A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

Mining and Overgrazing: Investigating Correlation Between Two Major Drivers of Rangeland Degradation in Mongolia

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ABSTRACT OF THESIS submitted by:

Jargalmaa SARANTUYA for the degree of Master of Science and entitled: Mining and Overgrazing: Investigating Correlation Between Two Major Drivers of Rangeland Degradation in Mongolia.

Month and Year of submission: June, 2024.

This study investigates the correlation between mining activities and overgrazing, two significant drivers of rangeland degradation in Mongolia, and aims to understand their collective impact on the pastoral ecosystems that are vital to Mongolia's economy, culture, and environment. Despite Mongolia's vast territory and low population density, the country faces severe land degradation due to climate change, the rapid increase in livestock numbers, and the expansion of mining activities. Acknowledging the lack of literature that investigates the correlation between mining and overgrazing, this study has sought to contribute to the literature. By using livestock population analysis, Geographic Information System (GIS) tools, remote sensing data and national rangeland monitoring assessment reports, the research compares regions with active mining operations to those without, analyzing the intensity of overgrazing and the extent of land degradation. The findings reveal a suboptimal correlation between mining activities and increased overgrazing pressures in the area with mining activity.

Keywords: Rangeland degradation, mining impact, nomadic pastoralists, land use, Mongolia

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1. Introduction

1.1. Background

The Mongolian Plateau is situated in a dry, desert region in the interior of Northeast Asia, where forest, grassland, and desert intersect horizontally. Climate change and human activities adversely affect Mongolia's land cover, leading to accelerated land degradation.

The rangelands lands of Mongolia hold profound significance, contributing to the nation's economic, cultural, and ecological well-being. Economically, these rangelands are the lifeblood of Mongolia's agricultural sector, providing forage for livestock, including sheep, goats, cattle, camels, and horses collectively and traditionally referred to as the "five jewels". The economic value derived from the rangelands is substantial, as it sustains the production of meat, wool, and dairy, forming a crucial part of the country's economy. Culturally, the grasslands are deeply ingrained in Mongolia's heritage, serving as the backdrop for the traditional nomadic way of life that has been practiced for thousands of years. Approximately 30 percent of Mongolia's population relies on nomadic herding for their entire livelihoods, emphasizing the integral role of the pasture in supporting local communities. Beyond economic and cultural dimensions, the pastureland provides vital ecosystem services, playing a key role in water regulation, carbon sequestration, and habitat preservation. The preservation of Mongolia's pasturelands is not only essential for sustaining the economic viability of the agricultural sector but also for safeguarding the rich cultural heritage and diverse ecosystems that define this landscape (Liu et al. 2021).

Despite Mongolia's expansive territory and low population density, there is a persistent threat of land degradation. The predominant anthropogenic factors—namely overgrazing and mining activities—stand out as major contributors to the issue of land degradation. Overgrazing is considered to be the major cause of degradation (Sternberg 2012, 811). In

1990, the number of livestock in Mongolia was approximately 25 million. In 2022, it rose to more than 71 million (National Statistics Office 2023). As of 2015, overgrazing activity affected 76.8% of all Mongolian territory (IMF 2019).

Mongolian nomadic pastoralists are extremely vulnerable to land degradation, as their way of life is heavily dependent on livestock production. The prevailing belief is that these pastoralists contribute largely to this issue by increasing their livestock numbers to boost their income. However, simply blaming the nomadic pastoralists could be shortsighted as the issue could be more complicated. Nomadic pastoralists are not the only ones who are using the land.

Mining activities are widespread and an important source of government revenue. However, mining has significant social impacts, including forced displacement and health issues for pastoralists. In Mongolia, there are 2,754 valid mineral licenses. Of these, 1,022 are exploration licenses and cover 5,108,045.10 hectares (3.2% of Mongolia's territory). There are also 1,732 mining licenses, covering 1,843,211.82 hectares (1.17% of Mongolia's territory).

Overgrazing and mining operations are thought to be separate drivers of land degradation. Considering that Mongolia stands as one of the least densely populated nations globally, one might initially assume that mining has a limited impact on rangeland reduction due to its seemingly small size. Nevertheless, the repercussions of mining extend beyond the immediate extraction site. Furthermore, the arid climate and sparse vegetation in Mongolia's rangelands necessitate larger areas to sustain a specific livestock count compared to more non-arid regions (Gankhuyag 2013). However, there is a lack of comprehensive studies on the correlation between these drivers.

1.2. Problem Statement

Mongolia’s rangelands are experiencing accelerated degradation and two of the major anthropogenic drivers are overgrazing and mining activities. Overgrazing, primarily driven by a significant increase in livestock numbers since the 1990s, is traditionally seen as the principal cause of rangeland degradation. However, the rapid expansion of mining activities, which occupy substantial portions of rangeland and affect directly and indirectly affect pastoral ecosystmes, also plays a significant role. Despite the vast territory and sparse population of Mongolia, the combined pressures from overgrazing and mining are intensifying, leading to the degradation of crucial pastoral ecosystems.

1.3. Research question and hypothesis

The research question guiding this study is: **To what extent does mining activity contribute to overgrazing in Mongolia's pastoral ecosystems?** The hypothesis posits that the surge in mining activities, including the physical loss of land and pollution, has significantly reduced the available grazing land for the nomadic pastoralist population. This reduction has intensified overgrazing pressure on their livestock. Given the arid climate and sparse vegetation of Mongolian grasslands, larger areas are required to support a specific number of livestock. Consequently, the reduction in available pastureland due to mining activities is significant despite Mongolia's sparse population. This study aims to explore and quantify this correlation to better understand the combined impact of these two major drivers on land degradation.

1.4. Research aims and objectives

The primary aim of this research is to investigate the correlation between mining activities and overgrazing in Mongolia's pastoral ecosystems, with the goal of understanding their combined impact on land degradation. To achieve this aim, the research will pursue the following five main objectives: First, conduct a comprehensive review of existing studies on the impact of mining and overgrazing on land degradation in Mongolia. Second, gather statistical data on mining activities and livestock numbers to establish a data-driven foundation for the analysis. Third, I will utilize remote sensing technology to calculate the Normalized Difference Vegetation Index (NDVI) over the years during which the most significant rangeland degradation has occurred. Fourth, compare the intensity of overgrazing in regions with active mining operations to those without such activities to identify correlations and contextual factors. These objectives are designed to provide a holistic understanding of the interplay between mining and overgrazing, informing sustainable resource management policies.

1.5. Thesis outline

In Chapter 2, I will present an overview of rangeland degradation in Mongolia, introducing the key drivers such as grazing, and precipitation, and outlining the major research gaps. Chapter 3 will detail the methodology, including data collection, study area selection, and analysis methods, with a focus on remote sensing and correlation analysis using difference-in-difference. In Chapter 4, I will present the significant findings from the livestock population analysis in the selected study areas and the NDVI results, illustrating the correlation between mining activities and changes in grazing intensity. Chapter 5 will discuss the implications of these findings in Mongolia, exploring how the results support or challenge the hypothesis. Finally, the last chapter will summarize the key findings of the study and suggest future research directions.

2. Literature review

2.1. Overview of rangeland degradation in Mongolia

Rangelands are among the world's major ecosystems, covering approximately 70% of the Earth's land surface, excluding Antarctica. In Mongolia, rangelands cover 109,584.6 square kilometers, which is 70.1% of the country's total area of 156,411.6 square kilometers. In a 2022 study reviewing existing literature on rangeland degradation in Mongolia, the authors highlighted that there is no single, universally accepted definition of "rangeland degradation."

