A Modified Resource Analysis of Very Large Scale PV (VLS-PV) System on the Gobi Desert by a Remote Sensing Approach

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ABSTRACT

A desert has a large unused land that is available for very large-scale photovoltaic generation system (VLS-PV system). Additionally, from a point that the desert has a strong solar irradiation, the desert is so much the better for VLS-PV system. VLS-PV-system has been studied in order to resolve the world energy problems. This study has defined conditions for suitable land for installing VLS-PV system as part of a project of VLS-PV system. Basic requirements for the land selection are considered that surface should be flat and rigid. This work has indicate that a detail classification algorithm to find suitable land by using remote sensing approach. Gobi desert has been researched as the object of this study. Authors investigated all of the Gobi desert by analyzing satellite images. In addition, the analyzed results have been modified by actual ground truth. It is concluded that the Gobi desert has a big potential of a resource for VLS-PV system and this proposed method can provide sufficient information for the planning of VLS-PV system installations.

Key word

Very large-scale photovoltaic generation system, Remote sensing, Satellite image, Gobi desert

1. Introduction

The energy demand in the world is continuing to increase with the economic growth in the world, and the increase in population. In addition, various environmental problems, such as global warming, desertification, and acid-rain issue will also increase in connection with it. On the basis of such background, large-scale photovoltaic generation system (VLS-PV system) are treated as important from the point which does not discharge carbon dioxide at the time of power generation. And VLS-PV system can provide a source of megawatt class electricity. In order to save the energy problems, a planning of large-scale PV system installed in a desert has been studied. Irradiation in a desert is very strong, it is a suitable land area for large-scale PV system. Therefore former project is thought that play an important role in a future energy source. However very unstable land like a sand dune is not suitable for installation of PV system. The area which is suitable for PV system is not a sand desert but a rock desert. The rock desert consists of flat land and arid area. Consequently, estimation for suitable land is needed. The Gobi desert has been researched as the object of this study. Authors investigated all of the Gobi desert by analyzing satellite images. In addition, Authors established the method of selecting the land which can install a VLS-PV system.

2. Method and Results

2.1 Subject Area and Remote Sensing

Subject area for this study has been located in the Gobi desert. Gobi desert is very vast. In addition, Gobi desert has many types of land surface. An analyzed satellite image is a JERS-1 image. JERS-1, an earth observing satellite that provides global coverage, is used for national land surveys, agriculture and forestry assessment, environmental protection, disaster prevention, and coastal monitoring, with a focus on resource management. Forest zone and removing area such as a sand dune zone is not most suitable zone, it is the priority matter of this study.

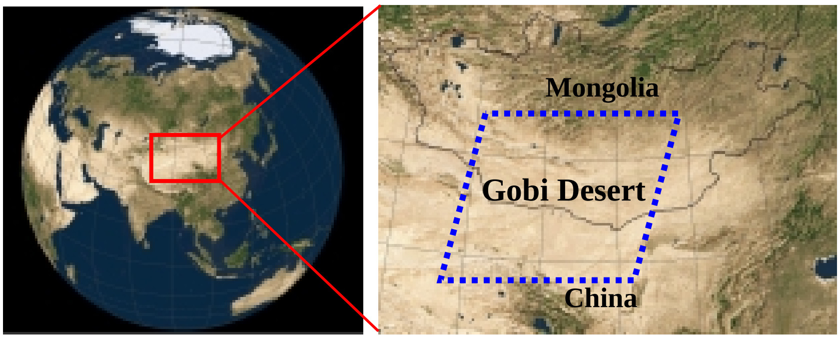
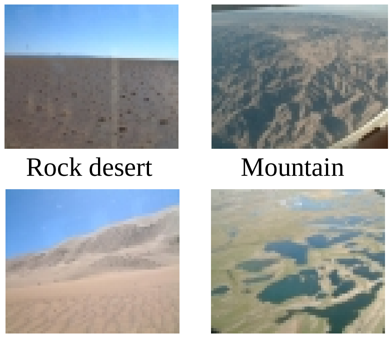


