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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

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«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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ASSESSMENT OF THE ECOGEOGRAPHICAL STATE OF THE TRANSFORMATION OF MODERN LANDSCAPES

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Abstract. *Relevance.* This research analyzes the ecogeographical state of modern landscapes in the Ajinohur foothills, Azerbaijan. Characterized by complex natural conditions and dynamic ecological processes, understanding this region’s stability and flexibility is crucial for future regional development strategies. *Purpose.* The study aims to assess the current ecogeographical state and anthropogenic transformation of the Ajinohur foothills using GIS technologies and a 100-point scoring system. *Methods.* The area’s ecogeographical state was analyzed via digital maps compiled through modern GIS technologies and smooth surface mapping. This approach enabled accurate quantitative and qualitative comparisons of various landscape elements and revealed functional relationships between natural complexes. A 100-point scale was applied to express the natural resource potential and the degree of anthropogenic loading, evaluating factors like climate, relief, land cover, and economic modifications using mathematical and statistical methods. *Results.* The study comprehensively examined individual anthropogenic impacts on arable lands, pastures, transport networks, gardens, and settlements. An ecological map was compiled, differentiating degraded and stable zones across 4 main landscape types. The complex assessment scores revealed that the Mountainous semi-desert type exhibits the highest stability (77 points), followed by Arid forest/shrubland (73 points), Plain forest (69 points), and Arid steppe landscape of plain (63 points). Statistically, 85% of the territory (3,760 km²) operates under a satisfactory ecogeographical state, while a critical 2% (103 km²) faces advanced degradation due to localized pasture failures scoring a low 33 points.

Keywords: climate action, zero hunger, landscape, anthropogenic transformation, Ajinohur low mountain, ecogeographical assessment, GIS modeling, land degradation

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ҚАЗІРГІ ЗАМАНҒЫ ЛАНДШАФТТАР ТРАНСФОРМАЦИЯСЫНЫҢ ЭКОГЕОГРАФИЯЛЫҚ ЖАҒДАЙЫН БАҒА БЕРУ

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Аннотация. *Өзектілігі.* Бұл зерттеу Әзірбайжанның Аджинохур тау бөктеріндегі қазіргі заманғы ландшафттардың экогеографиялық жағдайын талдайды. Күрделі табиғи жағдайлармен және динамикалық экологиялық процестермен сипатталатын бұл аймақтың тұрақтылығы мен икемділігін түсіну болашақ аймақтық даму стратегиялары үшін өте маңызды. *Мақсаты.* Зерттеудің мақсаты - Аджинохур тау бөктеріндегі қазіргі экогеографиялық жағдайды және антропогендік трансформацияны ГИС технологияларын және 100 балдық бағалау жүйесін қолдана отырып бағалау. *Әдістер.* Ауданның экогеографиялық жағдайы заманауи ГИС технологияларын және тегіс беткейлік картаға түсіруді қолдана отырып құрастырылған сандық карталар арқылы талданды. Бұл тәсіл әртүрлі ландшафт элементтерін дәл сандық және сапалық салыстыруға мүмкіндік берді және табиғи кешендер арасындағы функционалдық байланыстарды анықтады. Табиғи ресурстық әлеуетті және антропогендік жүктеме дәрежесін көрсету үшін 100 балдық шкала қолданылды, климат, жер бедері, жер жамылғысы және экономикалық өзгерістер сияқты факторларды математикалық және статистикалық әдістерді қолдана отырып бағалады. *Нәтижелер.* Зерттеу егістік жерлерге, жайылымдарға, көлік желілеріне, бақшаларға және елді мекендерге жеке антропогендік әсерлерді жан-жақты зерттеді. 4 негізгі ландшафт түрі бойынша деградацияланған және тұрақты аймақтарды ажырататын экологиялық карта жасалды. Кешенді бағалау ұпайлары таулы жартылай шөлді типтің ең жоғары тұрақтылықты (77 ұпай) көрсететінін, одан кейін құрғақ орман/бұталы алқап (73 ұпай), жазық орман (69 ұпай) және жазықтың құрғақ дала ландшафтының (63 ұпай) келетінін көрсетті. Статистикалық тұрғыдан алғанда, аумақтың 85%-ы (3760 км²) қанағаттанарлық экогеографиялық жағдайда өмір сүреді, ал маңызды 2%-ы (103 км²) жайылымдардың жергілікті деңгейде бұзылуына байланысты үдемелі деградацияға ұшырап, 33 ұпайдан төмен балл жинады.