In Mongolia, where rangelands cover more than 70 percent of the land area, the concepts of land degradation and rangeland degradation are often intertwined and frequently used interchangeably. In Mongolia, most studies assessed degradation through changes in vegetation or land cover, often using field data or remote sensing. In contrast, soil properties and other ecosystem components were less frequently measured. In the rangeland degradation literature, the most frequently mentioned drivers are grazing, precipitation, and temperature, each of which affects different ecological zones to varying degrees. Grazing is cited as the predominant driver of rangeland degradation, particularly in the steppe, forest steppe, and desert steppe zones. The intensity of grazing pressure, resulting from an increase in livestock numbers, particularly goats, since the 1990s, has led to significant changes in vegetation and soil properties (Sainnemekh et al. 2022).

The work of Jamsranjav et al. (2018) provides significant insights into this issue through a detailed application of a dryland degradation framework across various ecological zones in Mongolia. The study found that livestock use had minimal impact on soil properties, plant species richness, and standing crop biomass across the country's diverse ecological zones. However, subtle changes in vegetation were observed, with the most significant effects in the steppe zone, moderate effects in the desert steppe, and limited effects in the mountain/forest and eastern steppes. This challenges the prevalent narrative of severe livestock-induced degradation, revealing that very severe and irreversible degradation is rare, affecting only 1–18% of the land area, while most rangelands are slightly (33–53%) or moderately (25–40%) degraded.

Climate warming and human activities are both contributing to the deterioration of Mongolia's land cover, speeding up the degradation process. But it is difficult to say which one is the more prevalent driver. According to Batkhishig (2013), researchers agree that anthropologic factors dominate the current land degradation process in Mongolia. Key human activities contributing include mining, road erosion, overgrazing, agricultural soil erosion, and soil pollution. In his paper, mining activities have significantly degraded the land, with 16,061.5 hectares destroyed due to mining exploration and 1,904.5 hectares due to mining investigation. And it is only in 2010. In 2011, there were more 38 million hectares land (24,6 percent of the total land area) was subject to 4,728 mining licenses, which is quite substantial.

The prevailing academic consensus indicates that overgrazing is the most significant driver of rangeland degradation in Mongolia.

2.2. Issue of overgrazing

Overgrazing is a critical issue in Mongolia, primarily driven by the rapid increase in livestock numbers following the privatization of livestock in the 1990s, the livestock population rose from 25.6 million in 1992 to 71 million in 2023 before winter (NSO 2023). During the winter 2023 – 2024, Mongolia faced very severe dzud, a natural disaster unique to Mongolia, and lost at least 5.2 million livestock (OCHA 2024). At this time the total livestock population is around 64 million.

Sternberg (2012) provides a critical examination of the piosphere effect, focusing on areas around water points where livestock congregate and its impact on vegetation in the Mongolian steppe grasslands. Contrary to the common expectation that overgrazing would severely degrade these areas, the study found that vegetation density was actually higher near water points. This suggests that livestock grazing is not overly concentrated at these sites, challenging the conventional belief that overgrazing near water sources leads to significant environmental degradation. More importantly, Sternberg’s findings argue that climatic factors, particularly precipitation and temperature, play a more significant role in vegetation dynamics than grazing alone. This perspective highlights the resilience of cold steppe environments and the effectiveness of traditional nomadic pastoralism, which supports sustainable rangeland use through mobility and adaptive grazing strategies.

Complementing Sternberg's findings, Jamsranjav et al. (2018) applied a dryland degradation framework across Mongolia's diverse ecological zones, providing a broader view of rangeland degradation. Their study revealed that while livestock use does impact vegetation, the overall severity of degradation is often overstated. The research showed minimal effects on soil properties and plant biomass but noted subtle changes in vegetation cover and the abundance of palatable plants. This nuanced perspective challenges the dominant narrative of severe overgrazing-induced degradation and suggests that Mongolian rangelands possess a higher resilience, necessitating targeted, context-specific management approaches. By highlighting the variability in grazing impacts across different ecological zones, Jamsranjav et al. (2018) stated the importance of tailored management strategies that account for local environmental conditions.

In a more comprehensive study, Munkhzul et al. (2021) examined the effects of grazing on Mongolian steppe vegetation by analyzing data from 44 publications. Their findings indicate that heavy grazing generally reduces biomass, species richness, and vegetation cover, particularly in dry and desert steppes. These results highlight the detrimental impacts of intense grazing on certain steppe types, emphasizing the need for sustainable grazing practices that consider local environmental conditions.

These studies reveal how complex the issue of overgrazing can be. Not only the livestock population but also climatic factors, and traditional land use practices also impact the degradation that is caused by nomadic pastoralism. The traditional pastoralist practices are already well-suited for the ecosystem and have excellent potential for resilience and adaptive capacity. But there are social economic and environmental factors that might be influencing the overgrazing situation in Mongolia.

2.3. Impact of Mining on Nomadic Pastoralists and Pastoral Ecosystem

"Extractive industry and extensive livestock husbandry are increasingly at odds." (Asian Development Bank, 2013, p. 17). The intersection of mining activities and traditional pastoralism presents a complex landscape of economic, social, and environmental dynamics.

2.3.1. Economic impact of mining on nomadic pastoralists

Sternberg et al. (2022) highlight that the influx of mining activities has led to the displacement of herders, reduced access to grazing lands, and increased competition for water resources. These economic pressures force pastoralists to seek alternative livelihoods, often resulting in a partial or complete abandonment of traditional herding practices. The expansion of the mining sector in Mongolia has brought significant economic changes, often at the expense of traditional pastoral livelihoods. According to Lahiri-Dutt and Dondov (2017), many nomadic herders have turned to informal mining as a coping strategy in response to economic pressures, climate change, and state policies favoring mining investments. This shift is not solely driven by poverty but also by the allure of mineral wealth and the need to adapt to new economic realities(Lahiri-Dutt and Dondov 2017).

The socio-cultural fabric of nomadic pastoral communities is deeply intertwined with their traditional way of life. The transition from herding to mining involves significant social restructuring. Studies indicate that the move to mining has led to changes in household dynamics, with some family members migrating to urban centers or mining sites, while others remain to manage reduced herds (Sternberg, Mayaud, and Ahearn 2022). Lahiri-Dutt and Dondov (2017) argue that this transition also affects social cohesion and cultural identity. The traditional knowledge and skills associated with pastoralism are at risk of being lost as younger generations increasingly engage in mining and other non-pastoral activities.

2.3.2. Mining Impact on Pastoral Ecosystem

The environmental impact of mining on pastoral ecosystems is profound. Mining activities lead to land degradation, soil pollution, and water contamination, all of which directly affect the health of the grasslands and the livelihoods of pastoralists. Pecina et al. (2023) report significant soil pollution with heavy metals in mining areas, posing health risks to both humans and livestock. Additionally, the extraction processes disrupt the natural vegetation, leading to erosion and desertification. This degradation reduces the availability of pasture and water resources, exacerbating the challenges faced by pastoral communities in maintaining their herds (Pecina et al. 2023).

Mining leads to significant land disturbances, contributing to erosion, desertification, and loss of vegetation. Water usage and contamination by mining operations reduce the availability and quality of water for both humans and livestock, further stressing the ecosystem. The Asian Development Bank (2013) reports that extractive industry and extensive livestock husbandry are increasingly at odds. Mining activities require significant amounts of water, and mineral deposits are often located on lands traditionally used by herders. This creates increased competition for resources, frequently leading to the displacement of herding communities. The resulting loss of essential resources, including grazing areas, seasonal pastures, and water supplies, has a profound impact on pastoralist livelihoods. Even though some water is recycled, the projected consumption by mining operations remains substantial.

2.3.3. Economic and Social impact

Mining improves market access for nomadic pastoralists, which might lead to higher consumption and sale of livestock. Soums with moderate mining activity show about a 6% increase in livestock consumption compared to those without mining (Gankhuyag 2013)

However, the expansion of the mining sector has also added stress to the pastoral economy, which is already vulnerable to climate hazards and degraded pastures. The "Making Grasslands Sustainable in Mongolia" report (ADB 2013) highlights that the expansion of mining has led to the physical destruction of rangelands, displacement of nomadic pastoralist communities, and fragmentation of traditional grazing areas. This displacement forces nomadic pastoralists to concentrate their livestock in smaller, often less suitable areas.

