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Geospatial Model for Land Degradation Assessment in the Caspian region based on Integrated Multifactor Indicators

M.E. Amirkhanov¹, Y. Zhakypbek^{1*}, Sun Hao²

¹Satbayev University, Almaty, Kazakhstan

²China University of Mining and Technology, Beijing, China

*Corresponding author: y.zhakypbek@satbayev.university

Abstract. Land degradation and desertification are major environmental challenges in the arid Caspian region (Pri-Caspian) of Kazakhstan. This study assesses desertification susceptibility in the Mangystau region using an integrated GIS and remote sensing approach. Four controlling factors were analyzed: distance to active tectonic faults, terrain slope, vegetation cover derived from the Normalized Difference Vegetation Index (NDVI), and soil moisture conditions represented by the Water Requirement Index (WRI). Euclidean distance analysis was used to evaluate tectonic influence, slope gradients were derived from SRTM data, and NDVI and WRI were calculated from Landsat 8 OLI imagery. All factors were reclassified into standardized ordinal classes and integrated using a weighted sum multi-criteria evaluation model to generate a composite desertification susceptibility map. The results indicate strong spatial heterogeneity in degradation conditions. Areas near tectonic faults with steeper slopes, low NDVI, and low WRI values show the highest susceptibility to desertification, while regions with gentle slopes, higher vegetation cover, and better soil moisture exhibit greater environmental stability. The study demonstrates that land degradation in Mangystau is controlled by the combined effects of geological, geomorphological, and ecological factors. The proposed integrated framework provides a reliable tool for desertification assessment and supports sustainable land management in arid and semi-arid environments.

Keywords: land degradation, desertification, tectonic faults, terrain slope, NDVI, WRI, reclassification.

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1. Introduction

The Caspian region, which includes Atyrau and Mangystau of Kazakhstan has been experiencing increasing desertification over the past decades; this phenomenon threatens both the environment and local livelihoods. Land degradation is considered one of the main drivers of desertification, as it reduces fertility and vegetation cover.

Remote sensing data, such as Landsat images, have been widely used to monitor changes in vegetation and soil moisture; they provide valuable information for large and inaccessible areas. In addition, the digital elevation models (SRTM) allow researchers to analyze slopes, which affects erosion and water retention; these factors contribute to land degradation.

The Euclidean distance tool was used to determine the distance to active tectonic fault lines, which can influence soil moisture and land degradation. Vegetation indices, such as NDVI, have been applied to detect the loss of plant cover, whereas the Water Ratio Index (WRI) is used to assess soil moisture. Previous studies have shown that areas with steep slopes or low vegetation density are more vulnerable to degradation, which highlights the need for integrated assessments.

In this study, remote sensing indices, slope analysis, and distance metrics are combined to evaluate land degradation,

providing a comprehensive view of desertification patterns. Active tectonic faults, which influence groundwater distribution, are also considered as contributing factors to the spatial variability of soil moisture and vegetation, although this aspect is often overlooked in conventional studies.

The study is devoted to the important issue of land degradation and desertification in the Caspian region. The study is highly relevant because the increasing impacts of climate change and human activities have accelerated environmental degradation, threatening ecosystems and local livelihoods. One of the main problems is the lack of an integrated approach to accurately assess land degradation using multiple environmental factors and geospatial technologies.

The results of this research are expected to support sustainable land management strategies and help mitigate desertification risks in the Pri-Caspian region of Kazakhstan.

2. Materials and methods

2.1. Study area

The study area is in the Caspian region of Western Kazakhstan and mainly covers the territory of the Mangystau region (approximately 43.40°–45.70° N, 50.00°–55.00° E) with partial inclusion of adjacent areas of the Atyrau region

(approximately 46.00°–48.00° N, 50.00°–53.00° E) [1]. Mangystau region is situated in the southwestern part of Kazakhstan along the eastern coast of the Caspian Sea (Pri-Caspian area) and represents one of the most arid and environmentally sensitive regions of the country [2].

Geographically, Mangystau region is characterized by a complex relief that includes coastal lowlands, plateaus, depressions, and isolated mountain massifs [3]. A significant part of the territory lies below sea level, including the Karagiye Depression (approximately 44.02° N, 51.33° E), one of the deepest continental depressions in Central Asia [4]. The Mangystau Plateau and the Ustyurt Plateau dominate the eastern and northeastern parts of the region, forming elevated flat and dissected surfaces with steep escarpments [5]. The climate is sharply continental and extremely arid, with very low annual precipitation, high summer temperatures, strong winds, and intense evaporation. These climatic conditions contribute to soil salinization, sparse vegetation cover, and high susceptibility to desertification [6].

Geologically, the Mangystau region is influenced by complex tectonic structures related to the Caspian basin [7]. Numerous faults in Figure 1 and lineaments control groundwater movement and may affect spatial variations in soil moisture and vegetation distribution. These tectonic features, together with the fragile surface conditions, increase the sensitivity of landscapes to degradation processes [8].

