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The Effects of Anthropogenic Loads on Vegetation Cover and Natural Water Quality in the Ugii Lake Basin, Mongolia

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ABSTRACT

The Ugii Lake Basin, located in central Mongolia, has many natural parks with unique formations and is part of the International Ramsar Wetland Protection Agreement. To establish the "New Kharkhorum" city, it was necessary to plan and evaluate changes to the regional geological environment, including the Ugii Lake Basin. We aimed to assess changes in the vegetation cover, soil, and surface water of the Ugii Lake Basin. Field research, geochemical analysis of soil and surface water, and remote sensing image interpretation methods were used in this study. We interpreted Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data from 2000 to 2022 to investigate changes in vegetation cover. On the basis of this classification, soil and natural water samples were chosen for onsite observations at four locations. As a result, the boundaries of the Ugii Lake Basin have been defined; they are 1017 km long and cover an area of 14,300 km^2. Six normalized difference vegetation index categories were identified while the vegetation cover quality in the Ugii Lake Basin was assessed. The pH values of the surface water exceeded the standard by 0.05-0.21 in the area with a high anthropogenic load, whereas the other factors (Ca^{2+}, Mg^{2+}, Na^{+}+K^{+}, SO_4^{2-}, Fe, Cl^-, CO_3^{2-}, HCO_3^-, NO_2^-, NO_3^-, and physiochemical parameters) did not exceed the Mongolian National Standard. The pH values in natural water were relatively high near the lake, indicating human activity in the Ugii Lake Basin. Consequently, this should be considered when designing integrated measures to address climate change and anthropogenic impacts in the Ugii Lake Basin.

Keywords: vegetation cover, land degradation, water quality, heavy metals

INTRODUCTION

The scientific and logical determination of boundaries for the management and control of lake-type wetland parks is highly important for the sustainable protection and utilization of wetland resources (Chen et al., 2022). Wetlands in Mongolia are considered important natural resources for conservation because a considerable part of Mongolia is within arid and semiarid zones. The Mongolian dry-land ecosystem is virgin and vulnerable to both natural and anthropogenic changes. Therefore, it is very important not only to avoid losing wetlands but also to take appropriate actions and measures in a timely fashion to conserve them (Ramsar, 1999). The geological environment refers to the surface of the lithosphere, which is a component of the environment. Technogenic systems are various engineering structures, objects, and complexes formed on the surface and subsurface of a geological environment as a result of human activity. These anthropogenic systems affect the geological environment, known as the anthropogenic load (Batsukh, 2002; Verhozin, 2020). However, populations tend to be concentrated along rivers and lake basins because water provides fertile soil and irrigation opportunities. Social organization and governance are essential to maximize the use of water resources while simultaneously reducing the risks associated with human settlements (Huitema and Meijerink, 2017). The quality of drinking water in areas with high anthropogenic loads is polluted according to the parameters of drinking water requirements (pH, turbidity, mineralization, and heavy metals in the aquatic environment), which has become a source of disease in humans and animals. However, as the anthropogenic load decreases, pollution decreases along the Tuul River from the Nalaikh River to the confluence of the Orkhontuul River (Enkhjargal and Odontsetseg, 2017).

The environmental and climate studies conducted around Ugii Lake have yielded several key findings.

Climate Impact: Climate change has had a moderately negative impact on the water supply and quality in the region (Winkel et al., 2011). The average climate conditions in the area have experienced significant shifts due to global warming, which have affected the lake's size and volume. Specifically, studies have shown that over the past three decades, Ugii Lake's area has decreased by more than 10%, largely due to global warming (Erdenesukh et al., 2020).

Lake Evaporation: A study using the energy budget method to calculate lake evaporation (1986-2019) found that the evaporation rate consistently exceeded precipitation from 2013 to 2019. This period also saw a strong positive correlation between the lake's water surface area and its water level (Amgalan et al., 2020).

Land Cover Changes: The reduction in vegetation cover around the lake was identified using the Normalized Difference Vegetation Index (NDVI) in several years from 1989 to 2019. The study suggested that increased human activity, particularly from tourist camps and resorts near the lake, contributed to land cover changes (Gantulga et al., 2021; Magsar et al., 2021).

Water Quality: Research on the water quality of Ugii Lake has shown that, overall, the water falls within acceptable parameters for pH, dissolved oxygen, total organic carbon, and suspended matter. However, there was a significant increase in the concentration of PO_4^{3-} in 2018, exceeding Mongolian National Standards (MNS) by 2.7-3.4 times. This increase was linked to the rising number of tourists and animals around the lake (Amgalan et al., 2020).

Hydrological and Climatic Relationships: Research indicates that the flow rate of tributaries feeding Ugii Lake has decreased, while evaporation has increased. Precipitation rates, however, remained relatively stable. These factors have contributed to the lake's shrinkage over time (Erdenesukh et al., 2020). Batjargal and Batsukh (2022) highlight that changing climate patterns, including reduced precipitation and increased evaporation, could significantly stress groundwater resources. They point out that recharge rates of groundwater are variable and influenced by factors such as precipitation patterns, land use, and the geological characteristics of the region.

Overall Environmental Impact: The studies collectively point to the intensified climate warming in Mongolia since around 2000, which has led to a reduction in both the area and volume of lakes, with Ugii Lake being no exception. The highest degree of aridity is found in areas with significant climate reserves, indicating the growing challenges faced by water bodies in arid regions (Enkhbold et al., 2024).