The study (Gankhuyag 2013) finds that mining is associated with non-negligible increases in livestock mortality. Specifically, mining has a strong positive association with the mortality of small ruminant livestock (goats and sheep), while a puzzling negative association is found with large livestock (cattle, horses, and camels). Goats, which are significant for nomadic pastoralists' income due to cashmere production, show a higher mortality rate associated with mining activities. A 30% increase in the area mined in a soum would be associated with a 3.9 percentage points increase in goat mortality. Moreover, mining activity may also have health impacts on livestock. A study (Bataa et al. 2020) conducted in the Dornogovi province revealed that the lungs of livestock from mining areas exhibited inflammatory nodules, while other edible organs showed significant transitional changes. The study concludes that dust exposure from the mining areas may be responsible for these dysfunctions.

2.3.4. Mining areas of Mongolia

Following the re-enactment of the Minerals Law in 1997, the number of exploration licenses increased dramatically, peaking in 2004 with 2,024 licenses, covering 16.4% of Mongolia's territory. A notable decline occurred after 2006 when the Minerals Law was amended to require a tender process for license issuance. This decline was exacerbated by the 2010 ban on new licenses, which reduced the number of licenses to just 145 that year. The 2014 amendment introduced a system where licenses were issued only for government-approved areas, further reducing their number to 16 in 2015. The most recent amendment in 2017 shifted the issuance process exclusively to tenders, resulting in only 109 licenses being issued by 2021. Coal mining license areas alone make up 44 percent of all the mining licensed areas issued in Mongolia (MRPAM 2023). "Mongolia's economy expanded by 7.1% in 2023, mainly driven by coal mining and related transportation services" (World Bank 2024). Open-pit mining operations could also be intensifying climate change impacts, given that Mongolia is one of the most affected countries by climate change.

Unfortunately, the economic value of pastoral ecosystem services is often undervalued compared to the contributions of the mining sector to GDP. The government tends to favor mining companies because they significantly contribute to the economy.

In 2023, the mining and exploration license area covered 4 percent of the country's territory. However, it is worth noting that this number only represents the physical area of mining and exploration activities. We must also consider the environmental degradation caused by mining, such as water scarcity, contamination, soil degradation, road erosion, and urbanization following mining development. These indirect externalities significantly impact the livelihoods of nomadic pastoralists. These factors collectively indicate that mining activities could potentially contribute to overgrazing in Mongolia's pastoral ecosystems.

2.4. Studies that connect mining and overgrazing in Mongolia

The overgrazing and mining industry are mostly considered to be separate drivers of pasture degradation. There is a lack of studies that connect these two drivers.

The study by Juřička et al. (2019) investigates the impact of mining on overgrazing and forest retreat in Erdenet, Mongolia. The research highlights that mining activities have attracted herder households to the area, increasing the concentration of livestock near forest edges. This increased grazing pressure severely damages tree seedlings. He noted that the ongoing mining activities and associated grazing pressures will likely continue to degrade the forests, potentially transforming them into steppe ecosystems (Juřička et al. 2019).

In my review of the existing literature, I have not identified any studies that explicitly investigate the connection between mining activities and overgrazing. Given the evident competition for land resources, it is imperative to explore this relationship to inform more effective land management strategies.

3. Methodology

3.1. Study area selection

Figure 1. Study areas

Arkhangai and Tuv provinces are chosen for this study. Both provinces are located in central Mongolia. Currently there is no province in Mongolia that does not have a mining operation.

Of all the provinces of Mongolia Arkhangai province has one of the lowest mining areas. The study areas are chosen based on their similar ecologic zones, precipitation, livestock and human population. In both provinces, livestock production plays important role in livelihood. Both provinces' territories are similar in size.

Table 1. Comparison of the study area

Study area	**Tuv Province**	**Arkhangai Province**
Ecological zone	Steppe, mountain & forest steppe, alpine & taiga	Mountain & forest steppe, steppe, alpine & taiga
Annual Mean Surface Air Temperature (2022, 5-yr smooth)	-0.19 °C	-1.51 °C
Observed seasonal precipitation by mm (1991 – 2020)	DJF – 9.99 MAM – 46.51 JJA - 208.49 SON – 51.37	DJF – 8.72 MAM – 46.81 JJA - 214.65 SON – 43.73
Size in hectares	6,958,540	5,531,380
Pasture size in hectares	5,644,146	3,747,790
Human population (2023)	91,451	92,343
Herder households (2023)	17,377	19,773

Number of Livestock (2023)	4,9 million	4,8 million
Number of mining license	387 (Mining – 306, Exploratory – 81)	28 (Mining – 18 Exploratory – 10)
Mining license area size by thousand hectares	368.6	29.7
Percent of the total province's territory	5.0%	0.5%

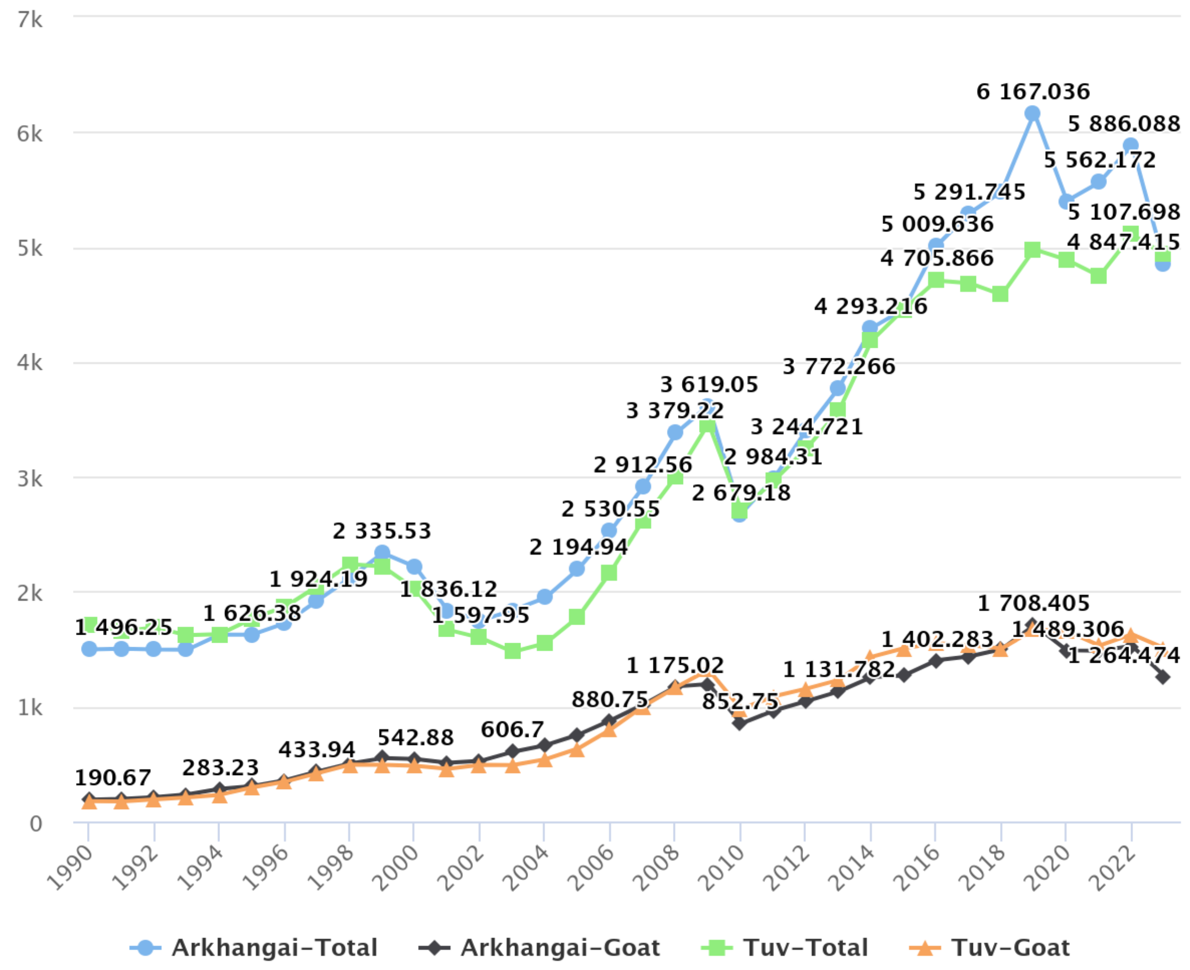


Figure 2. Total livestock and goat population of Arkhangai and Tuv provinces. *(Source: Data extracted from the Statistics Office of Mongolia)*