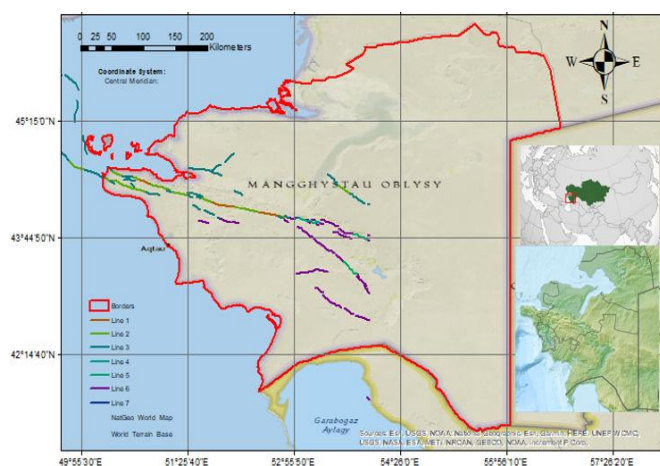


Figure 1. Active tectonic fault lines of Mangystau Pri-Caspian region

Due to the combined influence of arid climate, complex relief, tectonic activity, and fragile ecosystems, the Mangystau and adjacent parts of Atyrau regions represent a highly suitable area for investigating land degradation, desertification, and associated geomorphological processes using integrated GIS and remote sensing approaches.

2.2. Methodological framework

The methodological framework in Figure 2 of this study is based on an integrated GIS and remote sensing approach for assessing land degradation, desertification, and landslide susceptibility in the Caspian region. The workflow consists of several sequential stages, including data acquisition, factor extraction, reclassification, spatial integration, and final susceptibility mapping. The interaction between tectonic faults, slope, vegetation cover (NDVI), and soil moisture (WRI) forms an integrated system controlling soil degradation and desertification processes.

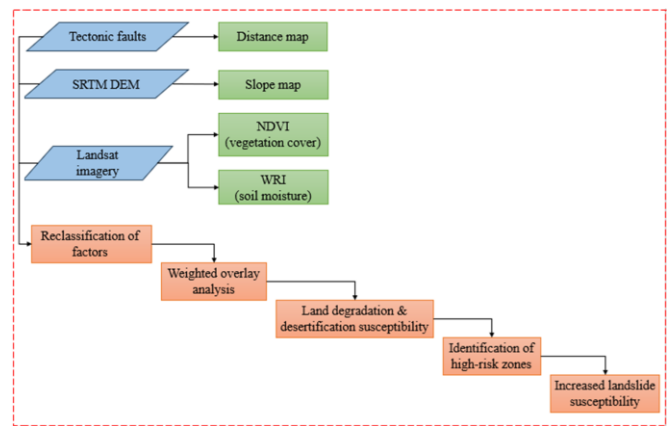


Figure 2. Workflow of the GIS-based methodological framework for assessing land degradation and desertification in the Mangystau region

Tectonic structures affect groundwater distribution, slope determines erosion intensity, vegetation protects soil from degradation, and soil moisture reflects surface stability. The combined influence of these factors increases the susceptibility of landscapes to degradation and landslide processes.

2.3. Assessment of tectonic fault control on land degradation processes

Previous studies have demonstrated that tectonic structures and associated geological processes influence vegetation distribution and soil conditions. For instance, Li et al. (2023) found that vegetation index values (NDVI) vary in relation to fault length density and elevation, suggesting that fault zones affect hydrothermal and ecological conditions – with lower NDVI in areas close to faults at certain elevations and contrasting patterns at higher altitudes [9]. Additionally, tectonic activity coupled with lithological controls has been shown to shape spatial patterns of soil and vegetation parameters in fault-controlled landscapes [10]. Tectonic and internal geomorphological dynamics also significantly contribute to erosion and sediment production rates, linking structural geology to soil degradation processes [11]. Moreover, fault zones tend to exhibit increased fracture density and reduced rock strength, which can enhance susceptibility to mass movement and surface instability under external triggers such as rainfall [12].

Figure 3 illustrates the relief of the Mangystau region in relation to the distribution of active tectonic faults and recorded seismic events. The terrain is predominantly represented by gently undulating plains and dissected plateaus, with local elevated areas corresponding to structural uplifts and residual mountain ridges.

Tectonic faults are shown as linear features of different colors, indicating their relative activity and confidence levels. The major fault zones form elongated, predominantly north-west–southeast trending structures, which reflect the regional tectonic framework of the Caspian basin. These fault systems control the structural pattern of relief and contribute to the formation of escarpments, depressions, and plateau boundaries. Seismic events are represented by blue circles, classified into major, middle, and minor categories according to earthquake magnitude. The concentration of seismic points near fault intersections suggests a strong spatial relationship between tectonic activity and seismicity. This spatial coincidence confirms the ongoing tectonic activity of the region and highlights the role of fault zones as zones of crustal weakness.

