Land cover change and land use of oases surrounding Taklimakan Desert in Xinjiang Uyghur, China derived from satellite images

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Abstract

Land cover change of the oases surrounding Taklimakan Desert in Xinjiang Uyghur in the past 40 years was examined by means of satellite images. From the results of the analysis of these images, the following have been explained. The farmland utilization ratio in average stands at 0.28 in the northern edge of Taklimakan Desert. In the meantime, the ratio stands at 0.13 in the southern edge, whereas 0.31 in the western edge. It is revealed that in the northern edge, area of the irrigation land is vast enough to be utilized. Small oases are much noticed generally in the southern edge, and accounted for usually less than 0.15 resulting in lowness in the utilization ratio of the farmland. However the smaller the value of the said ratio is, the higher the potential of the farmland development is. It is explained that the vegetation land is slightly expanded in the upper reaches of the river in the small oases in the northern edge, but the vegetation land is drastically changed to barren land in the lower reaches of the river. On the other hand, it is explained that the vegetation regions are being expanded year by year in the oases in the northern edge. Especially in Aksu, the farmland area was expanded accompanied with increase of the number of the development settlers.

1. Introduction

In recent years, it is reported that wide area of the land has been rapidly converted into sandy sites in the edges of the oases in Taklimakan Desert in the northern part of Xinjiang Uyghur, China and is suffering from violence of dust storms. Although the cause of the land being converted into sandy sites are not yet explained, it is widely conceived that overlapped actions between the change of weather or climate and human activities, e.g. overgrazing of livestock, outrageous lumbering, land degradation brought about by execution of inadequate irrigation onto farmland, etc. are the causes.

To explain how the land cover change in the regions surrounding Taklimakan Desert is, analysis was made by using the data of the earth observation satellites with the investigation of the distribution of the oases surrounding Taklimakan Desert and the land cover change in Pishan Oases in the southern edge and in the vicinities of the Aksu Oases in the northern edge, especially with the fluctuation in the vegetation regions.

2. Distribution of the oases in Taklimakan Desert and the district surrounding them

The oases of Takilamakan Desert comprise the river water from the mountains in the vicinities of the desert and a tiny amount of the underground water, and change of the horizontal distribution of the vegetation density of the farmland of the oases and desert regions is quite drastic. In Fig. 1, a distribution map of the vegetation indices of the Takilamakan Desert obtained by analyzing TERRA/MODIS data is shown. Great oases are noticed on an alluvial fan in the western end on Pamir Plateau and Tianshan Mountains in the western end and northern edge of Takilamakan Desert. On the other hand, the oases on the southern edge that have developed on an alluvial fan of Qunlun Mountains are relatively small in comparison with the one referred to above. Thus it is understood that the longitudinal width is shorter than the one of the western edge and of the northern edge.

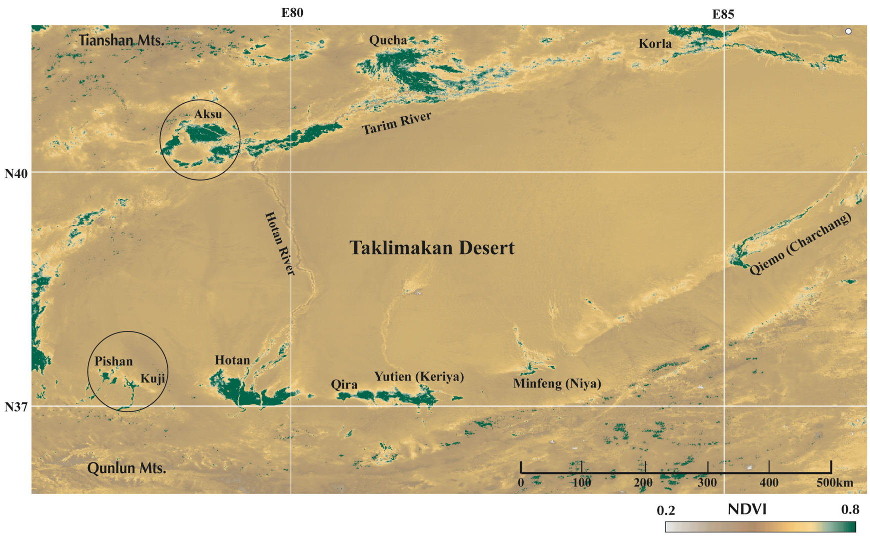

Fig. 1. Distribution of vegetation index of whole Taklimakan Desert derived from TERRA/MODIS data (May 1, 2000). The circles indicate the test sites.