GEOLOGICAL AND ENVIRONMENTAL BACKGROUND OF THE UGII LAKE BASIN

The Ugii Lake Basin (ULB) is an ecologically significant region located in central Mongolia (47°81'N, 102°48'E; Fig. 1), characterized by a unique hydrological system and a rich geological history. Spanning an area 12-20 km in width, the basin is situated between the Orkhon Valley to the west and the Khangai Mountain Range to the east. The lake itself, fed by the Nariin River and drained by the Ugii River, experiences slow water exchange, which leads to notable variations in water quality across both surface and depth (Munkhzul and Tuvaanjav, 2005). The ULB possesses a well-developed hydrological

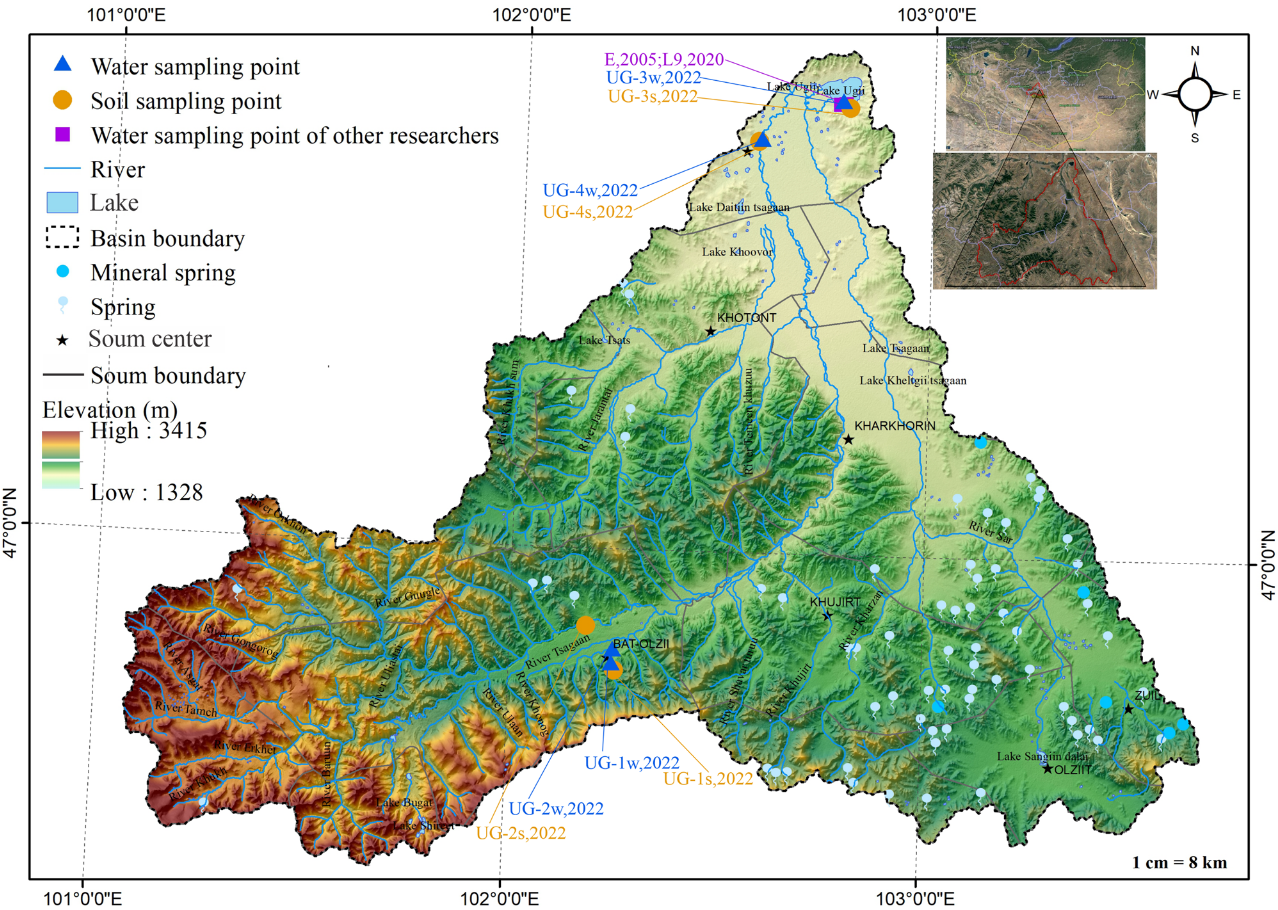


Fig. 1. Inset: Location of Ugii Lake in Mongolia. a) Hydrological map of the Ugii Lake Basin. The locations of the samples are also shown: blue triangles represent water samples and yellow circles represent soil samples from 2022. The pink square points represent L9 of Amgalan et al. (2020) and E of Munkhzul and Tuvaanjav (2005).

network, and Fig. 1 shows the distribution of surface water superimposed on elevation data.

Ugii Lake is the largest freshwater body in the ULB and holds ecological importance as it is designated as a wetland under the Ramsar Convention (Ramsar, 1999). Its formation is largely attributed to tectonic faults and fluvial processes (Altanbold et al., 2019). Over millennia, the basin has undergone substantial climatic shifts, with periods of aridity, increased moisture, and fluctuations in lake levels, as evidenced by sediment cores taken from the lake.

In recent decades, the ULB has been significantly impacted by climate change, with warming trends and drying conditions affecting local vegetation and the broader ecosystem. The region's forests play a critical role in regulating water resources, preventing soil erosion, and supporting biodiversity. However, pressures from both climate change and human activity have led to increasing land degradation, particularly near the lake, highlighting the need for comprehensive environmental monitoring.

