RESULTS OF USING SPECTRORADIOMETERS FOR IN SOIL MOISTURE OF MONGOLIAN STEPPE ECOSYSTEM

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ABSTRACT:

Determining soil moisture remains an important issue in environmental, agricultural, and crop fields. The use of remote sensing data in the study of soil surface moisture has many benefits, such as: saving time, resources, and money, as well as monitoring soil condition (surface soil moisture). Based on point data from field measurements, can be used to obtain results of soil moisture. The importance of this study is highlighted by the useof spectral measurements and laboratory-determined moisture content of a variety of soils with different geographical conditions spread over three different natural zones, combined with satellite data. The purpose of this research is to determine and analyse surface soil moisture using Sentinel-2 satellite data and Spectro radiometric measurements. For this research area, four areas representative of forest steppe, steppe, and Gobi eco-regions of Mongolia were selected, field research was conducted, data were collected, and Sentinel-2 satellite data was processed and analysed. According to the results of the spectral reflectance measured during the field research, the high reflectance of the wet soil spectrum in the forest field, and the low reflectance of the spectrum representing the Gobi region, respectively, this create the possibility of studying soil moisture by spectral measurement and analysis. The relationship between the spectral reflectance of the red (665 nm) and near-violet (842 nm) light regions shows that the soil of the forest-steppe region is relatively moist compared to the soil of the Gobi region and that the Gobi soil is drier, and the field soil is drier, and these parameters are confirmed by laboratory analysis. A model developed from a linear relationship between field-measured spectrometer reflectance and laboratory-determined moisture provides a formula that can be used for regular monitoring of moisture content using the Normalized Difference Water Index (NDWI) estimated from satellite data. Surface soil moisture (%) = -44.133*NDWI - 11.553. The NDWI calculated from the spectroradiometer compared to the humidity determined in the laboratory had a linear correlation of R2=0.74 or 74%, and when comparing the humidity calculated from Sentinel-2, the agreement was high. In terms of space, the results calculated from satellite data show that the forest and steppe areas have relatively high humidity compared to the Gobi region, and the total area representing the Gobi region has a lower moisture content. Based on these results, it is considered that it is possible to continuously determine the amount of moisture from satellite data using NDWI (surface soil moisture) in a certain space-time range and use it for soil control and monitoring.

1. INTRODUCTION

In our country, depending on the vast area, nature, and climate, regular monitoring of the soil moisture status is an important indicator for calculating the yield conditions of pasture plants. Moisture detection is time and money intensive, and the availability of manpower is not sufficient to generate data covering large areas. Therefore, determining and monitoring soil moisture on the surface by remote sensing methodology which is satellite data with time, space, and spectral accuracy is economically significant.

In recent years, remote sensing technology has been widely used in environment, plant, and agriculture studies, as well as its methods for recognizing soil properties using spectral results with satellite data and spectroradiometer measurements. The use of remote sensing methods, satellite data, and spectrum analysis will not only save time and money but also provide an opportunity for regular monitoring for our extensive area country.

Determining soil moisture remains an important issue in environmental, agricultural, and crop fields. The use of remote sensing data in surface soil moisture study has many benefits, such as: saving time, resources, and money, as well as monitoring soil condition (surface soil moisture) based on point data from field measurements and time frequency. It can be used to obtain results with spectral data from field research which is important for improving the methodology of optical sensing used in soil moisture research, and by analysing the results. Also, it contributes to solving practical solutions and catalogues the spectral measurements to use in future research on various types of soil.

After the research is done, a model will be developed to determine the soil moisture of the surface by using multi-channel remote sensing data of the optical spectrum. The model has advantages of using field measurements for research results, combining it with satellite data that saves time, and money, and results expressed in a constant space and time data, allowing to use in the food and agriculture sector.

The importance of this study is highlighted by the extreme nature and climate of Mongolia, the spectral measurements of various types of soil with different geographical conditions, and the analysis of soil moisture content determined in the laboratory in combination with satellite data. The purpose of this research is to determine and analyze surface soil moisture using Sentinel-2 satellite data and spectroradiometric measurements.

1.1 Researched status of the research work

Soil is a heterogeneous system, and its processes and mechanisms are one very complex ecosystem component. Traditional soil analytical methods are still used today to determine the physical, chemical, and microbiological properties of soil, the interaction of different soil components, their spatial variability, and soil quality and stability. Conventional methods are very expensive, labour-intensive, time-consuming. Although they are suitable for determining information by sampling in a small area they do not provide any information on the spatial variation of soil properties. Correct estimation of soil properties considering spatial variation has become an important issue for soil mapping, soil fertility management, sustainable land management, and precision agriculture. The use of spectral multi-channel satellite data is ideal for predicting various soil fertility characteristics, such as surface soil moisture data. Spectral reflection properties are greatly influenced by biogeochemical (mineral and organic) components and surface moisture content (Ben-Dor et al. 1999). Spectral analysis methods have been used in soil science research since 1950s and 1960s (Brooks, 1952; Bowers and Hanks, 1965). The benefits and importance of using spectral analysis in combination with satellite data are widely used nowadays. In addition to the use of electromagnetic waves in the visible and near-infrared (VIS-NIR: 400-2500 nm) regions (Chang et al. 2001; Dunn et al. 2002), spectral analysis methods are increasingly being used in the mid-infrared. (2500-25000 nm) (Madari et al. 2006). Visible and short-wavelength violet-red region spectra are more commonly used to determine soil moisture. As soil moisture increases, the value of reflectance measured in the visible color and near-infrared ranges showed a tendency to decrease (Zhan et al. 2007). The results of measurements in the visible and near-infrared spectral ranges of soil moisture modeling have been detailed in several studies, such as vegetation index (Gao, 1996), soil moisture reflectance method (Zhan et al. 2007) have published the results of identifying dry and wet soils using the red and near-violet ranges of visible color, respectively. In Mongolia, there are research works that determine soil moisture using satellite data (Luo et al. 2021; Natsagdorj et al. 2021; Kaihotsu et al. 2009), but not many published works that use it in combination with spectroradiometric measurements. In this study, a model was created to determine surface soil moisture using optical satellite data and spectral results measured in the field.

