Ground Surface Features of Taklimakan Desert

---Features of Spectral Reflectance of Soils, Vegetation etc.---

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Abstract

In an attempt to utilize satellite data to obtain land surface features of Taklimakan Desert in China, in situ measurements of spectral reflectance of the land surface is made with the portable spectro radiometer in the spectral range of 400 ~ 2500 nm. The analyses of the data show following features. (1) The difference in spectral reflectance of different soils is comparatively small. (2) There is a tendency that spectral reflectance of soils increases with increases of wavelength, for example, the average reflectance of the sands in the periphery areas of Taklimakan Desert is 21 and 38 % in visible and near infrared spectra respectively. (3) It is found that reflectance of the soils decreases with increase of moisture content. The large decrease is recognized in 1450 and 1950 nm spectra, water absorption bands. This fact suggests that the monitoring of soil moisture is possible by measuring the radiance at these spectra, thus Landsat TM Bands 5 and 7 will be effective for monitoring soil moisture content.

Introduction

The spatial distribution and temporal variation of various materials in wide arid and semi-arid zones are significant parameters for studies of a desert itself and desertification mechanism. To obtain these parameters for a wide area such as Taklimakan Desert is not so easy due to its large size and severe natural environments. With a capability of observing a wide area nearly simultaneously and repetitive manner with a same sensor, a satellite observation offers a powerful tool for this purpose. In order to obtain the land surface features accurately from the satellite data, information on spectral reflectance of materials on the desert surface is necessary. There are not a few papers on the spectral reflectance of land surface(Leu, 1977, Becker, 1985, Cierniewski, 1987, Jackson et. al., 1990, Hick and Russell, 1990), however there are only a few reports on the in situ observation on spectral reflectance over Taklimakan Desert(Tsuchiya et. al., 1991, Ishiyama et. al., 1992, 1993, 1994) .The moisture content in the sand is a very important parameter, particularly in arid and semi arid lands. If it is retrieved over the wide areas from the satellite data, the result can surely contribute to the studies of desert itself and desertification mechanism as well. Estimation of moisture content in the sands and soils may be possible, if the relation between the reflectance and the soil moisture content is determined experimentally. However, a simultaneous measurements of spectral reflectance and water content of sands and soils are not easy due to the difficulty in measuring the water content in situ.

In addition to the in situ measurements of spectral reflectance of various materials on the land surface of Taklimakan Desert, the various kinds of sands and soils were sampled in the southern and northern parts of the desert in the neighborhood of Hotan and Aksu respectively to obtain reliable background data on the relationship between soil moisture content and reflectance. Then spectral reflectance of sampled sands and soils was measured in the range between 400 nm and 2500 nm in the laboratory under different soil moisture content. In this paper, soil moisture content(SMC) is defined by the following equation,

$$SMC(\% \text{ in weight})=100(a-b)/a \qquad (1)$$

where a and b are weight of a sample and weight of a dried sample respectively.

Results

In Situ Measurements of Spectral Reflectance

The spectral reflectance of typical vegetations observed in Taklimakan desert are shown together with spectral solar irradiance in Fig 1. In the visible spectrum no significant difference in the spectral reflectance among the samples is recognized. However there is a large difference in near-infrared spectrum among the species. The spectral reflectance of Salsola collina and Halostashys caspica, distributed sparsely in a gobi desert (stony desert). Gates(1965), Allen(1968), Sinclair(1971) pointed out that the reflectance of plants in near-infrared is influenced by the leaf area, water content and cell structure of the leaves. Since the leaf area of the vegetations in the dry area is small compared with those of non-dry area, the reflectance of the vegetation in Taklimakan Desert will be smaller than that in non-dry area vegetation in near-infrared spectra. In case of Tamarix however leaf density is generally larger than that of the former two vegetation, thus spectral reflectance of Tamarix is larger than that of the two, especially in near-infrared spectra.