From 4.2 to 2.8 thousand years ago, Mongolia experienced arid conditions, followed by a more humid phase that has continued to the present (Schwanghart et al., 2008). Over the last 40 years, Mongolia has warmed at twice the global average rate, causing permafrost to melt and predictions of a drier future climate (Schwanghart et al. 2009). This warming has profound implications for Mongolia's socioeconomics, which are tied to ecosystem changes. Historical droughts, particularly during the mid-Holocene, were linked to higher temperatures and increased evaporation, exacerbating dryness (Wang et al., 2009, 2011). In the ULB, the climate shifted from mild and semi-humid to dry conditions, influencing vegetation and ecosystems.

Forests play a vital role in regulating water resources, preventing soil erosion, maintaining moisture, and providing habitats (Batsukh, 2020). However, distinguishing the effects of climate change and human activities on vegetation cover, particularly the NDVI, is complex (Enliang et al., 2021). Vegetation in arid regions is highly sensitive to climate, and the ULB has seen increased bare land over the past two decades due to fertility loss (Nomindari and Tsendmaa, 2019). Previous research has focused on changes in vegetation and water quality around Ugii Lake, emphasizing the need for further environmental monitoring (Pouyan and Hossein, 2023; Lkhagvasuren and Ariunsuren, 2005; Nomindari et al., 2022; Clesceri, 1998; Erdenesukh et al., 2020; Magsar et al., 2021; Gantulga et al., 2021).

Consequently, given the ongoing environmental changes in the Ugii Lake Basin (ULB), conducting geological environmental research is essential. Monitoring these changes will help develop effective management strategies for the lake and its basin, ensuring long-term sustainability amidst climate change and other environmental pressures (https://kharkhorum.gov.mn/).

We aim to conduct an environmental study of the Ugii Lake Basin to analyze the relationship between natural and human factors, utilizing satellite data from the past 20 years along with geochemical data from soil and water samples.

RESULTS

NDVI interpretation

Twenty years of continuous Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data obtained during the same period were processed, the NDVI categories were classified, and field research locations were systematically selected and verified via field measurements. MODIS satellite data interpretation from 2000 to 2022, as well as the calculated NDVI, revealed six distinct vegetation cover categories. These categories include aquatic areas, with NDVI values of -1-0.15; barren areas, with NDVI values of 0.15-0.2; sparsely vegetated areas, with NDVI values of 0.2-0.4; moderately vegetated areas, with NDVI values of 0.4-0.6; well-vegetated areas, with NDVI values of 0.6-0.7; and densely vegetated areas, with NDVI

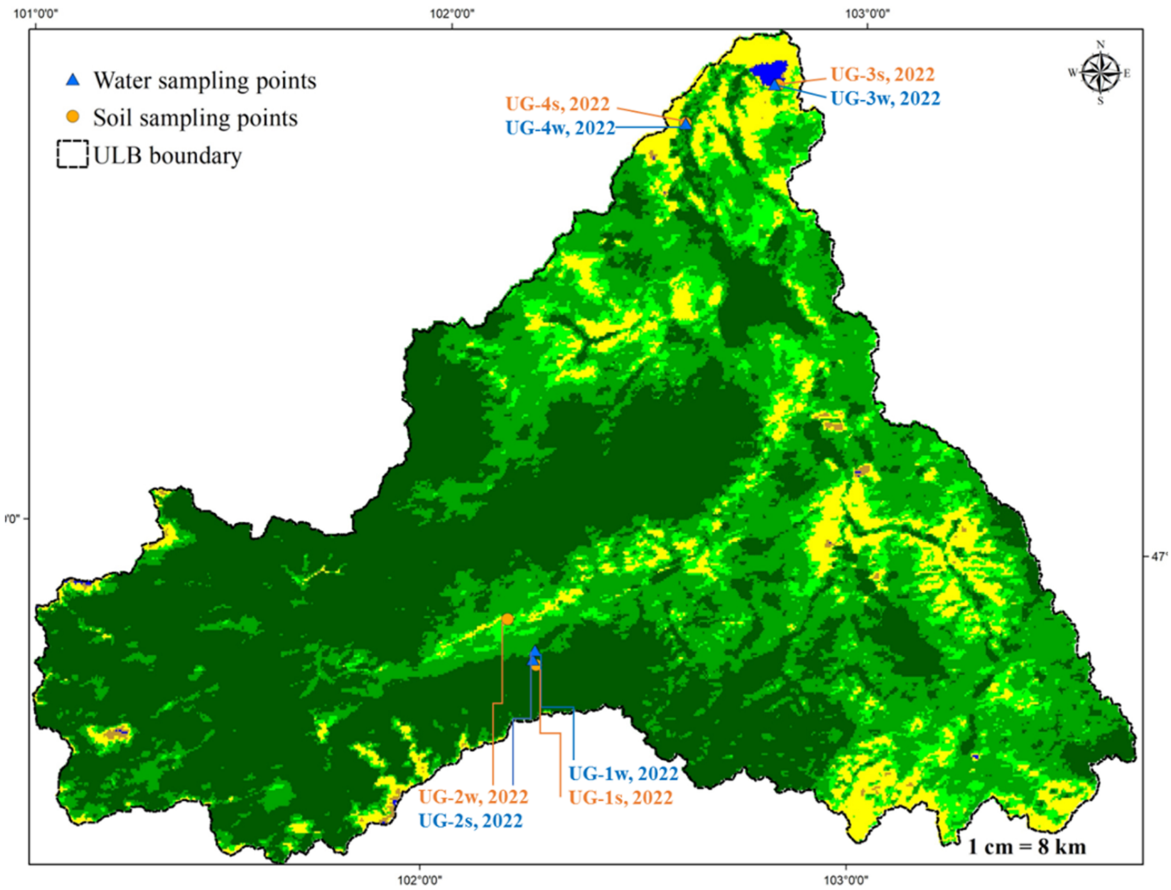


Fig. 2. NDVI categories and vegetation distribution map of the ULB for the second ten days of August 2022. The sampling was conducted during the same period