1.2 Research goals and objectives

Purpose: To determine the soil moisture of the surface to analyze using Sentinel-2 satellite data and Spectroradiometric measurements.

Objective :

- Considering different landscape and ecological conditions, the results of spectroradiometric measurements and determination of soil moisture in laboratory conditions are selected, and natural soil moisture is compared with spectral measurements.
- Develop a model for determining surface soil moisture by remote sensing.
- Data from the Sentinel-2 satellite corresponding to the selected points' positions will be downloaded, archived and processed. Produce a map showing surface soil moisture expressed in space.

2. METERIAL AND METHODS

2.1 Study area

Four areas representative of the forest-steppe, steppe, and Gobi regions of Mongolia were selected for the research area. Field research was conducted, data was collected, and Sentinel-2 satellite data was processed and analyzed (Figure 1). This research was carried out in the following geographical areas. It includes:

- Representing the forest-steppe zone, an area was selected in the territory of Delgerkhaan and Jargalthaan sums of Khentii province, located at longitude 108.34ºE - 109.84ºE, latitude 46.84ºN - 47.81ºN, 250 km southeast of Ulaanbaatar city, and 125 km west of Khentii province.
- Representing the steppe region, Delgertsogt, Dundgov Province, Deren Sum, longitude 106.31ºE - 107.69ºE, latitude 45.94ºN - 46.94ºN , 210 km south of Ulaanbaatar city, 70 km northeast of the center of Dundgovi province.
- Representing the Govi region, in the territory of Luus Sum, Dundgovi Province, longitude 105.007ºE - 106.41ºE, latitude 45.03ºN - 46.03ºN, 320 km from Ulaanbaatar, 55 km from Dundgovi Province, in the territory of Khanhongor Sum, Mungogov Province, longitude 103.76ºE - 105.1 2ºE, latitude 43.26 ºN – 44.23ºN, located 532 km from Ulaanbaatar city and 25 km from the center of Umnogovi province.

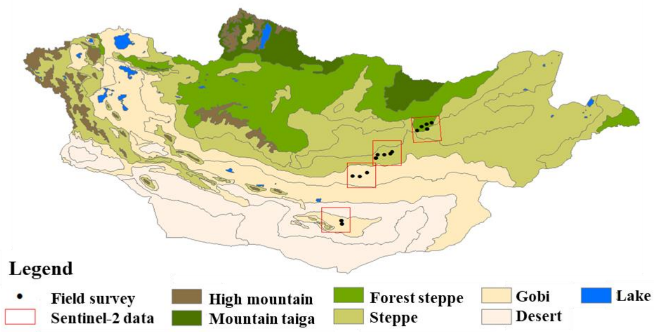

Figure 1. Field study area.

2.2 Methodology

The research was conducted through the stages of preparatory work, field research and data collection, data processing, and analysis. Within these stages, data and information were processed results were obtained. It includes:

- Preparation stage
  - *Research and study the topic, using academic articles and books*
  - *Download and archive Sentinel-2 satellite news*
  - *Create research software*
  - *Develop field research methodology and select representative sites*
- Field research and data collection phase
  - *Conducts field research in July and August 2021 using the data collected during the production internship.*
  - *Develop soil moisture report*
  - *Collects general soil information*
  - *Conduct spectral measurements of soil surface and 10 cm shear*
- Data processing and analysis stage
  - *Compare spectral measurements and soil moisture*
  - *Develop a model for determining surface soil moisture by remote sensing*

- *Download data from the Sentinel-2 satellite corresponding to the locations of the selected points, archive and process sequence such as by creating a spatially expressed soil surface moisture image.*

Satellite data: ***(Sentinel-2 Multispectral Instrument (MSI))*** satellite data with high resolution in terms of spatial and temporal resolution were used in the research. 10-60m resolution for spectral multi-channel space that maps in the short-wave violet-infrared range (350-2500 manometers). In terms of time, it is a twin satellite platform that collects data at a frequency of 5 days (ESA).

Sentinel-2 consists of satellites 2A and 2B which collect high spatial resolution and multi-spectral data, and one of the Sentinel series of satellites launched by the European Space Agency (ESA). is possible.

Archived Sentinel-2 satellite level-2A (L2A) data from August 5-15, 2021, during a low-cloud, fire-free period close to the time of the field study, at ESA for free download and archived use (time and location of Sentinel-2 satellite data from the study area are shown in Figure 2).

Software: SNAP software was used for digital satellite data and image data processing, and excel for statistical processing. The user license for the satellite data processing software (SNAP) is open source and available for free download.

Field data collection: For the field study, Delgerkhaan and Jargalthaan **sums of Khentii province represent the forest steppe zone**, Delgertsogt of Dundgov province represent **the steppe zone, Deren sum of Dundgov** province, Luus of Dundgov province and Khanhongor sum of Umungov province are selected respectively (locations are shown in Figure 1 and 2).

