OPEN ACCESS
PAPER

Mongolian Journal of Geography and Geoecology - MJGG

Received: 09 May 2025; Accepted: 12 June 2025; Published online: 1 September 2025
https://doi.org/10.5564/mjgg.v62i46.4130

Human impacts on pasture degradation (A case study of the Dornod, Sukhbaatar, Khentii provinces)

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CITATION
Narantsatsral Ts, Danzanchadav G, Telmen P, Urtnasan M, Ikhbayar Ts (2025) Human Impacts on Pasture Degradation (A case Study of The Dornod, Sukhbaatar, Khentii Provinces).
Mongolian Journal of Geograhy and Geoecology, 62(46), 1–8.
https://doi.org/10.5564/mjgg.v62i46.4130

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ABSTRACT
As Mongolia transitioned to a market economy, rapid population and economic growth have spurred human settlements and significant urbanisation. Over the last two decades, Mongolia's population has increased by 1 million and livestock numbers have soared by over 30 million. This growth, coupled with the expansion of urban areas and road networks, has intensified pressure on land resources, leading to degradation. Notably, pastureland constitutes over 80 percent of Mongolia's total land area. This study aims to identify and map the human impacts contributing to pasture degradation in Mongolia's eastern regions, i.e., Dornod, Sukhbaatar, and Khentii provinces. We developed a map that illustrates these human impacts by considering eight factors rooted in recent research and the particular land use characteristics of Mongolia. These factors include the proximity of wells, rivers and lakes, winter and spring camps, road networks, settlement areas, mining areas, cropland, and livestock density. To assess the human impacts, we produced individual maps for each of the eight selected factors, culminating in a comprehensive assessment map. Our findings reveal that 12.6 percent of the eastern region, equivalent to 3,607 thousand hectares, remains unaltered by human activities. In contrast, 62 percent of the region (17,742 thousand hectares) experiences low impact, 24.2 percent (6,935 thousand hectares) encounters moderate impact, and 1.2 percent (337 thousand hectares) is highly affected by human activities.

KEYWORDS
Pasture, Pasture degradation, Human impact

1. INTRODUCTION

In recent years, global warming and climate change have intensified aridification, desertification, and land degradation, with human activities significantly driving these processes. Population growth, urban expansion, growing road networks, and increased livestock numbers heighten pressure on the land. Economic and social growth drives various activities that degrade the natural environment and landscape. In addition, human activity impacts can serve as indirect indicator of changes in natural conditions [1]. According to Mongolia's Fifth Land Degradation and Desertification Assessment Survey, 76.9 percent of the country's territory is affected by land degradation [2]. From 2000 to 2023, Mongolia's population increased by over 1 million (43 percent) and livestock numbers doubled, rising from over 30 million to approximately 65 million (114 percent increase) [3]. Mongolia's transition to a market society and rapid population and economic growth have spurred urbanization. In the 1950s, over 20 percent of the population lived in urban areas, while as of 2023, this figure is 70.8 percent [3].

The State Report of the Unified Land Fund indicates that between 2001 and 2022, agricultural land decreased by 16,606.4 thousand hectares, a 13 percent decline, and forest land shrank by 4,372.1 thousand hectares, or 23 percent. Conversely, urban areas expanded by 585.7 thousand hectares, a 140 percent increase, and land for roads and utilities grew by 468.2 thousand hectares, or 127 percent [4]. As of 2023, pastureland accounts for 83 percent of Mongolia's total land area and 86 percent of its eastern region (Dornod, Sukhbaatar and Khentii provinces).