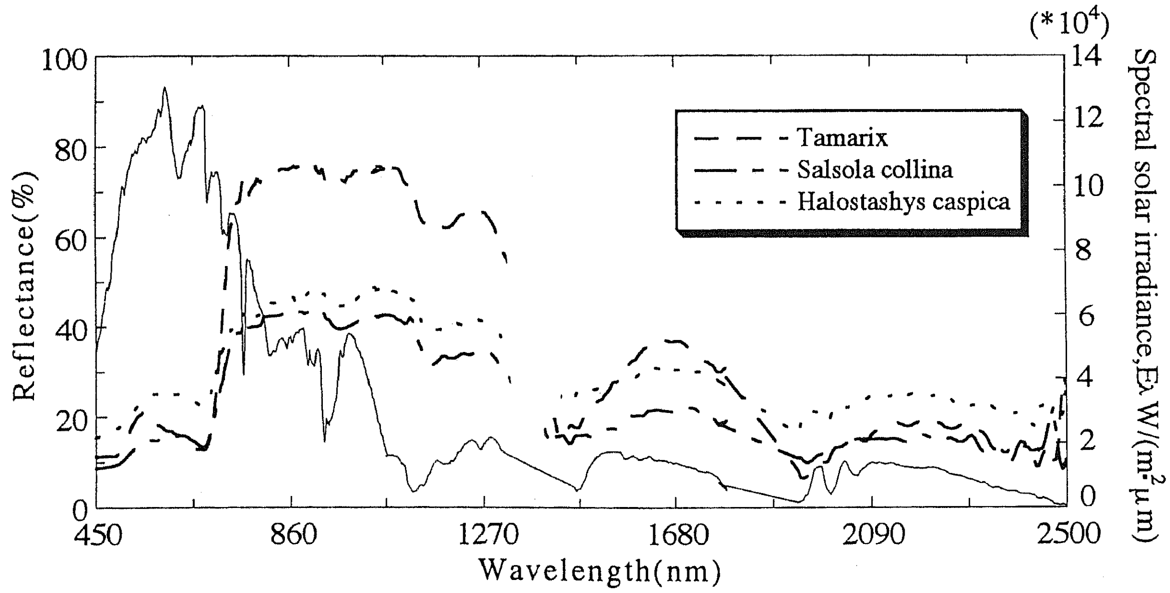

Fig. 1 Canopy reflectance of Sasola collina, Halastays caspica and Tamarix hispida together with incoming spectral solar irradiance.

Fig. 2 shows the spectral reflectance of sands at the surface and 4 different depth in the sand dune area located 30 km to the east of Kashgar (39:32N/ 76:10E). With increasing depth, the reflectance decreases showing the increase of moisture content toward deeper layer. Variation of reflectance with moisture contents is described later in detail. Fig. 3 indicates the spectral reflectance of rich and poor salined soils. The reflectance of salined soils is higher than that of slightly salined soils in whole spectral region. Salined sand is often observed in the river beds and agricultural land. In Hotan and Aksu areas, the suffering from damage of salt were frequently observed.

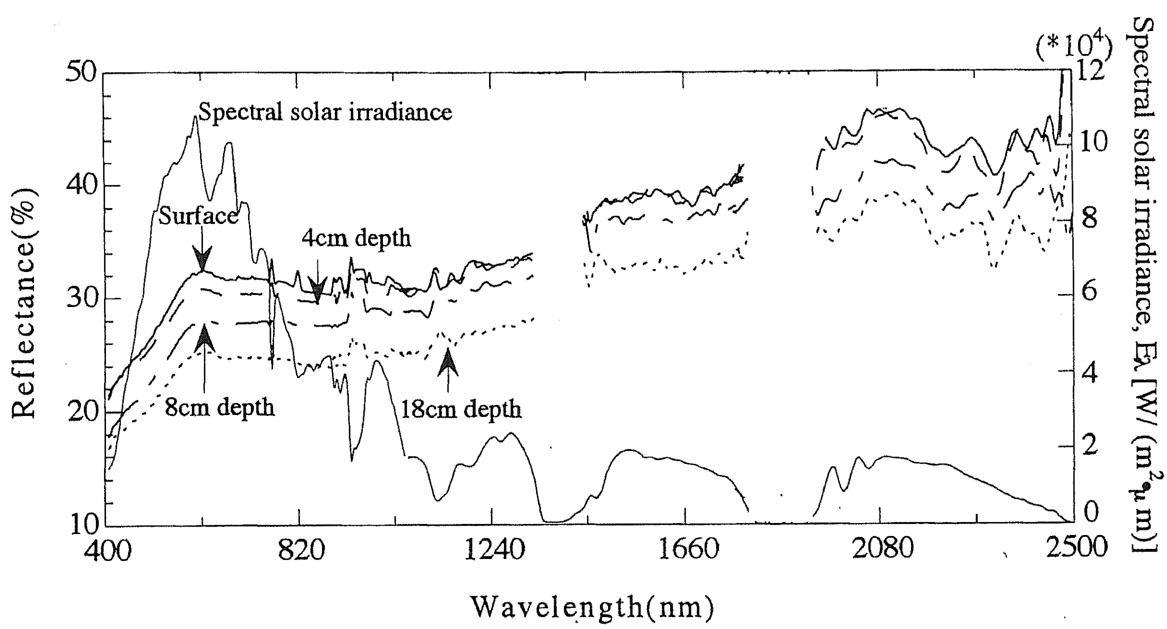

Fig. 2 Spectral reflectance of four different depth of sand dune and solar irradiance of located 30 km to the east of Kashgar(39:32N/ 76:10E) in situ survey.

