendency to decrease the growth of the ravine. This suggests that the fourth stage of the ravine growth is coming.

The sinusoid of the ravine growth constructed by the model on the site based on the data obtained is shown in Fig. 3.

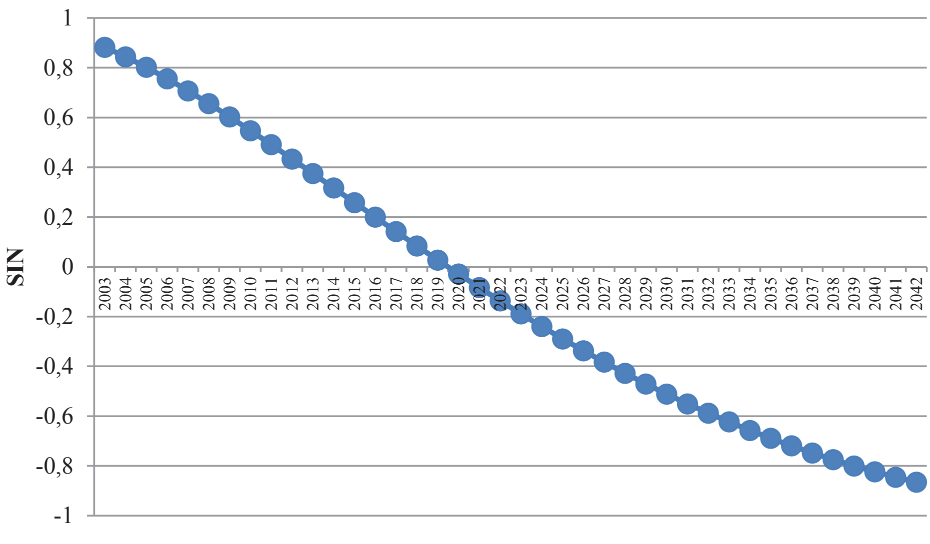

Figure 3. Sinusoid of the ravine growth between the villages of Krasnaya Gorka and Priishimka

The resulting sinusoid shows the attenuation of the growth of the ravine in the future. As can be seen in Figure 3, the growth curve is steadily decreasing, which probably indicates the development of the equilibrium profile of the ravine. It can be stated about the onset of this stage after 2020. The sinusoid turns into a negative trend, in subsequent years, the deepening of the ravine profile does not occur. It can be assumed that the growth of the ravine occurs in width under the influence of erosion processes. At the same time, the slopes of the slopes are washed away and collapse, which leads to the expansion of the bottom of the ravine. At a certain stage in the development of the ravine, the slopes reach a stable state, develop a certain angle of slope and overgrow with floral species. Under these conditions, the ravine transitions into a ravine or ravine.

It is possible to verify the reliability of the model based on the second and third measurements using GIS, in comparison with the results obtained in the forecast.

The forecast and analysis of the dynamics of the gully network allow the timely application of a set of characteristic measures for this stage. This will slow down or stop the growth of the ravine thanks to comprehensive scientifically based measures. All this is aimed at the safety of the population and the sustainable development of the territory (Beletskaya, 2019; Taizhanova, 1991). The system of measures aimed at stopping the growth of the ravine includes comprehensive measures aimed at eliminating the causes of gully erosion on the ravine itself and its catchment. Effective means are afforestation, both of the ravine itself and the adjacent territories, concreting of its tops and bottom, and the construction of earthen ramparts. The planting of the adjacent forest strips is not only a means of preventing ravine formation but also has aesthetic and ecological significance.

Conclusion

Erosion processes associated with the growth of the gully network can lead to many negative economic and social consequences. To avoid them, it is necessary to carry out work on fixing ravines and apply a set of measures to protect the land from gully erosion in the catchment area. The envisaged works should be aimed at eliminating the causes of the formation of ravines and turning them into forest lands. In this regard, it is necessary to use modern accessible, and reliable means and methods to monitor and forecast gully erosion. One of the promising tools for modeling a gully network is the use of geoinformation technologies. Based on the analysis of satellite images and software, it is possible to make a forecast of the growth of ravines threatening residential areas and the road network.

Currently, elementary geoinformation systems are widely available, through which it is possible to predict the growth of ravines without preliminary observations on the ground. Geoinformation systems are a source of scientific information and a means to solve problems with minimal time and financial costs. Moreover, the data from remote sensing of the Earth provide accurate and objective information for monitoring studies and the construction of models for predicting the dynamics of gully erosion. Electronic maps and satellite images are the basis for the visualization and mapping of data from monitoring studies of the growth of the gully network. These observations should be made especially carefully in those places where the growth of ravines is especially dangerous for the economy (where the ravines approach the road, buildings, or agricultural land). Any observations, no matter how interesting they may be, are important not in themselves, but as a means to choose the right measures that most effectively fix the ravines.

Based on the conducted research, the following conclusions can be drawn:

1. Ravines pose a serious threat to economic development, their growth can lead to human casualties. Based on the use of elementary GIS that are widely available, it is possible to predict the growth of ravines without preliminary observations on the ground. Satellite images, electronic maps, and other geoinformation tools are of genuine scientific interest for rapid and accessible monitoring, mapping, and forecasting of the growth of ravines.

2. Based on the developed model for predicting the growth rate of ravines, it can be concluded that the ravine in question on the section of the highway between the villages of Krasnaya Gorka and Priishimka is in the stage of slowing growth, but its growth continues. The transition to the beam stage began after 2020. Satellite images show that the ravine poses a threat to the roadbed of the A16 Petropavlovsk – Zhezkazgan highway. If appropriate measures are not taken to prevent the growth of the ravine, then judging by the forecast data obtained using the model, by 2025 it will cause significant damage to the road.

3. The main hydraulic structures for fighting ravines are: spray rollers, catchment earthen ramparts, and outflow ditches. In addition, afforestation of adjacent territories is necessary, the root system of trees and shrubs can absorb surface water runoff, and bond the soil. Forest plantations can prevent ravine formation, and also have ecological and aesthetic significance.

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