To create a map of human impacts on pasture and land degradation in the selected area, we considered eight factors, i.e., wells, rivers and lakes, winter and spring camps, road network, settlements, mining areas, croplands, and livestock density, based on recent research and Mongolia's land use characteristics. Pastoralists naturally setlle around wells and water sources, but intense grazing degrades surrounding areas. The limited water supply for pastures contributes to the degradation [5]. Currently, only about 50 percent of the country's total pastures have year-around water supply, leading to overuse [6]. Old hand wells in the Gobi and dry steppe regions cannot support large livestock numbers, causing nearby pastures to degrade [7]. Vegetation around wells and water points deteriorates due to insufficient surface water, making wells a significant human activity driven factor [8]. A survey of 317 herder households in Khentii and Dornod provinces found that herders rely on open water, e.g., rivers and lakes, for domestic use and livestock farming in summer and autumn [9]. Mongolia's unique nomadic pastoralism sees herders moving with their livestock across four seasons and using pastureland collectively. They settle near open water sources in the warm months and in sheltered spots, i.e., camps, for winter and spring, with land certificates issued for these camps. While essential to the country's economy, roads near settlements and temporary campsites contribute to pollution and soil degradation. Dirt roads, covering 90 percent of the country's road network, affect soil properties adversely [10].

Population size, distribution, and density negatively impact global biodiversity [11]. As mentioned, 70.8 percent of Mongolia's population resides in urban areas as of 2023. Intense industrialization and urban development contribute to human-induced soil erosion [12]. Mining create significant environmental burdens, causing surface damage, e.g., quarries, dumps, and tailings dams, and impeding geosystem recovery [1]. There are 28,940.1 hectares of mining-damaged land in Mongolia [2]. According to the 2023 Unified Land Fund report, 1,182.6 thousand hectares are cropland [13]. Mechanical pressure and constant loss of mineral nutrients due to cropping practices degrade soil structure, reduce fertility, and threaten natural plant species [1]. Livestock numbers are a major factor affecting pasture conditions and degradation, with numerous recent studies emphasizing the significant impact of grazing intensity on pastures. Excessive livestock numbers lead to high grazing pressure, which alters soil properties, causes damage, and accelerates degradation. This in turn negatively affects plant productivity, inhibits the growth of nutrient-rich species, and exacerbates signs of pasture degradation [14].

Overall, this study aims to assess human impacts on pastures and to map the areas affected by these impacts in the eastern region. We developed a spatial impact framework for each of the eight human factors affecting pasture degradation, assigning specific impact distances, to illustrate their effects as of 2020 and to produce a comprehensive map of human impacts.

2. RESEARCH METHODS

In this study, to identify human impacts affecting pasture degradation and to create a comprehensive map of human impacts, the classes and extent of the

factors were determined based on previous research studies. The impact map was created using the human impact mapping methodology developed by Sanderson in 2002 [15]. The class of influence was classified as high, moderate, low, and unaffected. When creating a factor map, the class of influence of each impact was determined, divided into specific hierarchical categories, and evaluated using the appropriate scoring method for each case. However, when creating a comprehensive assessment map of human impacts, a combination of the multi-criteria decision analysis (MCDA) method and the ranking matrix method were used.

The AHP (analytical hierarchy process) ranking matrix analysis method [16] is a method that ranks selected factors in order of importance and determines the weight value of the criteria ranking matrix (Saaty, T.L., 1977). It is calculated using the following formula:

$$CR = \frac{CI}{\text{RI}} \quad (1)$$

CR - Compliance Ratio
RI – Randomness Index
CI – Compliance Index.

$$CI = \frac{\lambda max - n}{\text{n}-1} \quad (2)$$

λ max- Matrix eigenvalue
n- Number of elements in the matrix
CR>0.1, the weighting ratio is not reliable and needs to be recalculated.
CR≤0.1 is less, the weight ratio is correct and the analysis continues.

When creating a comprehensive human impact assessment map, each factor layer is multiplied by the weight value determined for each factor and then summed. It is calculated using the following formula:

$$S_i = \sum X_i W_i \quad (3)$$

Xi – Factor
Wi – Factor weight value

3. RESULT

The scope and map of the impact of human factors on pasture degradation are presented in Table 1, based on previous studies.

Wells: The impact map for wells in Dornod, Sukhbaatar, and Khentii provinces shows that 20,395 thousand hectares (71,3 percent) remain unaffected. In contrast, 3,774 thousand hectares (13 percent) are affected by low impact; 3,167 thousand hectares (11 percent) by moderate impact; and 1,285 thousand hectares (4 percent) by high impact (Figure 1).