Table 1. Areas of cultivated (NDVI; 0.4-0.8) and irrigation (HD-NDVI; 0.6-0.8) land of oases around Taklimakan Desert derived from MODIS data.

Oasis	Cultivated Land	Irrigation Land	Delta	Ratio of NDVI
(Northern)	(km^2)	(km^2)		
Aksu	2,830.3	486.6	969	0.17
Awat	709.9	549.0	160.9	0.78
Qucha	4,114.0	378.0	3736	0.09
Korla	843.3	340.6	502	0.40
Yuli	1,539.9	260.1	1280	0.17
				Average 0.32
(Western)				
Yarkand	3,290.7	1,277.4	2014	0.399
Kashgar	3,017.8	670.9	2347	0.222
				Average 0.31
(Southern)				
Qiemo	846.5	97.6	749	0.115
Yutien	1,060.2	125.5	934	0.118
Qira	421.4	68.7	352	0.163
Hotan	2,464.9	365.9	2099	0.148
Pishan	296.9	41.9	255	0.141
				Average 0.14

In Table 1, the area of the oases surrounding Takilamakan Desert that is calculated from MODIS data is shown. The area in question is obtained from the number of the pixels of the vegetation indices calculated from the satellite data. As the introduction equation of the vegetation indices, normalized vegetation indices (NDVI) were used. At this stage, NDVI (0.4-0.9) takes up the district ranging from a region of open vegetation to a region with high vegetation density as an objective. In this study, the regions shall be expressed as cultivatable land. On the other hand, the vegetation indices (HDNDVI: high density NDVI, 0.6-0.9) indicates an inner oases farmland with high vegetation density. The area ratio of both the former and the latter can be expressed as farmland utilization ratio (= irrigation land/cultivatable land). The values of the land utilization ratio in average are 0.28 on the northern edge of Takilamakan Desert, 0.13 on the southern edge, and 0.31 on the western edge, according to Table 1. Akus and Qucha in the northern edge and Yarkand and Kashgar in the western edge are oases exceedingly immense, and the utilization area of the irrigation land is shown to be particularly vast. On the contrary, oases rather small in comparison with those in the northern or western edge are generally found in the southern edge. The ratio of the area of the individual oases is usually lot less than 0.15, and the utilization ratio of the farmland is very low. However the smaller the value of the ratio is, the higher the potential of the farmland development is. It is made known that the utilization of the farmland is also low in Hotan in the southern edge, which is a relatively great oasis.

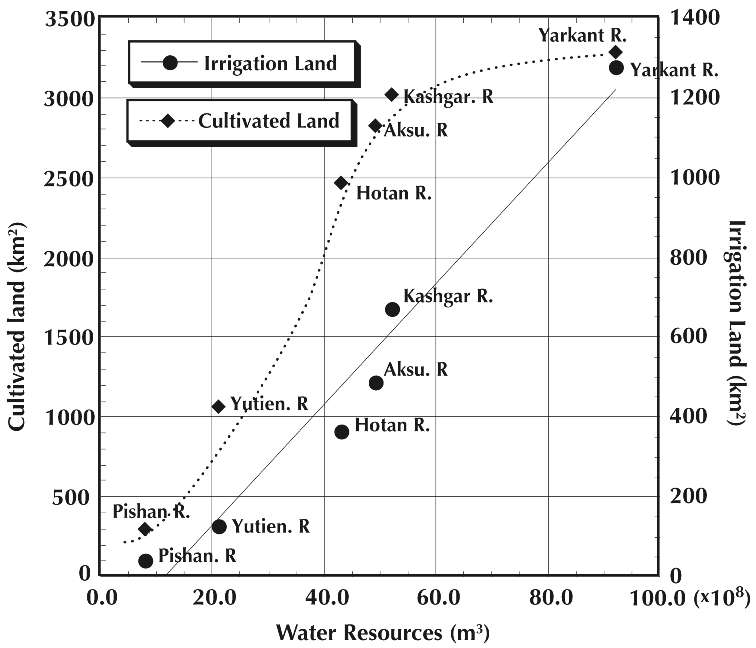

Fig. 2. Relationship among total water resources and irrigation, cultivated land in drainage of Taklimakan Desert. The areas of irrigation and cultivated land derived from MODIS data.