The mining license area of Tuv province, excluding the exploration licenses, is almost fifteen times bigger than Arkhangai province. Although Arkhangai's pasture area size is much smaller than Tuv province, by 1.9 million hectares, the total livestock and goat population (Figure 2) has been historically similar since the 1990s. Goat population data was also compared, considering goats have a more detrimental impact on pasture.

3.2. Conceptual framework

This subsection is dedicated to analyzing and identifying correlations between mining sites and livestock numbers in the Tuv province by using statistical methods, specifically the Difference-in-Difference (DID) approach. DID is an econometric technique that helps to determine the effect of an intervention (in this case, mining activity) by comparing the changes in outcomes over time between a treatment group and a control group. Under certain conditions, the DID method can establish robust causal estimates that can isolate the effects of the treatment from other factors that may influence the outcome variable, which is livestock numbers in this case. However, this analysis does not intend to establish causality using the DID method. The approach was used due to its statistical power to assess and explore potential patterns in mining activities and livestock numbers in target regions.

Four soums with active mining sites were selected from Tuv province to form the treatment group. These are Delgerkhaan, Sergelen, Erdenesant and Zaamar soums where large-scale mining operations have been taking place since the 1990s (Tuv Province Governmental Office, n.d.)**.** Respectively, the control group consisted of soums from Arkhangai province where there is a significant absence of mining and matches well with Tuv province on human and natural capital dimensions (see Figure Q). To determine the best matches for the treatment groups the Euclidean distance method was initially employed to conduct matching, and the selection was later hand-picked manually by considering geographic and climatic similarities between regions, identical features in population and livestock growth rate. The control group consists of soums Chuluut (which comes as the best match for two of the treatment units), Ulziit, and Khashaat.

The year of 2000 was selected as the treatment period for all the groups. Determining treatment cut-off points imposed a considerable amount of challenges due to the severe lack of available data on the internet on the start date of mining operations and related legislation at the national and municipal levels. As mining activities and operations also differ, choosing a single date that can be equally applied to the whole country was preferred at the cost of robustness in the estimation. This preference supports the objectives of this analysis which is to explore statistical patterns and correlations. The primary reason for choosing the year 2000 was due to the Minerals Law of 1997 which caused a surge in mining and exploration license applications and issuance. By using the observational data from the Statistics Office of Mongolia, the collection of the data on livestock growth from 1980 to 2023 was prepared.

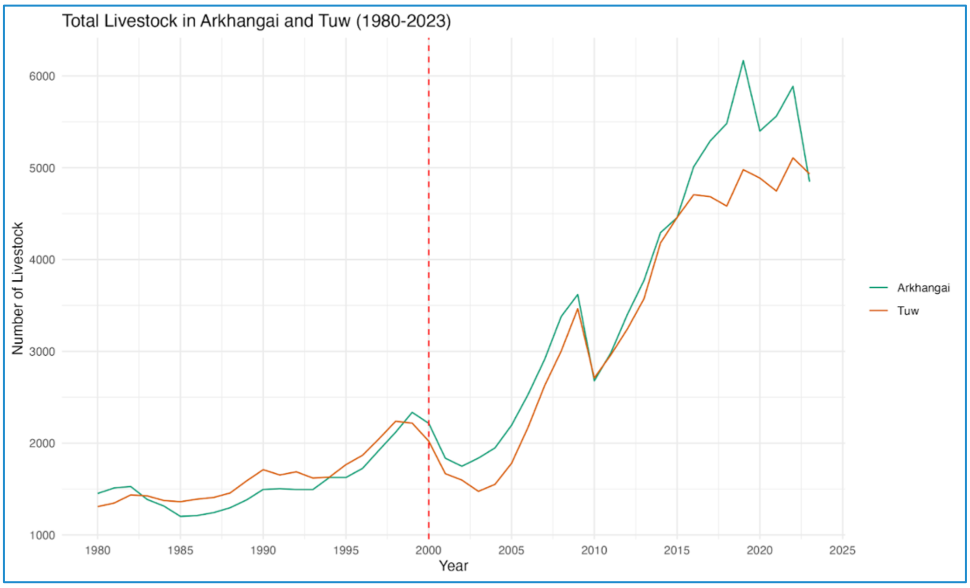


Figure 3. Total livestock growth rate (in thousands) in Arkhangai and Tuv provinces between 1980 and 2023. Notes: The chart presents total growth of livestock over time in select provinces. The red line indicates the chosen intervention period. Source: self-generated chart using Statistical Office of Mongolia data, 2023

3.3. Methodology for livestock population analysis

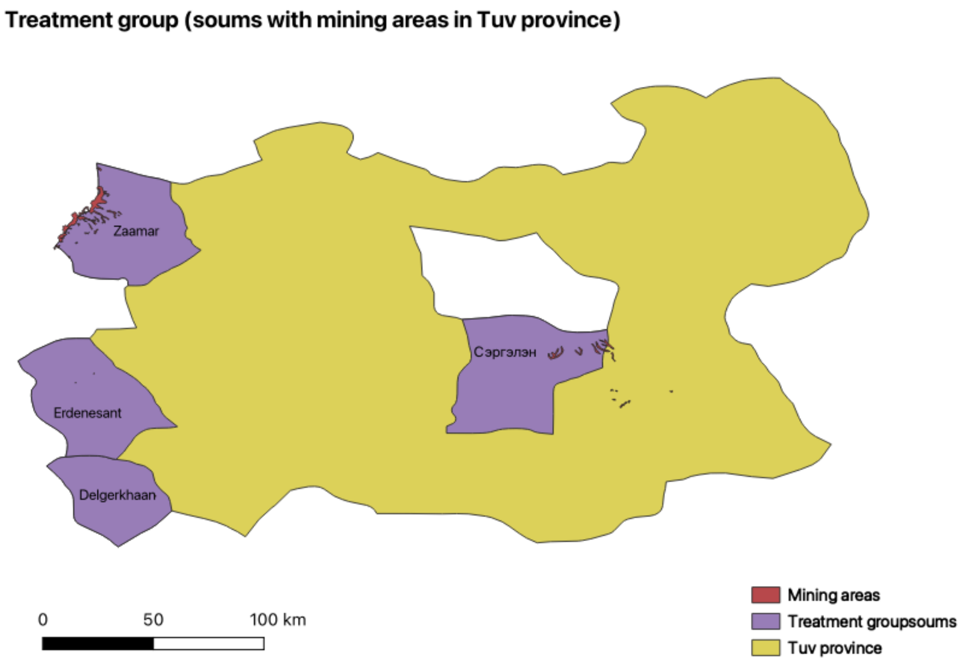


Figure 4. Treatment group (soums with mining areas in Tuv Province), (Maus et al. 2022).