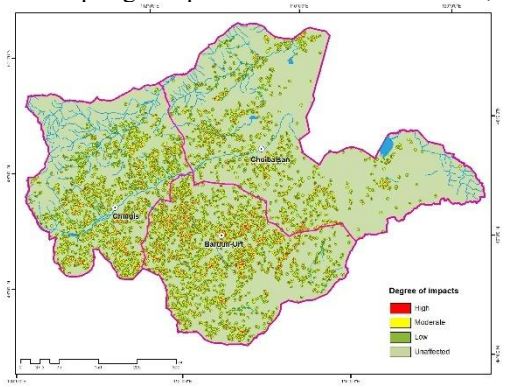
Table 1. Human impacts affecting pastures, scope and class of influence

Impacts		Degree of impact				Source	Scale
		Unaffected	Low	Moderate	High		
Wells		More than 3 km	2-3 km	1-2 km	Up to 1 km	Topographic map	1:100000
Rivers and lakes		More than 3 km	2-3 km	1-2 km	Up to 1 km	Basemap	1:1000000
Winter and spring camps		More than 4 km	3-4 km	2-3 km	Up to 2 km	Open Data Portal, Government of Mongolia	1:100000
Road network	National level	More than 3 km	500 m-3 km	90-500 m	0-90 m	National Atlas of Mongolia	1:5000000
	Local level	More than 500 m	90-500 m	0-90 m	-		
	Railway	More than 500 m	-	90-500 m	0-90 m		
Settlement areas	Provincial center	More than 10 km	5-10 km	Up to 5 km	-	Land cover classification, Landsat satellite image	1:60000
	Soum center	More than 5 km	Up to 5 km	-	-		
Mining areas		More than 10 km	5-10 km	1-5 km	Up to 1 km	Mineral resources and	1:100000

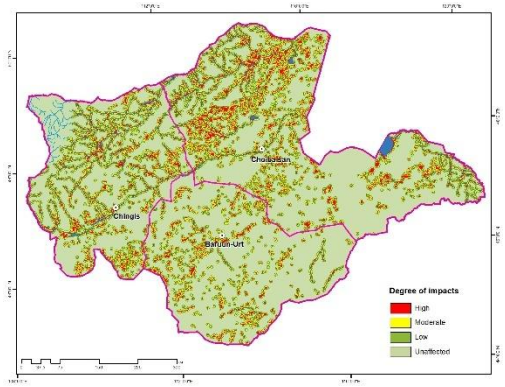
					Petroleum Authority of Mongolia	
Cropland	-	arable land	-	cultivated area	Land cover classification, Landsat satellite image	1:60000
Livestock density	Under 50	50.1-100	100.1-500	More than 500.1	Mongolian Statistical Information Service	-

Rivers and lakes: According to the human impact map for rivers and lakes in the three provinces, 17,790 thousand hectares (62 percent) remain unaffected. However, 3,381 thousand hectares (12 percent) are highly affected; 3,828 thousand hectares (13 percent) are moderately affected; and 3,622 thousand hectares (13 percent) are slightly affected (Figure 1).

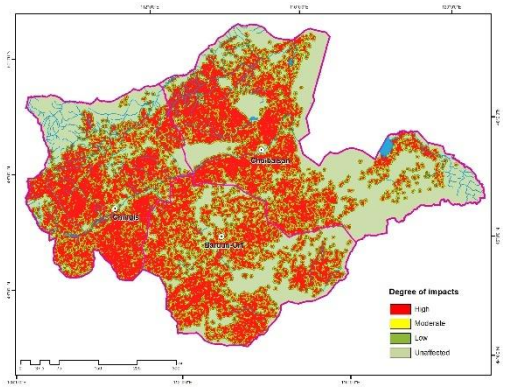
Winter and spring camps: The impact map of herders winter and spring camps indicates that a total of 19,490 thousand hectares of land across the three provinces are affected. Of this, 12,249 thousand hectares (43 percent) are impacted by high disturbance; 4,556 thousand hectares (16 percent) experience moderate impact; and 2,685 thousand hectares (9 percent) are affected by low impact. Conversely, 9131 thousand hectares (32 percent) of the area remain unaffected (Figure 1).