Түйін сөздер: климаттық әрекет, аштық нөл, ландшафт, антропогендік трансформация, Аджинохур аласа тауы, экогеографиялық бағалау, ГАЖ модельдеу, жердің деградациясы

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ОЦЕНКА ЭКОГЕОГРАФИЧЕСКОГО СОСТОЯНИЯ ТРАНСФОРМАЦИИ СОВРЕМЕННЫХ ЛАНДШАФТОВ

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Аннотация. *Актуальность.* В исследовании анализируется экогеографическое состояние современных ландшафтов предгорий Аджинохура в Азербайджане. Данный регион характеризуется сложными природными условиями и динамичными экологическими процессами, поэтому оценка его устойчивости и трансформационного потенциала имеет важное значение для разработки стратегий регионального развития, рационального природопользования и предотвращения деградации земель. *Цель.* Оценить современное экогеографическое состояние и степень антропогенной трансформации предгорий Аджинохура с использованием ГИС-технологий и 100-балльной системы оценки. *Методы.* Экогеографическое состояние территории анализировалось на основе цифровых карт, составленных с применением современных ГИС-технологий и методов картографирования сглаженных поверхностей. Такой подход позволил провести количественное и качественное сопоставление различных элементов ландшафта и выявить функциональные взаимосвязи между природными комплексами. Для оценки потенциала природных ресурсов и степени антропогенной нагрузки использовалась 100-балльная шкала, учитывающая климат, рельеф, растительный покров и хозяйственные изменения. Обработка данных осуществлялась с применением математических и статистических методов. *Результаты и выводы*. В исследовании комплексно изучены антропогенные воздействия на пахотные земли, пастбища, транспортные сети, сады и населенные пункты. Составлена экологическая карта, на которой выделены деградированные и стабильные зоны по четырем основным типам ландшафта. Комплексная оценка показала, что горные полупустынные ландшафты характеризуются наибольшей устойчивостью (77 баллов), далее следуют аридные леса и кустарники (73 балла), равнинные леса (69 баллов) и аридные степные ландшафты равнины (63 балла). Установлено, что 85% территории, или 3760 км², находится в удовлетворительном экогеографическом состоянии, тогда как 2% территории, или 103 км², характеризуется сильной деградацией, связанной преимущественно с локальным ухудшением состояния пастбищ, и имеет низкую оценку - 33 балла. Полученные результаты подтверждают необходимость территориально дифференцированного подхода к управлению ландшафтами и разработке мер по снижению антропогенной нагрузки..

Ключевые слова: борьба с изменением климата, нулевой голод, ландшафт, антропогенная трансформация, Аджинохурская низкая гора, экогеографическая оценка, ГИС-моделирование, деградация земель

