Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

PMAS
Proceedings of the Mongolian Academy of Sciences

ARTICLE

The effect of copper mining on vegetation disturbances in and out of Oyu Tolgoi mining site

Sainchuluu Amarsanaa[1]*, Ariuntsetseg Lkhagva[2], Bolormaa Tsooj[3] and Erdenechandmani Jargalsaikhan[4]

[1] School of Agroecology, Department of Ecology, Mongolian University of Life Sciences, Ulaanbaatar, Mongolia
[2] School of Arts and Sciences, Department of Biology, National University of Mongolia, Ulaanbaatar, Mongolia
[3] Institute of Geography and Geoecology, Department of Ecology Mongolian Academy of Sciences, Ulaanbaatar, Mongolia
[4] School of Agroecology, Department of land management, Mongolian University of Life Sciences, Ulaanbaatar, Mongolia

ARTICLE INFO: Received: 27 Jul, 2021; Accepted: 29 Mar, 2022

Abstract: Since 2005, the mining sector has been a vital part of Mongolia's economy. This sector is one of Mongolia's most important sources of revenue. Primary outputs of Mongolia's mining industry are copper, gold, and coal. On the other hand, mining has a negative impact on the environment causing soil erosion, noise pollution, water pollution, and biodiversity loss. The Oyu Tolgoi copper mine is located in a semi-arid zone in the Mongolian Gobi. The impact of mining was investigated by sampling eight plots both in and out of this giant mining site. Vegetative cover, species richness, biomass, and basal gap of perennial plants were compared within and outside the perimeter of the Oyu Tolgoi mining site. The mining sites have a harmful impact on the environment. According to our findings vegetation cover, species richness, biomass, and perennial plant gaps were not different between the paired plots outside and inside of the mining site. Mining activities had little effect on vegetation, according to the findings.

Keywords: *mining activity effects; mining vegetation; vegetation parameters;*

INTRODUCTION

If a nation has sufficient mineral resources, mining is essential to its economic progress. Mineral resources are abundant in Mongolia. Primary outputs of Mongolia's mining industry are copper, gold, and coal. Mining has contributed to the expansion of Mongolia's infrastructure and socioeconomic system. Since 2005, the country's mining industry has experienced rapid expansion. With over 6,000 mineral deposits and occurrences of 80 distinct minerals, including coal, copper, gold, petroleum, and uranium, Mongolia has a substantial mining potential.

***corresponding author: sainchuluu@muls.edu.mn** **https://orcid.org/0000-0001-8070-2085**

The industry has propelled the country's gross domestic product (GDP) growth for decades [1] to come. Over the five-year period from 2015 to 2018, mining industry contributed an average of 23.03 per cent of Mongolia's GDP [2]. Another crucial aspect of Mongolia's growth is livestock husbandry [3]. Livestock husbandry is a significant industry in Mongolia because the country's economy is highly dependent on the state of its grazing lands. Livestock produce were the economy's pioneering industry up until 2010 when mining started to play a significant role economically. Animal husbandry has existed in the Mongolian rangelands for many centuries. Climate variability and human activities both have an impact on differences in rangeland vegetation across the country. Variability in vegetation is influenced by hydrological variables, soil moisture, and annual precipitation [4]. Climate change is one of that many factors that led to rangeland degradation in Mongolia. Compared to desert vegetation, livestock breeding seems to have more of an impact on rangeland in the mountain steppe zone [5]. Throughout the twentieth century, the average temperature in central and semi-arid North-Eastern Asia increased significantly [6]. The average yearly temperature in Mongolia has increased by 2°C over the preceding 70 years [7]. In addition, since 1960, Mongolia's precipitation patterns have changed: Precipitation has increased in the country's eastern and southern regions while decreasing by 1-2.0 mm annually in other areas [8]. Animal husbandry and other land uses are negatively impacted by climate change.

The exploitation of minerals offers both internal and external economic benefits. The people have job opportunities within the country, and beyond it, there has been a large influx of foreign capital [9]. However, mining is thought to be a significant cause of environmental woes in the rangelands and a threat to the livelihood of the herders [10]. Biological and hydrological ecosystems are significantly harmed by mining [11]. The mining industry faces a number of issues, including effects on local biodiversity, soil erosion, noise, water pollution, and dust [12]. Additionally, mining extraction may have detrimental environmental effects. The primary causes of worry are the decline in biodiversity and the state of the environment [13].

Concerns about mining also have an impact on infrastructures, such as commercial buildings, highways, trains, airports, pipelines, landfills, dams, and other transit centers.

A number of environmental problems arise from poorly organised mining operations.

In Mongolia, illegal mining activities have destroyed 8,000 hectares of land that have never been rehabilitated [14]. In recent years, Mongolia's mining boom has had an impact on the local herdsmen, shrinking their rangelands and damaging their mode of life. Additionally, the size of cattle grazing grounds has been directly impacted by mining operations. One of the most detrimental effects of mining in Mongolia on the environment is the alteration of hydrological cycles. Additionally, they use chemicals that contaminate the soil, water, and air [10]. The mining industry in Mongolia has a significant impact on the environment. First, because of changeable hydrological regimes, placer gold mining produces excessive effluent and poses a risk of uncontrolled slurry discharges. In addition, tailings are poured into surface waterways and rivers are unlawfully dredged. Second, waste-rock piles and tailing repositories are a significant issue for medium- and large-scale mining operations.