- **Selection of Treatment and Control Groups**: The treatment group includes four soums with active mining sites, while the control group comprises soums without mining activities. This selection helps in comparing the impact of mining.
- **Euclidean Distance Method**: This method was used to calculate the distance between mining sites and its counterfactuals with the same or similar sized grazing areas.
- **Difference-in-Difference (DID) Analysis**: Statistical technique to compare the changes in livestock numbers over time between the treatment and control groups. The key assumption is that, in the absence of mining activities, the treatment and control groups would have followed parallel trends in livestock numbers.

- **Results Interpretation and Limitations**: The DID analysis will help to identify whether there is a statistically significant difference in livestock numbers attributable to mining activities. Any observed differences can then be used to understand and explore correlations and patterns of mining impact on herders life.

3.4. Data collection

3.4.1. Mining data

I utilized the global mining dataset developed by Maus et al. (2022) for this study. This comprehensive dataset includes 44,929 polygon features covering 101,583 km² of mining areas worldwide, which encompasses large-scale mining (LSM) and artisanal and small-scale mining (ASM). The data is publicly available and was instrumental in analyzing the spatial extent and impact of mining activities. QGIS was used to define mining areas in Mongolia.

I collected data on mining and exploration licenses from the Computerized Mining Cadastre System (CMCS), which is implemented at the Cadastre Division of the Mineral Resources and Petroleum Authority of Mongolia (MRPAM). The CMCS aims to improve administrative procedures and public services, providing a reliable and up-to-date source of information on mining activities in Mongolia and Mineral Resources and Petrolium Statistics reports also from MRPAM.

3.4.2. Rangeland Data

Livestock population data for each province and soum administrative unit and data on herder households are extracted from National Statistics Office of Mongolia. Ecological data from World Bank Climate Knowledge Portal which provides global data on historical and future climate, vulnerabilities, and impacts. (World Bank, n.d.)

For the assessment of rangeland degradation in the study areas, I utilized a comparative analysis of photo monitoring reports from 2016 to 2020. These reports were conducted by the General Agency for Land Administration, Management, Geodesy, and Cartography of Mongolia. It is expected to be accurate. Their data was systematically collected since 2011 by a cohort of 320 meteorological professionals from 1,516 monitoring points nationwide. Agro-meteorological engineers ensure the quality control of these primary quantitative data and enter them into the National Rangeland Monitoring Database. This database facilitates the compilation of a national report on grassland status every three years and the annual publication of updated maps on grassland regeneration capacity.

3.4.3. Remote sensing data

The data to visualize NDVI (Normalized Difference Vegetation Index) was collected from the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite, specifically utilizing the MODIS/061/MOD13Q1 Image Collection available in Google Earth Engine (GEE). The data was filtered to focus on the summer months (June 1 to September 1) for the years 2000, 2005, 2010, 2015, 2020, and 2023, ensuring the analysis captured peak vegetation growth periods. Additionally, the dataset was refined to include only the images within the defined area of interest (AOI), allowing for a targeted study of the region's vegetation dynamics.

For each year, the NDVI band was extracted from the dataset, and the mean NDVI value was calculated over the specified period to produce a composite image that represented the average vegetation health. This composite image was then clipped to the AOI. To visualize the data effectively, a consistent visualization parameter (ndviVis) was established with a range from 0 to 10,000 and a color palette to highlight different NDVI values. The processed mean NDVI images were added to the map using these parameters, creating visual representations of NDVI for each year, which facilitated the assessment of temporal changes in vegetation health across the study period.

4. Results

4.1. Graphical Analysis

Figures 5 to 7 present plot comparisons between treated groups, soums with active mining activities, and control groups, soums that have no active mining operations but share significantly similar characteristics with the treatment groups. The graphs illustrate how a parallel trend can be observed across all comparisons evidently to some extent before the chosen treatment period began with minor covariances in Figure W and Figure T. While Figures E and Figure R, show strong parallel trends consistent until 2000. In the Figure t, Zaamar soum shares a parallel trend with its counterfactual until early 1990s and rapidly changes. This could be explained by the start date of operations of the mines in Zaamar which is assumed to be the one of the longest running mines in Tuv province.

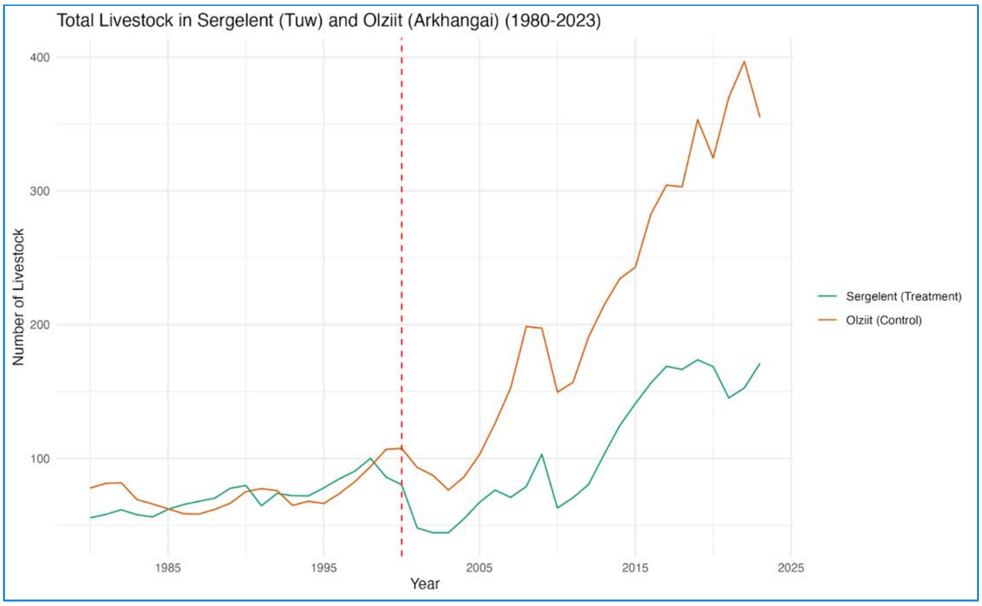


Figure 5. Total livestock growth rate (in thousands) in Sergelent (treatment) and Olziit (control) between 1980 and 2023. Notes: The chart presents total growth of livestock overtime in select provinces. The red line indicates the chosen intervention period. Self-generated chart, data source Statistical Office of Mongolia 2023.

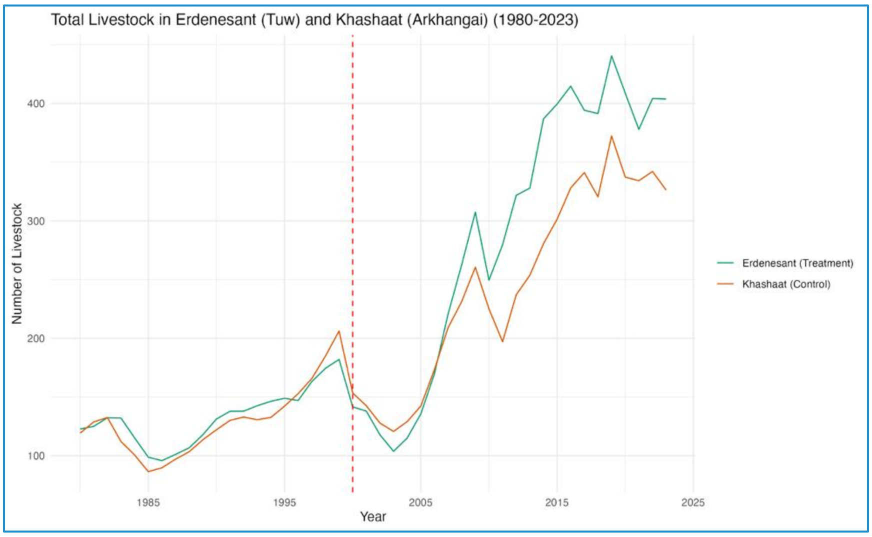


Figure 6. Total livestock growth rate (in thousands) in Erdenesant (treatment) and Khashaat (control) between 1980 and 2023. Notes: The chart presents total growth of livestock overtime in select provinces. The red line indicates the chosen intervention period. Self-generated chart, data source Statistical Office of Mongolia 2023.