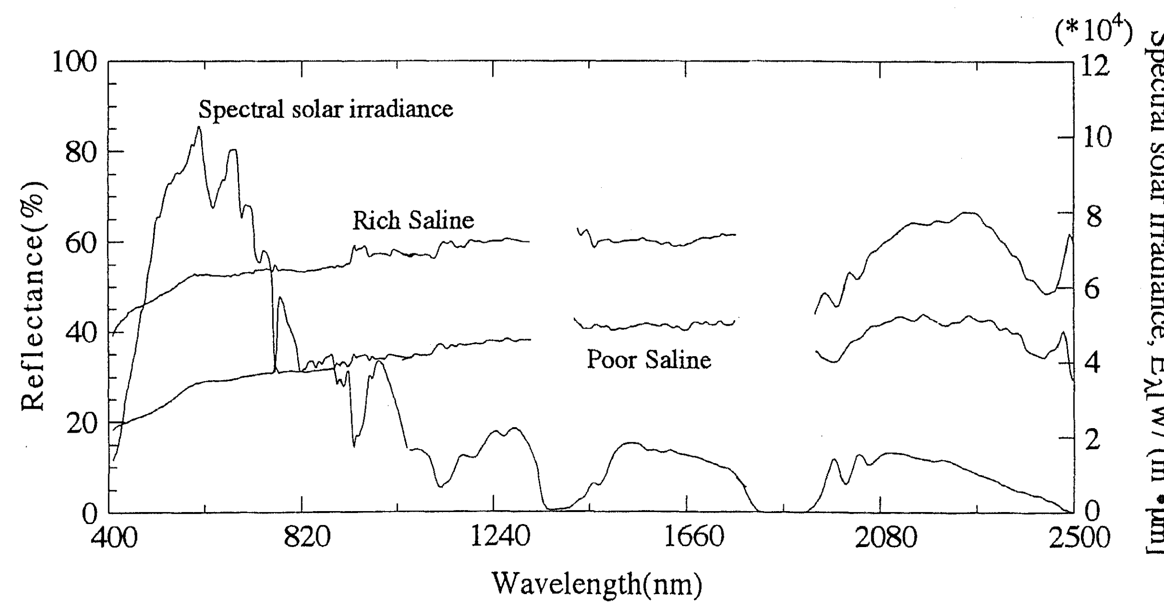

Fig. 3 Spectral reflectance of saline soil at two levels of salinization and spectral solar irradiance at a sample point.

Laboratory measurements of spectral reflectance of sampled sands and soils

The samples of sands were dried up in an air oven at constant temperature of 100°C for 10 hours. After cooling them in a desiccator, the spectral reflectance of the samples was measured with a spectro-radiometer, GER Mark IV in the spectral range from 400 to 2500 nm under different soil moisture content. As a light source 500W tungsten lamp was used. The reference reflectance was a standard white paint manufactured by Kodak. Soil moisture content was controlled through spraying distilled water on the samples in a vinyl pouch and mixed well by shaking. Thus measurements were made first under a completely dry condition then under the condition of gradual increment of soil moisture content. Fig. 4 shows the spectral reflectance of dry sands sampled in the periphery of Taklimakan Desert. The reflectance of red sand sampled in Kashgar is smaller than that of other sands. On the other hand reflectance of salined sand sampled in Hotan is comparatively high due to the fact that the sand surface is covered with a thin whitish crust of salt.