Most industrial mining waste rock heaps in Mongolia are unstable and prone to erosion.

Stones and mud wash into the grazing areas during heavy rains, contaminating the region.

Third, the illegal use of mercury by small-scale placer gold miners pose serious environmental and human health threat. Fourth, there is a significant risk to human health from air pollution and dust. Dust can impair vegetative growth and reproductive structures [15]. Finally, artisanal and small-scale miners in protected regions are extracting minerals without any official permit, leaving the mining sites damaged beyond repair.

Artisanal mining in Mongolia refers to small-scale mining, the majority of which is prohibited. Additionally, mining operations degrade soil and change its characteristics and functionality [16]. Several environmental concerns are being caused by the extraction of

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

natural resources in other nations, including erosion, pollution and large holes in the ground, soil nutrient loss, biodiversity loss, heavy metal poisoning of groundwater and surface water, and biodiversity loss [5]. As a result of the disruption of plant communities caused by mining, the landscape and biological community suffer significant damage.

The Oyu Tolgoi (OT) mining site is located in Mongolia's semi-arid region in the south of the country in the Gobi desert. In the semi-arid region, mining is one of the main contributors to land degradation [17]. Precipitation has the greatest abiotic influence on plant cover and biomass in dry and semi-arid environments [8]. With a 430,000-ton copper production capacity per year, OT started operations in 2013 and is already among the largest copper mines in the world. 34 per cent of the business is owned by the government of Mongolia, while the remaining 66 per cent is owned by the Canadian Turquoise Hill Resource LTD. Since the Oyu Tolgoi mining operations began, a fence was constructed around the huge mine site, dividing the interior from the exterior. Around the world, arid and semi-arid regions are primarily linked to coal and copper mining sites [14]. Opencast mining operations harm the environment by altering topography, interfering with biological processes, reducing plant cover and biodiversity, and contaminating groundwater and surface waters [19].

OT is one of the two most important copper mines in Mongolia. The other copper mine, Erdenet in the north of the country, generates almost one half of all foreign exchange and provides close to a quarter of all governmental income. The installation and laying of the foundation for the OT mine's development began in 2010. Mongolia's economy has expanded since the OT agreement was signed, with GDP growth rates exceeding 17.5 per cent in 2011 [20]. Locals claim that numerous rangeland elements, including flora, soil, water, rangeland acreage, climate, animals, cattle, and herders' worldviews and behaviours, are rapidly changing as a result of the activation of the OT site.

They also ascribe these shifts to a variety of other factors, including climatic change, the expansion of the mining industry, the construction of new roads and infrastructure, and an increase in the quantity of cattle, a dearth of enabling laws, and conventional wisdom and practices.

The effects of mining on vegetation in arid and semi-arid mining sites are seldom studied in Mongolia and also throughout the world. As a result, there is a need to examine the effects of mining on vegetation in the surrounding regions and to manage the semi-arid environment.

The purpose of this study is to quantify the impact of mining activities on vegetation in the neighbourhood of and in the mining region. Vegetation is an important component of the ecology; nevertheless, mining operations can disrupt it [21]. Furthermore, vegetation is an important indication of biological conditions. As a result, vegetation change can give important information about environment, resource management, and especially in mining regions with sensitive ecosystems [4]. Proceeding from this premise, our study team has been looking at the impact of copper mining on vegetation in semi-arid areas. In order to investigate the impact of the mining site, we created eight monitoring plots and examined their vegetation cover, species richness, and basal gap of perennial plants inside and outside of the OT mining site. The vegetation cover, biomass, and species richness are critical criteria in mining control and assessing environmental sustainability [17]. The environmental impact of mining activities, particularly on vegetation in semi-arid areas is a major concern. [22]. The majority of the consequences are likely to have an influence on and impair the mining vegetation, either directly or indirectly [23].

MATERIALS AND METHODS

Study area

According to Grubov's classification, the research area is situated in Dornogobi, Alashaan district in terms of vegetation and geographic location. Oyu Tolgoi (OT) is a copper mining firm in the Mongolian province

DOI: https://doi.org/10.5564/pmas.v62i01.2086

of Umnugobi that is located 45 kilometers from Khanbogd soum, 210 kilometers from Dalanzadgad (the provincial capital), and 640 kilometers from Ulaanbaatar (Figure. 1). The mining site is located on the territory of the Gaviluud and Javkhlant baghs (smallest rural administrative unit in Mongolia) and OT's administration subsidies some herders whose winter camps are situated in the impact zone of the mining site in Khanbogd soum, which has four baghs, namel, Nomgon, Javkhlant, Bayan, and Gaviluud. The territory of the Khanbogd soum (the second largest administrative unit after province or aimag) is 15,150 km2 in size, situated in the Gobi Desert area, and is primarily dry due to limited precipitation. Dominant soil is light brown and red-brown Gobi soil distributed in the OT mining site. 193 species of 119 genera of 42 family of plants were registered here.