Illustration of the Earth A blow up of the Gobi desert

Fig.1 Subject area for research



Dune River basin

Fig.2 Land surface of Gobi desert

2.2 Vegetation Index

First, Authors calculated a Modified Soil Adjusted Vegetation Index (MSAVI) in order to investigate the vegetation. MSAVI was calculated by using reflectance values from two channels (NIR:860nm, RED:672nm). The MSAVI comprises density and quantity of vegetation. In more depth, when the vegetation cover has a low density, normally the soil reflectance increases in both the red and infrared channels. To describe more adequately this soil-vegetation system, other indices were proposed. To minimize the effect of bare soil, the Modified Soil Adjusted Vegetation Index was developed by Qi et al [2].

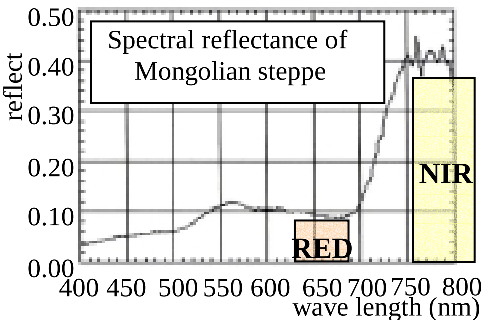
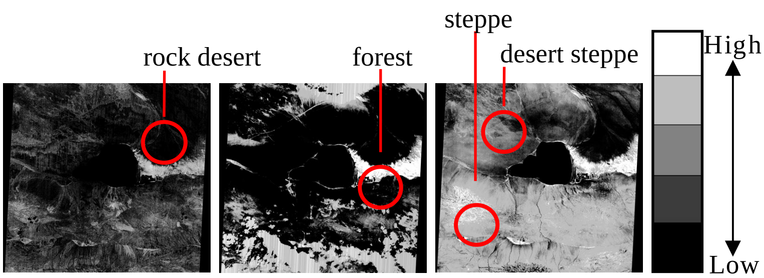


Fig.3 Spectral reflectance of Mongolian steppe

$$MSAVI = \frac{2NIR + 1 - \sqrt{(2NIR+1)^2 - 8(NIR - RED)}}{2} \quad \text{--- (1)}$$

NIR --- Near infrared spectrum
RED --- Red spectrum

We list the necessary care to be taken and problems encountered on applying MSAVI. The problems lie in seasonal changes in MSAVI by the difference in date of satellite images. In order to correct the defect, authors estimated seasonal changes in MSAVI. seasonal changes in MSAVI was estimated by three images which are same area but difference in date. The results of estimation among these images are depicted in Fig.4 and Fig.5. Because only three sample data are existed, all year variation in MSAVI as basic data is quoted from Mei et al. With these parameters, authors created three pattern images by threshold lines as in Fig.5. This suggests that the images shown as suitable area were created for three patterns.



April image July image October image

Fig.4. seasonal changes in MSAVI

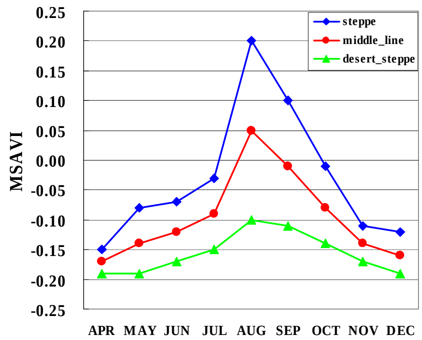


Fig.5 seasonal changes in MSAVI

2.3 Classification of the Gobi Desert

Secondly, authors classified the surface of Gobi desert into seven patterns from satellite image according to Visual Evaluation Standard (VES) of Natural Color. Natural Color image is a composed image with blue and red filters applied on in two visible bands and a green filter on in a near-infrared band. Forests and grasslands displayed in bright green and city areas, in magenta. It is different from actual color. At this point, seven patterns are shown below.