The results of the measurements of spectral reflectance in visible and near-infrared spectra for the dry sands sampled in southern and northern edges of Taklimakan Desert are given in Table 1. The sand reflectance in Bachu and Turfan is smaller than that of other samples. These samples may consist of a similar type of the reddish brown soils which are found frequently in the areas from Kashgar as shown in Fig. 4 to Bachu and Turfan in northern part of Taklimakan Desert. The average reflectance of the soil in southern and northern edge of Taklimakan Desert is 21.2 and 28.8% in visible and near-infrared spectra respectively showing that the reflectance in near-infrared part is fairly larger than that in visible part (for dry soil). Table 2 indicates reflectance within the spectral bands of Landsat MSS and TM, SPOT HRV for various dry sands sampled in southern and northern west edge of Taklimakan Desert. They were calculated from the spectral reflectance measured in the laboratory. Since the observed spectral reflectance data of the soil in the visible to IR part in Taklimakan Desert is few, these results will be useful for interpretation of satellite image data of Taklimakan Desert.

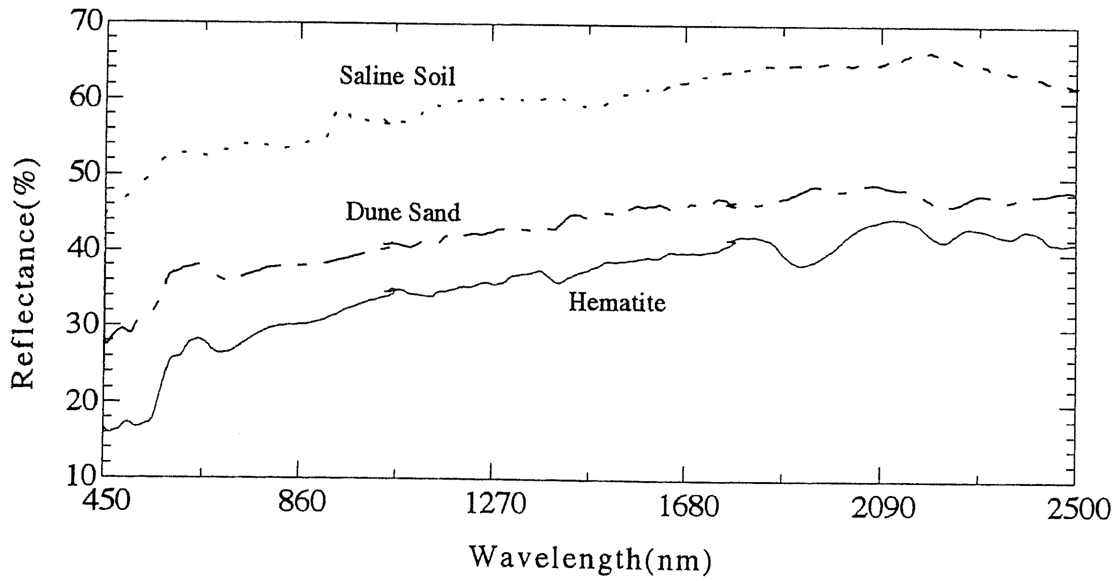

Fig. 4 Spectral reflectance of Hematite, Dune sand and saline soils collected at Kashgar(39:48N/77:26E), Sache, Hotan(37:10N/ 80:02E) respectively.