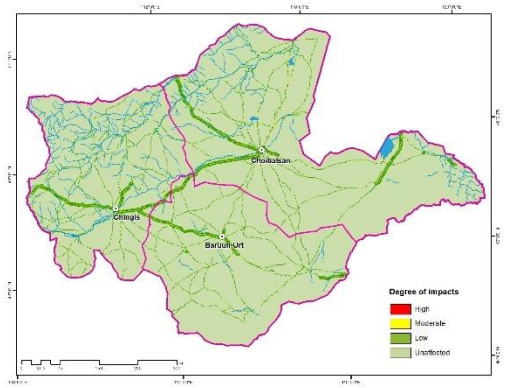
Wells



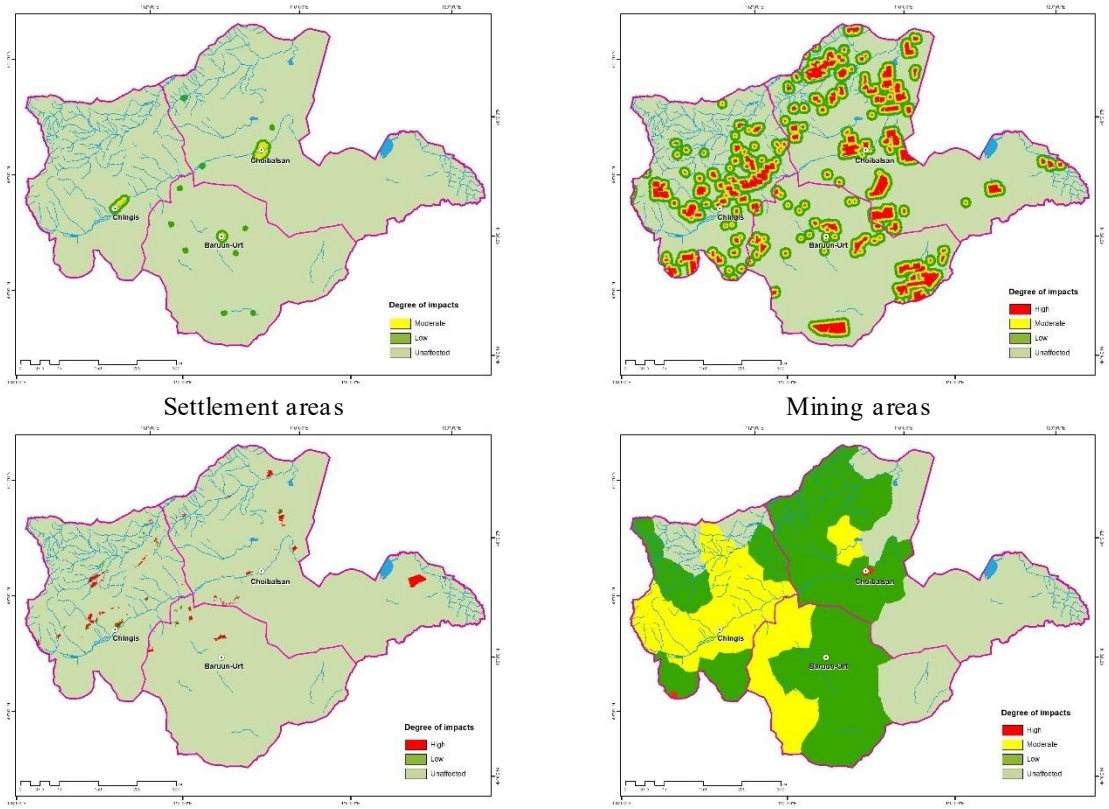
Rivers and lakes



Winter and spring camps



Road network



Settlement areas | Mining areas

Cropland | Livestock density

Figure 1. Impact of each factor

Road network: Based on the assessment of road impact, the total area of the three provinces is 26,742 thousand hectares. Of this, 93.4 percent (25,000 thousand hectares) were not affected. Additionally, 1,533 thousand hectares (5.4 percent) experienced low impact, 318 thousand hectares (1.1 percent) were affected by moderate impact, and 28 thousand hectares (0.1 percent) faced high impact (Figure 1).