Table 1. NDVI classification and interpretation of vegetation cover in the ULB

NDVI value	-1-0.15	0.15-0.2	0.2-0.4	0.4-0.6	0.6-0.7	0.7-1.0
Area category	Watery area	Bare area	Sparsely vegetated area	Moderately vegetated area	Well vegetated area	Thick vegetated area
Interpretation	Lake	Anthropogenic overloaded and degraded area	The anthropogenic load is medium to high	Anthropogenic load is normal	No anthropogenic load	Forest No anthropogenic load

Table 2. Geochemical and physiochemical characteristics of water samples in the ULB, 2022

Indicator	Measurement unit	Measurement points				MNS 0900:2018
		UG-1w	UG-2w	UG-3w	UG-4w	
Ca^{2+}	mg/l	16.03	15.03	31.06	26.05	100
Mg^{2+}		2.43	4.26	17.63	6.69	30
$Na^{+}+K^{+}$		16.16	12.56	59.73	30.99	-
Fe		0.09	0.025	0.100	0.06	0.3
CI^{-}		5.31	7.09	12.41	7.09	350
SO_4^{2-}		17	14	84	48	500
CO_3^{2-}		0	0	36	27	-
HCO_3^{-}		73.20	70.15	140.30	67.10	-
NO_2^{-}		0.017	0.011	0.015	0.012	1
NO_3^{-}		0.10	0.46	0.02	0.02	50
General mineralization		130.33	123.62	381.26	213.01	1000
pH		7.00	6.87	8.55	8.71	6.5-8.5
General hardness	mEq/l	1	1.1	3	1.9	-
Electrical conductivity	µS/cm	261	247	763	426	-
Color	degree	colorless	colorless	colorless	colorless	-
Smell	score	odorless	odorless	odorless	odorless	-

values of 0.7-1.0 (Fig. 2 and Table 1).

As presented in Table 1, an aquatic area with NDVI values of -1-0.15 corresponds to a lake, a densely vegetated area with NDVI values of 0.7-1.0 represents forest, and a barren area with NDVI values of 0.15-0.2 indicates degraded land with a high anthropogenic impact. Field research was conducted to elucidate the distinctions between sparsely vegetated areas under stress (NDVI values of 0.2-0.4) and densely vegetated areas (NDVI values of 0.6-0.7).

Water quality

The UG-1w and UG-2w samples were collected from well-vegetated areas with no anthropogenic load and NDVI values ranging from 0.6 to 0.7 (Figs. 1-3). Their general mineralization values range from 130.33 to 123.62 mg/l at pH 7 to 6.87 (Table 2). Samples UG-3w and UG-4w were collected near the Ugii Lake area, which is sparsely vegetated and has a medium to high anthropogenic load (Figs. 1-3), and they exhibited general mineralization values of 213.01-381.26 mg/l and pH values of 8.55-8.71 (Table 2).

Soil properties

Fig. 3 shows a distinct contrast between the well-vegetated and sparsely vegetated areas. Soil sampling sections UG-2s, UG-3s, and UG-4s were located in a low-fertility, sparsely vegetated area, whereas UG-1s was situated in a high-fertility, well-vegetated area. The soil geochemical data are summarized in Table 3.

Four samples were obtained along the vertical section of UG-1s (Fig. 4A, Table 3). The samples exhibited relatively high Mo and Cu concentrations at depths of 0.0-0.15 m, whereas the Cr, Co, Ni, V, and Zn concentrations were elevated in the 0.6-0.9 m range. However, the heavy metal concentrations at UG-1s did not

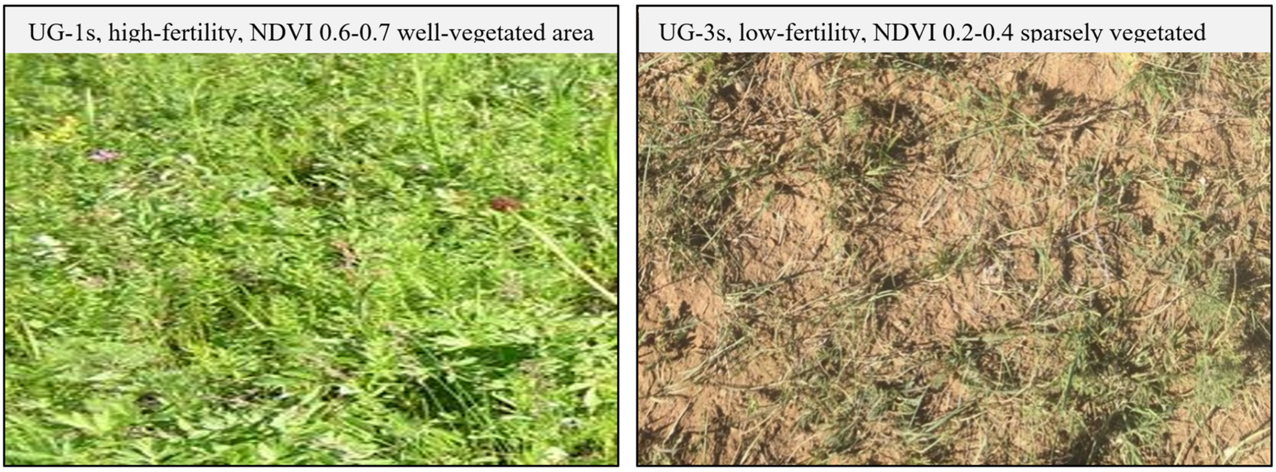


Fig. 3. The site visibility of the different locations of the UBL demonstrated that well-vegetated areas with no anthropogenic load contrasted with sparsely vegetated areas exhibiting medium to high anthropogenic loads