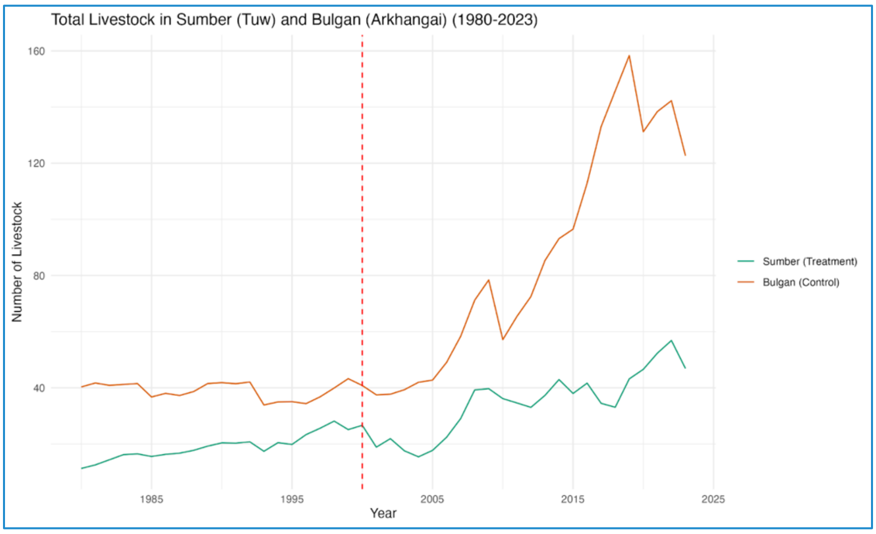


Figure 7. Total livestock growth rate (in thousands) in Sumber (treatment) and Bulgan (control) between 1980 and 2023. Notes: The chart presents total growth of livestock overtime in select provinces. The red line indicates the chosen intervention period. Self-generated chart, data source Statistical Office of Mongolia 2023.

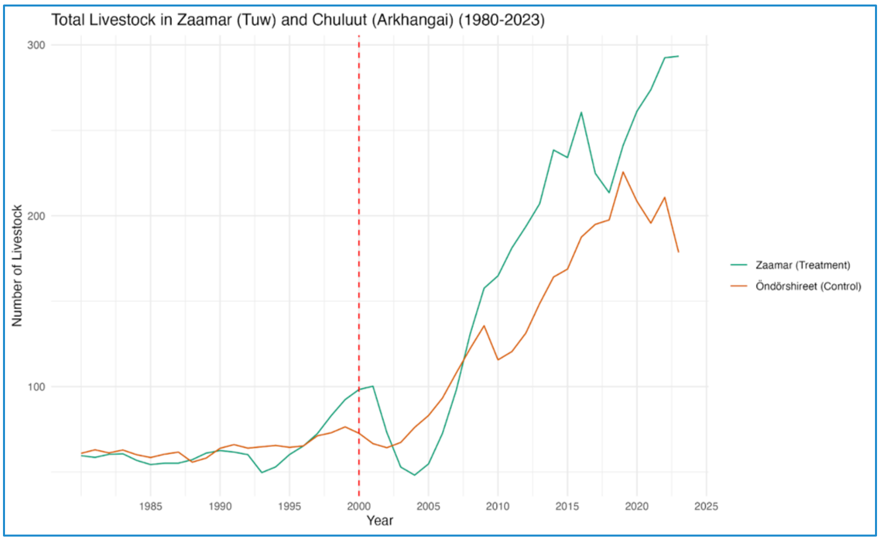


Figure 8. Total livestock growth rate (in thousands) in Zaamar (treatment) and Chuluut (control) between 1980 and 2023. Notes: The chart presents total growth of livestock overtime in select provinces. The red line indicates the chosen intervention period. Self-generated chart, data source Statistical Office of Mongolia 2023.

4.2. Difference-in-Difference Analysis

Table 3 shows the DiD estimates of each comparison. The Difference-in-Differences (DID) analysis compared matched units within the Arkhangai and Tuv regions before and after the year 2000, serving as the treatment year. The analysis aimed to identify the differential impact of the treatment (assumed to start in 2000) on the treatment groups compared to their respective control groups.

The analysis provides insights into how different units responded to an assumed treatment that started in the year 2000. The significant negative effect in Sergelent vs Olziit suggest that external factors or policies implemented around the year 2000 had differential impacts across these regions. This suggests that Sergelen experienced a relatively worse outcome compared to Olziit after 2000. This requires further attention. For Delgerkhaan vs Chuluut, the treatment effect was not statistically significant. This indicates that the changes observed in Delgerkhaan after 2000 were not significantly different from the changes observed in Chuluut. Erdenesant vs Khashaat and Zaamar vs Chuluut also show no significant estimates.

Table 2: Difference-in-difference estimate results for each comparison group.

Pair	Intercept Coef	Intercept P-value	Treatment Coef	Treatment P-value	Post Coef	Post P-value	Interaction Coef	Interaction P-value
Delgerkhaan vs Chuluut	63.8630	0.000	-1.2420	0.927	75.1920	0.000	-25.0876	0.172
Sergelent vs Olziit	73.4220	0.000	-1.7005	0.928	139.3668	0.000	-104.6670	0.000***
Erdenesant vs Khashaat	129.1510	0.000	3.7740	0.878	116.1115	0.000	38.9943	0.242
Zaamar vs Chuluut	63.8630	0.000	-1.8910	0.908	75.1920	0.000	36.4431	0.102

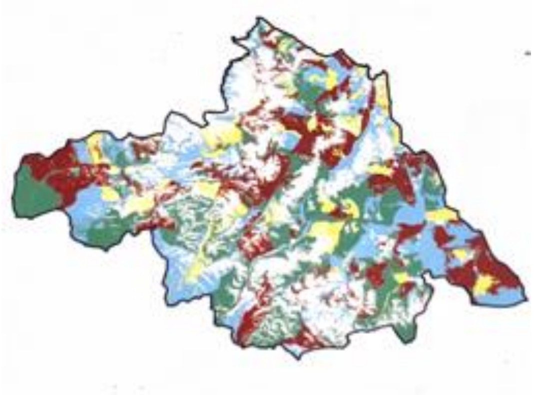
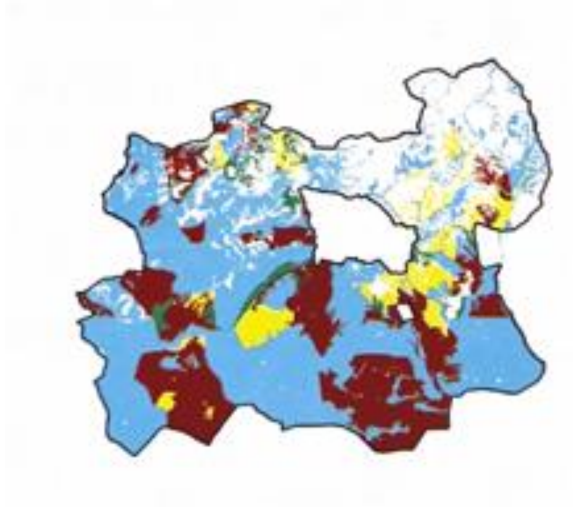
4.3. Limitations to the DID models

The models suffer from a lack of data and uncontrolled factors. By enriching data and identifying exact dates of treatment commencement we can better analyse the correlation between livestock growth or decrease in mining activities in soums. The lack of specific and accurate data causes the model to also suffer from overgeneralization of the terms and omitted-variable biases. Overall generalizability of this model is not strong enough to be applied, however, the graphical analysis shows us a pattern of the parallel trend continuing most part to the 2000s, and abnormal levels of changes occur. Improvements can be made by using a much larger sample of data, and comparing sub-types of livestock rather than the total sum of the livestock may improve the analysis.