Introduction. The landscape as a whole plays the role of an ecological environment in which various biological groups, including humans, live (Amanova et al., 2024a). In fact, the landscape functions as a unifying ecological platform where abiotic and biotic components interact continuously, forming a stable yet sensitive environmental system. Such interactions determine the sustainability of habitats and the adaptability of species living within these environments. On the one hand, the landscape is an open system, and therefore close relationships are observed between natural systems (Sadigov and Mustafayev, 2024). This openness ensures constant energy and matter exchange, making landscapes responsive to even minor environmental fluctuations. As a result, landscapes can rapidly transform under the influence of climatic, hydrological, and anthropogenic drivers, which necessitates their continuous monitoring. The formation of a landscape as a natural system depends more on external influences than on the landscape (Adili et al., 2024). External factors such as solar radiation, atmospheric circulation, and regional tectonic shifts often determine the fundamental direction of landscape evolution over centuries. Their prolonged influence can reshape surface morphology, modify soil fertility, and alter vegetation composition. The strength of the external landscape system (tectonic, cosmic influences on climate change, etc.) is related to the concepts of landscape development and dynamics (Jasinavičiūtė and Veteikis, 2022). Therefore, understanding these large-scale drivers is crucial for correctly interpreting current environmental processes and predicting future changes in landscape structure. Therefore, landscape ecology can be approached from two points of view: internal landscape and external landscape. This dual approach allows researchers to evaluate not only the internal components such as soil, vegetation, and microclimate but also the broader regional processes that shape the ecological system as a whole.

The landscape structure of the territory, especially in mountainous regions, the sharp selection of the height differentiation of the geosystem, the complexity of the geological base, the predominance of sharp and variable forms of relief (Khalilov and Eminov, 2024; Tokbergenova et al., 2025), the sharp contrast of absolute height and slope inclination, and the rapid change of meso-and microclimate play a key role in the formation of ecological problems in landscapes and spatial development (Li et al., 2025; Sowińska-Świerkosz et al., 2021). Such mountain-plain transitional zones are particularly sensitive because elevation gradients significantly affect temperature regimes, humidity fluctuations, vegetation distribution, and soil formation processes. These sharp contrasts create fragmented ecological niches, each with distinct environmental pressures, which makes the study of spatial patterns more challenging yet scientifically valuable. Furthermore, relief irregularities often intensify erosion processes, accelerate sediment transport, and influence land degradation dynamics. As human activities expand into these territories, the interplay between natural processes and anthropogenic impacts becomes even more pronounced, further complicating the ecological balance.

Researchers note that indicators of the ecological situation should be identified on the basis of actual materials available in the area (Katarzyna and Wiater, 2025). Field-based observations remain the primary source of reliable data, as remote sensing methods, although useful, cannot fully replace on-site ecological assessments. Detailed field measurements allow establishing a more accurate baseline for environmental monitoring and help correlate landscape changes with quantitative indicators. For comparison, it is necessary to obtain indicators of the territory, and then indicate the causes of the processes (Amanova et al., 2024b), the interaction of natural and anthropogenic factors, and the criteria that determine the development of these factors (Belčáková et al., 2021). This comparative approach ensures that environmental dynamics are not interpreted in isolation but within a broader spatial and temporal context. It also allows researchers to distinguish between naturally occurring fluctuations and human-induced transformations, which is essential for preparing accurate environmental forecasts. This, in turn, creates conditions for the development of measures to combat negative factors (Pérez-Aristizábal et al., 2025). Such measures may include soil protection strategies, reforestation efforts, regulated grazing systems, erosion control programs, and other targeted interventions aimed at stabilizing degraded ecosystems.

The study area corresponds to the areas where mountains and plains meet. This refers to densely populated areas. Human settlements historically concentrated in these regions due to favorable environmental conditions and strategic geographic positions. As a result, population pressure continues to shape land-use patterns and intensify ecological stress. Such areas have fertile soils, rich flora, a healthy climate, and abundant water resources. These advantages attract agricultural expansion, industrial development, and infrastructure growth, all of which increase the anthropogenic load on landscapes. Irrigated agriculture is one of the factors that causes the population and settlement to move from high relief to low relief (Myachina et al., 2024). Over time, the intensification of irrigation systems has transformed large tracts of natural land cover, affecting hydrological cycles and sometimes leading to salinization or waterlogging in low-lying areas.