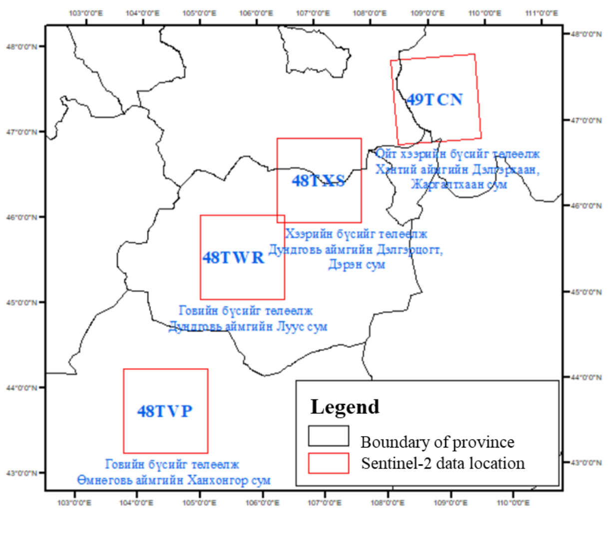

Figure 2. The location of the field used to download satellite data representing the natural zone.

The field survey was conducted between August 13-22, 2021, and total of 15 points were cut at depth of 0-10 cm. Filed survey amples' location, spectral measurements, and records shown in Table 1.

No	Natural belt belt	Point number	Point exchange
1	Forest steppe zone	S181	109°23'44.331"E 47°35'15.956"N
2		S182	109°8'46.750"E 47°21'19.684"N
3		S183	109°8'42.240"E 47°21'17.395"N
4		S184	109°8'37.409"E 47°21'15.608"N
5		S185	109°8'29.944"E 47°21'12.445"N
6	Steppe zone	S261	106°27'3.887"E 46°14'27.247"N
7		S262	106°27'5.060"E 46°14'32.914"N
8		S263	106°27'7.275"E 46°14'39.278"N
9		S264	106°27'8.430"E 46°14'44.234"N
10		S265	106°27'10.863"E 46°14'49.397"N
11	Govi zone	S240	104°45'26.737"E 43°36'0.583"N
12		S241	104°45'22.467"E 43°35'58.847"N
13		S242	104°43'46.404"E 43°44'19.876"N
14		S243	104°43'47.563"E 43°44' 20.300"N
15		S245	104°43'46.509"E 43°44'22.150"N

Table 1. Location of field survey sites.

Spectroradiometric measurement: Remotely sensed data were collected using a hand-held spectroradiometric instrument in the field, and 0-10 cm section was selected to measure the soil spectrum in the exposed area. As for spectroradiometric instruments, the 350-2500 manometer wave spectrum is used for measuring in the range of visible light, near violet-infrared rays, medium and short-wave violet rays, and automatically leveling and accurately measuring electromagnetic waves when the air temperature is between -10 0 C and $^{+40}$ 0 $^{C.}$ instruments with measurements were used. The spectroradiometer measures at a certain degree angle (Figure 3). Measurements were made at 20 meters above the ground in the selected area, and the reflectance corresponding to 350-2500 nanometer waves was measured.

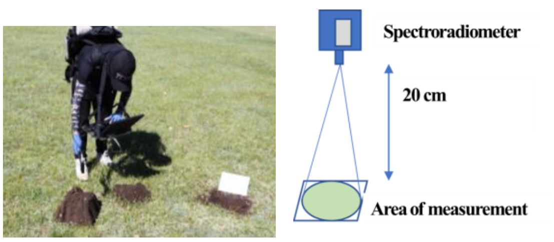

Figure 3. Methodology of soil spectrum measurement using spectroradiometer.

Adjustment using a white plate, match the time when the sun is as high as possible, between 11:00 and 14:00, without clouds, without rain, and with low wind has been done before each spectrum measurement.

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Figure 4. Photo of soil sampling

Sampling of the soil: Select representative point of the area, dig 0-10 cm, use cylinder of 100 m^3 to take sample, put it in moisture-proof sample bag, record the sample number, store it in cool environment, and get the results for analysis in the laboratory (Figure 4).

The results of the samples taken at each soil research point, its spectrum measurements, field recording, are presented in combined data finding section. The field measurement results including spectroradiometer measurements, field recording results, spectrum measurement diagrams, and photographs show the field and environmental conditions where the measurements were taken.

Satellite data / Sentinel-2 / processing and analysis: The digital raw data measured in the red-green-blue regions of the visible color were given to the red-green-blue color of the image processing by the color combination method and the actual surface color of the research area was extracted and the general condition was obtained.

Using the color composite or RGB creation command of SNAP image processing software, channels 12, 8, and 3 of Sentinel-2 were given red, green and blue colors, and an image with a color combination indicating the condition of the soil was processed. The area with soil appears in light pink color in the picture.

Index: The Normalized Water Index (NDWI) is the primary and basic index for water indices and has been used extensively in a wide variety of applications (McFeeters, 1996). It is often used to detect water areas and lakes from satellite data and to calculate water areas. In this study, we used field-measured spectroradiometric measurements and spectral reflection of Sentinel-2 satellite data to determine surface soil moisture.