Needless to say, the oasis utilization ratio is dependent on the amount of the water supplied from rivers and on the volume of the underground water. In Fig. 2, a relation among the total amount of the water resources of the principal rivers forming the oases, cultivatable land shown in Table 1, and irrigation land is shown. The irrigation land area and total amount of the water resources are almost in a linear relation. However with correlation between the cultivatable land (including natural vegetation land) and total amount of the water resources, it is noticed that the both factors are in a linear relation to the extent that the total amount of the water resources is almost 5 billion cubic square kilometers. However when the amount exceeds the said value, the cultivatable land is saturated. On condition that all the water resources are utilized with good efficiency, it is to be expected that the cultivatable land will also be increased accompanied with expansion of the irrigation land. However as a matter of fact, no increase can be seen with the cultivatable land despite the fact that the riverside district is enlarged as seen in Yarkand and Kashgar in the southern edge. This might mainly stem from the reason that in these regions, under development of the irrigation channels and inferiority in water control technology compel the water resources to be wasted exceedingly purposelessly. Also the land where salts were accumulated owing to inadequate irrigation laws is much seen in Yarkand, Kashgal, Akus, etc. This is linked with the difficulty to develop cultivatable land because of the lowness of the level of the area.

3. Land cover change in the southern and northern edges in Takilamakan Desert

3.1 Land cover change in the oases in the southern edge

To examine the land cover change in the southern edge in Takilamakan Desert, comparison was made among the different images obtained from the earth observation satellite launched into space in 1972 at the time of observation. However in the northern edge, almost none of regions with great land cover change that was vast enough to be identified from the images of the satellite could be extracted. However on-the-spot investigation reports that the tiny land cover change that is hardly discernible from images of the satellite, e.g. invasion of the sand of moving dunes into the oases or erosion of the vegetation regions by domestic animals is found. On the other hand, expansion of the farmland by irrigation or enlargement of vegetation by afforestation is seen. Thus it can safely be said that change of the land surface is a quite complicated one owing to complexity of natural phenomena and human activities(1, 2).