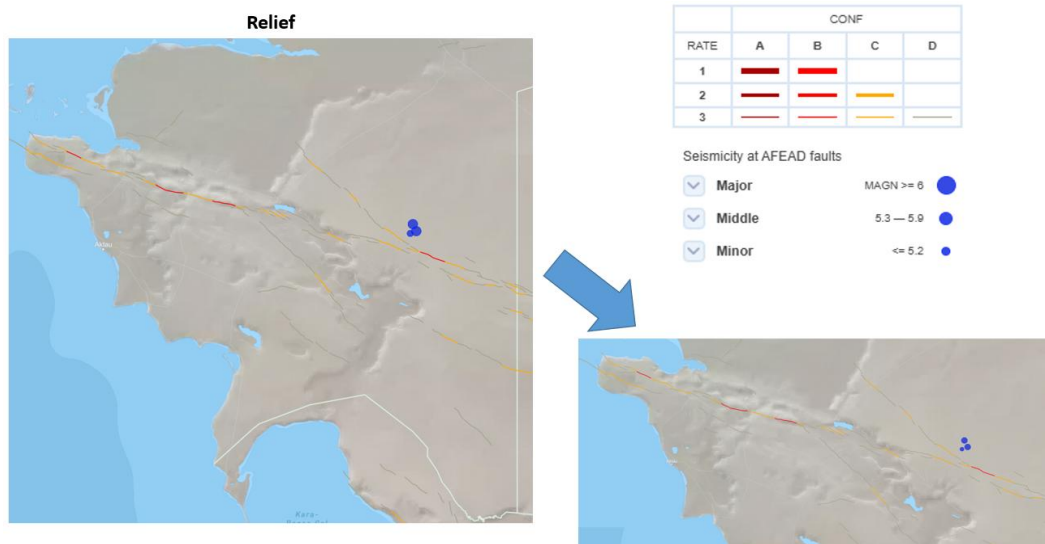


Figure 3. Relief and distribution of active tectonic faults and seismic events in the Mangystau region

The relief shading emphasizes elevation differences and slope variations, which are more pronounced in areas adjacent to major fault lines. These zones are characterized by increased surface dissection and geomorphological instability, making them more susceptible to erosion, soil degradation, and slope failure processes. The integrated visualization of relief, tectonic faults, and seismicity demonstrates that tectonic structures play a key role in shaping the landscape of the Mangystau region. Their influence extends beyond geological formation and directly affects surface stability, hydrological conditions, and land degradation patterns.

Tectonic faults are represented by colored linear features corresponding to different confidence and activity classes. The major fault zones extend predominantly in a northwest-southeast direction, forming continuous structural corridors across the region. These fault systems divide the territory into distinct geomorphological blocks and control the spatial organization of surface features. The satellite image reveals that fault zones often coincide with linear valleys, subtle relief breaks, drainage anomalies, and variations in surface reflectance, indicating their strong control over geomorphological and hydrological processes shown in Figure 4.

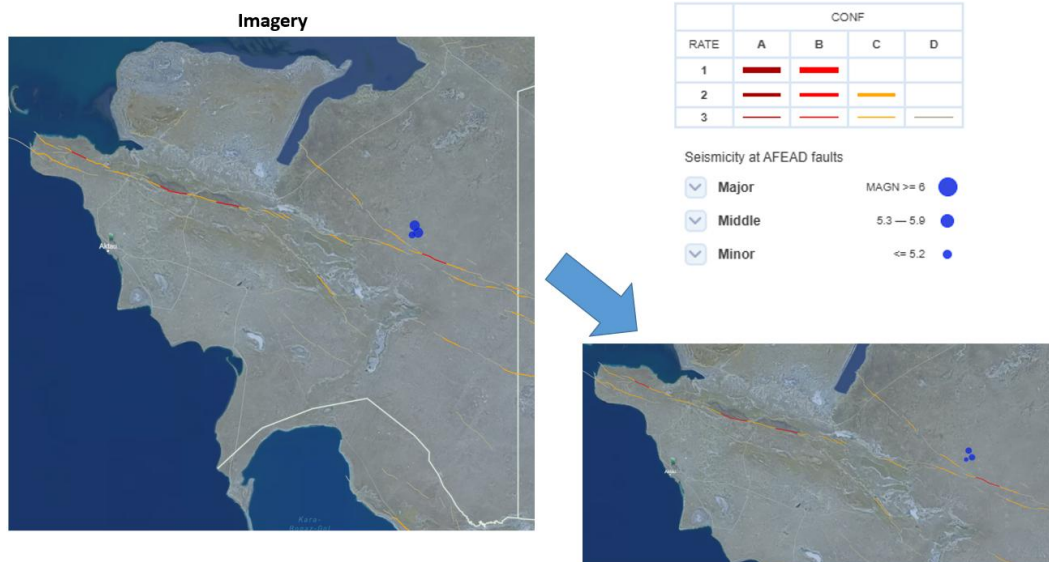


Figure 4. Satellite imagery of the Mangystau region shows the spatial distribution of active tectonic faults and seismic events

These zones act as preferential pathways for groundwater movement and influence soil moisture distribution.

Seismic events are shown as blue circles and are spatially clustered near the major fault intersections. This spatial association confirms the tectonic activity of the region and supports the reliability of the mapped fault structures. The integrated analysis of satellite imagery and tectonic data indicates that fault zones represent key controlling factors for surface instability, soil degradation, and landscape fragmentation in the Mangystau region.