Normalized Difference Water Index:

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)} \quad (1)$$

$$Spectroradiometer\ NDWI = \frac{(560\ nm - 842\ nm)}{(560\ nm + 842\ nm)} \quad (2)$$

$$Sentinel-2\ NDWI = \frac{(Band3 - Band8)}{(Band3 + Band8)} \quad (3)$$

The Normalized Moisture Index (NDMI) is the primary and base index for moisture indices and has been used extensively in a wide variety of applications (Gao, 1996). It is an index that is often used to determine the moisture content of plant leaves. In this study, we used a combination of field spectroradiometric measurements and spectral reflectance data from the Sentinel-2 satellite.

Normalized Difference Moisture Index:

$$NDMI = \frac{(NIR - SWIR)}{(NIR + SWIR)} \quad (4)$$

$$Spectroradiometer\ NDMI = \frac{(842nm - 1610\ nm)}{(842\ nm + 1610nm)} \quad (5)$$

$$Sentinel-2\ NDMI = \frac{(Band\ 8 - Band\ 11)}{(Band\ 8 + Band\ 11)} \quad (6)$$

the image processing software SNAP, the normalized water index (NDWI) shown in Equations (3) and (6) is calculated using the Sentinel-2 satellite's green channel 3 and near-infrared channel 8, and near-infrared It was calculated using the 8th channel of the infrared ray and the 11th channel of the short-wave violet-red ray respectively. The result map is showing the state of the soil surface. L2A data from Sentinel-2 satellites have undergone atmospheric processing and primary processing, so they will be directly processed and used.

Color soil moisture can be deciphered using spectral reflectance in the red and near-violet regions, and it was recognized by the results of study in China that low reflectance values in the red region indicate moist soil and high reflectance values indicate dry soil (Zhan et al. 2007). A comparison of the spectral reflectance at 665 nm from our field study with natural moisture determined in the laboratory also confirmed this result. In the study of Chinese researchers (Zhan et al. 2007), the spectral reflectance of dry soil is relatively higher than moist soil (Mondal, BP 2018). Hyperspectral analysis of soil properties for soil management. Advances in Agriculture for Sustainable Development, 59-65.

Model development for estimating soil moisture: When developing a moisture calculation model using color soil spectroradiometer measurement data and Sentinel-2 satellite data (Figure 5), the natural soil moisture determined by laboratory analysis is taken as basic information, and corresponding to each measurement point (data from the time of field measurement) spectral measurement, from satellite news NDWI and NDMI were calculated respectively. Statistical processing of natural soil moisture determined by laboratory analysis based on NDWI and NDMI values was performed using Excel software to derive a formula for calculating surface soil moisture using linear regression analysis, as well as using that formula to calculate surface soil moisture from satellite data.

$$\boldsymbol{Soil\ Surface\ Moisture}\ (\%) = \boldsymbol{-44.133 * NDWI - 11.553} \quad (7)$$

Soil moisture was calculated using the Band Maths command of the SNAP software using the methodology shown in Equations (3) and (6) (this simulation has a 75% confidence level, making it suitable for use in forecasting surface fertility).

Interpretation of soil laboratory results: The results of the soil laboratory analysis are described in the results section according to the following categories.

Classification of soil humus content (nomenclature changes depending on the nature zone): More than 5% is Black soil, meadow swamp and alluvial soil, 3-5 % Dark brown, 1-3 % Brown, 0.5-1.0 % Brown, Light brown, 0.1-0.5 % Desert brown-gray soil (Dorjgotov, 2003).

Soil Reaction Environment (NRCS Soil Survey Handbook): Strong acidity 5.1–5.5, Moderate acidity 5.6–6.0, Weak acidity 6.1–6.5, Neutral 6.6–7.3, Weakly alkaline 7.4–7.8, Moderately alkaline 7.9–8.4, Strongly alkaline 8.5–9.0, Very strongly alkaline > 9.0.

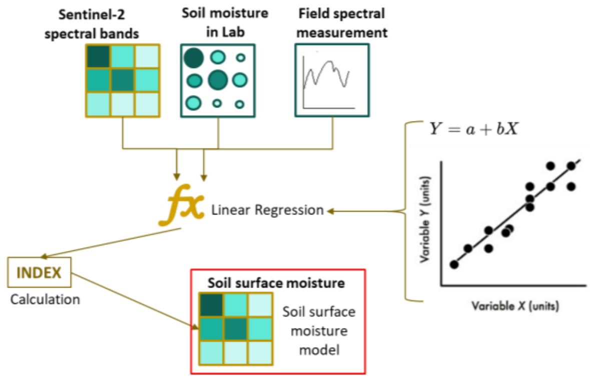

Figure 5. Methodological scheme for surface soil surface moisture calculation model development

Soil salinity: Describe soil salinity (EC-dS/m) depending on part of categories belongs to: 0 < 2 dS/m No salt, 2 < 4 dS/m Very weak salinity, 4 < 8 dS/m Low salinity, 8 < 16 dS/m Moderate salinity, ≥ 16 dS/m High salinity (NRCS Soil Survey Handbook). In the category of high salinity, it is likely to occur only in Gobi, dry deserts and saline valleys.

Phosphorus and potassium content of the soil: comparing the classification shown in Table 2 with the results of the laboratory analysis, high, low and medium level is determined and the results are presented according to the classification of Machigin.

Level	K_2O	P_2O_2
Very little	<10	<1
Less	10-20	1-1.5
Average	20-30	1.5-3
Great	30-40	3-4.5
A lot	40-60	4.5-6
Too much	>60	>6

Table 2. Classification of soil phosphorus and potassium content.

