The Analysis of Desertification Process in Mu-Us Sandy Land Using Satellite Remote Sensing, GIS and Field Survey

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Abstract: In order to make the desertification map of the Mu-Us Sandy Land, the current status of desertification was detected spatially with the satellite images. The causes of desertification was analyzed on the comparison between the desertification image and GIS-based thematic data and the results of interview to local people. The denuded area ratio of each village was related to the sand dune ratio. Desertification in this area was strongly affected by the activity of sand dunes. The revegetated area ratio had a close relationship with the cropland ratio. The development of cropland and the surrounding forestation contributed to revegetation of denuded area. Denuded areas were mainly distributed in the pastoral area. The highest relationship between the denuded area and the animal population was seen in the density of goats. The results of interview also showed that goat density was high in the denuded sites. Overgrazing by goat was considered to be the main factor of current desertification here.
Keywords: desertification, satellite image, GIS, desertification map, Mu-Us Sandy Land, socio-ecology

1 Introduction

The decision-making style of desertification control is pursued to change from top-down to bottom-up approach based on local consent. In such approaches, local-scale hazard map of desertification would be useful in environmental recognition of local people, land-use planning and the application of techniques against desertification. As a fundamental study for local desertification map, we analyzed the state of desertification in Mu-Us Sandy Land, China, using satellite data.

Some different opinions have been proposed about the causes of desertification in Mu-Us Sandy Land. In past, extensive crop cultivation was considered as the main factor of desertification here. Recently, overgrazing is often called as an important factor. The first purpose is the identification of the main factor of current desertification in Mu-Us Sandy Land. The geographical image of desertification was analyzed with thematic GIS and statistical data in order to study the factor of desertification. The actual states of vegetation, soil and land management were also studied by field survey.

In order to develop an idea of sustainable land use in pastoral area, it is important to clarify the carrying capacity of grassland for animal grazing. However, values are quite different among reports. The team of Inner-Mongolia University (1990)[1] reported that the animal-carrying capacity of grassland in Mu-Us Sandy Land was 0.3 to 1.0 head/ha, based on the relationship between the productivity of grass and the diet of a sheep. The Japanese team of the Institute of Agro-Environmental Science (1996)[2] reported 4 head/ha, based on the data of sheep-breeding experiment for 3 years in Kerqin Sandy Land. Correct value of carrying capacity is needed for the direction of sustainable land use.

Socio-economic factor is considered to be important in the mechanism of desertification, particularly for bottom-up action. Structural factors of current desertification in Mu-Us Sandy Land including socio-economic backgrounds were discussed through the multiple analyses.

2 Study site and method

2.1 Study site

Study site was set on Wu-Shen Banner, Inner-Mongolia Autonomous Region. Wu-Shen Banner is located on Ordos Plateau. The total area is 12,000 km2 and the range of altitude is 1,200 m to 1,500 m.

The range of study area spreads from 38.05° N to 39.40° N and from 108.40° E to 109.67° E, partly restricted by the range of satellite data. The mean temperature and the mean annual precipitation of Wu-Shen-Chao Meteorological Station are 6.5℃ and 345 mm, respectively. The study range contains 11 villages.

2.2 Extensive monitoring and analysis of desertification using satellite image, GIS and statistics

LANDSAT/MSS data 137/33 of 17 August, 1978 and LANDSAT/TM data 128/33 of 5 September, 1996 were taken and rectified with GPS data. Land cover type was classified into 6 categories by unsupervised ISODATA method with ERDAS/IMAGINE8.4. 2 classes and 4 classes of MSS image were identified as bare area and vegetation-covered area, respectively. In TM data, 1 class and 5 classes were identified as bare area and vegetation-covered area, respectively, and another 1 class was recognized as semi-vegetated area. Two land-cover image were compared and changed area were identified. Changed area from vegetation-covered area to bare area was judged as denuded area. Changed area from bare area to vegetation-covered area was judged as revegetated area.

Thematic maps attached to "Natural Condition, Improvement and Use of Mu-Us Sandy Land[3]" were put into GIS. Statistic data about population, animal population and land use area of each village in 1980 were also inputted. The factor of denuded area and revegetated area was analyzed with these data-sets.

2.3 Intensive analysis of desertification by the field survey

1:300,000 satellite image map was made from LANDSAT/TM image with mesh of latitude and longitude, scale and main roads. 14 sites of field survey with various levels of denudation were picked up all around the study site of extensive survey, and were plotted on the satellite image map. In the summer of 2000, we approached study sites accurately by car and on foot with the map and GPS. Vegetation and soil were surveyed in each site. 21 host family was interviewed about population and animal population, land types and areas, income, fuel type, well depth and so on. Complex factors of desertification were analyzed by the comparison of these data.