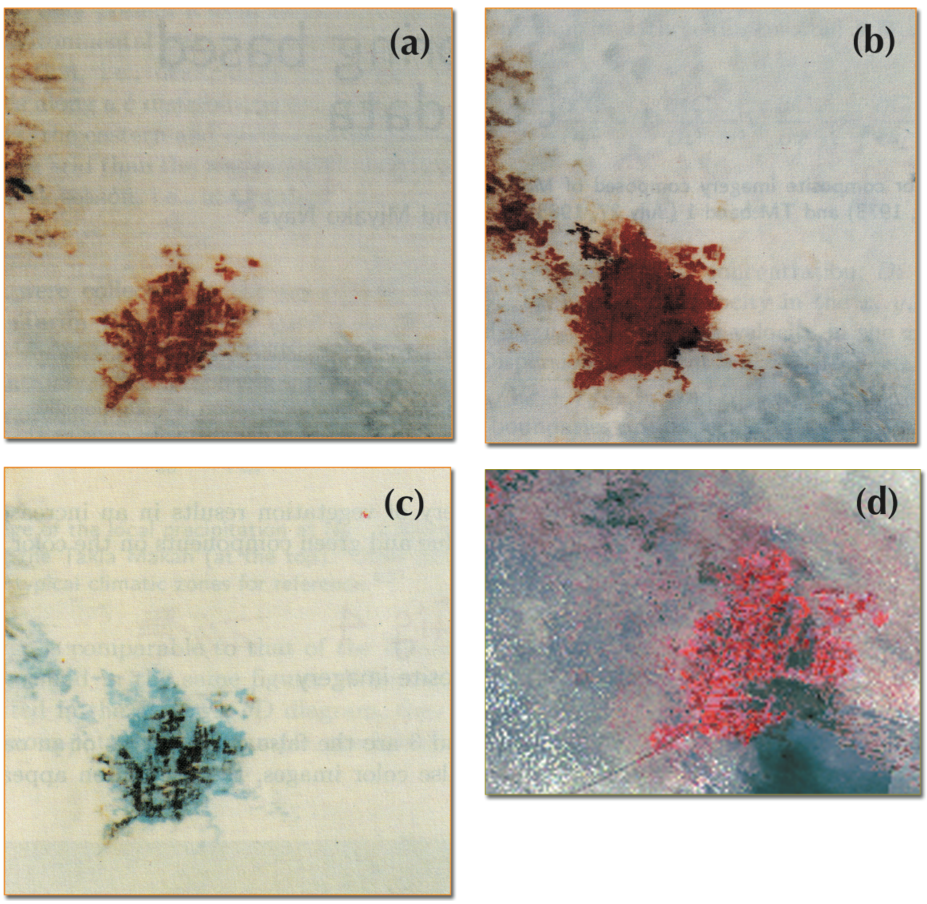

Fig. 3. Comparison of land cover condition of the small oasis of eastern edge of Lop based on Landsat MSS(1973), TM(1988) and Terra/ASTER (2001).Fig. 3 (a). Landsat/ MSS on July 24, 1973., Fig. 3 (b).LANDSAT/ TM on July 27, 1988., Fig. 3 (c). The extraction of 56% rise in vegetation areas (light blue) derived from composite imagery composed of MSS band 4 image (July 24,1973) and TM band 1(July 27, 1988), (d). The land cover condition derived from TERRA/ ASTER on April 27, 2001.

In Fig. 3, change of small farmland in the eastern edge of Lop District, Hotan City is shown. The figure reveals that the city is separated from Lop District as is seen in Fig. 3a (Landsat MSS, 1973), but it is explained from the analytical result that Lop District is partially connected with the vegetation region in 1988, i.e. 15 years after the separation as is seen in Fig. 3b

(Landsat TM). Thus it is made known that the area of the connected part is expanded as widely as 56% (Fig. 3c). Furthermore it is explained from comparison of ASTER image in 2001 in the same region with Landsat TM in 1988 referred to above that Lop District is again divided, but the vegetation region is increased 7% in a downstream direction (Fig. 3d). Thus at least in the southern edge of Takilmakan Desert as seen above, change of land surface situation complicated enough to repeat expansion and shrinkage of the vegetation region in the oases is shown. In the oases developed along a great river, such districts where vegetation regions are being expanded accompanied with expansion of the farmland or afforestation are also in existence. Land degradation as seen in conversion into desert rather appears outwardly to be in a state of stagnation.

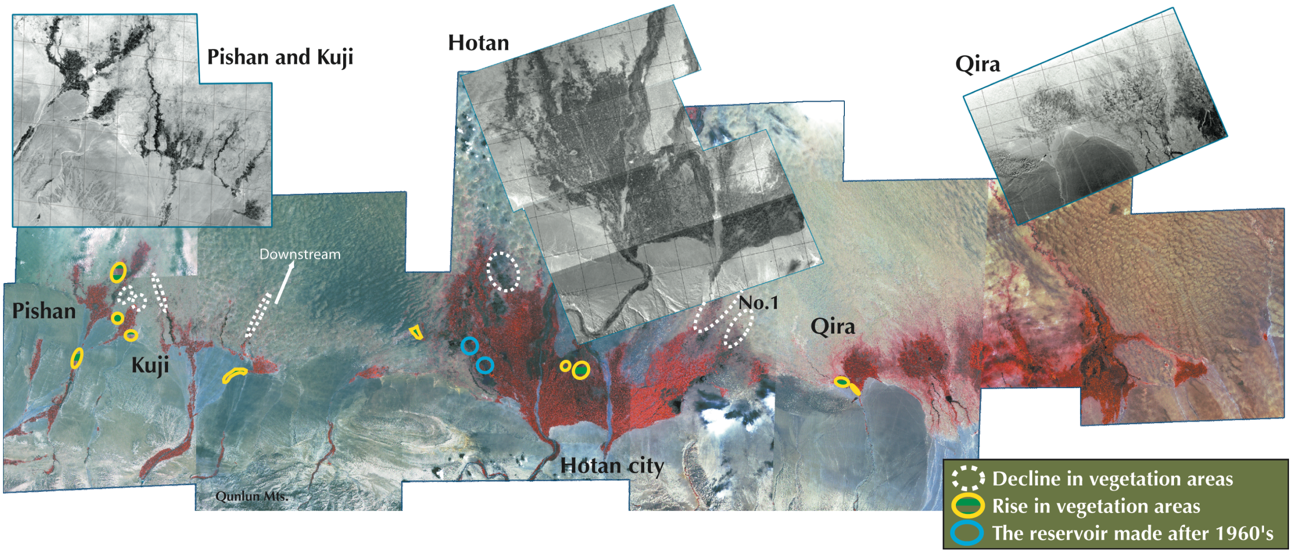

Fig. 4. Comparison of CORONA photographic image (1960) and ASTER image (2001) in land cover condition of southern edge of Taklimakan Desert. Top gray scale images are shown CORONA satellite image.

