G-2 A Pilot Study in North-East Asia for Developing Desertification Assessment and Constructing an Early Warning System

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1. Introduction

The development of Benchmarks and Indicators in order to monitor and assess desertification and the establishment of operational and cost-effective Early Warning Systems (EWS) for drought and desertification are among the principal items on the agenda drawn up by the Committee on Science & Technology (CST) under the UN Convention to Combat Desertification. The ad hoc Panel Report on international trends in drought/desertification EWS reveals that at present, there is no operational desertification EWS. The Report recommends that more emphasis be placed on the neglected issue of land vulnerability, and that for the sake of risk management, urgent priority should be given to the initiation of a pilot study to establish a desertification EWS.

Desertification occurs through a complex combination of elements at a local scale. But at the same time, the phenomenon manifests itself at a larger scale. The difficulty of combining breadth of scope and depth of complexity in a single examination has meant that conventional desertification research has been compartmentalized according to the different spatial scales involved in each respective project.

2. Research Objective

This project will implement recommendations of the ad hoc Panel on EWS, which have been adopted by the CST. The Government of Japan has also previously supported activities and recommendations of the ad hoc Panel on EWS. The integrated model envisaged in the study plan will provide a common foundation for the integration of what has hitherto been treated as separate issues: desertification benchmarks and indicators, both large-scale and regional in scope; desertification monitoring and assessment; and desertification EWS.

The integrated model created by this research project will make it possible to use land vulnerability as a criterion to assess local-scale desertification, so that land managers and decision-makers can identify the most appropriate land use and establish ecosystem management plans. The integrated model will also enable local assessment results to be extrapolated across a wide area, and the data thus derived to be included in the respective National Action Programmes (NAPs), which have hitherto often lacked scientific and technological information.

3. Research Framework

This project integrates the observation of desertification indicators at a large scale (studied in sub-theme 2, (2) hereafter) and the desertification processes in relation to anthropogenic disturbances in various geographical conditions (in sub-theme 3, (3) hereafter), through building models for long-term trend assessment and for scenario assessment (in sub-theme 1, (1) hereafter) (Figure 1).

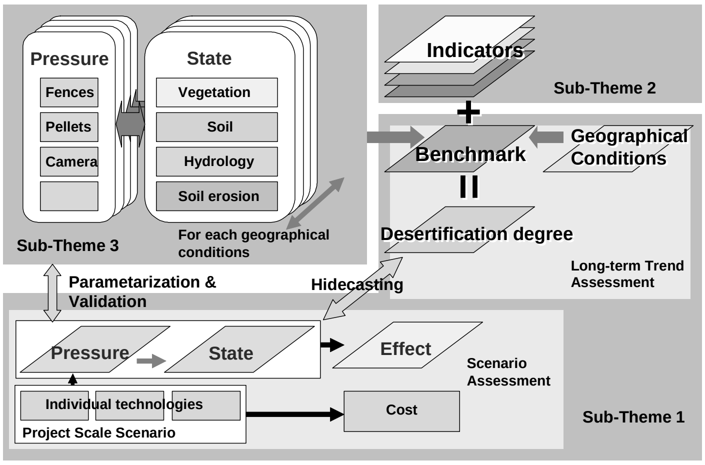

Figure 1 Structure of this project

It is known that the ordination of survey plots by major desertification indicators within a particular geographical condition exhibits a series on the plane, and the ordination within another geographical condition shows another series. Therefore, the ordination of the survey plots by indicators which can be derived at a large scale would enable large-scale assessments to be conducted by using the landscape ecology method and multiple-point field surveys. Scenario assessment will be implemented by combination of an ecosystem model which can simulate the relation of desertification with anthropogenic disturbance in various geographical conditions, and a mathematical programming model which includes the cost and effectiveness of individual desertification countermeasures and the limitations due to the social receptivity and capacity to put environmental policies into practice.

4. Methods and results

A. Sub-theme 2 Desertification Indicators for Long-Term Monitoring

Sub-theme 2 inquires into the standardization of the methods, and providing of desertification indicators at a large and long-term scale. To monitor the gradual, long-term process of desertification, soil erosion rate, which is one of the most robust factors of desertification, was estimated.