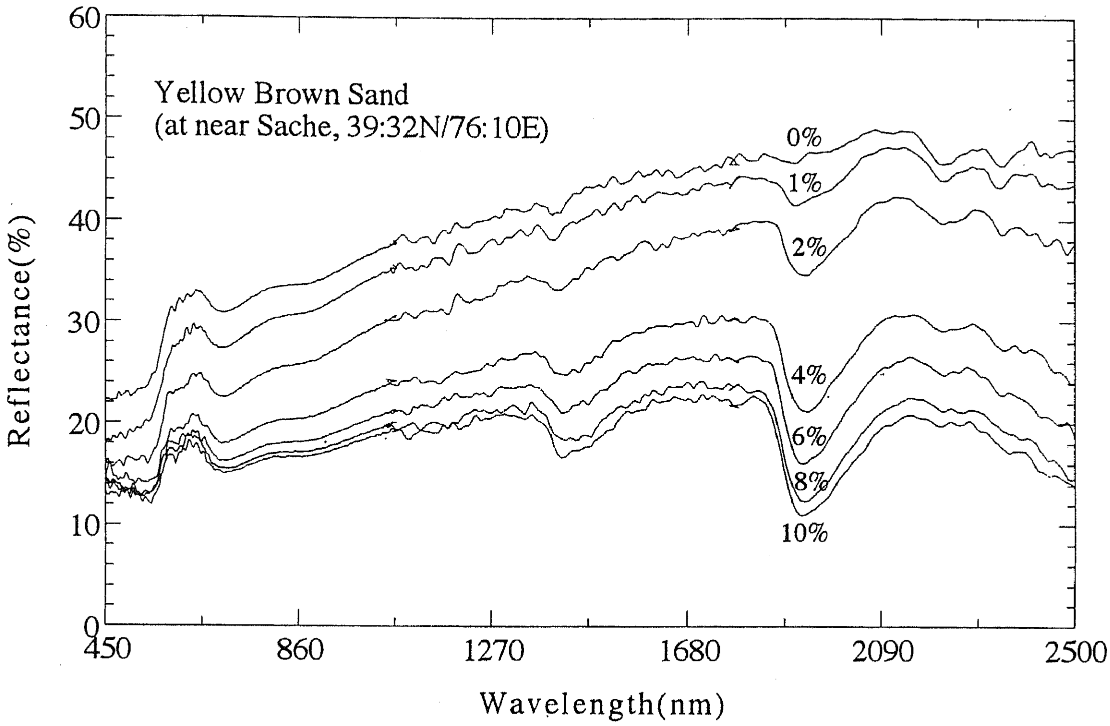

Fig. 5 Moisture content vs spectral reflectance relationship for yellow brown sand sampled near Sache in southern part of Taklimakan Desert.

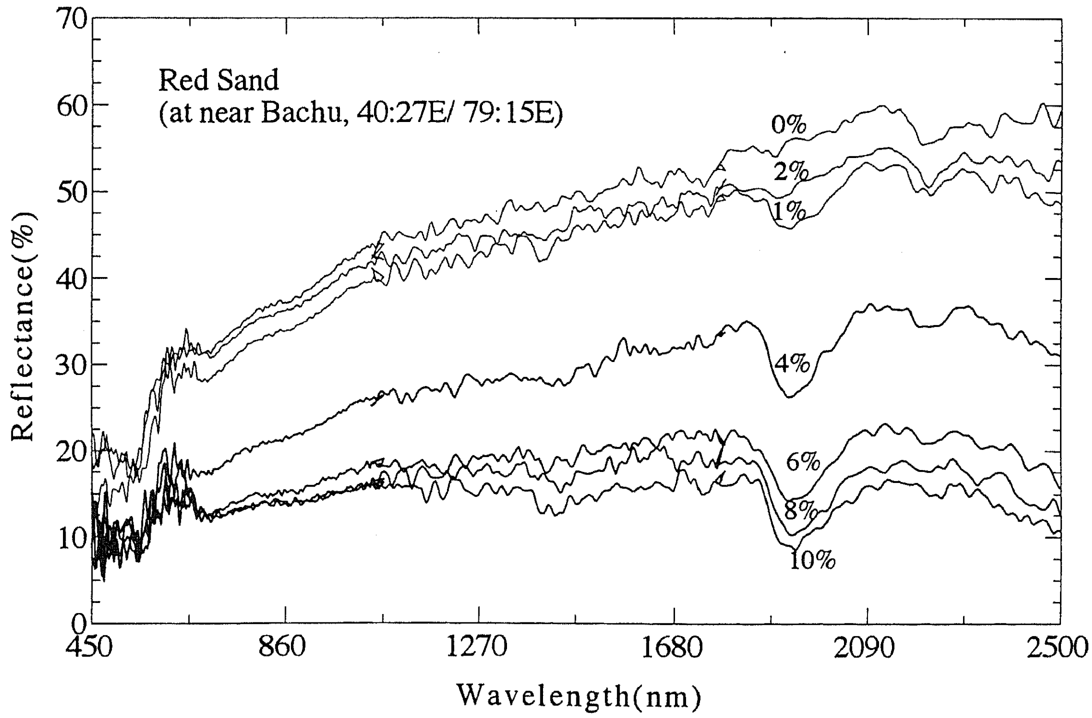

Fig. 6 Moisture content vs spectral reflectance relationship for reddish silt sampled near Bachu in northwestern part of Taklimakan Desert.

Laboratory experiments of spectral reflectance vs moisture contents

Fig. 5 shows moisture content vs spectral reflectance relationship for a yellow soil sampled near Sache of southern part of Taklimakan Desert. At 0.5% moisture content, an effect of moisture contents on spectral reflectance is small. At 1.0 % moisture content, however it is reduced by 5.6%. Above 3.0% of water content, the variation becomes smaller in visible region.
At 1452 and 1941 nm H_2O absorption bands, a rate of decrease of reflectance is larger than that in visible spectra. This is ascribed to the strong absorption of water. Ishiyama et. al.(Ishiyama et. a., 1992) reported that the decreases in the reflectance with the water contents can be explained by the relative decrease of the refractive index. This explains the decrease in the reflectance in the visible light when the water content below is 3.0 %. On the other hand, the large rate of reflectance decrease in near-infrared region is ascribed to the strong absorption of water itself along with the effect of relative decrease of refractive index of sand with water.