Settlement areas: In Dornod, Khentii, and Sukhbaatar provinces, 98.6 percent of the total area remains unaffected by settlement development. Nonetheless, 267 thousand hectares (0.9 percent), are impacted by low-intensity settlement activities, while 123 thousand hectares (0.4 percent) experience moderate impacts (Figure 1).

Mining areas: Approximately 31.5 percent of the total land area in the eastern provinces is affected by mining activities. Of this, 1,735 thousand hectares (6 percent), are affected by low impact; 3,012 thousand hectares (11 percent) by moderate impact; 4265 thousand hectares (15 percent) by high impact (Figure 1).

Cropland: The cropland impact map shows that 99.1 percent of the total area, or 28,377 thousand hectares, remains unaffected. Slight impacts are observed on 0.2 percent or 51 thousand hectares, while 0.7 percent or 193 thousand hectares are highly affected (Figure 1).

Livestock density: In the three eastern provinces, livestock density measured as sheep per unit area (1 per km^2) reveals that three soums have more than 501 sheep/km^2, accounting for 0.2 percent of the total study area; sixteen soums have 101–500 sheep/km^2, covering 23.4 percent of the area; nineteen soums have 51–100 sheep/km^2, representing 42.9 percent; and seven soums have fewer than 50 sheep/km^2, comprising 33.5 percent (Figure 1).

Integrated assessment of human impact: In addition to the individual maps for the eight selected factors influencing pasture and land degradation in Dornod, Sukhbaatar, and Khentii provinces, a comprehensive assessment map was developed. The impact weightings used to generate the integrated assessment map are shown in Table 1.

Table 1 . The weight of factors

Factors	Weight
Wells	33.132
Rivers and lakes	23.066
Winter and spring camp	15.724
Road network	10.59
Settlement areas	7.094

Mining areas	4.768
Cropland	3.27
Livestock density	2.356

The combined impact map shows that 12.6 percent of the total area in the eastern region, or 3,607 thousand hectares, remains unaffected by human activities. About 62 percent or 17,742 thousand hectares are slightly impacted; 24.2 percent or 6,935 thousand hectares face moderate impact; and 1.2 percent or 337,0 thousand hectares are highly affected (Figure 2, Figure 3).

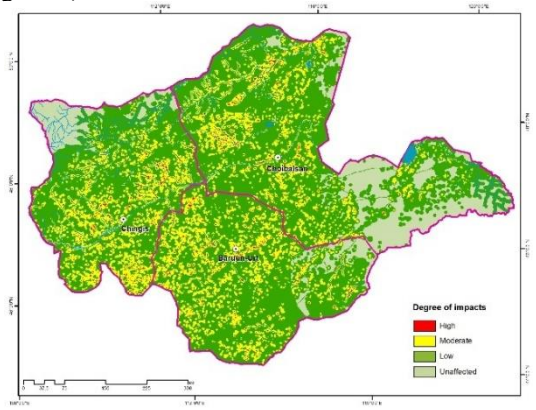


Figure 2. Integrated assessment of human impacts

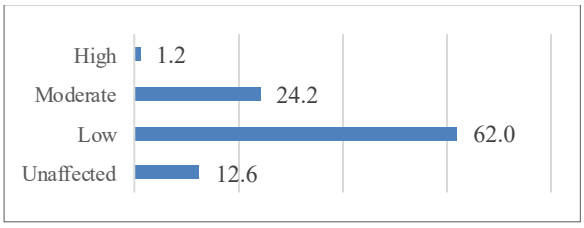


Figure 3. Area affected by human impacts (%)

4. DISCUSSION

In this study, the influence of each of the eight selected factors was quantified and mapped. Specifically, the extent of influence of wells was categorized as follows: high impact within a distance of up to 1 km, moderate impact between 1 and 2 km, low impact between 2 and 3 km, and no influence beyond 3 km. The map was developed based on these classifications.