In Fig. 4, an outline is shown with the change of the land cover of the whole of the southern edge of the newest TERRA/ASTER images taken place after 40 years in the same region where the images of CORONA satellite (KH-4B resolution: 15m) manifested itself in the primary period of 1960. The result obtained by visually discerning both the types of the images is depicted on the image of ASTER. It is ascertained from the depiction that with the small oases such as Pishan or Muji on the districts surrounding the boundary on the desert, vegetation regions are in a declining trend. Meanwhile on the upstream district of these oases or on the place close to the irrigation canal, situations are quite reverse and the vegetation region is expanded. In the north of Lop Region (No. 1, district) of Hotan City in Fig.4, sand of the dunes rushed to these districts starting from the beginning of 1980. The farmland could not but be deserted because of such rush of sand, according to the local farmers. However in Moyu located in the west of Hotan City, the farmland was developed by introducing the water from 5 irrigation cisterns situated along Karakash River. The area of the said 5 irrigation cisterns is the greatest in the southern edge. On the other hand, it is also made known from the on-the-spot investigation in September 1991 that sand protection by means of afforestation in recent years prevents the dunes from being invaded. In Fig. 5, geographical positions of the change of the area of the vegetation region of the oases in the southern edge are shown. From the figure, it is made plain that regression of the vegetation region is remarkable in the downstream part of the oasis. On the other hand, it is understood that the great expansion of the vegetation region seen in the center of the figure is dependent on the existence of large cisterns in the vicinity of Moyu District, Hotan City.

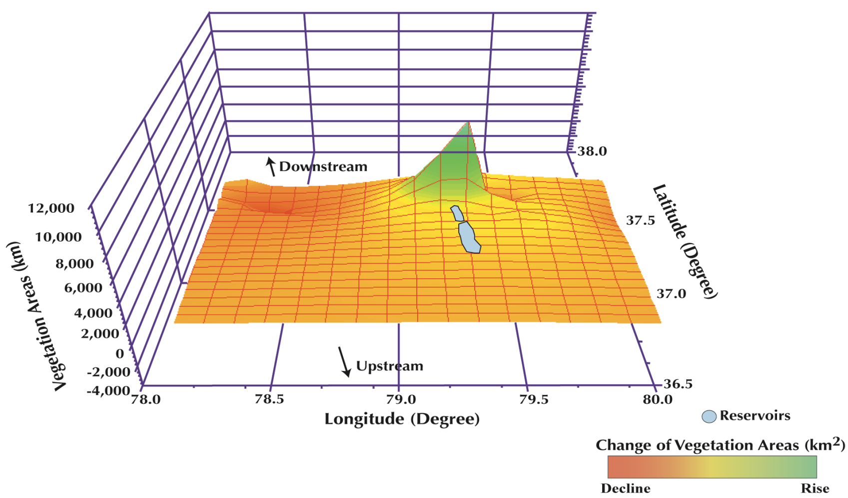

Fig. 5. Three dimensional image of distribution of fluctuation of vegetation areas during 1960's and 2001 around southern edge of Taklimakan Desert.

3.2 Distribution of the land cover change on a district surrounding Pishan

Comparison between ASTER image of the CORONA satellite in the beginning of 1960 and the one obtained 40 years later made it possible to extract the change regions where land cover was in progress. The extraction was in accordance with the following method. The CORONA image, which was printed on 70mm monochrome film, was digital-converted by means of a scanner. The image in question, in which the geometrical distortion brought about during the observation is contained, was deprives of its geometrical distortion by referring to the GCP (ground control point) obtained from ASTER image in the same region with which geometrical correction is made. The images obtained in this manner were classified into 10 clusters in accordance with the ISODATA classification method (Non supervisor classification). From all the clusters, the clusters believed to be in vegetation region were extracted by visually discerning them. By the extracted clusters, which were furthermore re-classified into the ones in the vegetation region and the ones in the non-vegetation region, extraction of the vegetation region was successfully made at the final stage. On the other hand, the area of the vegetation region, barren land, etc. were respectively calculated from the number of the pixels of the analyzed satellite images.