3. RESULT AND DISCUSSION

The results of soil field measurement samples analyzed in the laboratory are summarized in the following tables according to the physical and chemical properties of the soil (Table 3).

Point number	Sampling depth /cm/	Natural moisture %	pH	CDCH, ds/m	Humus, %	Salt, %	CO_2	Nutrient elements mg/100 g			Adsorbed bases, mg-eq/100g		
								P_2O_5	K_2O	No_3	Ca+Mg	Ca	Mg
S181	0-10	8.41	7.69	0.052	9.38	0.03	0.00	5.6	44	-	44.8	39.4	5.4
S182	0-10	16.12	7.81	0.055	6.98	0.03	0.00	4.1	37	-	21.2	19.1	2.1
S183	0-10	10.87	7.75	0.052	2.62	0.03	0.00	2.1	19	-	18.1	16.2	1.9
S184	0-10	8.30	7.79	0.026	2.33	0.01	0	2.2	24	-	19.8	16.6	3.2
S185	0-10	15.72	7.8	0.052	3.35	0.03	0	3.1	28	-	23.2	20.2	3.0
S261	0-10	1.5	8.61	0.046	2.46	0.02	0	1.3	24	-	18.6	17.8	0.8
S262	0-10	1.74	8.54	0.044	2.44	0.02	0	1.9	23	-	21.8	17.0	4.8
S263	0-10	2.85	8.77	0.81	2.63	0.04	0	1.7	22	-	27.1	20.4	6.7
S264	0-10	1.34	8.72	0.042	2.14	0.02	0	1.6	21	-	22	17.2	4.8
S265	0-10	1.13	8.85	0.046	2.53	0.02	0	2.3	21	-	22.2	19.8	2.4
S240	0-10	1.34	9.75	0.125	0.81	0.06	2.64	1.2	16	-	11.8	10.4	1.4
S241	0-10	1.84	9.78	0.118	0.34	0.06	3.13	0.9	16	-	13	9.5	3.5
S242	0-10	1.90	8.79	0.047	0.91	0.02	0	1.9	24	-	18.8	16.2	2.6
S243	0-10	1.85	9.18	0.077	1.04	0.04	1.96	2.2	15	-	19.3	11.3	8
S245	0-10	1.87	9.18	0.085	1.24	0.04	0.66	1.9	21	-	13	7.4	5.6

Table 3. Results of laboratory analysis of chemical and physical parameters of soil.

3.1 Results of spectroradiometric measurements

Field research was conducted in Delgerkhaan and Jargalthaan **sums of Khentii province representing the forest-steppe zone, Delgertsogt of Dundgov province representing the steppe zone**, Deren sum of Dundgovi province, Luus of Dundgovi province and Khanhongor sum of Umungovi province representing **the Govi region,** and field research between August 13-22, 2021. was conducted, and a total of 15 points were cut at a depth of 0-10 cm, samples were taken, and the results of spectral measurements are shown in Table 4, and the average of the measurement results representing the forest, steppe, and Gobi region is shown graphically in Figure 6. As seen from the graph, the relatively low reflectance of the forest field indicates that the moisture content is relatively high, and the Gobi region has a relatively high reflectance or low moisture content compared to the forest field region. As for the field region, the spectral reflectance and moisture content were average compared to the forest field and Gobi region. These results show a trend that is consistent with laboratory test results.

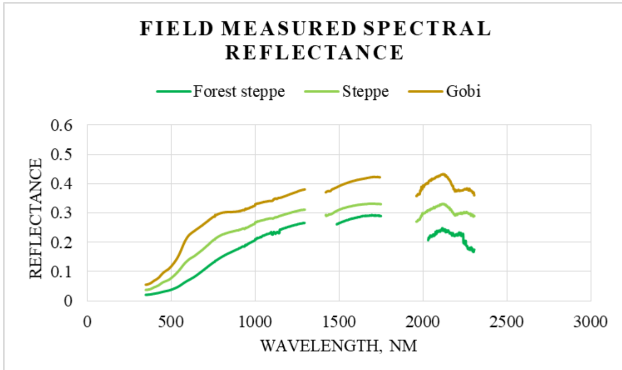

Figure 6. Spectral measurement results representing forest-steppe, steppe, and gobi regions.

Point Number		Spectral reflection corresponding to the length of the electromagnetic wave										
		490 nm	560 nm	665 nm	705 nm	740 nm	783 nm	842 nm	865 nm	945 nm	1610 nm	2190 nm
Forest steppe	**S181**	0.058	0.078	0.110	0.124	0.134	0.150	0.172	0.180	0.201	0.412	0.395
	S182	0.026	0.042	0.077	0.094	0.109	0.125	0.141	0.146	0.167	0.230	0.208
	S183	0.034	0.056	0.105	0.127	0.144	0.165	0.188	0.195	0.228	0.329	0.297
	S184	0.032	0.051	0.090	0.109	0.128	0.147	0.163	0.168	0.178	0.234	0.183
	S185	0.029	0.046	0.081	0.098	0.113	0.129	0.148	0.153	0.176	0.225	0.201
Field	**S261**	0.069	0.106	0.145	0.163	0.180	0.199	0.211	0.213	0.222	0.301	0.259
	S262	0.062	0.098	0.150	0.171	0.190	0.208	0.222	0.225	0.237	0.317	0.280
	S263	0.074	0.112	0.163	0.181	0.198	0.217	0.233	0.237	0.247	0.329	0.289
	S264	0.071	0.110	0.163	0.181	0.198	0.215	0.227	0.231	0.236	0.300	0.269
	S265	0.090	0.137	0.200	0.221	0.240	0.259	0.275	0.278	0.305	0.389	0.365
Gobi	**S240**	0.164	0.247	0.330	0.348	0.363	0.379	0.385	0.385	0.404	0.548	0.506
	S241	0.151	0.235	0.328	0.352	0.374	0.395	0.405	0.405	0.432	0.536	0.488
	S242	0.077	0.127	0.204	0.222	0.239	0.254	0.260	0.261	0.267	0.373	0.331
	S243	0.097	0.153	0.228	0.243	0.255	0.266	0.270	0.271	0.276	0.352	0.320
	S245	0.065	0.103	0.156	0.167	0.179	0.191	0.195	0.196	0.190	0.257	0.230