1 : rock desert 5 : forest
2 : dune or desert steppe 6 : snow or cloud
3 : desert steppe or steppe 7 : water
4 : shadow

Authors classified surface of Gobi desert into seven patterns with the use of Maximum Likelihood Classifier (MLC). MLC is known as a classification technique.

$$L(x,c) = \frac{1}{(2\pi)^{K/2}\left|{}_cV\right|^{1/2}} \exp\left\{-\frac{1}{2} d^2{}_M(x,c)\right\} \quad \text{--- (2)}$$

C : classification class
$L(x,c)$: likelihood
$d^2{}_M(x,c)$: Maharanobis distance
${}_cV$: covariance matrix

Parameters of MLC were set up as reflection level of band1/band2, reflection level of band2/3 and reflection level of band1/3 (table.1). The Gobi desert classification by MLC played an importable role in excepting areas such as water basin, cloud, snow and shade. This classification provided an available area to analyze.

Table 1. Parameters of MLC

	band1/band2	band2/band3	band1/band3
dune_or_desertsteppe	0.78	1.12	0.87
gobi	0.82	1.26	1.04
desertsteppe_or_steppe	0.74	1.03	0.76
forest	0.90	0.65	0.57
snow_or_cloud	1.00	1.00	1.00
shadow	1.02	1.40	1.43
water	1.43	2.45	3.54

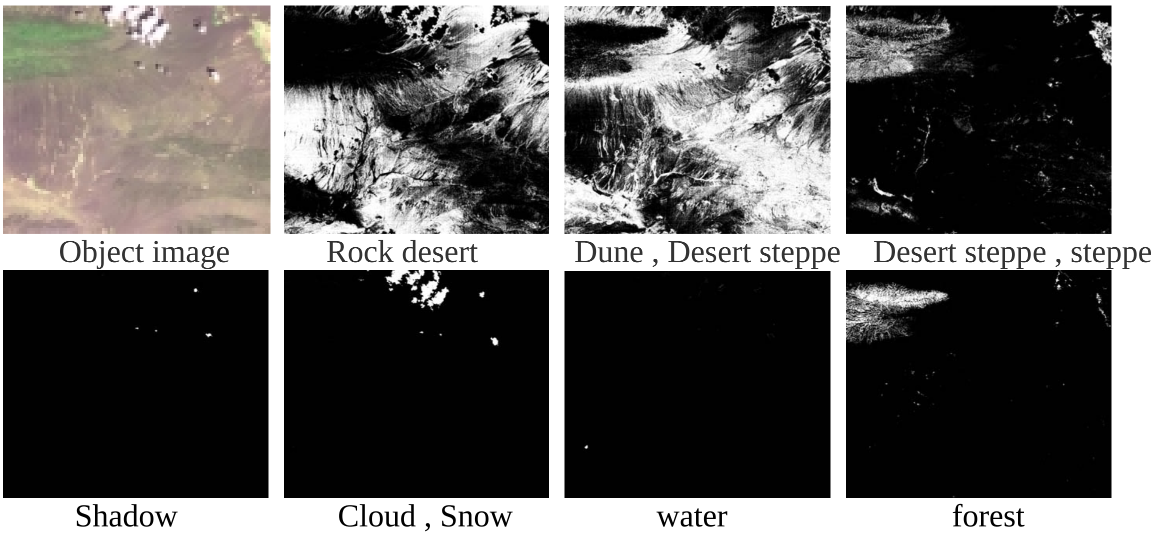


Fig.6 An example of results of classification based on MLC

An example of results of classification based on MLC is displayed in Fig.6. The results were obtained agreed approximately with those expected. Additionally, as these data suggest, it was shown that Gobi desert of ground level is various and turned out that sand dune, a forest, and a water area were very few. From this result, it is able to forecast that PV system installation for right land is very large and have big potential possibilities of electric power generation. Unfortunately, this classification includes some problems, for example, the problems lie in misclassification caused by relief shading. Relief shading makes a shadow, have a weak reflex. In this study, we excepted the shadow area in order to reduce the misclassification. In addition, this algorithm can't adapt to the all satellite images of Gobi desert because the color of these images is unstructured. Sun's altitude causes difference of reflection level, it is difficult to adapt same algorithm. In order to resolve these problems, we corrected color tone of adjacent satellite images.