The degree of ecological stress can vary depending on space and time (Khamit et al., 2024). Temporal changes may be seasonal, annual, or long-term, meaning that landscape responses often evolve gradually rather than abruptly. Spatial differences, on the other hand, are shaped by landform diversity, soil structure, and anthropogenic activity levels. Ecological measures taken against negative impacts prevent pollution, sometimes completely destroy it (Mammadov and Abdullayev, 2024). However, long-term environmental stability requires continuous management, periodic reassessment, and the integration of both scientific knowledge and local ecological practices.

Material and Methods. A scoring system was used to assess the ecological status of landscapes. The following formula was used to assess the ecogeographic status of individual anthropogenic modifications within landscapes:

$$EA_{A..M} = (\quad - C_{A.F}) \text{ x } 100$$

Here $EA_{A.M}$ – ecological value of anthropogenic modification (in points); L_N – area of natural landscape (area of landscape where current anthropogenic modification is not observed); L_M – area of modern landscape, $C_{A.F}$ – coefficient of anthropogenic factors having a negative impact. This coefficient differs according to its intensity and duration. Anthropogenic impacts are assessed as weak (1), medium (2) and strong (3) and are ultimately taken into account with a value of 100 points, and since they are year-round and intensive in road landscapes and seliteb complexes, the coefficient is 0.3, since they are seasonal in pastures, 0.2, and although they are seasonal in crops and gardens, fertilizers are applied to the soil to increase productivity, therefore, the coefficient in crops and gardens was estimated as 0.1. After determining the ecogeographic values of individual modifications, a complex ecogeographic assessment of landscape types was carried out according to the following formula:

$$C.\ E.\ A = (EA_c + EA_p + EA_s + EA_r + EA_g) : n$$

Where C. E. A - complex ecogeographic value of the landscape type (points); EA_s - ecogeographic value of selected complexes (points); EA_c - ecogeographic value of the cultivated area (points); EA_g - ecogeographic value of gardens (points); EA_r - ecogeographic value of road landscapes (points); EA_p - ecogeographic value of pasture complexes (points), n - indicates the total number of indicators.

Result. After a complex ecogeographic assessment of individual landscape types was conducted, the natural landscape types were combined into certain groups and, a map “Ecogeographical status of landscapes in the Ajinohur foothills and adjacent areas” was generated using ArcGIS software (Figure 1).

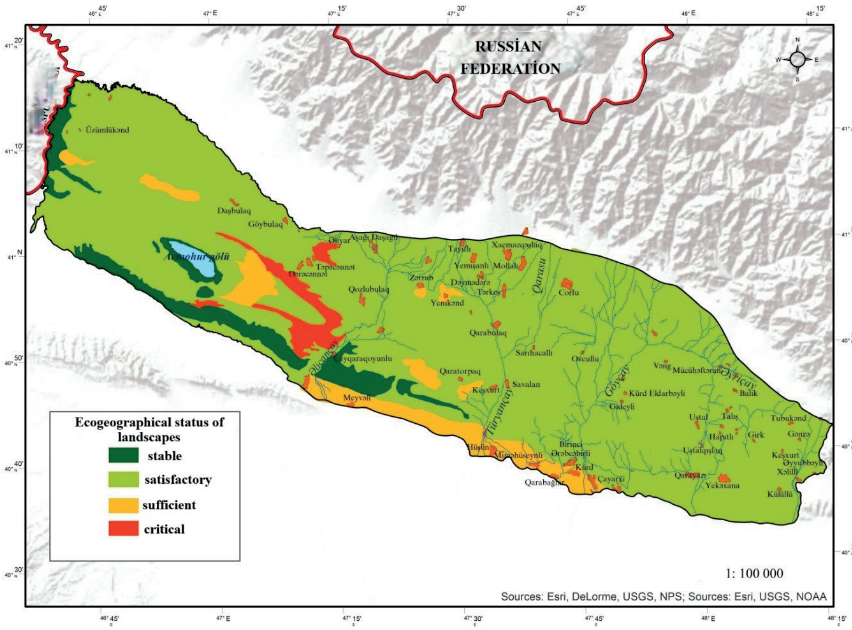

Figure 1. Map of the ecogeographical status of landscapes in the Ajinohur foothills and adjacent areas in the central part of the Republic of Azerbaijan.