Tectonic faults represent an important geological factor influencing groundwater circulation, soil moisture conditions, and surface stability. Therefore, the distance to tectonic fault zones was considered as a controlling parameter in the assessment of land degradation and desertification susceptibility.

Euclidean distance analysis was applied to measure the proximity of each pixel to active tectonic fault lines, which were obtained from regional geological surveys and have been shown to affect groundwater availability in arid environments. Before processing, all raster datasets were

resampled and aligned into a unified coordinate system to avoid spatial mismatches; however, minor discrepancies in pixel boundaries were encountered, and these were corrected through geometric adjustment. Each index was classified into degradation-related categories based on thresholds commonly reported in similar studies, which allowed meaningful comparison across variables.

2.4 Role of terrain slope in soil degradation and desertification processes in the Mangystau region

Several studies have demonstrated that topographic factors, particularly slope gradient, play a crucial role in soil degradation processes. Steeper slopes tend to enhance surface runoff and increase sediment yield, thereby accelerating soil erosion and the loss of soil particles under rainfall events (Chen et al., 2022) [13]. Wind and water erosion processes interacting with slope characteristics further intensify soil property changes, with upper slope areas losing soil organic matter and nutrients more rapidly than lower slope positions [14]. Research also shows that slope gradients influence the distribution of soil organic carbon, indicating that slope contributes not only to physical erosion but also to chemical and biological aspects of soil degradation [15]. Studies in hilly landscapes reveal significant impacts of slope gradient on soil physicochemical properties, underlining the need to consider topographic variations in land degradation assessments [16].

The images were acquired for the vegetation period to ensure consistent phenological conditions, and cloud-contaminated scenes were excluded to maintain data reliability. Shuttle Radar Topography Mission (SRTM) elevation data with 30-meter resolution were incorporated to generate slope values, since terrain inclination is known to influence erosion processes and water redistribution.

2.5 NDVI and WRI for assessing land degradation and desertification in the Mangystau region

NDVI is widely used as an indicator of vegetation condition and has been extensively applied to assess land degradation and desertification patterns in arid and semi-arid environments [17]. In addition, spectral water indices provide indirect information on surface wetness and soil moisture (WRI) conditions, which are closely linked to degradation processes in drylands [18].

In the arid environments of the Mangystau region, vegetation degradation and surface drying are key manifestations of soil degradation and desertification. The Normalized Difference Vegetation Index (NDVI) derived from Landsat imagery is widely applied to quantify vegetation cover and its decline, which is commonly interpreted as an indicator of land degradation and desertification dynamics. At the national scale, desertification-sensitive areas in Kazakhstan are concentrated in the western and southwestern regions, including Mangystau and Atyrau, highlighting the relevance of vegetation-based remote sensing monitoring for the Caspian zone [19].

To complement NDVI-based vegetation assessment, spectral water indices can be used to characterize surface wetness conditions associated with soil moisture variability. The Water Ratio Index (WRI) is defined using visible, NIR, and SWIR bands and is commonly used for water/wetness detection in multispectral data; comparative assessments of water indices explicitly include WRI and discuss its sensitivity to moisture-related spectral contrasts [20]. Because soil

moisture strongly controls vegetation productivity and erosion resistance in drylands, combining NDVI with WRI provides an integrated view of vegetation stress and surface wetness patterns that are relevant for mapping land degradation and desertification susceptibility in Mangystau.

3. Results and discussion

3.1 Spatial distribution distances to active tectonic faults

The spatial distribution of the Euclidean distance to active tectonic faults in the Mangystau region is shown in Figure 5. Nine major active fault lines (Line 1 – Line 9) were considered in the analysis. For each grid cell, the minimum Euclidean distance to the nearest fault line was calculated, producing a continuous distance surface.

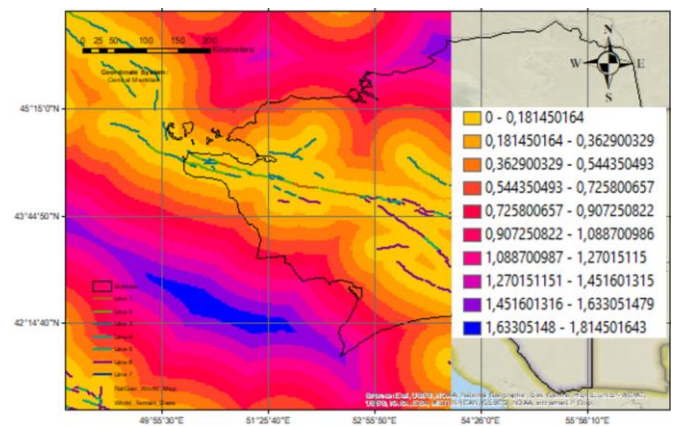


Figure 5. Proximity map to active tectonic faults in Mangystau

The results indicate a clear spatial gradient in distance values across the study area. Areas located near the fault systems are represented by low distance values (yellow to light orange colors), while regions situated farther from the tectonic structures exhibit higher distance values (purple to blue colors).