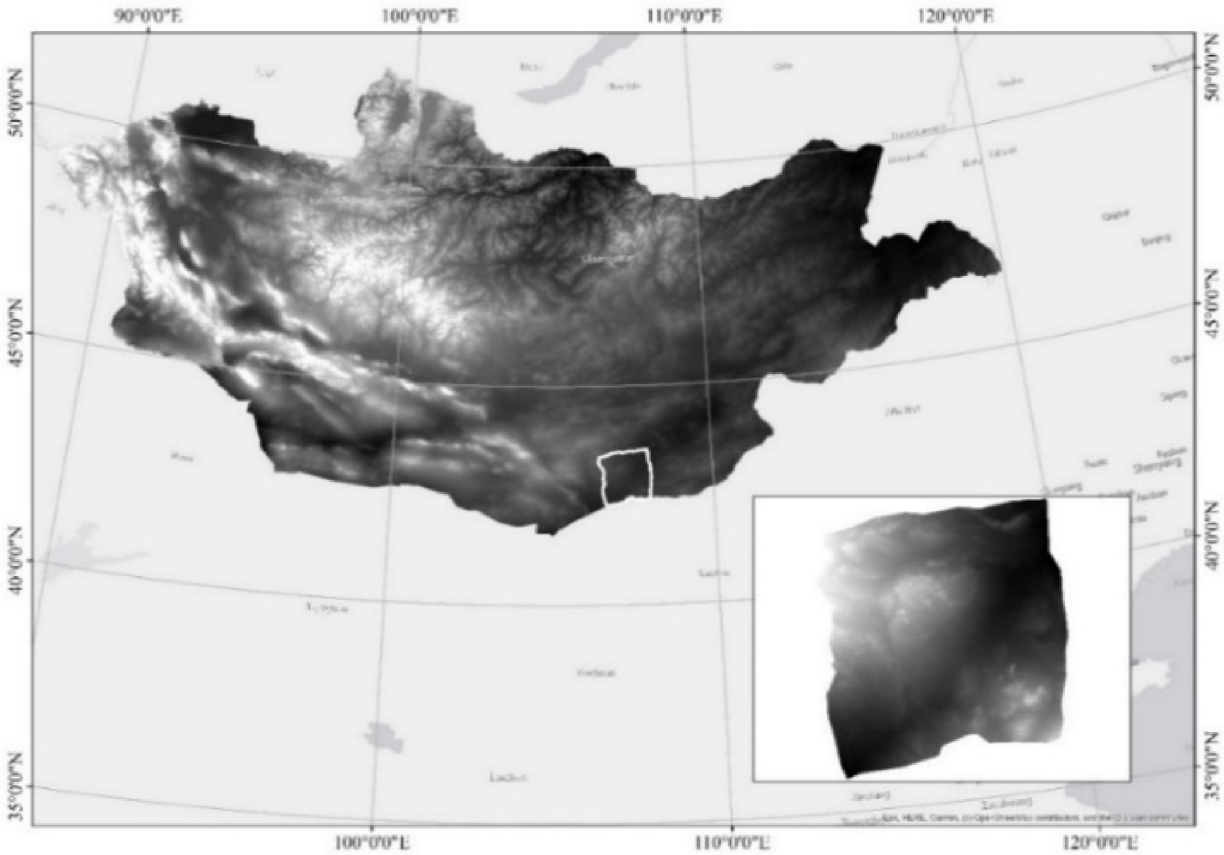

Figure 1. Location of Khanbogd soum in south Mongolia (Source: Image Landsat 2016 and Google search)

Khanbogd soum is situated in Mongolia's arid region. Khanbogd's climate is distinguished by a lack of precipitation, high summer temperatures, and average annual precipitation of 80-90 mm. Khanbogd soum has a mean annual temperature of 5°C, a mean temperature of -14°C in January, and a mean temperature of plus 23°C in July. In the last 30 years, there has been little change in precipitation from January to December (Figure 2). Winds are highest from late March to early April, with reduced wind speeds in fall and winter. The average wind speed in April is 5.5 meters per second, and it varies between 4-6 meters per second for the rest of the year.

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

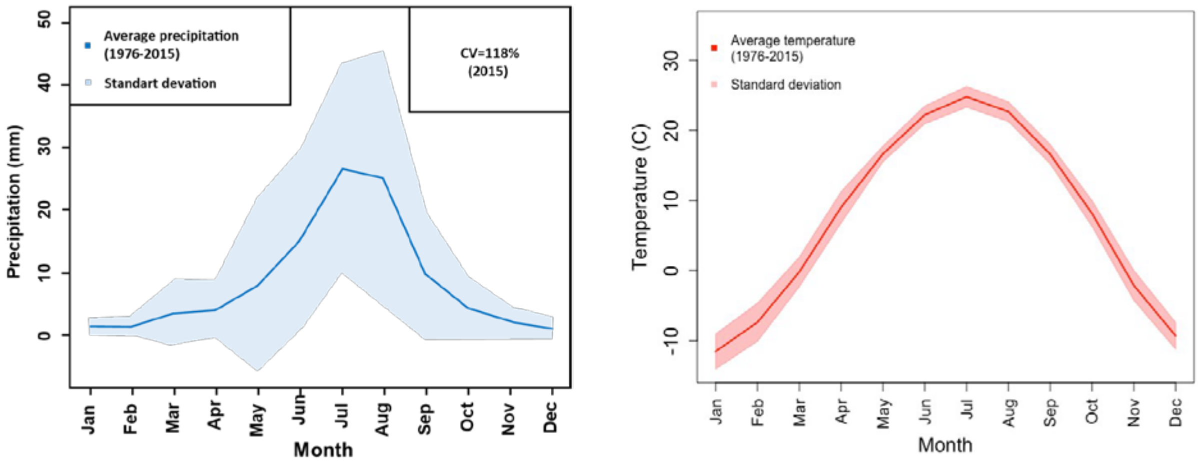

Figure 2. Mean temperatures and precipitation in Khanbogd soum
a) avarege precipitation (1976-2015), b) avarege temperature (1976-2015)

In 2015, the average annual temperature was 7.4°C, while the average temperature over the previous 30 years, from 1976 to 2006, was 7.3ºC (Table 1). The average annual precipitation from 1976 to 2006 was 93.7 mm, and the total annual precipitation in 2015 was 72.8 mm. The rainy season was primarily from May through October. June was the wettest month (20 mm). The summer of 2015, on the other hand, was drier than the previous thirty years.