4.4. Foto monitoring rangeland degradation assessment

Comparing the two study sites' degradation level. Tuv province has significantly more severe rangeland degradation. Good conditioned rangeland of Arkhangai is 10 times more than Tuv Province.

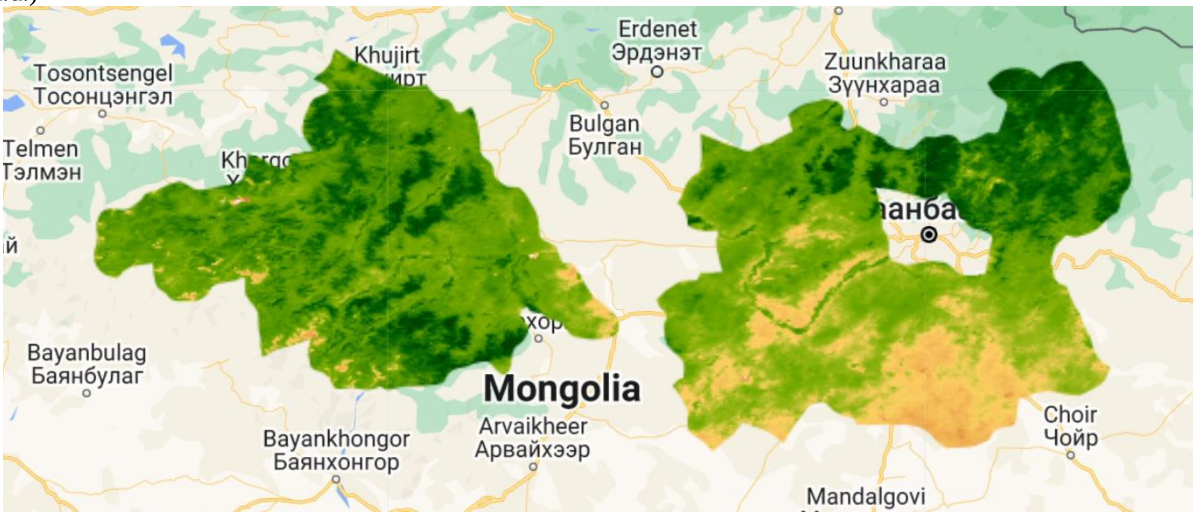
Table 3. Rangeland degradation assessment by General Agency for Land Administration, Management, Geodesy, and Cartography of Mongolia (2016 – 2020)

	
Arkhangai Province Rangeland in Good Condition: 1,327,131 hectares Rangeland Showing Improvement: 451,381 hectares Rangeland in Severe Degradation: 886,953 hectares (requiring a significant decrease in grazing pressure	**Tuv Province** Rangeland in Good Condition: 107,572 ha. Rangeland Showing Improvement: 372,150 ha. Rangeland in Severe Degradation: 1,485,915 ha. (requiring a significant decrease in grazing pressure)

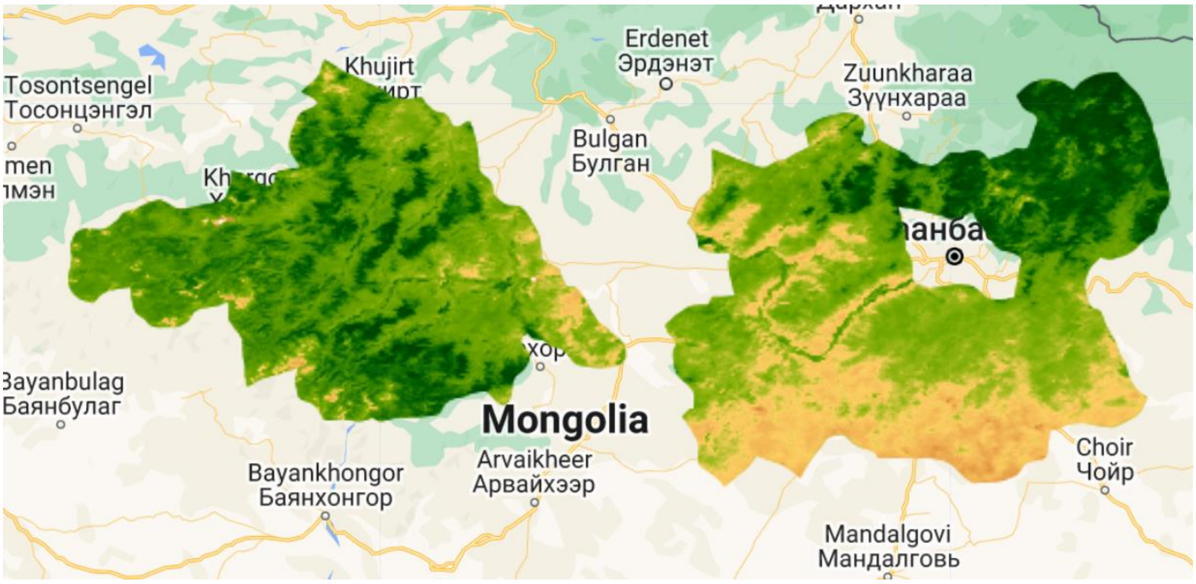
4.5. NDVI visualization during the years 2000 to 2023

NDVI result showed Tuv province has low vegetation throughout the years especially in the south except the year 2023.

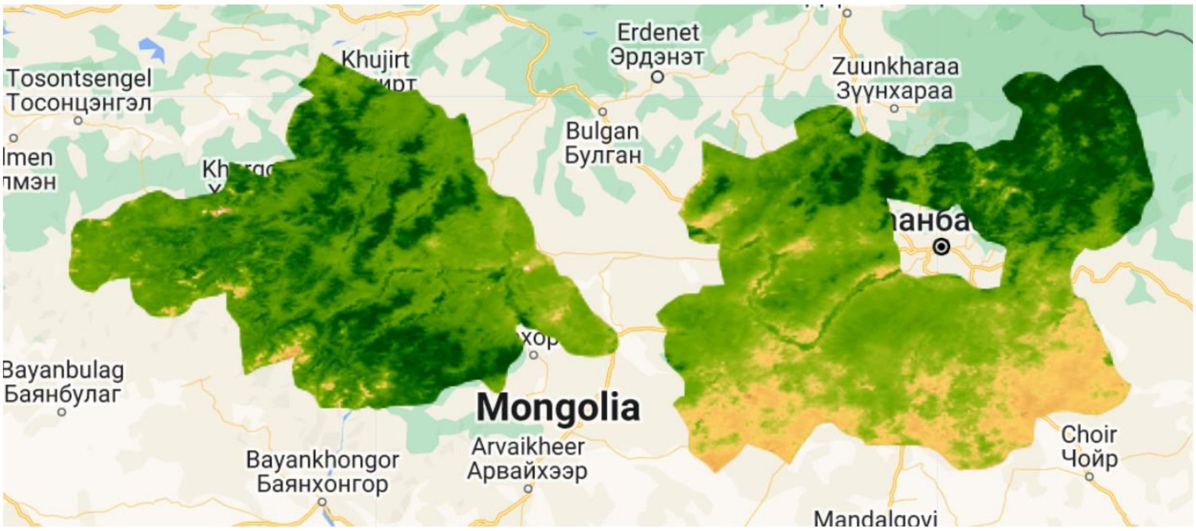
Table 4. NDVI 2000 – 2003 in the study area (Source: MODIS(NASA LP DAAC at the USGS EROS Center, n.d.)