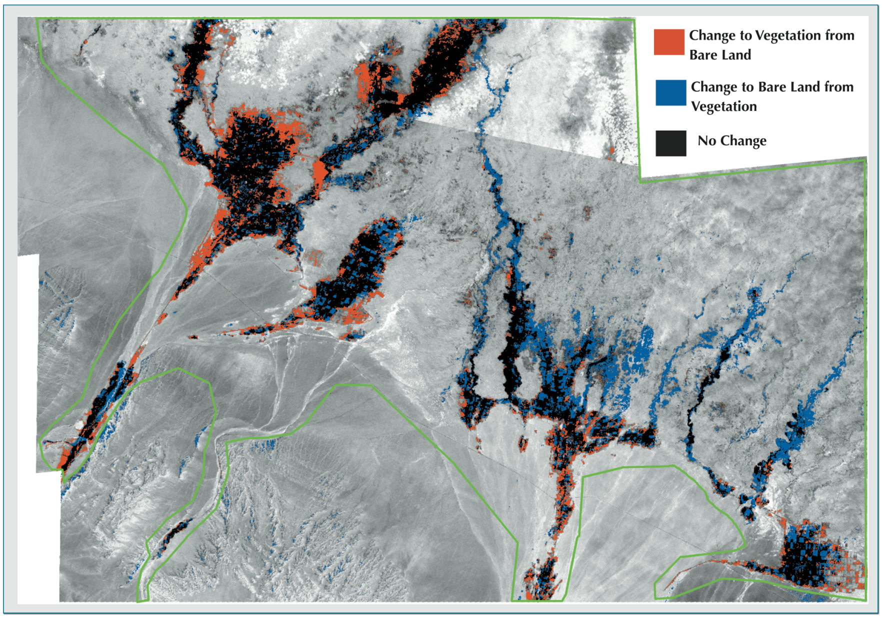

Fig. 6. Distribution of the land cover change on the district surrounding Pishan was obtained from the images of ASTER image of the CORONA satellite in the beginning of 1960 and the one obtained 40 years later. The green line shows border of the test site in this study.

Table 2. Land cover change in Pishan oasis of during 1960 and 2000 derived from CORONA and ASTER data.

Fluctuations	Pishan (km^2)
Change to Vegetation from Barren Land	75.0
Change to Barren Land from Vegetation	106.9
No Change (Vegetation)	161.5
No Change (Barren Land)	1680.3

Distribution of the land cover change on the district surrounding Pishan that was obtained from the images of the 2 periods referred to above (Fig. 6) is shown. With the small oases such as Pishan, Muji, etc. expanding on the fan of Qunlun Mountains, slight expansion of the farmland owing to existence of the small-sized irrigation cistern and irrigation channel was noticed as a result of the analysis of the satellite images. Expansion of the farmland was seen in the upper reaches of the small rivers, but contrarily vegetation is in regression on the down reaches of these rivers. A single piece each of small cistern is respectively in existence in Pishan and Muji at present, but each of them appear to have been not constructed around 1978. For this reason, a sufficient amount of irrigation water was not provided in the lower reaches and expansion of farmland is believed to have been a difficult one. Especially on the tip of the oasis, invasion of sand from dunes plunges the oases into a crisis of being converted into desert. Meanwhile on the southern edge, Hotan that developed on the alluvial fan of the Karakax River, the largest river, and the Yurunkaxi River are blessed with utilizable water in comparison with Pishan.

Several large-sized cisterns were constructed, and they contribute to expansion of farmland (Fig. 4). Area of the 40-year-old change of the land cover that is obtained from satellite data is shown in Table 2. In Pishan or Muji, things are dependent on the small rivers and a tiny amount of underground water. However such water of the rivers and underground water are very scanty in their absolute amount, and therefore expansion of farmland will be hard to be accomplished in future as well. In such an environment, there is a possibility that the pressure applied onto the agriculture in the lower reaches and land degradation will be expedited. It can safely be said that Xinjiang Government's water resources control, e.g. adequate distribution of water to the regional residents, will be a key factor to promote a countermeasure for oases to be converted into desert.

3.3 Aksu in the northern edge

The oases in the northern edge are blessed with the utilizable river water derived from the Tiansian Mountains. The area is vast enough generally in comparison with that of the oases in the southern edge. Especially Aksu is the largest oasis in the northern edge.

The satellite data used for this study are CORONA (KH-4B, Aug. 8, 1969) and multi-temporal Landsat images, whereas the sensors are MSS, TM, and ETM. The Landsat data were converted from the digital number to brightness value by referring to the meta-data of the individual sensors. Composite images were formulated from the blue, red, green, and near-infrared bands of the obtained brightness values, and the images obtained in a manner the same as that of the CORONA images are classified into 10 clusters in accordance with the ISODATA classification method (Non supervisor classification). A cluster believed to be in the vegetation region is visually discerned to be extracted from all the clusters, and furthermore is re-classified into the ones in the vegetation region and in the non-vegetation region. Thus at the final stage, the one in the vegetation region was extracted. The images of the 3 scenes in a district surrounding Aksu were mosaic-processed to cut out the range as wide as the CORONA image. Thus the vegetation cover area was calculated. The vegetation region extracted from the CORONA image of 1969 is shown in Fig. 7(a), whereas the vegetation regions of 1976, 1990 and 2002 extracted from the Landsat image are shown in Fig. 7(b), Fig. 7(c) and Fig. 7(d). It is understood from these that the cover area of vegetation is continuously increased every year starting from 1969. It is also understood that the area is being expanded especially along the district surrounding Aksu City and its eastern side. The developing farm is expanded from the left bank of the Aksu River to Aral to reach the Tarim River. This corresponds to the vegetation region as the farmland extracted from the satellite image. In Table 3, aging (year variation) of the vegetation cover area is shown.