Table 1. Mean temperature and precipitation in 2015, compared to averages from the period of 1976-2006. (Source: Khanbogd soum's weather station 2016).

Years	**Temperature, °C (mean)**	**Precipitation, mm (accumulated)**
1976-2014	7.3	93.7
2015	7.4	72.8

Design of the study

Based on four criteria, we compared the plant communities inside and outside of the Oyu Tolgoi site (biomass, species richness, cover and gap of perennial plants). The sample method was substantially based on the methods of the MOR2 (Mongolian Rangeland and Resilience) study (Warner College of Natural Resources 2015). To begin, the impact of mining was studied by measuring four pairs of monitoring plots both within and outside the mine (Figure 3). The monitoring plots for the study were all 50 m × 50 m (2,500 m2) in size. A total of eight plots were selected, one on the inside and one on the outside of the OT mining site. The matched plots were separated by a maximum of two kilometers. Plots with comparable landscape types and soil characteristics were paired

.

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

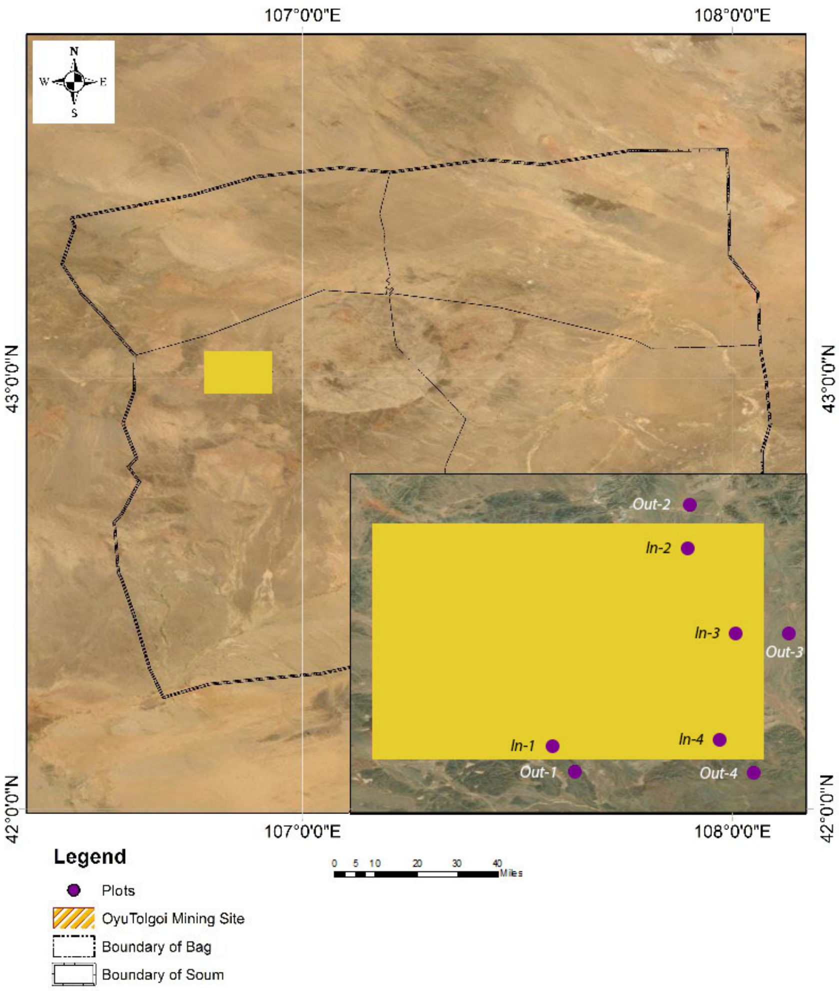

Figure 3. Location of eight plots inside and outside of the mining site. (Source: Rangeland monitoring report in Khanbogd soum 2015).

Sampling methods

All of the monitoring plots in this study area are divided into five transects with a total length of 10 meters (0, 12.5m, 25m, 37.5m, 50m) and a rectangular shape of 50m x 50m. The vegetation cover, basal gap of perennial plants, biomass, and species richness were all determined using the line point intercept (LPI) method for each plot. Due to wind and water erosion, the basal gap of perennial plants is vulnerable to the loss of fertile topsoil. Four distinct scales and intervals were established to quantify the spacing between plants: 25-50 cm, 51-100 cm, 101-200 cm, and >200 cm respectively. Plant, litter, pebbles, gravel, and bare ground vegetation cover was measured every 1m along each transect. Within each $1m^2$ area, plant species were documented. Geomorphological data, such as height, slope, aspect, landform and geographic position were also gathered for each plot.