Table 4. Field measurements of spectroradiometer.

Figure 7 shows the spectral measurement results of points representing the forest-steppe zone. As seen from the figure, S182, S184, and S185 points showed similar reflectance values, while S181 showed the highest reflectance or relatively low natural moisture (Table 4). For spectral measurements representing the field region, the reflectance of soil points S261, S262, S263, and S264 is close, and the spectral reflectance of soil point S265 is relatively high. Most of the parameters of the laboratory analysis of the points in the field zone showed similar values, and the content of mobile phosphorus in S265 was higher than other points in the field zone of 2.3 mg/100 g (Table 4). However, different spectral reflectance was shown for the soil points representing the Gobi region. The spectral reflectance of soil points S240 and S2041 showed higher reflectance than other points, and salinity and carbon content showed slightly different values from other points (Table 4). Soil site S265 showed relatively low reflectance compared to other sites and the lowest calcium content. Refereeing from these comparison diagrams, the spectral reflectance represents the characteristics of the soil at that point. Short-wave near-violet rays (800-2500nm) represent soil fertility information while visible colors and near-violet rays (490-800nm) indicate moisture content.

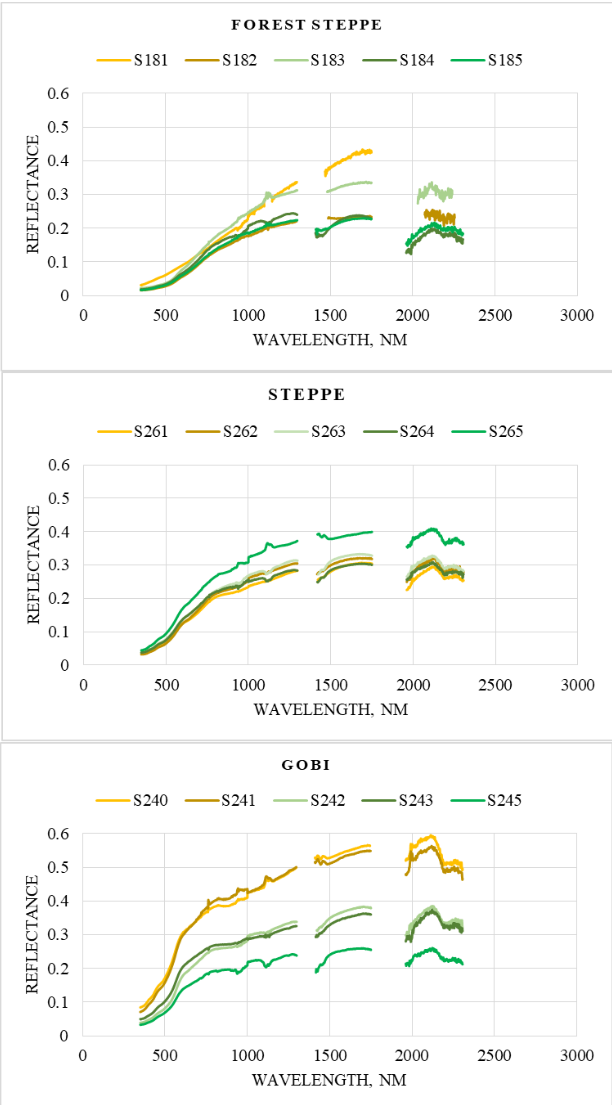

Figure 7. Comparison of spectral measurement results of points representing the forest-steppe, steppe, and Gobi region.

3.2 Comparison analysis of spectroradiometric spectral measurements with laboratory analysis

Table 5 shows the results of laboratory analysis, moisture, humus, pH, spectral measurement values measured in the red (665 nm), near-violet (842 nm) range, NDWI and NDMI calculated from the spectroradiometer, and correlation diagrams are shown in Figure 8 , 9. respectively.

Correlation between NDWI calculated from spectroradiometer, laboratory determined moisture R ^{2} =0.74 or 74%, NDMI with humus R ^{2} =0.74 or 74%, red (665 nm) region reflectance with reaction medium or pH R ^{2} =0.85 (85%) results showed the relationship, respectively. If these relationships are determined by linear regression, the following formulas for determining moisture and humus are proposed in this study (Formula 7). In other words, moisture can be determined by NDWI. This formula is a model derived from a linear relationship between spectroradiometric reflectance measured in the field and moisture determined by laboratory analysis, so regular monitoring of moisture content can be done using NDWI calculated from satellite data.