Short distances to active faults are mainly concentrated in the central and northern parts of the region, reflecting the dense distribution of tectonic structures in these zones. In contrast, the southern and southwestern parts of the study area are characterized by relatively larger distances, indicating weaker direct tectonic influence.

The generated distance map provides a quantitative spatial representation of tectonic proximity and serves as an important geomorphological indicator for subsequent spatial analyses of land surface processes in the Mangystau region.

The Euclidean distance values to active tectonic faults were further reclassified into ten ordinal classes to facilitate spatial interpretation and comparative analysis (Figure 6). The reclassification scale ranges from Class 1 to Class 10, where Class 1 (Red) represents the shortest distance to active fault lines, and Class 10 (Blue) corresponds to the greatest distance.

The reclassified map reveals a clear spatial pattern of tectonic proximity across the Mangystau region. Zones classified as Classes 1-3 are primarily distributed along the central tectonic fault systems, indicating strong spatial association with active structural features. Intermediate classes (Classes 4-7) form transitional belts surrounding the major fault zones. The highest distance classes (Classes 8-10) are mainly concentrated in the southern and southwestern parts of the study area, reflecting weaker tectonic influence.

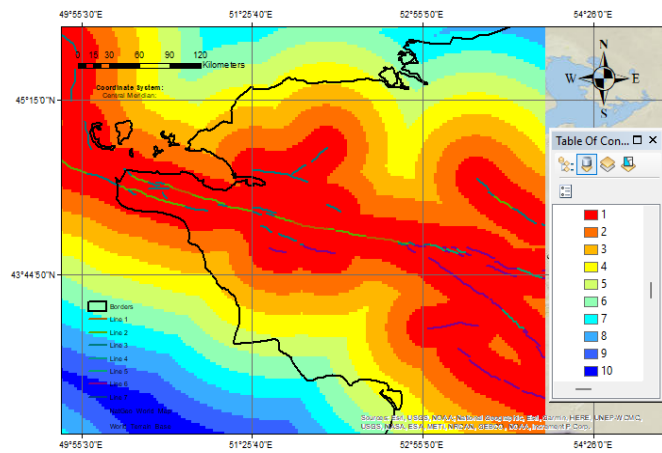


Figure 6. Reclassified distance to active tectonic faults

This classification scheme provides a standardized spatial framework for distinguishing areas with different levels of proximity to active tectonic structures and improves the interpretability of the distance surface for subsequent spatial analyses.

The combined analysis of the continuous Euclidean distance surface and its reclassified version demonstrate a consistent and reliable spatial pattern of proximity to active tectonic faults in the Mangystau region. Both representations confirm that tectonic structures exert a strong spatial control on the regional geomorphological framework.

3.2. Slope gradient distribution

Figure 7 presents the spatial distribution of terrain slope in the Mangystau region. The slope values were derived from the digital elevation model and classified into ten ordinal categories ranging from flat surfaces to strong slope gradients, to enhance spatial interpretation and geomorphological differentiation.

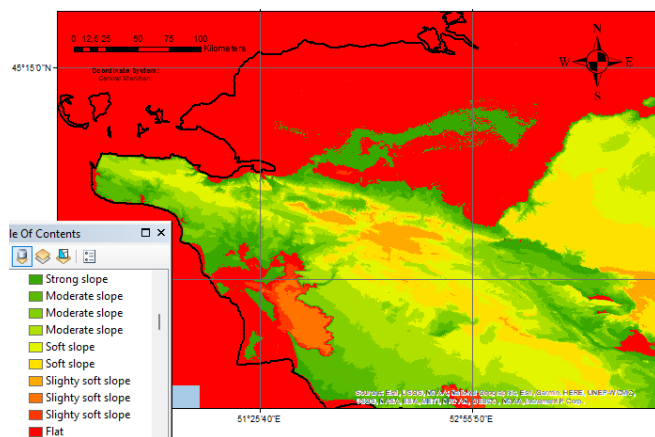


Figure 7. Slope gradient distribution derived from DEM in the Mangystau region

Flat and very gentle slope classes dominate the northern and coastal parts of the region, indicating extensive low-relief plains. These areas are characterized by minimal elevation variation and relatively stable geomorphological conditions. Gentle and moderately gentle slope classes are widely distributed across the central part of the study area, forming transitional zones between plains and elevated terrains.

Moderate slope classes are mainly concentrated along elongated belts in the central and southeastern parts of the

region, reflecting the presence of structural and erosional landforms. Slightly steep and steep slope classes are limited to spatial extent and are primarily associated with hilly terrains, escarpments, and tectonically influenced zones.

The steepest slope classes occupy only a small proportion of the total area and are mainly restricted to localized topographic highs and dissected relief features. These areas represent zones of enhanced geomorphological activity and increased surface instability.

Overall, the slope classification reveals a clear spatial differentiation of relief conditions in the Mangystau region and provides an important quantitative basis for further geomorphological, hydrological, and environmental analyses.