Data collection

Data from mining sites were obtained in August 2015. The line point intercept (LPI) approach was applied, and vegetation cover, a basal gap of perennial plants, and species richness were assessed at each position. In addition, geomorphological data such as height, slope, aspect, landform, and geographic position were gathered in each plot.

Data analysis

We used a two-sample t-test to assess the vegetation cover, species richness, and basal gap of perennial plants inside and outside of the OT mining site. Furthermore, the Bray-Curtis similarity index compared the biomass of the outside and inside OT sites.

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

RESULTS AND DISCUSSION

Vegetation cover

Mean vegetation cover in the OT mining site area was 22 per cent, and it was 20 per cent lower inside the mining site than outside (24 per cent). However, the difference was not statistically significant (p=0.38), yet variation was greater within the site than outside (Figure 4).

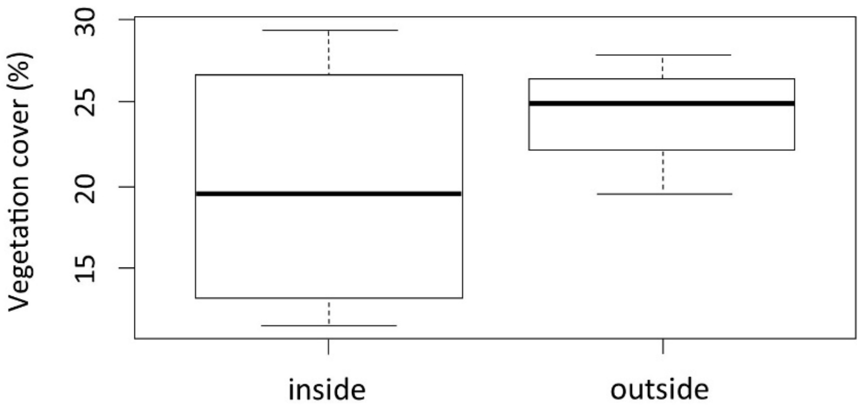

Figure 4. Box plot showing vegetation cover inside and outside the OT mining site

All functional groups, with the exception of perennial grass, did not show statistically significant differences in coverage (Table 2). However, there was a statistically significant difference in perennial grass cover on both sides of the OT mining site (P=0.03).

Table 2. Results of two-sample t-test of perennial plants gap (inside and outside of the mining site)

	Annual grass	Perennial grass	Shrubs	Annual forbs	Perennial forbs	Litter
Outside and inside	1	0.0388	0.7624	-	0.9343	0.6074

The most abundant plant functional groups at OT, both inside and outside the mining site, were shrubs and perennial grasses. Outside the mining site, perennial grasses, annual grasses, and litter had a greater cover than inside the mining site. Inside the mining site, shrubs and perennial forbs had a greater cover than outside. Allium found in an annual forb was not found within or outside the mining site (Figure 5).

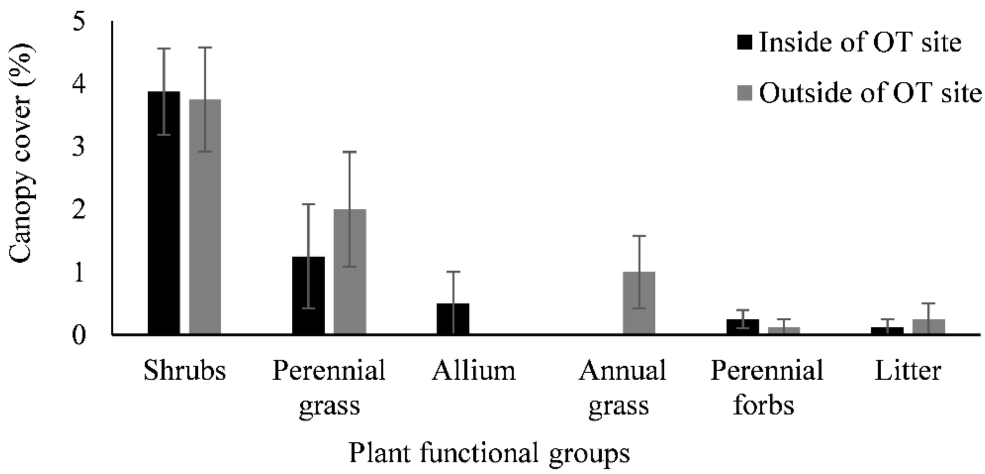

Figure 5. Total vegetation cover by plant functional groups, inside and outside of the OT site. Each bar represents mean ±1 SE

Species richness

20 different plant species were identified both inside and outside the OT mining site. In comparison to outside, the mining site's average species richness was 14. Outside, it was 17.3. (Figure. 6). As a result, the species richness inside and outside the mining site differed (P=0.03).