Wind erosion was estimated by the Wind Erosion Assessment Model (WEAM) developed by CSIRO in Australia. WEAM estimates wind erosion rate from various parameters such as climate, vegetation, hydrology and soil. In this project, soil moisture, of which estimation accuracy was low, was estimated by direct observation by microwave satellite remote sensing. By analyzing the results of field experiments to derive the characteristics of the microwave, a model which can estimate soil moisture from satellite imagery was developed, and applied to estimate soil moisture in the entire dryland area in North-East Asia from 1988 to 2002 (Figure 2). By using this data, the wind erosion rate was estimated (Figure 3). By comparing the observation data of several ground weather stations, the estimated rate was confirmed to be reasonable.

Water erosion was estimated by Revised Universal Soil Loss Equation (RUSLE) developed by the University of Michigan. RUSLE estimates erosion rate by climate, topography, soil and vegetation. Because RUSLE is a kind of empirical equation, it is necessary to tune and validate using field observation data. By correlating with sub-theme 3, experiment sites were established in Northern Mongolia, and the observation data was used to examine the accuracy of RUSLE. Then, 11-year water erosion data was estimated by RUSLE (Figure 4).

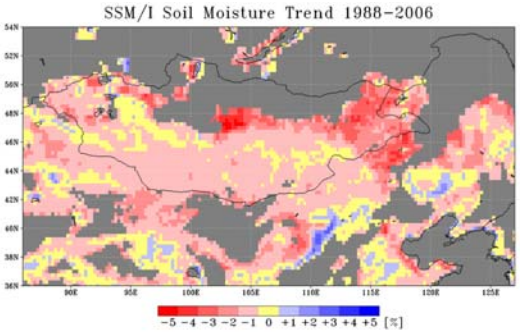

Figure 2 Trend of soil water content estimated by microwave remote sensing (1988-2006)

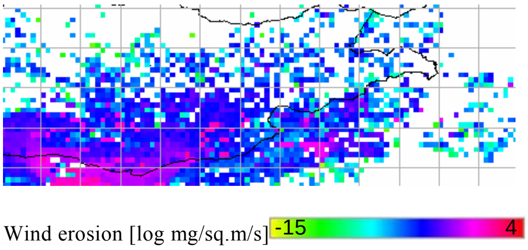

Figure 3 Average estimated wind erosion rate (1988～2002)

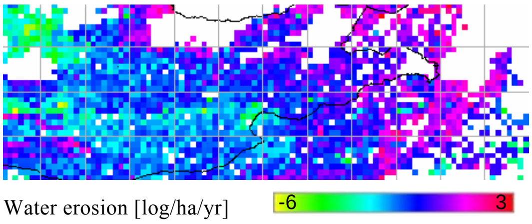

Figure 4 Average estimated water erosion (1988～1999)

B. Sub-theme 3 Land Vulnerability Assessment by Soil/Vegetation/Hydrological Analysis

This sub-theme aims to investigate desertification processes and establish desertification benchmarks in various geographical conditions. This sub-theme consists of two sub-sub-themes. In sub-sub-theme 1, by field survey, various desertification indicators are measured at places under various intensities of grazing and in various geographical conditions, for comprehensive analyses of desertification processes and benchmarks. Because more than one factor sometimes shows parallel change, in sub-sub-theme 2, germination and growth experiments will more accurately determine the key factors of desertification processes.

Sub-Sub-Theme 1 Land Vulnerability Assessment by Field Survey

In this sub-sub-theme, the following two types of surveys were used to investigate desertification processes in various geographical conditions. In (a) intensive survey, several fences were established at locations which have different grazing histories, and benchmarks were estimated by investigate the restoration rate. In (b) extensive survey, we surveyed various geographical conditions.