Table 3. Heavy metal contents along the vertical sections: A) UG-1s, B) UG-2s, C) UG-3s, and D) UG-4s

Sampling sections	Sample interval, m	Heavy metal concentration (mg/kg)										
		Cr	Co	Ni	Sr	Mo	Cd	Sn	Pb	Cu	V	Zn
UG-1s	0.00-0.14	19.59	6.80	31.33	225	2.78	<0.5	2.64	22.79	31.49	28.81	72.35
	0.14-0.17	12.54	5.06	21.35	226	1.72	<0.5	2.97	24.18	22.00	23.02	67.15
	0.17-0.60	10.95	3.72	17.90	202	1.63	<0.5	2.17	22.48	16.25	17.61	50.70
	0.60-0.90	31.60	9.55	33.48	254	1.65	<0.5	2.55	17.03	17.64	50.81	76.03
UG-2s	0.00-0.21	28.50	8.48	33.18	123	1.79	<0.5	3.77	16.81	36.66	38.93	79.79
	0.21-0.30	13.65	4.29	22.42	89.2	1.72	<0.5	2.62	14.67	23.23	13.52	33.74
	0.30-0.39	16.42	5.60	24.94	98.6	2.44	<0.5	3.12	15.90	31.20	19.56	46.52
	0.39-0.50	13.19	5.20	23.00	95.3	1.57	<0.5	3.38	13.71	27.59	20.58	45.72
	0.50-0.56	16.06	5.97	22.55	116	1.39	<0.5	3.52	14.69	26.96	31.91	59.30
	0.56-0.65	11.51	4.47	17.75	101	1.35	<0.5	2.89	14.39	20.32	23.09	41.79
	0.65-0.80	19.45	5.99	21.10	121	1.52	<0.5	3.70	14.79	21.46	30.05	50.03
	0.80-0.95	30.76	8.06	20.28	165	1.43	<0.5	3.96	15.52	17.18	50.50	71.92
	0.95-1.15	11.89	5.48	16.61	121	1.08	<0.5	3.26	6.69	15.46	31.01	60.01
UG-3s	0.00-0.15	19.61	5.50	18.28	195	1.49	<0.5	2.01	13.36	21.36	35.52	49.73
	0.15-0.23	12.11	5.02	1764	185	1.59	<0.5	1.77	12.74	18.62	35.33	50.77
	0.23-0.39	15.14	5.13	16.69	208	1.21	<0.5	1.90	13.95	18.38	38.88	48.57
	0.39-0.45	18.18	5.94	20.65	225	1.33	<0.5	2.07	14.92	24.94	37.31	45.65
	0.45-0.80	11.73	4.64	13.55	212	1.11	<0.5	1.92	14.19	15.24	33.08	42.95
UG-4s	0.00-0.21	22.19	7.15	24.51	219	1.82	<0.5	2.02	13.00	27.48	34.82	50.51
	0.21-0.34	9.01	3.89	13.94	258	1.44	<0.5	1.95	14.40	15.16	20.43	30.71
	0.34-0.50	27.86	8.83	23.82	274	1.41	<0.5	2.41	15.46	20.25	51.62	69.25
	0.50-0.70	14.53	4.79	14.19	238	8.41	<0.5	2.00	12.35	16.67	31.50	44.13
Soil quality MNS 5850:2019		150	50.00	50.00	800	5.00	3	50	100	100	150	300

exceed the soil quality standards at any depth. Nine samples were collected along the vertical section of UG-2s. At this sampling point, the depth interval of 0.8-0.95 m exhibited slight differences from the other intervals. The interval exhibited elevated Cr, Co, Sr, Sn, Pb, and Zn levels but did not exceed the soil quality standards at any depth (Fig. 4B, Table 3).

Five samples were obtained along the vertical section of UG-3s (Fig. 4C, Table 3). These samples exhibited relatively high Cr and Zn concentrations at depths of 0.0-0.15 m, whereas the Cr, Co, Ni, Sr, Sn, Pb, and Cu concentrations were elevated in the 0.39-0.45 m range.