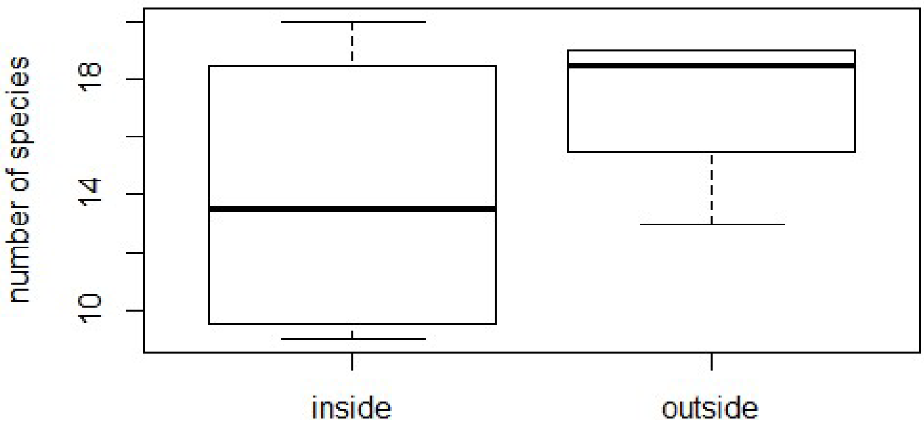

Figure 6. A box plot showing species richness inside and outside the OT mining site

A total of 20 plant isolates were recorded inside and outside the OT mining site, belonging to 19 genera and 12 families (Table 3). Eight species are represented by the top three families, Asteraceae, Amaranthaceae, and Poaceae (40 per cent).

Table 3. Plant species composition recorded inside and outside of the OT mining site

№	Plant species	Inside				Outside			
		I	II	III	IV	I	II	III	IV
1	*Popululus diversifolia* Schrenk	+	+	+	+	+	+		+
2	*Betula fusca* Pall ex Georg.	+		+	+	+	+		+
3	*Convolvulus Ammanii* Desr.	+	+	+	+	+	+	+	+
4	*Anabasis brevifolia* C. A. Mey.	+	+	+	+	+	+	+	+
5	*Salix Ledebouriana* Trautv.	+	+	+	+	+	+	+	+
6	*Cleistogenes squarrosa* (Trin.) Keng.	+	+	+	+	+	+	+	+
7	*Eleocharis acicularis (*L.*)* Roem. et Schult.	+		+	+	+	+	+	+
8	*Thymus gobicus* Tscherneva.	+	+	+	+	+	+	+	+
9	*Acroptilon repens* (L.) DC.	+	+	+	+	+	+	+	+
10	*Gypsophilla desertorum* Fenzl	+	+	+	+	+	+	+	
11	*Descurainia Sophia (*L.*)* Webb ex Prantl.	+	+	+	+	+	+		
12	*Chamaerhodos sabulosa* Bge.	+		+	+		+	+	
13	*Kochia prostrata* (L.) Schrad.	+	+	+	+		+		
14	*Chenopodium hybridium* L.	+	+	+	+	+	+		+
15	*Saussurea salsa* Spreng.	+	+	+	+	+	+		
16	*Crepis flexuosa* C Clarke	+		+	+				
17	*Allium tenuissimum* L.	+	+		+				
18	*Allium anisopodium* Ledeb.	+	+	+			+		
19	*Halogeton glomeratus* (M. B.) C. A.Mey	+	+	+	+		+		
20	*Aristida Heymannii* Rgl.	+		+	+				
	Total	**20**	**15**	**19**	**18**	**13**	**17**	**9**	**10**

+ *shows the presence of a species*

The outside OT site has a larger species composition than the interior (Figure 7). When the number of plant species inside and outside the plot was recorded, the analysis indicated that there were more species outside the plot. There was no variation in species richness between inside and outside the OT mining site (P=0.07).

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

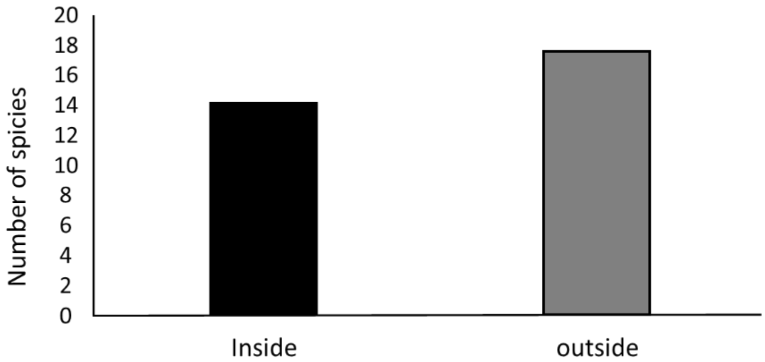

Figure 7. Species richness inside and outside of the OT site. Each bar represents mean ±1 SE.

Biomass

The biomass cluster analysis revealed 58–97 per cent commonality in the OT mining location. The majority of the biomass ranged from 82 to 95 per cent, whereas the minority ranged from 58 to 81 per cent (Figure 8).

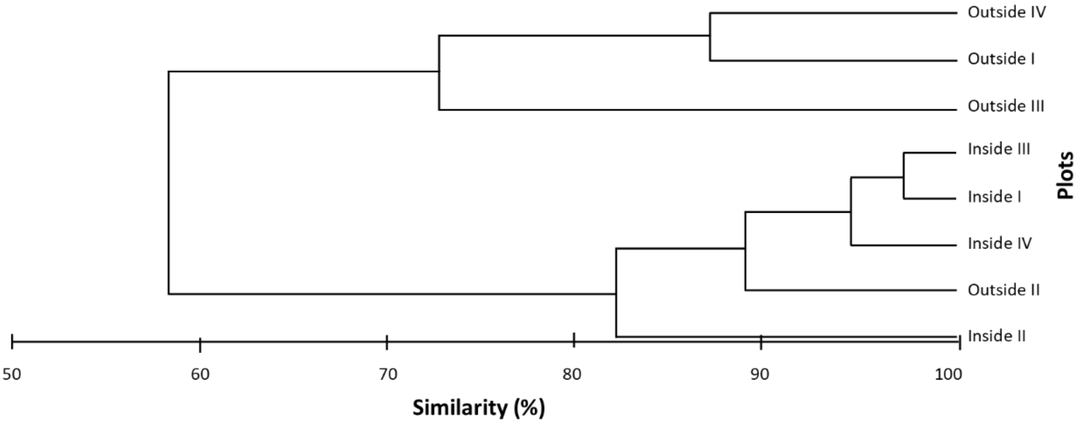

Figure 8. Clustering analysis of inside and outside of OT mining site (Bray–Curtis similarity)