3 Results and discussion

3.1 Extensive analysis

Mu-Us sandy land is classified into the following 4 major land types as hill, plain, active sand dune and fixed sand dune[4]. Figure 1 shows the ratio of denuded area per total area of each land type. On the result of GIS analysis, denudation dominated fixed sand dune area. In particular, 10% of fixed sand dune area was changed into active sand dune on plain. This result means that the change from fixed sand dune to active sand dune is the actual major phenomenon of desertification, here. It also illustrates that the erosion on hill is not severe rather than on plain, even though the soil moisture condition is severe on hill.

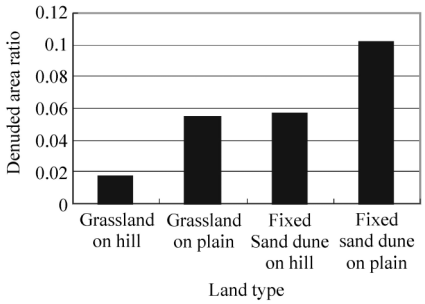

Fig. 1 Saltation tragectories

The distribution of denuded area was studied for 11 villages in Wu-Shen Banner. Denuded area ratio and cropland area ratio had a closely negative relationship except 1 village indicaetd by arrow (Fig. 2). Since this village is located in the eastern boundary of the banner, adjacent to Shanxi Province, the proportion of agricultural Han people might be higher than the other villages. The wholly tendency shows that the degree of desertification is low in the agricultural area.

Positive relationship was also found between cropland area and revegetated area except two villages shown by arrows (Fig. 3). Since these two villages are located in the northern boundary of sandy land, the

proportion of vegetation area had been apparently high in 1978. Although cropland development had been called as the primary factor of desertification in past, it changed to the promotion factor of revegetation now.

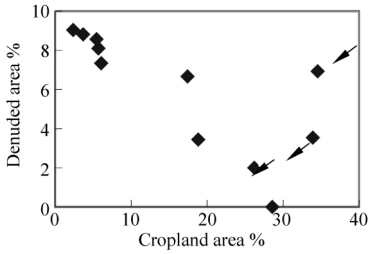

Fig.2 Relationship between the percentage of cropland and denuded area for each village

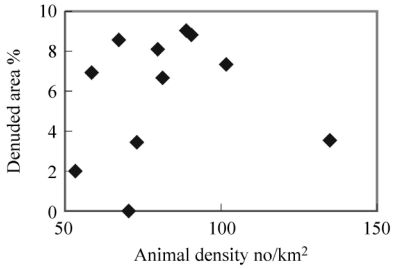

Fig.3 Relationship between the percentage of cropland and the revegetated area fro each village

On the other hand, denudation area ratio was weakly correlated with the number of animals (Fig. 4). In particular, goat number had highest relationship with denudation (Fig. 5). Arrows in Fig. 4 and 5 show the village in the northern boundary of sandy land, where land condition is resistant to wind erosion compared to other villages. Though the critical value of animal density was vague, denuded area ratio was high in the case that the animal density was more than 0.7/ha and the goat density was more than 0.2/ha.

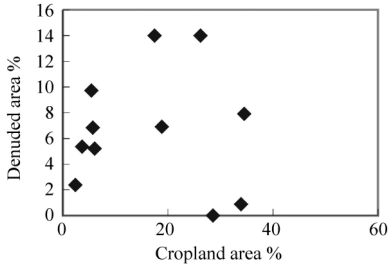

Fig.4 The relationship between to breeding animal density and the percentage of denuded area for each village

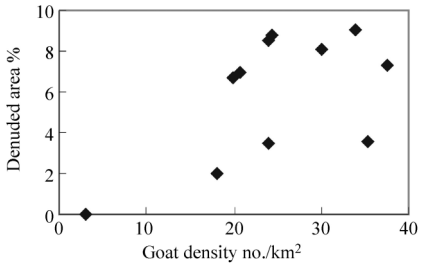

Fig.5 The relationship between the goat density and the percentage of denuded area fro each village

3.2 Intensive analysis

Results of field survey show that the animal density in the desertification-advanced area was higher compared to stable area (Fig. 6). If the animal density is more than 2/ha, the land tends to be damaged. However, there are exceptions and the critical value was not clear.