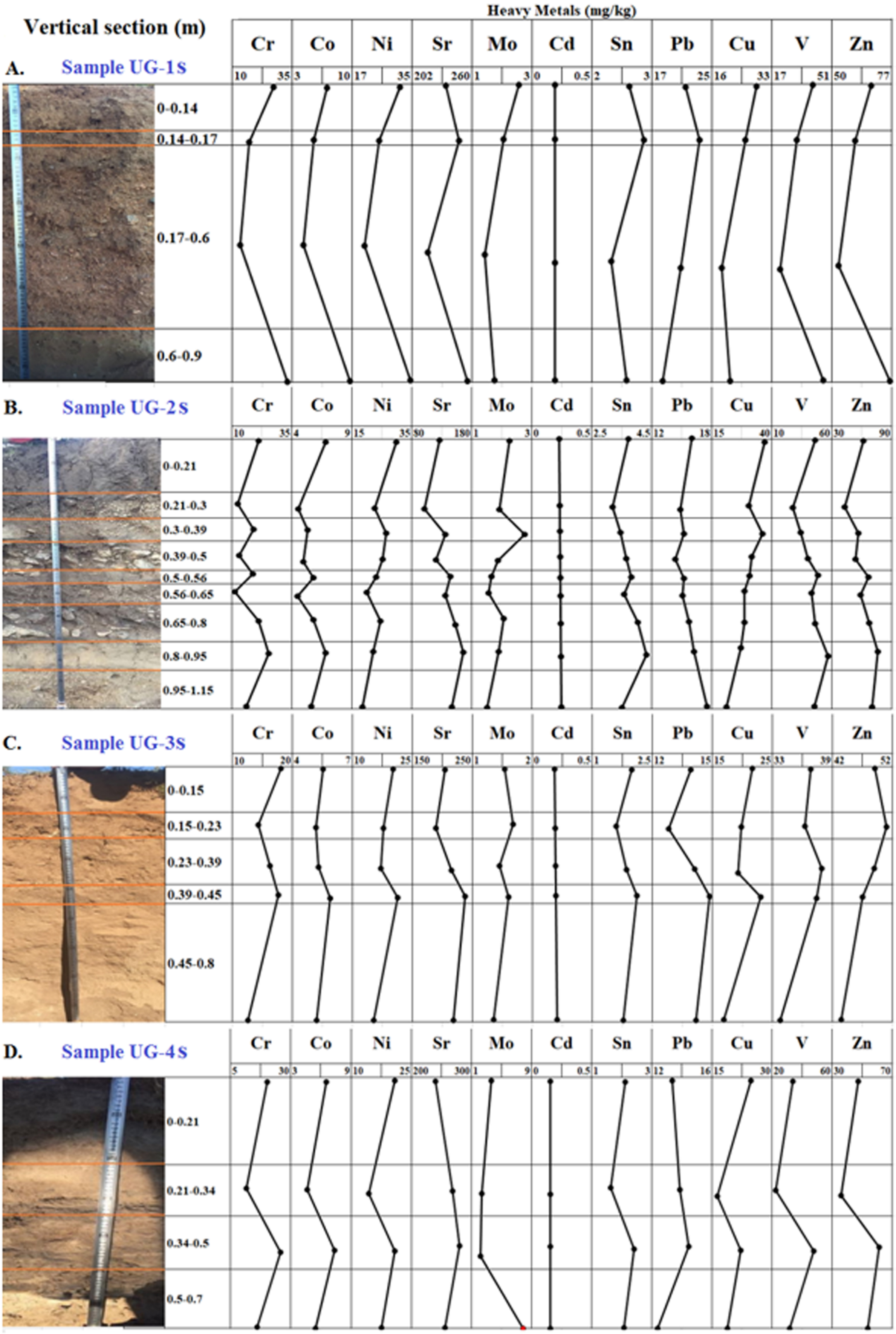


Fig. 4. Heavy metal content along the vertical sections of soil sampling points. A) UG-1s, B) UG-2s, C) UG-3s, and D) UG-4s

However, the heavy metal concentrations in UG-3s did not exceed the soil quality standards at any depth.

Fig. 4D and Table 3 present information from the four samples collected along the vertical section at UG-4s. These samples indicated that Cr, Co, Ni, Sr, Sn, Pb, V, and Zn were prevalent at depths ranging from 0.34-0.5 m. At depths of 0.5-0.7 m, the Mo content exceeded the soil quality standard by 3.41 mg/kg (MNS 5850:2019). The elevated Mo content in the soil may be attributed to overgrazing.

DISCUSSION

NDVI *vs* land degradation

Our research has the advantage of being conducted not only in the area of Ugii Lake but also in the entire ULB area of 14350 km^2. On the basis of the interpretation of NDVI values, we categorized the vegetation cover types into six categories (Fig. 2, Table 1). Notably, the classification was performed by analyzing changes in the vegetation index over a 20-year period rather than solely utilizing numerical indicators. The results are summarized in Table 3. According to our interpretation, the vegetation cover improved throughout the year under the ULB scenario (Table 4). However, this trend was not observed in Ugii Lake.

Statistical analyses were conducted to ascertain the impacts of anthropogenic activities and natural factors on land cover changes in the ULB. Table 5 presents the correlation coefficients of the selected factors contributing to anthropogenic loads that influence land degradation. These factors are clearly subject to various other influences and do not singularly affect land cover. For example, between 2011 and 2015, the number of livestock in the basin increased by 1.84 times compared to previous years of 2006-2010. This growth has influenced the purchasing power of the local population, resulting in a moderate increase in the number of vehicles. Consequently, the correlation between vehicle numbers and land degradation has shifted to a strong positive correlation (0.769). During this period, precipitation in the basin decreased by 36 mm in 2012 compared to 2011, while soil temperatures increased by 4.6°C in 2015 vs 2014. These changes contributed to a stronger inverse correlation between precipitation and land degradation between 2011 and 2015, with the correlation coefficient reaching -0.481 (Fig. 5). A further example is that, since 2016, the expansion of agricultural activities has been associated with an increase in precipitation, with precipitation levels in 2016-2020 rising 2.07 times compared to 2010-2015. This increase has resulted in a correlation of 0.582 between cultivated land area and land degradation. In the basin, favorable conditions of precipitation and surface

Table 4. Vegetation cover changes in the ULB from 2000 to 2020, as assessed by NDVI values

NDVI		2000		2005		2010		2015		2020	
Category	Values	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Watery area	-1-0.15	37	0.26	22	0.15	32	0.23	21	0.15	26	0.18
Bare area	0.15-0.2	46	0.32	48	0.34	33	0.23	18	0.12	20	0.14
Sparsely vegetated area	0.2-0.4	6337	44.33	5721	40.04	4293	30.03	2291	16.02	2690	18.82
Moderately vegetated area	0.4-0.6	6246	43.69	6004	42.03	7756	54.25	8469	59.25	7130	49.87
Well vegetated area	0.6-0.7	1243	8.69	1665	11.65	1852	12.95	2185	15.29	2039	14.26
Thick vegetated area	0.7-1.0	386	2.7	827	5.79	332	2.32	1311	9.17	2391	16.72
Total area (km^2)		14295	100	14287	100	14297	100	14295	100	14296	100