The slope gradient map of the Mangystau region reveals a predominance of flat to gently sloping terrains, indicating that low-relief plains constitute a major part of the study area. These landforms reflect relatively stable geomorphological conditions and limited vertical dissection of the surface. Moderate slope classes form transitional belts that correspond to structural and erosional landforms, while steep and strongly sloping areas are spatially restricted and mainly associated with localized uplands and tectonically influenced zones. The limited extent of high-slope areas suggests that intense geomorphological processes are confined to specific topographic features. The spatial pattern of slope gradients demonstrates clear geomorphological heterogeneity across the region and provides an essential basis for assessing surface processes, land stability, and environmental sensitivity in the Mangystau region.

3.3. NDVI and WRI spatial distribution

Figure 8 illustrates the spatial distribution of the Normalized Difference Vegetation Index (NDVI) in the Mangystau region. The NDVI values were classified into ten categories to enhance visual interpretation and to distinguish surface types based on vegetation density.

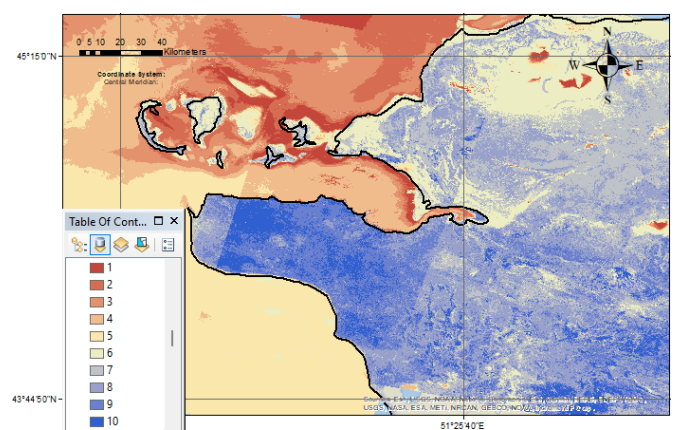


Figure 8. NDVI-Derived vegetation distribution in the Mangystau region

Low NDVI values (red tones) are primarily associated with water bodies and non-vegetated surfaces, indicating minimal or absent vegetation cover. These zones are mainly located along coastal and lacustrine areas. Moderate NDVI classes represent sparsely vegetated or mixed surface conditions, reflecting transitional environments between barren land and vegetated areas.

High NDVI values (blue tones) dominate the central and southern parts of the region, corresponding to areas with

relatively dense and healthy vegetation cover. These zones indicate more favorable ecological conditions for plant growth compared to surrounding arid surfaces.

The NDVI map demonstrates a clear spatial contrast between water, barren land, and vegetated surfaces, highlighting the heterogeneity of land cover in the Mangystau region. This spatial pattern provides an important basis for further ecological and environmental assessments.

Figure 9 shows the spatial distribution of the Water Requirement Index (WRI) in the Mangystau region. The WRI values were classified into ten ordinal classes, where Class 1 (red) represents the lowest soil moisture conditions and Class 10 (blue) indicates the highest soil moisture levels.

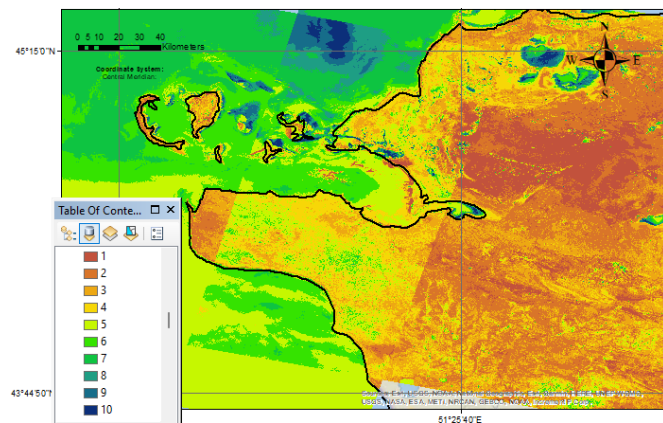


Figure 9. Water requirement index (WRI) map of the Mangystau region

Low WRI values (Classes 1-3) dominate large parts of the eastern and southeastern regions, reflecting arid surface conditions and limited soil water availability. These areas are characterized by high dryness and weak moisture retention capacity. Moderate WRI classes (Classes 4-7) form transitional zones, indicating intermediate soil moisture conditions.

High WRI values (Classes 8-10) are mainly concentrated in localized northern and coastal zones, as well as near water bodies and low-lying terrains. These areas represent relatively humid soil conditions and higher water availability for vegetation.

Overall, the WRI map demonstrates strong spatial heterogeneity in soil moisture conditions across the Mangystau region and provides an important indicator for evaluating hydrological and ecological variability within the study area.

The combined analysis of NDVI and WRI maps reveals a strong spatial consistency between vegetation distribution and soil moisture conditions in the Mangystau region. Areas characterized by high WRI values, indicating elevated soil moisture, generally correspond to zones with higher NDVI values, reflecting healthier and denser vegetation cover. This spatial agreement confirms the dominant role of soil moisture availability in controlling vegetation development under arid and semi-arid climatic conditions.