The gap between perennial plants

Perennial plant gaps were smaller at 20-50 cm than other gaps, while 51-100, 101-200 cm gaps were similar within and outside of the OT mining site (Figure 9). On both sides of the OT mining site, a gap of more than 200 cm was detected.

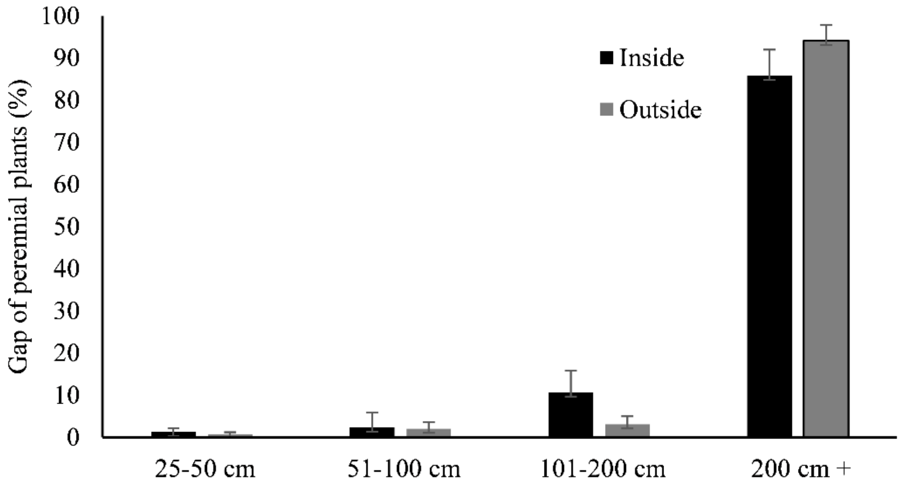

Figure 9. Gap of perennial plants inside and outside of the OT site. Each bar represents a mean ±1

There were no significant differences between the 25-50, 51-100, 101-200, and more than 200 cm perennial plant gaps inside and outside of the OT mining site (Table 4).

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

Table 4. Results of two-sample t-test of perennial plants gap (inside and outside of mining site)

Source of variation	t	df	p-value
25-50 cm	1.6657	6.6654	0.1419
51-100 cm	1.6639	6.1451	0.146
101-200 cm	1.7305	4.955	0.1446
200 cm +	-2.3376	6.4411	0.0551

In Mongolia, there has been little research into the effects of mining on vegetation. We expected that the vegetation inside the OT mining site had more plant cover and species richness than the vegetation outside the mining site since animals are not allowed. However, there was no difference in vegetation cover, perennial plants, or biomass gaps between the paired plots outside and inside the mining site. The species richness did not differ either. On both sides of the OT mining site, shrub cover was greater than that of other plant functional groupings. This study discovered a considerable disparity in species richness between the OT mining site and the surrounding area. On both sides of the OT mining site, there were substantial changes at 25-50, 51-100, 101-200 cm, and more than 200 cm perennial plant gaps. The findings suggest that mining activities had little effect on vegetation. Other studies have found that mining sites have a detrimental influence on the environment, such as disrupting hydrological regimes, unlawful heavy metals (mercury and sodium cyanide) consumption, air pollution (dust), and destroying soil characteristics and function. Coal mining causes environmental harm in the surrounding areas, causing substantial ecological disruption [17].

In response to our study question, the findings show that mining operations had no impact on the vegetation. To determine the consequences of mining on vegetation, we advocate long-term monitoring. For comparison study, we recommend building a gated area with monitoring plots that are free of cattle grazing, as well as neighbouring grazed areas.

CONCLUSIONS

In this study, the responses of plants to disturbance in copper mining was evaluated and examined. The results indicate that the study area's vegetation was not negatively impacted by mining activities. Further investigation on how mining affects vegetation is required. The mining site should ideally have more plots sampled and monitored over a longer period of time, both inside and outside, with the data gathered being recorded in a database.

Acknowledgments: I would like to express my gratitude to Dr. Altanzul Tsevlee and Azjargal Jargalsaikhan for their valuable advice, help, and administration of the OT project.