Table 5. Input variable correlation coefficient- Factors causing anthropogenic load that affect land degradation

Factors			Correlation coefficient between anthropogenic loads and affecting factors			
			2000-2005	**2006-2010**	**2011-2015**	**2016-2020**
Human related factors	Agriculture	Crop land	0.001	-0.172	-0.307	0.582
		Number of livestock	-0.457	0.332	-0.723	0.098
	Water management	Well	0.193	0.467	-0.768	0.000
		Irrigated crop land	-0.654	0.181	0.468	-0.299
	Mine	Open pit mining	-0.275	-0.194	-0.622	0.329
	Urban	Urban areas	-0.025	-0.116	-0.688	-0.150
		Tourist	-0.610	-0.170	-0.592	0.856
		Number of cars	-0.117	0.017	0.769	-0.185
		Solid waste	-0.109	0.082	-0.741	-0.258
	Line type infrastructure	Asphalt road	-0.025	-0.256	0.000	0.000
		Gravel road	0.000	-0.257	0.000	0.000
		Unpaved road	-0.207	0.001	-0.590	0.000
Natural factors	Climate parameters	Total annual precipitation	-0.280	-0.349	-0.481	-0.047
		Surface temperature /May-August/	0.317	0.357	-0.314	-0.252

temperature contributed to a 1.2-fold increase in tourist numbers between 2015 and 2020, compared to the previous period. Consequently, the relationship between tourist numbers and land degradation became significantly positive as 0.859 from 2016 to 2020 (Fig. 5).

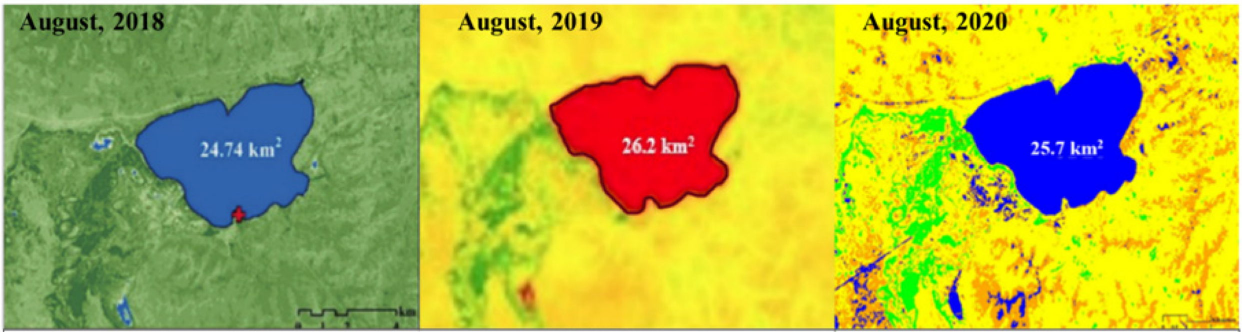
Previous investigations have focused on the Ugii Lake area, which is approximately 36 times smaller than the ULB (Schwanghart et al., 2008; Amgalan et al., 2020; Erdenesukh et al., 2020; Magsar et al., 2021; Gantulga et al., 2021). To facilitate comparisons between previous research and the present study, data processed from the Landsat 8 satellite at a 30 m resolution were utilized (Fig. 5).

Magsar et al. conducted a study encompassing the Ugii Lake area, reporting NDVI values ranging from -1.0 to 1.0, with negative values primarily generated by clouds, water, and snow, whereas values near zero were predominantly associated with rocks and bare soil. Low NDVI values (0.1 and lower) correspond to barren areas of sand and snow. Low values (0.2-0.3) represent shrub and unhealthy grassland or sparse vegetation, moderate values (0.4-0.5) indicate healthy vegetation, high values (0.6-0.8) signify very healthy vegetation, and the highest values (0.9-1.0) represent the maximum possible density of green vegetation and tropical rainforests (Magsar et al., 2021). Gantulga and Altanbold determined the NDVI of the Ugii Lake area and reported that there is a 0.73 correlation between the number of livestock and the NDVI and that the change in vegetation cover around Ugii Lake is attributable to anthropogenic factors that are independent of climate parameters, such as air temperature and precipitation (Gantulga et al., 2021). Erdenesukh utilized Landsat satellite NDWI multichannel data to calculate the values of the Ugii Lake surface area from 1986 to 2018 and concluded that the satellite data were validated by measuring the lake water level (r=0.95). The lake surface area decreased by 13.5% from 1986 to 2018 (Erdenesukh et al., 2020).

We conclude that our NDVI category classification is the most effective fundamental classification because it is based on data from the entire basin over a 20-year period and is comparable to previous classifications.

Water quality changes *vs* human activity

The results of the analysis of the ULB water samples, including the major anion and cation contents, as well as the physicochemical parameters of each sample, were compared with the drinking water standard of Mongolia (MNS 0900:2018) presented in Table 2. The values and contents that exceeded the permissible limits of the MNS standard are highlighted in red. The parameters evaluated in the comprehensive water analysis of sample UG-3w exhibited



NDVI category and interpretation (Magsar et al., 2018)		NDVI value (Gantulga et al., 2019)	NDVI category and interpretation (this study)	
-1-0	Water and snow	min -0.235	-1-0	Water and wetlands
0-0.1	Barren area		0.15-0.2	Bare area, sand
0.1-0.2				
0.2-0.3	Unhealthy grassland		0.2-0.4	Sparsely vegetated area
0.3-0.4				
0.4-0.5	Healthy plants		0.4-0.6	Moderately vegetated area
0.5-0.6		max 0.502		
0.6-0.7	Very healthy plants		0.6-0.7	Well vegetated area
0.7-0.8			0.7-1.0	Thick vegetated area
0.8-0.9				
0.9-1.0	Tropical rain forest			

Fig. 5. Comparison of NDVI interpretation in the Ugii Lake area in 2018 (Magsar et al., 2021), 2019 (Gantulga et al., 2021) and 2020 (this study)

higher contents and values than those of samples UG-1w, UG-2w, and UG-4w. Moreover, the hydrogen ion concentration pH of samples UG-3w and UG-4w exceeded the acceptable limit (Table 2).