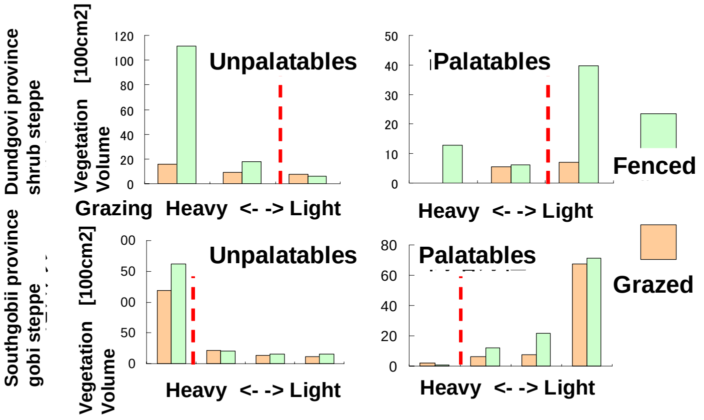

Figure 5 Vegetation volume of fenced and grazed sites after 2-year restoration experiment

For (a) intensive survey, we selected two sites around which livestock concentrates, such as a winter camp or a water point, and established sets of several fences at different distances from the sites. After two years of restoration, the vegetation inside and outside the fences was surveyed and analyzed in terms of palatability (Figure 5). As a result, we found a relationship between the grazing intensity at which plant functional type (PFT) changes, and that at which the restoration rate differs. Therefore, we concluded that the PFT change can be a desertification benchmark. Then in (b) extensive survey, we surveyed the vegetation response to different grazing intensities in various geographical locations, and found that 3 major types of vegetation response exist (Figure 6). In steppe regions, palatable grass is dominant in lightly grazed areas, and vegetation type changes and amount decreases as grazing pressure increases. In shrub-steppe regions, shrubs are dominant under light grazing, and vegetation amount decreases as grazing pressure increases. In Gobi-steppe

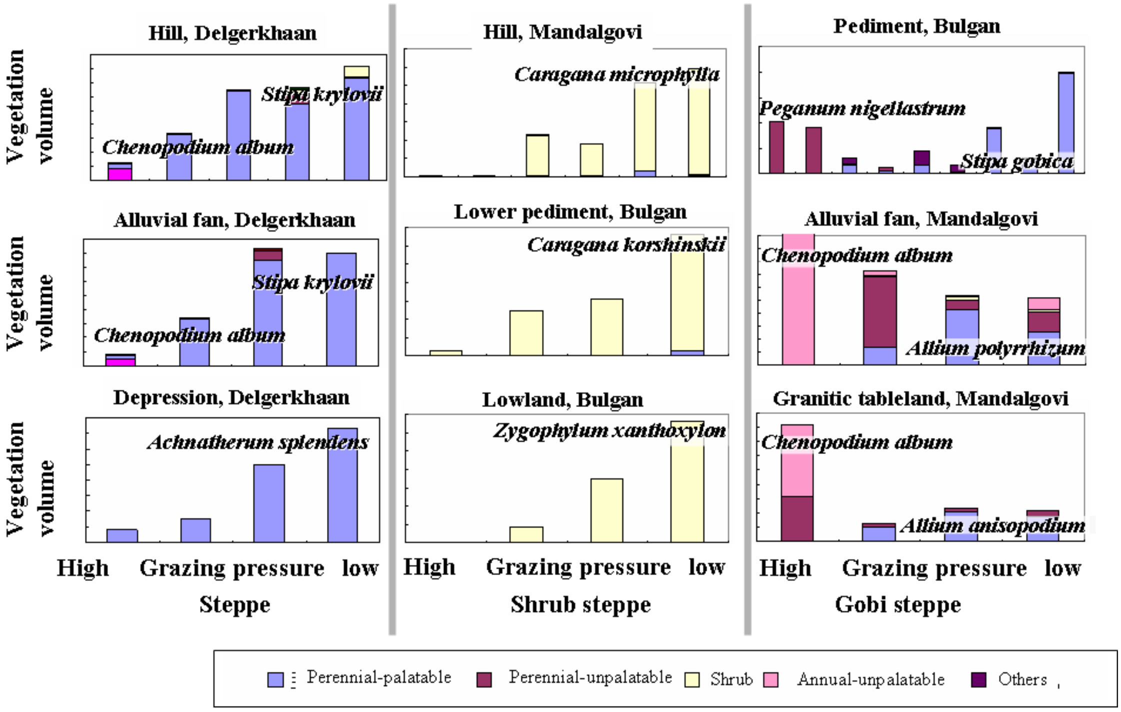

Figure 6 Vegetation responses to grazing pressure in various geographical conditions

regions, palatable grass is dominant in lightly grazed areas, and vegetation type changes but vegetation amount does not decrease as grazing pressure increases. The pellet-count method was used to estimate grazing pressure for the locations where vegetation survey was done, to reveal the relationship between grazing pressure and vegetation response.