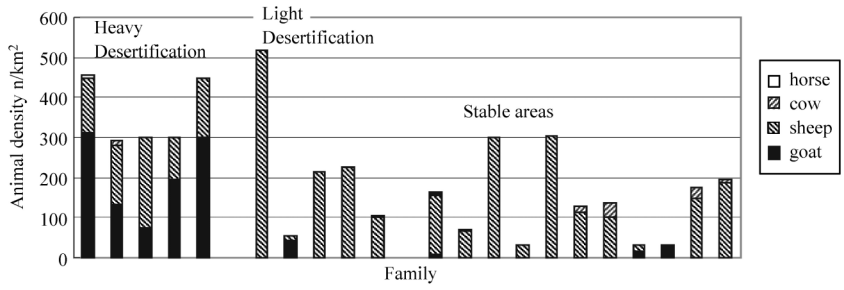

Fig.6 Owned animal density per grassland area of sampled family

The presence of much population of goats was eminent in the severe-denuded sites (Fig. 6). Other breeding animals usually graze grasses. But goat browses even the shoot of shrub. Therefore,

goat-attacked vegetation changed to annual grasses with poisonous plants. The areas covered by such vegetation are apt to be eroded by water-flow and wind. Regarding the result of extensive survey, animal grazing should be the main factor of desertification and the role of goat is particularly important for the soil erosion.

By the way, the critical value of animal density was quite different between the result of extensive survey and intensive survey. Since the value of intensive survey is examined in the actual field, it might be more reliable. The data of extensive survey owed to statistics provided by local government. Local statistics should be biased by any factors like the false statement by local people or social situations.

Fig. 7 shows the result of interview about income of sampled families. In heavy and light denuded sites, the income of 10 families per 11 sampled families was more than 10,000 Yuan. In stable area, the income of 7 families per 11 sampled families was less than 10,000 Yuan. Though income is primarily related to the area of grassland and cropland, economic productivity was higher in denuded sites. In such areas, high density of animals or goat breeding brought high income. Since goat provides cassimere wool, high income can be earned from goat. The extension of market economy into the pastoral area seemed to promote the increase of goats and to become the background of desertification.

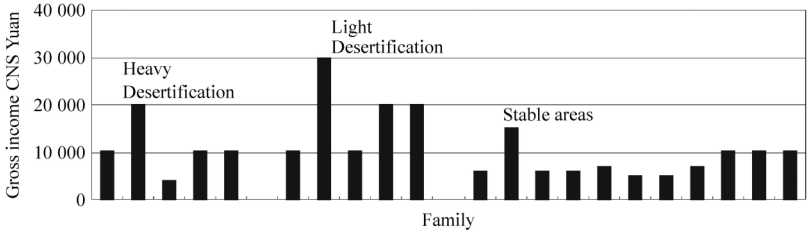

Fig. 7 Annual income of sampled family

Denudation was not recognized around the agricultural village under the control of land use and in the region of village under the strict control of goat breeding. The vegetation was stable in the own land of environment-conscious family who did not breed goat to save land.

The danger by fuel gathering was not high, because fuel has changed from natural shrubs to planted trees, coal and gas in most areas. In some places, shrub gathering caused the degradation of vegetation. Tree planting had the secondary effect on the save of shrub gathering.

The effect of climate changes was not clear. In 2000, the year of our field survey, the decrease of well-depth was apparent because of less rains. Some villagers talked about the decrease of groundwater. However, clear tendency of groundwater decrease for decades could not be found out. Further studies are required for the understanding of the effect of climate change.

4 Conclusion

Current status of desertification could be monitored for Mu-Us Sandy Land. The major field of desertification was attributed to fixed sand dune on plain. The attention for desertification control should be continuously paid for fixed sand dune area.

Though the extensive agriculture had been called as the primary factor of desertification in Mu-Us Sandy Land, agricultural land use had inversely positive effect for the conservation or rehabilitation of vegetation cover. Appropriate management of cropland and the organized effort for forestation might bring the good effect. However, the danger of desertification remains high in cropping village of sandy area. In such area, careful attention should be paid for the extensive development of cropland.

Irrigation agriculture is now extending and brought the positive effect on revegetation in fact. However, there are some apprehensions. The excess consumption of groundwater does not secure the future. The careful monitoring and management of groundwater should be organized for sustainable area development.

The effect of overgrazing was apparent. In particular, goats caused severe erosion. From the result of our study, animal density more than 2 heads/ha possibly bring the negative effect on vegetation. Goat

breeding has the apparent negative effect on vegetation and promotes the soil erosion. Maximum attention must be paid for land management in goat breeding.

The high income provided by goat breeding seemed to be the background factor of desertification. On the other hands, there are some environment-conscious livestock farmers who avoid goat breeding. Desertification did not dominated in the villages where comprehensive environmental policies were functioning. These facts suggest that the appropriate policy and the spread of environmental education are most important for the control of desertification.

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