REFERENCES

1. National Agency for Meteorology and Environmental Monitoring and Ministry of Environment, “National report of pasture condition of Mongolia” 2015.
2. The World Bank, "The role of the State in Mongolia's Mining sector", 2021
3. Sh. Enkhbayar, " Mongolia's Livestock sector: Vital for the Economy and People, but Vulnerale to Natural Penomena", 2015.
4. S. Liu, W. Li, W. Qiao, Q. Wang, Y. Hu, and Z. Wang, “Effect of natural conditions and mining activities on vegetation variations in arid and semi-arid mining regions,” Ecol. Indic., vol. 103, no. March, pp. 331–345, 2019, doi: 10.1016/j.ecolind.2019.04.034.
5. Ministry of Environment and Tourism, “Mongolia Second Assessment Report on Climate Change 2014,” vol. 7, no. 2, pp. 1-16, 2014.
6. C. Dulamsüren, M. Hauck, M. Khishigjargal, H. H. Leuschner, and C. Leuschner, “Diverging climate trends in Mongolian taiga forests influence growth and regeneration of Larix sibirica,”

Vol. 62 No 01 (241) 2022
DOI: https://doi.org/10.5564/pmas.v62i01.2086

Oecologia, vol. 163, no. 4, pp. 1091–1102, 2010, doi: 10.1007/s00442-010-1689-y.
7. M. E. Fernández-Giménez, B. Batkhishig, B. Batbuyan, and T. Ulambayar, "Lessons from the Dzud: Community-Based Rangeland Management Increases the Adaptive Capacity of Mongolian Herders to Winter Disasters," World Dev., vol. 68, no. 1, pp. 48–65, 2015, doi: 10.1016/j.worlddev.2014.11.015.
8. MARCC, "Mongolia: Assessment Report on Climate Change 2009," Minist. Nat. Environ. Mong. United Nations Environ. Program. United Nations Dev. Program., 2009.
9. U. O E and A. J I, "Effect of Mining Activities on Vegetation Composition and nutrient status of Forest Soil in Benue Cement Company, Benue State, Nigeria," Int. J. Environ. Agric. Biotechnol., vol. 2, no. 1, pp. 297–305, 2017, doi: 10.22161/ijeab/2.1.39.
10. A. J. I. Unanaonwi O E, "A Review of Environmental Social Impacts of the Mining Sector," no. May, 2006.
11. M. H. D. and J. S. N., "An Assessment of Mining Activities Impact on Vegetation in Bukuru Jos Plateau State Nigeria Using Normalized Differential Vegetation Index (NDVI)," J. Sustain. Dev., vol. 4, no. 6, pp. 150–159, 2011, doi: 10.5539/jsd.v4n6p150.
12. 2005 Coal Resource, "The Coal Resource - a Comprehensive Overview of Coal, The Coal Resource - Where Does Coal Come From ? What Is It," World Coal Inst., pp. 1-44, 2005.
13. Y. Yang, P. D. Erskine, A. M. Lechner, D. Mulligan, S. Zhang, and Z. Wang, "Detecting the dynamics of vegetation disturbance and recovery in surface mining area via Landsat imagery and LandTrendr algorithm," J. Clean. Prod., vol. 178, no. February, pp. 353–362, 2018, doi: 10.1016/j.jclepro.2018.01.050.
14. M. mining Corporation, "Annual Report 2020," AIMS Allergy Immunol., vol. 5, no. 1, pp. 33–37, 2021, doi: 10.3934/allergy.2021003.
15. A. M. Farmer, "The effects of duston vegetation," vol. 79, no. August 1991, pp. 63-75, 1993.
16. P. Li, X. Zhang, M. Hao, Y. Cui, S. Zhu, and Y. Zhang, "Erratum: Effects of Vegetation Restoration on Soil Bacterial Communities, Enzyme Activities, and Nutrients of Reconstructed Soil in a Mining Area on the Loess Plateau, China. Sustainability 2019, 11, 2295," Sustain., vol. 11, no. 19, 2019, doi: 10.3390/su11195171.
17. Y. Yang, P. D. Erskine, S. Zhang, Y. Wang, Z. Bian, and S. Lei, "Effects of underground mining on vegetation and environmental patterns in a located watershed with implications for resilience management," Environ. Earth Sci., vol. 77, no. 17, pp. 1-12, 2018, doi: 10.1007/s12665-018-7796-5.
18. T. Qian, H. Bagan, T. Kinoshita, and Y. Yamagata, "Spatial–Temporal Analyses of Surface Coal Mining Dominated Land Degradation in Holingol, Inner Mongolia," IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., vol. 7, no. 5, pp. 1675–1687, May 2014, doi: 10.1109/JSTARS.2014.2301152.
19. Q. Ma, C. He, and X. Fang, "A rapid method for quantifying landscape-scale vegetation disturbances by surface coal mining in arid and semiarid regions," Landsc. Ecol., vol. 33, no. 12, pp. 2061–2070, 2018, doi: 10.1007/s10980-018-0726-9.
20. Оюу Толгой 1957-2018 (Oyu Tolgoi, 1957-2018), 2018.
21. Y. Huang, F. Tian, Y. Wang, M. Wang, and Z. Hu, "Effect of coal mining on vegetation disturbance and associated carbon loss," Environ. Earth Sci., vol. 73, no. 5, pp. 2329–2342, 2015, doi: 10.1007/s12665-014-3584-z.
22. Y. Liu, S. G. Lei, X. Y. Chen, M. Chen, X. Y. Zhang, and L. L. Long, "Disturbance mechanism of coal mining subsidence to typical plants in a semiarid area using O-J-I-P chlorophyll a fluorescence analysis" Photosynthetica, no. October, 2020, doi: 10.32615/ps.2020.072.
23. D. F. O. R. Government and I. Relations, "Deputy director for government Khanbogd soum report on environmental protection , reclamation work and implementation of environmental monitoring programme - 2011," Khanbogd soum. 2011.