Conversely, regions with low WRI values are mainly associated with low NDVI levels, indicating sparse or absent vegetation cover. These areas represent environmentally stressed zones where limited water availability restricts plant growth. Transitional zones with moderate WRI values exhibit intermediate NDVI levels, highlighting gradual ecological gradients across the landscape.

Overall, the integrated interpretation of NDVI and WRI demonstrates that soil moisture is a key limiting factor for vegetation distribution in the Mangystau region. The strong correlation between these two indices provides a reliable basis for ecological monitoring, land degradation assessment, and environmental management in arid environments.

Figure 10 presents the overall modeling framework used to assess land degradation and desertification sensitivity in the Mangystau region. The model integrates geomorphological, geological, and ecological indicators within a GIS-based multi-criteria evaluation approach.

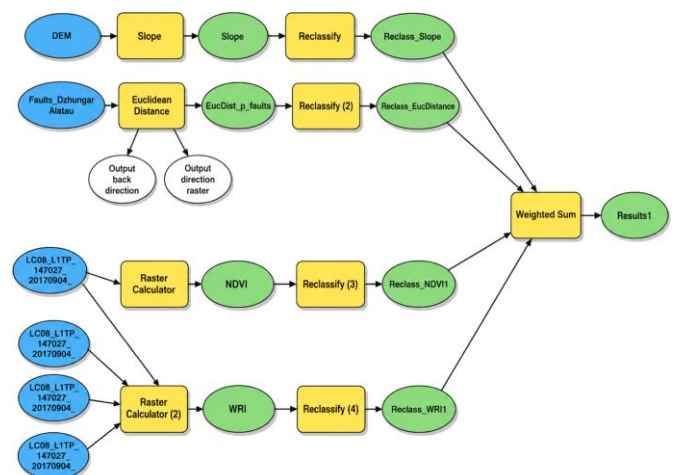


Figure 10. Integrated spatial modeling framework for desertification assessment

Four main thematic factors were included in the model:

1. Terrain slope, derived from the digital elevation model (DEM) using the *Slope* tool and subsequently reclassified into ordinal classes.
2. Distance to active tectonic faults, calculated using the *Euclidean Distance* tool based on mapped fault lines and then reclassified to represent different levels of tectonic influence.
3. Vegetation cover, represented by the Normalized Difference Vegetation Index (NDVI), calculated from Landsat 8 OLI imagery using the raster calculator and reclassified into vegetation density classes.
4. Soil moisture conditions, represented by the Water Requirement Index (WRI), also derived from Landsat 8 OLI imagery and reclassified into soil moisture classes.

Each factor layer was standardized through reclassification to ensure a uniform scale and comparability among variables. The reclassified layers were then integrated using the *Weighted Sum* method, where each factor contributes proportionally to the final composite index based on its relative importance.

4. Conclusions

The integrated analysis of tectonic faults, terrain slope, vegetation cover (NDVI), and soil moisture conditions (WRI) demonstrates that land degradation and desertification processes in the Mangystau region are controlled by a complex interaction of geological, geomorphological, and ecological factors.

Active tectonic faults significantly influence groundwater movement, soil moisture distribution, and slope stability. As a result, areas located in proximity to tectonic structures are more prone to soil instability and surface degradation due to enhanced structural weakness and hydrological disturbances.

Terrain slope plays a key role in regulating surface runoff and erosion intensity. Increasing slope gradients lead to higher runoff velocity, stronger soil erosion, and accelerated loss of fertile soil layers. Consequently, steeper areas exhibit greater susceptibility to land degradation.

Vegetation cover, represented by NDVI, reflects the protective function of plant communities. Low NDVI values indicate sparse vegetation, which reduces soil protection, increases evaporation, and enhances erosion processes. This results in reduced ecosystem stability and increased vulnerability to degradation.

Soil moisture conditions, expressed by WRI, represent the hydrological status of the land surface and the availability of water for vegetation growth. Low WRI values correspond to dry soil conditions, which directly promote soil degradation and intensify desertification processes.

When analyzed together, these factors form an integrated environmental system: tectonic structures control hydrological conditions, terrain slope determines erosion intensity, vegetation cover regulates surface stability, and soil moisture reflects the current degradation state. Their combined interpretation provides a comprehensive framework for assessing land degradation and desertification processes in arid and semi-arid regions. This integrated approach allows a more reliable identification of environmentally vulnerable zones and offers a scientific basis for sustainable land management and desertification control strategies in the Mangystau region.

The final output represents the spatial distribution of land degradation and desertification sensitivity, reflecting the combined influence of tectonic, topographic, vegetation, and hydrological conditions.

This integrated modeling framework allows a comprehensive and systematic evaluation of land degradation processes and provides a robust spatial basis for environmental assessment and land management planning in arid and semi-arid regions.