2.4 Filtering of Satellite Image

Suitable areas for PV system installation must be a flat surface. Up and down hills were extracted with the use of Gaussian filter and Laplacian filter for band3. Up and down hills include a valley and trace of flood. In addition, the processed image was divided into white and black color by threshold level and morphology filter. Morphology filter includes dilation and erosion. Threshold level is decided by the number of pixels from either end of histogram for processed images. Authors set the number of pixels at 10 percent of the all number of pixels. The area shown white as in Fig.8 exist edge, and the area shown black indicate flat areas. Secondly, the circumference of the neighborhood of the edge line was painted all white. Fig.8 shows these results. Herewith, these methods were useful in solving above misclassification problem that was caused by relief shading. However, several problems arise along with these methods. Process of dilatation paints the circumference of the neighborhood where the edge line is extracted, but enlarges noise together. Process of constriction reduces noise, but reduces important information of ground level. This algorithm depends in good part on ground resolution, and authors estimate that the more ground resolution is higher, the more fine edge line can be extracted. The ground resolution that authors applied is approximately 24.2m. As before, surface feature as a boom hoisting and a construction smaller than it can't been recognized. If this algorithm is applied to higher resolution images, it is considered that appreciation accuracy of up and down hills is improved dramatically. These generalizations must be evaluated with caution, lengthy and careful consider should be given to these countermeasures.

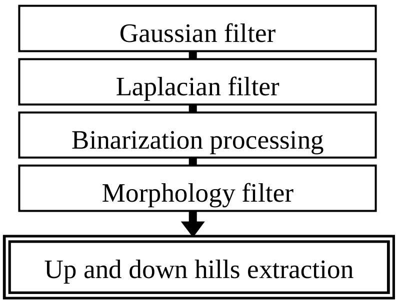


Fig.7 Process of up and down hills extraction

Band3 image Edge lines image Example of Dune

Fig.8 The results of edge lines extraction

2.5 A Resource Evaluation of PV System

Estimation of the PV system installation for suitable land was evaluated by integrating with three processed images, i.e. the image which was presumed as suitable land by MSAVI, the image which was presumed as not suitable land by MLC, and the image which was suitable land by edge lines extraction. Authors have indicated three different analyzed results by three different category in order to define suitable area for installing VLS-PV system. Therefore, although three different analyzed results have been estimated, analyzed results in the case of middle line was shown in this article. Black areas as in Fig.9, 10, 11 show the suitable land of the PV system installation. With these methods, the area percentage for suitable land was estimated at 40 percent. From this result, it is able to forecast that PV system installation for suitable land is very large and have big potential possibilities of electric power generation.