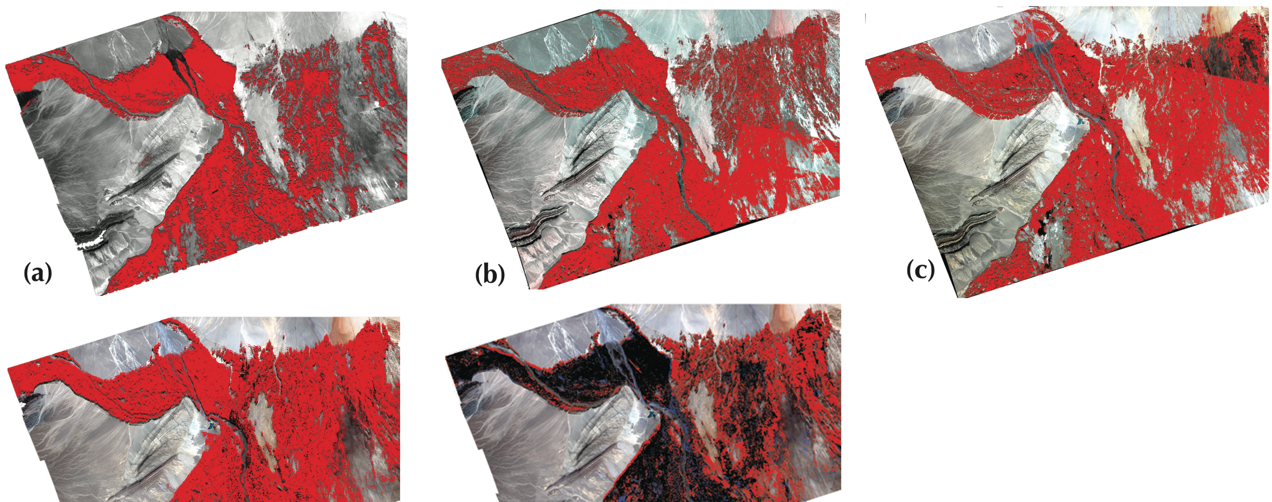

Fig. 7. The vegetation region extracted from multi temporal satellite images in Aksu, the CORONA image of 1969 in Fig. 7(a), whereas the vegetation regions of 1976, 1990 and 2002 extracted from the Landsat image in Fig. 7(b). Fig. 7(c). and Fig. 7(d). , Fig. 7(e) is shown the land cover change of Aksu obtained from composite of the image of CORONA satellite in 1969 and Landsat image 33 years later.

Table 3. Fluctuation of vegetation areas in Akus oasis derived from satellite data.

1970	**2386.1** (km^2)
1976	**2321.3**
1990	**2712.0**
2002	**2718.6**

The population that was changed in Takilamakan Desert in recent 40 years, which was 3,047,300 in 1949, was 1,104,200 as the whole of the northern edge(3). However the values referred to above were reversed in 1980 to be 5,138,600 in the southern edge and 6,919,400 in the northern edge. Meanwhile in Fig. 8, population fluctuation in Aksu City in recent years is shown. It is understood from this that the population of 7,000,000 in 1953 was increased to reach 1,500,000. Furthermore the population became 1,715,900 in 1990. The population increase starting from the middle of 1900 was brought about owing to the fact that the Chinese Government shifted the development settlers from the other regions for the purpose of farmland development in the northern edge. It is comprehended that aging of the vegetation cover area shown together with the change curve of the population well corresponds to the increase in population. Shown in Fig. 7(e) is the land cover change of Aksu obtained from composite of the image of CORONA satellite in 1969 and Landsat image 33 years later on the region the same as that of the former. It is comprehended from the figure that the vegetation region is increased in the left coast of the Aksu River, whereas the vegetation region remains almost unchanged in the right bank in the vicinity of Awat the same as in 1969. Contrarily to the above, the region where the vegetation region is in regression was also observed.