The statistical indicators obtained based on mathematical and statistical methods were analyzed. According to the obtained mathematical bases, the landscapes were divided into 4 gradations based on a 0–100-point scale. Each division interval was justified as 25 points. Based on the statistical indicators, landscape types with an ecogeographic value of 75–100 points were classified as landscapes with a stable ecogeographical state, types with a score of 50–75 points were classified as landscapes with a satisfactory ecogeographical state, types with an ecogeographic value of 25–50 points were classified as landscapes with a sufficient ecogeographical state, and types with a score of 0–25 points were classified as landscapes with a critical ecogeographical state.

According to this formula, the complex ecogeographic score in the Mountainous semi-desert and arid steppe landscape type is 77 points, in Arid steppe landscape of plain it is 63 points, in Arid forest and shrubland it is 73 points, and in Plain forest landscape it is 69 points (Table 1).

According to this formula, the complex ecogeographic score in the mountainous semi-desert and arid steppe landscape type is 77 points, in dry steppes it is 63 points, in arid forests and shrubs it is 73 points, and in plain forests it is 69 points (Table 1).

Table 1. Evaluation of the ecogeographical situation by landscape type in the Ajinohur foothills and adjacent areas.

Landscape type	Settlements (points)	Crops (points)	Pastures (points)	Gardens (points)	Roads (points)	Complex ecogeographical assessment (points)
Mountainous semi-desert and arid steppe	69	71	85	90	69,8	77
Arid steppe landscape of plain	67	59	33	85	69,8	63
Arid forest and shrubland	67	78,8	61,7	87,9	69,8	73
Plain forest landscape	52	55	83	85	69,5	69

In this respect, the area of landscapes with stable ecogeographical status is 259 km² (6%), the area of landscapes with satisfactory ecogeographical status is 3,760 km² (85%), the area of landscapes with sufficient ecogeographical status is 297 km² (7%), and the area of landscapes with critical ecogeographical status is 103 km² (2%).

When analyzing the ecological status of settlements within the mountainous semi-desert landscape type, it was determined that the score of pastures and gardens here is equal to 100. The area of roads is quite small compared to the total area, equal to 69.8 points. Settlements and crops were evaluated with 69 and 71 points, respectively. Crops in this landscape type occupy a large area. Within the type, the area of landscape types with a stable ecogeographical status is 155 km² (32%), the area of landscape types with a satisfactory status is 160 km² (33%), and the area of landscape types with a sufficient status is 176 km² (35%) (Table 2).

Table 2. Statistical analysis of ecogeographical situation by landscape types.

Landscape type	Ecological status	Area (in km²)	Share within type (in%)	Score (point)
Mountainous semi-desert and arid steppe	stable	155	32	75-100
	satisfactory	160	33	50-75
	sufficient	176	35	25-50
Arid steppe landscape of plain	stable	54	2	75-100
	satisfactory	2614	90	50-75
	sufficient	121	4	25-50
	critical	103	4	0-25
Arid forest and shrubland	stable	50	16	75-100
	satisfactory	262	84	50-75
Plain forest landscape	satisfactory	724	100	50-75

Within the pristine zones of the Arid steppe landscape of plain, where anthropogenic modification is completely absent, the baseline ecological value reaches 100 points. However, across functionally modified zones, settlements are rated at 67 points, crops at 59 points, pastures at 33 points, and gardens at 85 points. In the ecogeographical situation of this type, pastures predominate, although the operational livestock impacts here are highly seasonal. Crops hold the second largest functional share after pastures. Within this landscape type, the area of landscape components with a stable ecogeographical situation is 54 km² (2%), the area with a satisfactory condition is 2,614 km² (90%), the area with a sufficient condition is 121 km² (4%), and the area in a critical condition is 103 km² (4%).