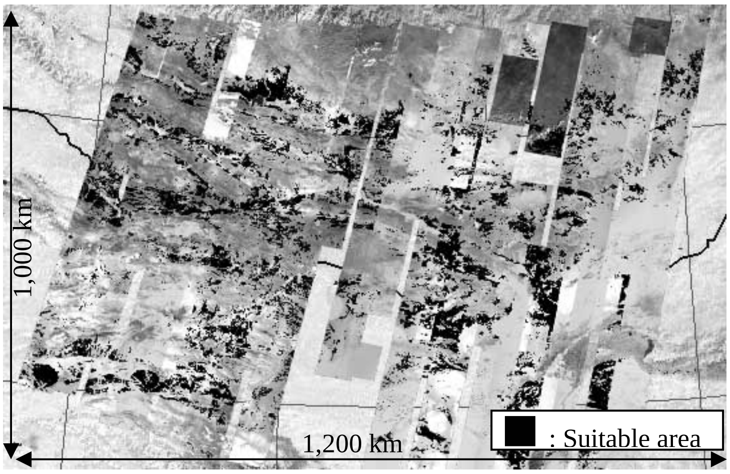


Fig.9 The suitable areas for VLS-PV system

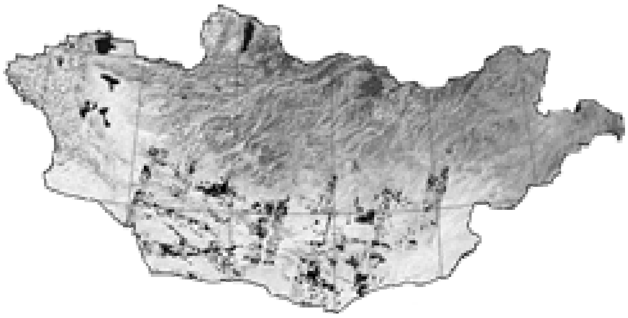


Fig.10 The suitable areas in Mongolia

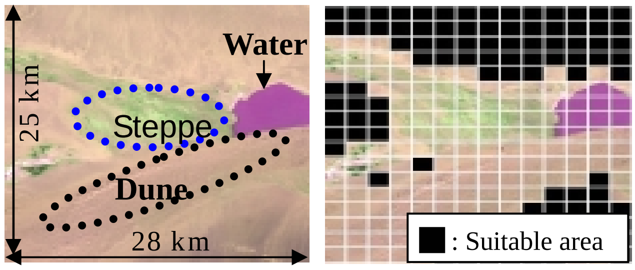


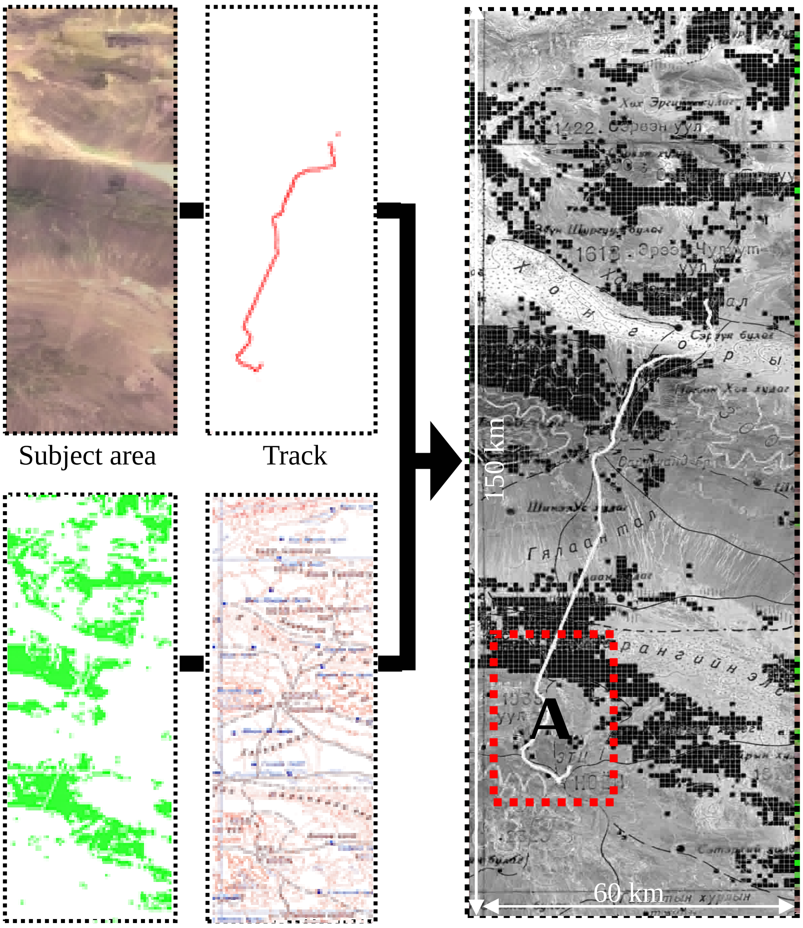
Fig.11 An example of analyzed images

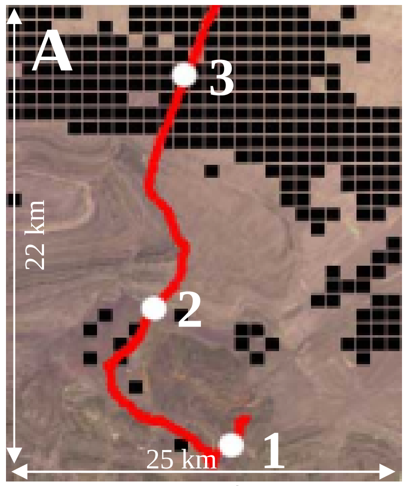
2.6 Actual Ground Truth

Authors examined the accuracy of estimated results by actual ground truth. Ground truth operation compares estimated result with actual field examination by using a GPS receiver. Fig.12 shows technique for doing actual ground truth. Red line displays track of ground truth, and white points display actual field photograph as in Fig.12. The white points number indicates a photograph number. "S, A, B, C rank" as standard of evaluation was shown below.

S rank --- Most suitable ground condition by reason of stable surface geometry.
A rank --- Although surface geometry is flat and rigid, the up and down hills is visible to the eye well ahead.
B rank --- Although the ground is ups and downs, surface geometry is not as intense as C rank.
C rank --- Most unbefitting ground surface by reason of rugged surface geometry

Actually, point number "3" evaluated as "S rank" indicated suitable area which was estimated by classification algorithm. However, although ground condition is evaluated as "S lank" in the actual field photograph, a point that is evaluated as unbefitting ground surface also existed. This is attributed to the fact that threshold level for extraction of suitable ground condition is configured tightly. Additionally, this is also attributed to the fact that detail edge lines are extracted as unbefitting ground surface. However, threshold level for extraction of suitable ground condition is configured loosely, unbefitting ground surface is extracted as suitable ground condition. Under such circumstances, it would appear that presumed accuracy drop to a lower value. From these point, it would appear that tighten threshold level is better than loose threshold level. Therefore, sufficient results were obtained.