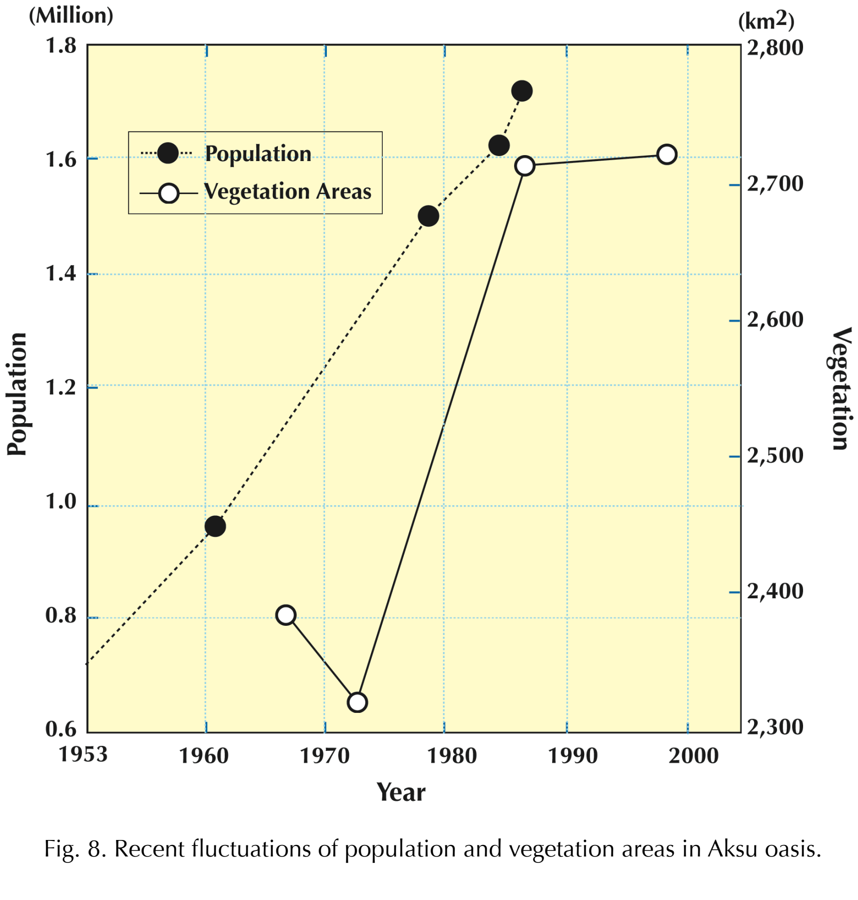

Fig. 8. Recent fluctuations of population and vegetation areas in Aksu oasis.

4. Conclusions

Papers concerning the study on land degradation such as conversion of oases into desert in Takilamakan Desert are publicized mainly by Chinese researchers. However very few papers describing change of the land cover throughout the whole of Takilamakan Desert quantitatively are available. In this paper, land cover or land use in oases surrounding Takilamakan Desert was analyzed by using satellite data. On the other hand, quantitative analysis was made with the change of land cover of the representative oases in the southern and northern edges of Takilamakan Desert. Thus several fruitful outcomes have been obtained. This is the first report concerning the land cover and land use on the district surrounding the oases in the whole of Takilamakan Desert.

With the change of land cover and land use in a vast region where natural condition is very severe as seen in Takilamakan Desert, the whole situation cannot be grasped until analysis is successfully made with satellite data that can make observation of wide region for a long-term. Conversion of oases into desert makes progress not only by climate change but also by human environmental change. Concurrently with this, it is also possible to prevent such progress from being accomplished to a certain degree of extent. However with the oases dependent on small rivers or a tiny amount of underground water, it is exceedingly difficult to prevent the sand from dunes from invading to the oases when the social foundation such as irrigation cisterns, water course, windbreaks, etc. are poorly provided. This can commonly be said especially with the oases in the southern edge that are short of river water and underground water.

Environmental dynamics in Takilamakan Desert is considerably complicated, and long-term and multi-temporal observation is required. In this region as well in recent years, frequency of dust storm is increased resulting in severe damage in humans or livestocks. On the other hand, more than 90% of water resources are supplied from glaciers. Thus when global warming is intensified in future resulting in shrinkage of the glaciers in Qunlun Mountains, Tianshan Mountains, and Pamil Plateau, drastic change of the environment will be caused in the oases and their surroundings.

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