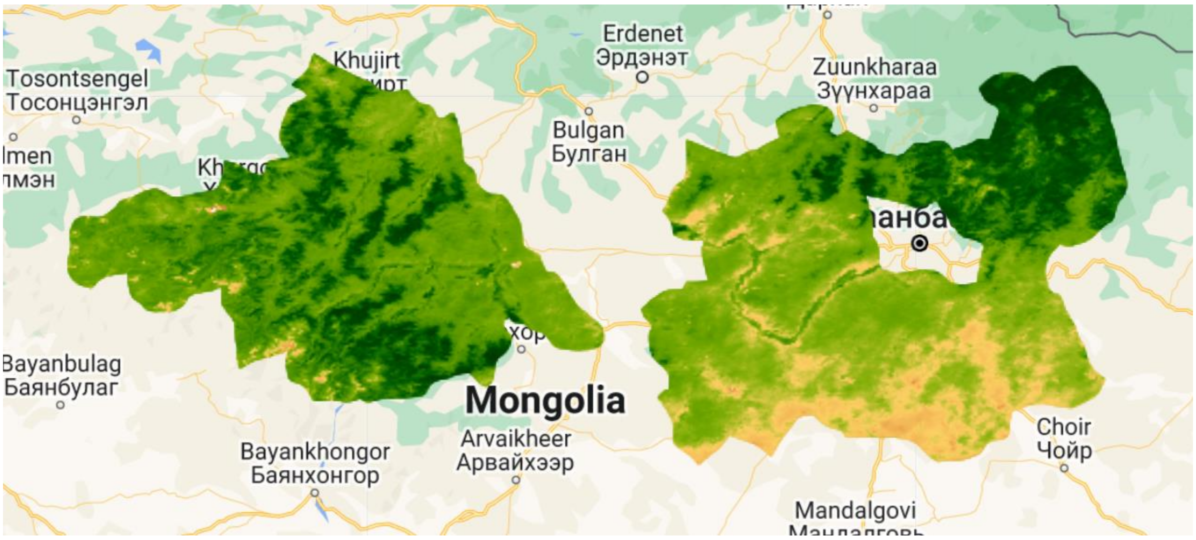
Normalized Difference Vegetation Index (NDVI) of Arkangai and Tuv Province in 2000



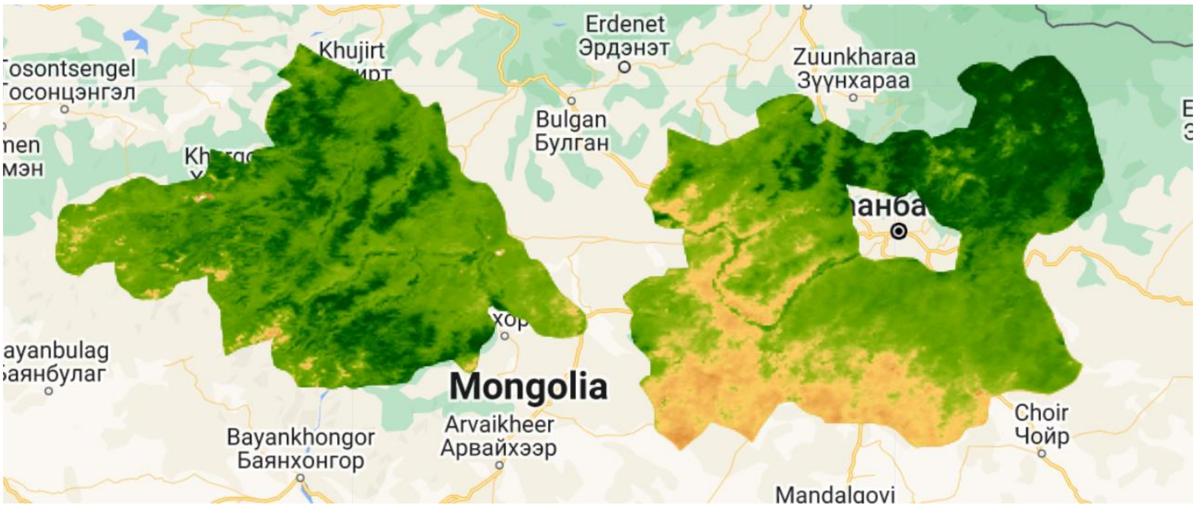
Normalized Difference Vegetation Index (NDVI) of Arkangai and Tuv Province in 2005



Normalized Difference Vegetation Index (NDVI) of Arkangai and Tuv Province in 2010



Normalized Difference Vegetation Index (NDVI) of Arkangai and Tuv Province in 2015



Normalized Difference Vegetation Index (NDVI) of Arkangai and Tuv Province in 2020

Normalized Difference Vegetation Index (NDVI) of Arkangai and Tuv Province in 2023

5. Discussion

The mining and agriculture sectors are two of the most important economic pillars of Mongolia. This study aimed to explore the potential correlation between mining activities and overgrazing in Mongolia's pastoral ecosystems. While the results do not definitively conclude that mining causes overgrazing, they suggest a possible correlation between the two factors.

By comparing Tuv and Arkhangai provinces, which have similar ecological zones, precipitation patterns, and human and livestock populations, I observed notable differences in the rate of land degradation. Ideally, the degradation rates should be comparable between these regions due to their similarities. However, Tuv province, which has extensive large-scale mining operations, exhibits distinct degradation patterns. This indicates that mining activities could be contributing to the observed differences in land degradation.

The analysis of livestock populations in soums with and without mining operations provided additional insights. In soums with active mining, there was either a stagnation in livestock population growth or unusually high livestock numbers. These findings suggest that mining may influence pastoral practices and land use, potentially leading to overgrazing in the remaining available pastureland.

These preliminary findings underscore the complexity of the relationship between mining activities and overgrazing. While the data does not conclusively establish causation, it highlights the need for further research to understand the nuanced interactions between these two sectors. Future studies should aim to:

Conduct Detailed Longitudinal Studies: Tracking changes over an extended period to observe long-term impacts of mining on grazing patterns and rangeland health.

Include More Variables: Incorporate additional variables such as soil quality, water availability, and detailed land use patterns to capture the broader impacts of mining.

Use Advanced Analytical Tools: Employ more sophisticated statistical and GIS tools to analyze spatial and temporal data with higher precision.

Explore Socio-Economic Impacts: Investigate how mining influences the socio-economic dynamics of pastoral communities, including changes in herding practices and household livelihoods.

In conclusion, while this study could not definitively prove that mining causes overgrazing, the observed correlations warrant further investigation. Understanding the interplay between mining and pastoralism is crucial for developing integrated land management policies that balance economic development with the sustainability of Mongolia's rangelands. Future research should aim to build on these findings, providing a more comprehensive understanding of how these sectors interact and impact the environment and local communities.

6. Conclusion

The interaction between overgrazing, mining, and rangeland degradation in Mongolia is complex and multifaceted. Traditional pastoral practices have long adapted to the harsh and variable environment of the Mongolian steppe, ensuring a balance between grazing and the ecosystem. However, modern pressures such as increased livestock numbers and extensive mining activities now pose significant challenges. Both mining companies and nomadic pastoralists are major land users, leading to intense competition for natural resources. As rangelands are state-owned by law, herders often find themselves at a disadvantage regarding land rights, exacerbating their vulnerability.

Nomadic pastoralists are particularly affected by the changing climate, which further complicates their traditional ways of life. While the majority of studies suggest that overgrazing is the primary driver of rangeland degradation, the role of mining and the competition between livestock and extractive industries for land resources cannot be overlooked. These factors contribute to the degradation of rangelands, impacting both the environment and the livelihoods of pastoral communities.

It is crucial to consider the intricate connections between these drivers of degradation in future research and policymaking. Understanding the combined impacts of overgrazing, mining, and climate change will be essential for developing effective management strategies. Such strategies must aim to balance the needs of all stakeholders, ensuring the sustainability of Mongolia's rangelands and the resilience of its nomadic pastoralist communities.

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