Fig. 6 shows spectral reflectance of the soil(reddish tan color silt) sampled near Bachu of north western part of Taklimakan Desert. In the visible spectrum, reflectance is small at 1 % moisture content. The color of the soil changes from red tan to dark red in response to increase of soil moisture content up to 2 %. Beyond 4 % the color change becomes negligibly small. In near-infrared spectrum, however, a large change in the reflectance is observed in similar way as shown in Fig. 6.

Table 1 Average reflectance(%) of soils sampled in the periphery of Taklimakan Desert in visible, near and middle infrared spectra

Stations	Reflectance(%)		
	Visible Spectrum (400-700nm)	Near, middle Infrared Spectra (750-1050nm)	(700-2500nm)
Hotan(37:10N/ 80:02E)	25.2	33.8	
Sache(38:20N/ 77:03E)	24.0	35.0	
Kashgar (39:13N/ 76:10E)	24.9	30.2	
Kashgar (39:13N/ 76:10E)	22.9	29.3	
Kashgar (39:13N/ 76:10E)	23.9	32.1	
Bachu(39:48N/ 77:26E)	15.2	20.5	39.7
Bachu(38:30N/ 76:46E)	24.4	36.8	33.7
Bachu(40:27N/ 79:15E)	19.4	36.1	39.1
Bachu(40:03N/ 78:41E)	15.4	31.2	41.4
Turfan(42:54N/ 89:29E)	14.1	21.7	
Turfan(42:54N/ 89:29E)	14.5	18.6	
Average Reflectance(%)	21.2	29.3	38.4
Average Reflectance for 400-2500nm			30.0
Standard Deviation(σ)	4.19	6.21	2.89

Table 2 Estimated spectral reflectance(%) in the spectral bands of Landsat MSS, TM and SPOT HRV for various dry soils sampled in southern and northern edges ol Taklimakan Desert

Target	Spectral Reflectance(%) of the Soils												
	Landsat MSS Bands				Landsat TM Bands						SPOT HRV Bands		
	4	5	6	7	1	2	3	4	5	7	1	2	3
Hotan (1)	29.5	33.7	32.4	35.1	27.2	31.4	33.7	33.4	45.9	46.7	30.5	34.0	33.5
Sache (2)	25.5	31.5	31.1	33.7	22.1	26.3	31.6	32.1	45.2	48.2	24.9	31.8	32.2
Sache (3)	32.6	37.3	36.9	39.1	28.9	33.4	37.4	37.8	46.2	47.6	32.2	37.6	37.9
Kashgar (4)	20.0	27.2	28.1	32.1	16.6	20.8	27.5	29.9	27.2	43.3	19.4	27.5	30.1
Kashgar (5)	22.1	30.8	32.4	38.3	19.9	22.6	31.2	34.9	47.3	53.2	21.4	31.2	35.2
Bachu (6)	21.1	30.4	31.5	37.2	18.4	22.0	30.5	33.7	47.2	50.4	20.4	30.6	33.9
Standard Deviation	5.0	3.4	2.8	2.7	4.9	5.3	3.3	2.7	2.8	3.4	5.4	3.4	2.7

Concluding Remark

The foregoing analysis leads to the following conclusion. The average reflectance of the soil in the periphery area of Taklimakan Desert is 21.2 and 28.8% in visible and near-infrared spectra respectively. In the longer part of near infrared spectrum the reflectance increases to 38.4%. The effect of soil moisture content is larger in 1450 and 1950 nm water absorption bands and decreases in accordance with increase of soil moisture content. Although the use of radiance at Landsat TM bands 5 and 7 are theoretically effective for monitoring soil moisture content, the relationship between reflectance and moisture content is too weak to predict accurate water moisture content. In order to overcome this situation, the absolute values of radiance should be utilized. In this case, however, the removal of atmospheric effect is required since its effect is same order of magnitude as that of water content.

The spectral reflectance of vegetations and soils of Taklimakan Desert obtained in this research will be useful for interpretation of satellite image data of Taklimakan Desert.

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