Point number	Spectroradiometer				Laboratory analysis		
	NDWI	NDMI	Red: 665 nm	NIR: 842 nm	Moisture %	pH	Humus %
S181	-0.377	-0.411	0.110	0.172	8.41	7.690	9.380
S182	-0.541	-0.240	0.077	0.141	16.12	7.810	6.980
S183	-0.539	-0.273	0.105	0.188	10.87	7.750	2.620
S184	-0.524	-0.179	0.090	0.163	8.30	7.790	2.330
S185	-0.524	-0.207	0.081	0.148	15.72	7.800	3.350
S261	-0.332	-0.176	0.145	0.211	1.50	8.610	2.460
S262	-0.387	-0.178	0.150	0.222	1.74	8.540	2.440
S263	-0.350	-0.171	0.163	0.233	2.85	8.770	2.630
S264	-0.346	-0.137	0.163	0.227	1.34	8.720	2.140
S265	-0.335	-0.172	0.200	0.275	1.13	8.850	2.530
S240	-0.220	-0.175	0.330	0.385	1.34	9.750	0.810
S241	-0.265	-0.138	0.328	0.405	1.84	9.780	0.340
S242	-0.344	-0.179	0.204	0.260	1.90	8.790	0.910
S243	-0.276	-0.131	0.228	0.270	1.85	9.180	1.040
S245	-0.306	-0.138	0.156	0.195	1.87	9.180	1.240

Table 5. Comparison of spectral measurements and laboratory analysis.

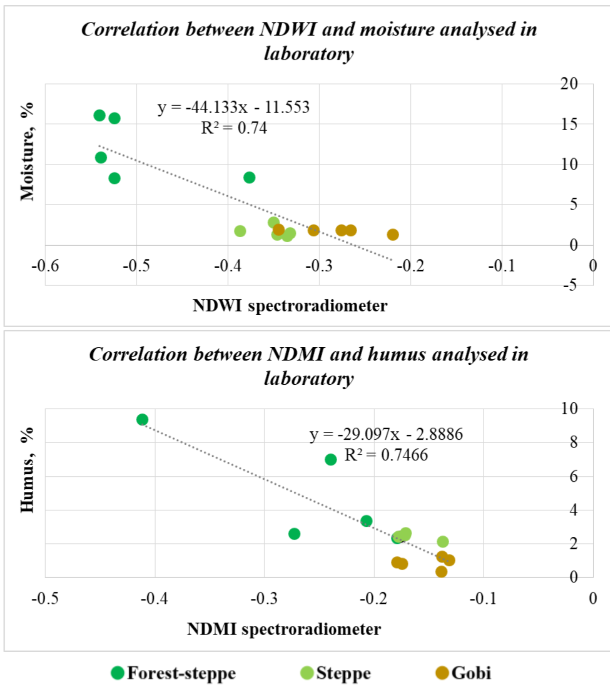

Figure 8. Correlation between NDWI and NDMI calculated from spectroradiometric measurements of moisture and humus as a result of laboratory analysis.

The NDWI and NDMI values calculated from the spectroradiometer are low in the forest-steppe region and relatively high in the steppe and Gobi region (Figure 8). In other words, the low values of NDWI and NDMI can indicate high levels of moisture and humus. However, the reaction environment (pH) in the Gobi area is relatively high compared to the forest area. A high reflectance value in the red (665 nm) region indicates a high reaction medium. The red (665 nm) and near-violet (842 nm) light regions are the main spectral regions that represent soil moisture, and the low spectral reflectance of these regions indicates moist soil, while the high reflectance identifies dry soil (Figure 9). It can be seen that the soil of the forest-steppe region is relatively moist compared to the soil of the Gobi region. Comparison of spectral measurements and laboratory analysis shown in the Table 5.

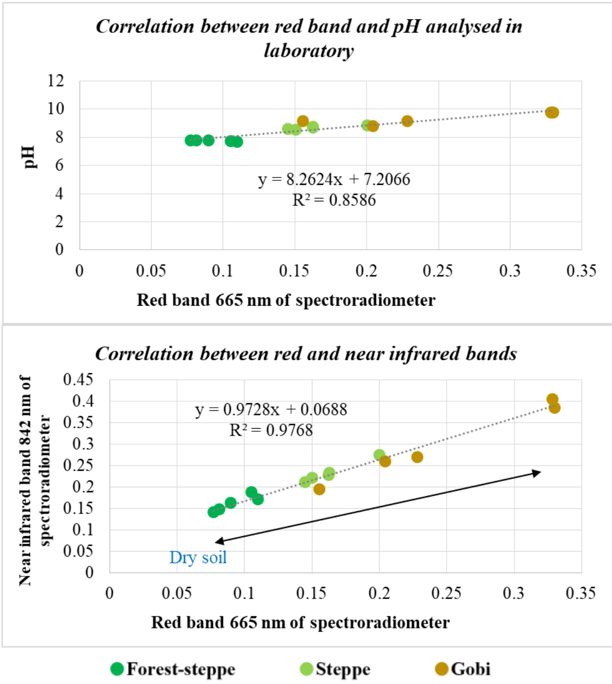

Figure 9. Correlation between pH, red and NIR region spectral measurements reflectance.

3.3 Results of determination of surface soil moisture distribution from Sentinel-2 MSI satellite data

Sentinel-2 satellite atmosphere treated L2A product was used to give channel 12 red, channel 8 green, and channel 3 blue color combination, green (560nm) or channel 3 and near violet-red (842nm) or channel 8 as a normalized water index NDWI, near violet (842 nm) or channel 8 and shortwave violet (1610nm) or channel 11 as a moisture normalized index were calculated respectively the results are shown in Figure 10.