A back-up of "A" zone

Table 2. photograph in "A" zone

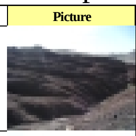
	Picture	Latitude	Longitude	Time	Evaluation
1		43.09254	102.0835	10:37:55	C
2		43.12416	102.0531	15:06:20	C
3		43.19209	102.0659	15:45:09	S

Fig.12 examine the accuracy of estimated results

3. Conclusion

Authors demonstrated an efficacy of technique for investigating the suitable area of PV system installations by using remote sensing. And, Authors examined the accuracy of estimated results by actual ground truth, sufficient results were obtained. It is concluded that this proposed method can provide sufficient information for the planning of PV system installations. Additionally, a potential of solar photovoltaic generation system in the Gobi desert has been evaluated about all of the Gobi desert. However, the following points are left as future problems. One difficulty with this method is in selection of the training area. Ambiguity will be produced because training area is selected by Visual Evaluation Standard. Secondly, It is necessary to continue developing the algorithm of estimation of the PV system installation for suitable land. The investigation on estimation of Gobi desert is summarized above and it is evident that more work using different approaches is necessary. At the end, the author would like to express his sincere gratitude to Mr. Amar, who provided related data.

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[1] MITI/NASDA retains ownership of JERS-1 data

[2] Qi, J., Chehbouni, A., Huete, A. R. and Kerr, Y. H., "Modified Soil Adjusted Vegetation Index (MSAVI)", Remote Sensing of Environment, 48, 119-126, 1994.

[3] Michael Burkart, Sibylle Itzerott, "Classification of Vegetation by Chronosequences Of NDVI from Remote Sensing and Field Data: the Example of Uvs Nuur Basin"