This assessment is based on the research findings that indicate that the watering radius for livestock is 2.5 km during summer and autumn and 3 km during winter and spring [6]. Additionally, according to the methodology for developing the "Soum Territorial Development Plan," the watering radius for livestock is defined as 2.5 km for sheep, goats, and cattle, and 5 km for horses in medium-yield pastures in mountainous areas, and similarly, 2.5 km for sheep, goats, and cattle, and 5 km for horses in medium-yield steppe pastures [17]. Moreover, a study on pasture irrigation in the Gobi provinces estimated a watering radius of 3 km for small livestock and 5 km for large livestock. However, in practice, both small and large livestock are watered within a radius of 3 km [7]. Also, considering the radius of livestock watering and tourism along the rivers and lakes, the map was developed as follows: within 1 km of a river or lake, the impact level was high; between 1 and 2 km, the impact level was moderate; between 2 and 3 km, the impact level was low; and beyond 3 km, there was no impact.

The location data of herders winter and spring camps were selected as a factor influencing pasture degradation. This selection is supported by a study indicating that, during winter and spring, small livestock graze within a radius of 2 km from their camps, while large livestock graze within a radius of 4 km [18]. Accordingly, the impact of winter and spring camps was classified as high within a 2 km radius, moderate between 2 and 3 km, low between 3 and 4 km, and nonexistent beyond 4 km from the camp locations.

Regarding roads, they are used with varying intensity and load; based on two research studies, the impacts were assessed as follows. For national roads, impact was considered high within 0-90 meters, moderate between 90 and 500 meters, low between 500 meters and 3 km, and no impact beyond 3 km. For local roads, impact was rated as moderate within 90 meters, low between 90 and 500 meters, and nonexistent beyond 500 meters [19], [20].

Settlements are classified according to the scale of Mongolian administrative units. Since population concentration varies between aimag centers and soum centers, the impact zones were categorised as follows: areas within 5 km of an aimag (province) or soum center are considered to have moderate impact; distances from 5 to 10 km are considered to have low impact; and areas beyond 10 km are considered to have no impact. The impact zone of mining is determined differently for areas up to 5 km from the soum center, with no impact assigned to areas beyond 5 km. Each mine determines its impact zone differently, for example, Oyu Tolgoi LLC has set its impact zone at 10 km, and Energy Resources LLC has set its impact zone at 1 km [21]. The Ministry of Energy and Mineral Resources also states that the impact zone of active mining activities is 1 km in radius [22]. Therefore, based on these sources, the distance from the mining areas up to 1 km is assessed

as high impact, the distance from 1 to 5 km is moderate, the distance from 5 to10 km is low impact, and the distance from 10 km is no impact. The study used vector data of agricultural land, and agricultural land was classified as high impact and adjacent landas low impact. Also, as livestock density increases, pasture use in a given environment becomes more intensive, so livestock density data was processed as a per unit area (per 1 sq.km. area). The impact level map was based on [23] the Desertification Atlas of Mongolia (MET, 2021). The scope and extent of each factor's impact were determined and mapped based on 2-3 research sources.

5. CONCLUSION

This study attempted to identify and map the human factors influencing pasture and land degradation, adjusted to the characteristics of land use in Mongolia. The results indicated that over 80 percent of the total land area in the eastern region (Dornod, Sukhbaatar and Khentii provinces) has been affected by human influence to varying degrees, ranging from low to high. Specifically, 1.2 percent of the area was found to be under high impact, while 24.2 percent experienced a moderate impact.

The study assessed human impacts on actively used pastureland by analyzing livestock density per unit area, along with data for rivers, wells, water points, and winter and spring camps. Availability of open data on livetsock numbers per herder family would have enabled more precise and detailed mapping.

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