The results calculated from the Sentinel-2 satellite data and the results of determining the spatial distribution of the moisture content of the soil surface using the modelling shown in formula 7 are shown in Figure 11, and the graph comparing the moisture calculated from Sentinel-2 with laboratory results is shown in Figure 12 shown respectively. Areas with high humidity are highlighted in blue and are spatially distributed in the forest-steppe area (Figure 11). Compared to the Gobi region, the amount of moisture is relatively high in the forest-steppe and steppe regions (Figure 11).

The total area representing the Gobi region has low moisture content. According to these results, it is possible to continuously determine the amount of moisture from satellite data using NDWI (surface soil moisture) in a certain space-time range and use it for soil control and monitoring (Figure 12).

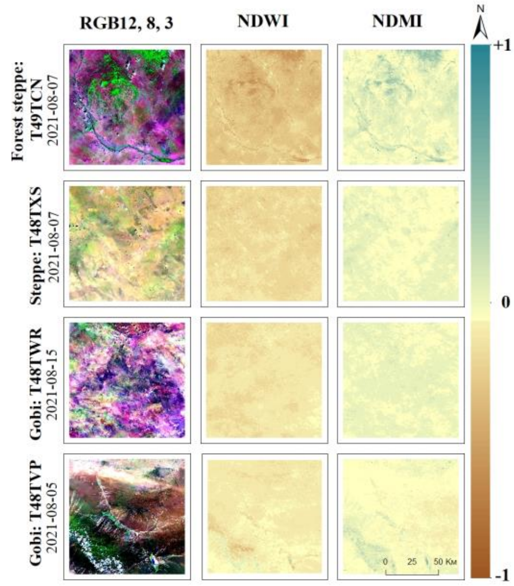

Figure 10. Representative results of forest-steppe, steppe and gobi regions of NDWI and NDMI indices calculated from Sentinel-2 satellite data.

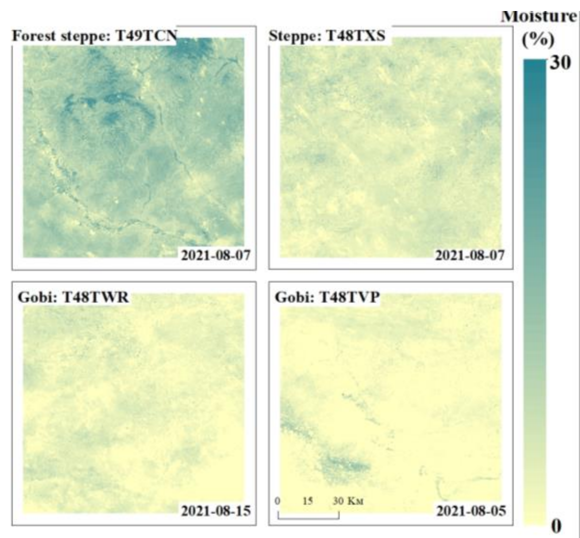

Figure 11. Spatial distribution of moisture content representing forest-steppe, steppe, and gobi regions estimated from Sentinel-2 satellite data.

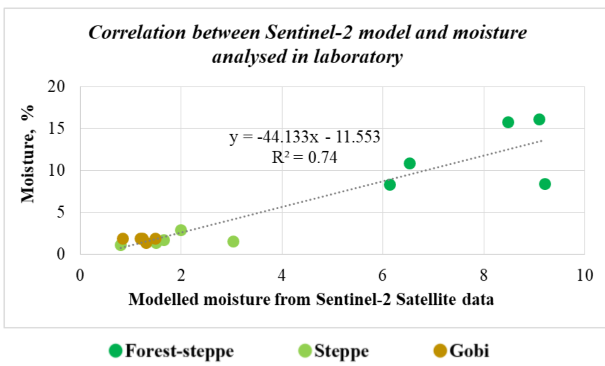

Figure 12. Correlation between moisture from laboratory and moisture calculated from Sentinel-2.

4. CONCLUSION

The following conclusions are taken from the results of the research on surface soil moisture determination using Sentinel-2 satellite data and spectroradiometric measurements. It includes:

- The spectral reflectance measured during the field research is shown the high reflectance of the moist soil spectrum of the forest field and the low reflectance of the spectrum representing the Gobi region. It indicates the possibility of studying soil moisture by spectral measurement and analysis is useful?.
- The relationship between the spectral reflectance of the red (665 nm) and near-violet (842 nm) light regions shows the soil of the forest-steppe region is relatively moist compared to the Gobi region soil surface, and the Gobi soil is dry and the field soil is drier.
- A model developed from a linear relationship between field-measured spectroradiometric reflectance and laboratory-determined moisture provides a formula for routine monitoring of moisture content using NDWI estimated from satellite data.

Soil moisture (%)= -44.133*NDWI - 11.553

- NDWI calculated from spectroradiometer compared to moisture determined in the laboratory had a linear correlation of R^2 =0.74 or 74%, and moisture calculated from C entinel-2 showed a high agreement.
- In terms of space, the results calculated from satellite data show that the forest and steppe areas have relatively high humidity compared to the Gobi region, and the total area representing the Gobi region has lower moisture content. Based on these results, it is considered that it is possible to continuously determine the amount of moisture from satellite data using NDWI (surface soil moisture) in a certain space-time range and use it for soil control and monitoring.

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