Author contributions

Conceptualization: MEA, YZ; Data curation: YZ, MEA; Formal analysis: MEA, YZ, SH; Funding acquisition: YZ, MEA; Investigation: YZ, MEA; Methodology: MEA, YZ; Project administration: YZ, MEA; Resources: YZ, SH; Software: MEA, SH; Supervision: YZ, SH; Validation: MEA, YZ; Visualization: MEA, SH; Writing – original draft: MEA, YZ; Writing – review & editing: SH, YZ. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Интегралды көпфакторлы көрсеткіштер негізінде Каспий маңы өңірі жерлерінің деградациясын бағалаудың геокеңістіктік моделі

М.Е. Амирханов¹, Ы. Жакыпбек^{1*}, Сунь Хао²

¹Satbayev University, Алматы, Қазақстан

²Қытай тау-кен және технологиялар университеті, Бейжің, Қытай

*Корреспонденция үшін автор: y.zhakypbek@satbayev.university

Аңдатпа. Шөлейттену және жер деградациясы Қазақстанның Каспий маңы өңіріндегі негізгі экологиялық проблемалардың бірі болып табылады. Бұл зерттеуде интеграцияланған ГАЖ және қашықтықтан зондау әдістерін пайдалана отырып Маңғыстау облысының шөлейттену үрдісіне ұшырауы бағаланады. Төрт бақылаушы фактор ретінде: белсенді тектоникалық жарылымдарға дейінгі қашықтық, жер бедерінің еңістігі, өсімдіктердің нормаланған айырмашылық индексі (NDVI) негізінде есептелген өсімдік жамылғысы және су қажеттілігі индексі (WRI) ұсынған топырақ ылғалдылығы шарттары. Тектоникалық әсерді бағалау үшін евклидтік қашықтықты талдау қолданылды, жер бедерінің еңістік градиенттері SRTM деректерінен алынды, ал NDVI және WRI Landsat 8 OLI суреттерінен есептелді. Барлық факторлар стандартты реттік класстарға қайта жіктелді және шөлейттенуге ұшырау картасын жасау үшін анықталған нәтижені көп критерийлік бағалау үлгісін пайдалана отырып біріктірілді. Нәтижелер жер деградация жағдайларының күшті кеңістіктік гетерогенділігін көрсетеді. Тік беткейлері, төмен NDVI және WRI мәндері бар тектоникалық жарылымдарға жақын аймақтар шөлейттенуге бейім, ал жұмсақ беткейлері, жоғары өсімдік жамылғысы және топырақтың ылғалдылығы жақсы аймақтар экологиялық тұрақтылықты көрсетеді. Зерттеу Маңғыстаудағы жердің деградациясы геологиялық, геоморфологиялық және экологиялық факторлардың жиынтық әсерімен бақыланатынын көрсетеді. Ұсынылған жүйе шөлейттенуді бағалаудың сенімді құралы болып табылады. Сонымен қатар, құрғақ және жартылай құрғақ жерлерде жер ресурстарын тұрақты басқаруды қолдайды.

Негізгі сөздер: топырақ деградациясы, шөлейттену, тектоникалық жарылымдар, жер бедерінің еңістігі, NDVI, WRI, қайта жіктеу.

Геопространственная модель оценки деградации земель Прикаспийского региона на основе интегральных многофакторных показателей

М.Е. Амирханов¹, Ы. Жакыпбек^{1*}, Сунь Хао²

¹Satbayev University, Алматы, Казахстан

²Китайский университет горного дела и технологий, Пекин, Китай

*Автор для корреспонденции: y.zhakypbek@satbayev.university

Аннотация. Деградация земель и опустынивание являются основными экологическими проблемами в засушливом Прикаспийском регионе Казахстана. В данном исследовании оценивается подверженность Мангистауской области опустыниванию с использованием, интегрированной ГИС и дистанционного зондирования. Были проанализированы четыре контролирующего фактора: расстояние до активных тектонических разломов, уклон местности, растительный покров, рассчитанный на основе нормализованного разностного индекса растительности (NDVI), и условия влажности

почвы, представленные индексом потребности в воде (WRI). Для оценки тектонического воздействия был использован анализ евклидовых расстояний, градиенты склонов были получены на основе данных SRTM, а NDVI и WRI были рассчитаны на основе снимков Landsat 8 OLI. Все факторы были реклассифицированы в стандартные порядковые классы и интегрированы с использованием модели многокритериальной оценки взвешенной суммы для создания карты подверженности опустыниванию. Результаты указывают на сильную пространственную неоднородность условий деградации. Районы вблизи тектонических разломов с более крутыми склонами, низкими значениями NDVI и WRI наиболее подвержены опустыниванию, в то время как регионы с пологими склонами, более высоким растительным покровом и лучшей влажностью почвы демонстрируют большую экологическую стабильность. Исследование демонстрирует, что деградация земель в Мангистау контролируется совокупным воздействием геологических, геоморфологических и экологических факторов. Предлагаемая система представляет собой надежный инструмент для оценки опустынивания и поддерживает устойчивое управление земельными ресурсами в засушливых и полузасушливых районах.

Ключевые слова: деградация земель, опустынивание, тектонические разломы, уклон местности, NDVI, WRI, реклассификация.

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