The Ugii Lake water was characterized as slightly alkaline, with a pH range of 8.5-8.7 and a general mineralization of 382 mg/L in 2022, whereas the pH values were 7.6-8.5 and 358.3 mg/L in 2005 (our UG-3s sampling point geographically corresponds to the E sampling point of Munkhzul and Tuvaanjav, 2005), indicating a deterioration in general mineralization and pH (Fig. 6).

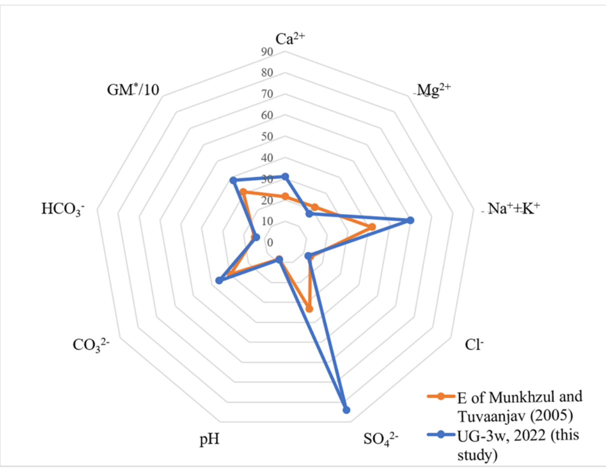


Fig. 6. Comparison of water quality in UG-3w of 2022 (this study) and E of Munkhzul and Tuvaanjav (2005)

The concentration of hydrogen ions (pH) affects numerous biological and chemical processes in natural waters. The reproduction and activity of aquatic plants, stabilization of various forms of elements, adverse effects of water on metals and concrete, and alterations in toxicity are all directly correlated with pH.

Consequently, when natural water quality data and the NDVI are utilized, the characteristics of natural changes in water near the Ugii Lake area, which represents the highest level of human activity and demonstrates a significant degree of environmental pollution, can be observed (Table 6). According to the 2022 data (Fig. 6), the water pH at the UG-3w and UG-4w points exceeded the MNS water quality standard (MNS 0900:2018). Solid waste accumulation and seasonal tourism have a negative impact on the environment surrounding Ugii Lake. As reported by Magsar et al. (2021), 83% of households near Ugii Lake utilize lake water for washing and livestock watering, irrespective of its quality. This practice directly influences the pH of the water.

Table 6. Comparison of natural water quality over the year

	2005 Munkhzul and Tuvaanjav (2005)	September, 2017 (Amgalan et al., 2020)	August, 2018 (Amgalan et al., 2020)	August 2022 (this study)
Sample #	E	L9	L9	UG-3
pH	7.6-8.5	8.2-8.7	8.33-9.26	8.5-8.7
General mineralization	358.3			382

Soil properties *vs* geological background

Relatively limited research has been conducted on soil pollution in the UBL. In this study, vertical section analysis of soil was performed at sites with minimum and maximum anthropogenic loads in the UBL to assess changes in soil heavy metal contamination and vegetation cover. The heavy metal concentrations in the soil samples from all four sampling points were compared with the Mongolian National Standard for the permissible limits of pollutants in soil (MNS 5850:2019).

The UG-1s and UG-2s locations, which are located in areas with high fertility and NDVI values ranging from 0.6-0.7 and are well vegetated, exhibited relatively high concentrations of Ni, Zn, and Cu, which are attributed to the geological background and bedrock characteristics. For example, the granitic rocks in the Permian Khangai Complex distributed in the UG-1s and UG-2s locations have undergone alteration and are associated with W-Au and Sn-Cu-Au mineralization (Enkhbayar et al., 2022a). The Quaternary sediments include sandstone, siltstone, and conglomerate. The sedimentary rocks of the Kholbootolgoi Formation are distributed in the UG-3s and UG-4s locations, and no significant mineralization or alteration has been identified (Enkhbayar et al., 2022b).

CONCLUSION

The boundaries of the ULB are defined as 1017 km long and encompass an area of 14,300 km^2. Six NDVI categories were identified during the assessment of vegetation cover quality in the ULB. The vegetation cover of the ULB has undergone changes influenced by multiple factors, with anthropogenic and natural factors being predominant.

The composition and characteristics of natural water were evaluated via 16 indicators. With respect to general mineralization, the natural water in the ULB met the requirements of the Mongolian standard of Drinking and Domestic Water Standard MNS 900-2018. However, the pH levels in the UG-3w and UG-4w Ugii Lake areas exceeded the pH standard due to anthropogenic activity, particularly the utilization of lake water for household and livestock purposes. The elevated pH values in natural water corroborated the presence of significant anthropogenic pollution in the Ugii Lake area.

The soil assessment revealed no evidence of anthropogenic pollution; however, certain points related to alteration and mineralization of the geological background exhibited higher contents than the contents of the MNS 5850:2019 standard. In areas with high fertility, the NDVI values of 0.6-0.7 for well-vegetated areas indicated relatively high concentrations of Ni, Zn, and Cu, which are attributed to the geological background and bedrock characteristics.

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