In the Arid forest and shrubland landscape type, roads were rated 69.8 points, gardens 87.9 points, settlements 67 points, crops 78.8 points, and pastures 61.7 points. Within this specific landscape type, the area of landscape variants with a stable ecogeographical state is 50 km² (16%), and the area with a satisfactory state is 262 km² (84%).

In the Plain forest landscape type, the score of roads is equal to 69.5. Pastures are consistently ranked at 83 points, and gardens are ranked at 85 points. Within this specific matrix, settlements exhibit a baseline score of 52 points, while crops cover a substantial spatial extent, registering an indicator of 55 points. All territorial components of this landscape type (724 km²) belong exclusively to landscapes with a satisfactory ecogeographical state.

In general, to evaluate the ecogeographical aspect of the study area, the average score was obtained from the ratio of the sum of the ecogeographical values of anthropogenic modifications to their number. If we compare by landscape types, the ecogeographical situation is more stable in the mountainous semi-desert landscape type. The main reasons for this are the arid climate, high temperature, low precipitation, etc. The ecogeographical situation is more sensitive in the dry steppe landscape type and arid forests and shrubs, which have more favorable natural conditions. This is due to the presence of natural winter pastures in the dry steppe landscape type, sufficient precipitation and humidity in arid forests and shrubs, as well as favorable relief conditions.

A modernization of the structure of arable land and crop rotation in the distribution of perennial grasses in agrolandscapes is of great importance. This structural approach is directly justified by the lower indicators observed in highly modified zones. For instance, the low ecogeographical value of crops in the plain arid steppe (59 points) is closely related to the rapid depletion of soil organic matter and humus imbalance. For optimization, the long-term use of perennial grasses, increasing the content of legumes, mathematically counteracts continuous tillage pressures and increases overall productivity while mitigating erosion.

Based on the quantitative point thresholds obtained in this study, the geoecological optimization of the territory should be organized according to the following specific priorities:

Justification of Geoecological Monitoring (77 points): Although the Mountainous semi-desert and arid steppe landscape type achieved a complex score of 77 points—placing it within the “stable” gradation—this value sits critically close to the satisfactory threshold line (75 points). This marginal positioning scientifically dictates that a comprehensive geoecological monitoring of the landscape fund must be organized to detect early-stage aridification and soil salinity variations before the ecosystem shifts into a lower stability category.

Pasture Reclamation and Grazing Controls (33 points): The alarmingly low pasture score within the Arid steppe landscape of plain (33 points) directly isolates overgrazing as the primary driver of land degradation. Excessive and irregular grazing has a negative impact on the botanical composition and biological productivity of plants, leading to the destruction of useful forage plants in the winter pastures. To reverse this, ecological optimization must enforce strict rotational grazing boundaries, ensure the preservation and restoration of natural coenoses, and introduce temporary small seasonal reserves to allow vegetative recovery.

Preservation of Agro-landscapes: In zones where intensive anthropogenic activity reduces the area of arable land, optimization must look to the preservation and restoration of water supply to the territories, while fully taking into account the local landscape-geographical, biological, and cultural resources.

Conclusion. In the Ajinohur foothills and adjacent areas, agriculture occupies a leading place among the areas of material production in terms of production and importance. As a result of anthropogenic activity, fertile soils are polluted, the area of arable land is reduced, and productivity is reduced. One of the main ecological problems for the study area is the gradual degradation and withdrawal of agriculturally suitable lands from circulation.

Grazing has a negative impact on the botanical composition and biological productivity of plants. Excessive and irregular grazing leads to the destruction of useful plants in the vegetation. The purpose of taking livestock to winter pastures is to feed them with useful forage plants. In this case, these plants are destroyed, and plants that the livestock do not feed on develop relatively well. The calibrated 100-point scoring model deployed in this study successfully operationalizes these ecological dynamics, providing a quantitative framework to support long-term landscape-geographical and biological conservation planning.

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