The detailed wind and water erosion rate in relation to ground surface conditions was also observed. Two wind erosion censors was established inside and outside of a long-term fence in Dundgovi Province in Mongolia and friction velocity and the amount of eroded soil were measured. Water erosion observation sites were established in Northern Mongolia inside and outside of fences and eroded soil was trapped and the amount measured. These detailed soil erosion data were used to tune and validate the soil erosion models used in sub-themes 1 and 2.

Sub-sub-theme 2 Physiological and ecological assessment of soil degradation

In this sub-sub-theme, the physiological characteristics of the key species of desertification were experimentally investigated. First, key species were found from the results from sub-sub-theme 1 and various literatures. Then, in 2004 and 2005, the seeds of 7 species in Horqin sandy land in China and 2 species in Selenge Province in Mongolia were collected. Then, the germination and growth rate in relation to light, water and nutrient conditions were determined by experiments. These characteristics were used for the input parameters for the ecological model used in sub-theme 1.

C. Sub-theme 1 Constructing an Integrated Model for Desertification EWS

Sub-theme 1 is the core study group for the model integration, to carry out long-term trend assessment, and scenario assessment. For long-term trend assessment, the indicators derived from sub-theme 2 and benchmarks from

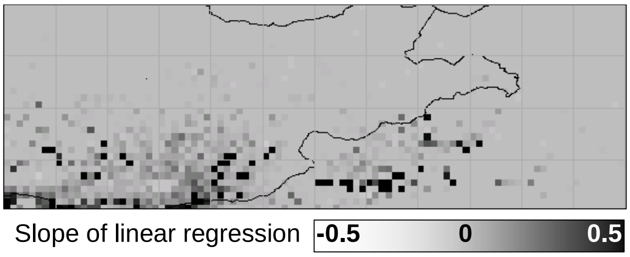

Figure 7 Trend of wind erosion (1988～2002)

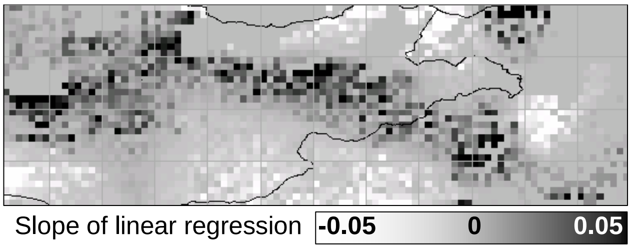

Figure 8 Trend of water erosion (1988～1999)

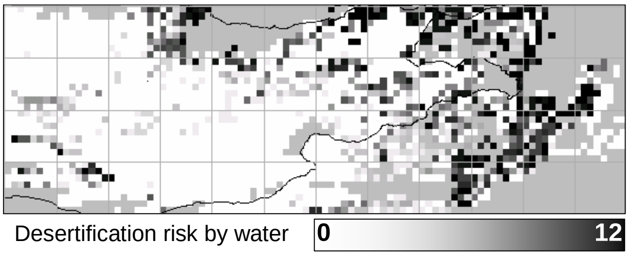

Figure 9 Desertification risk by water

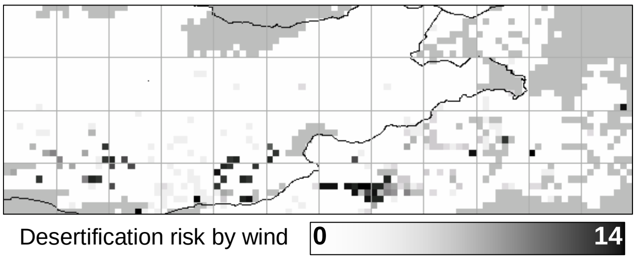

Figure 10 Desertification risk by wind

sub-theme 3 were combined to assess the desertification state at a large scale. First, the soil erosion rate derived from sub-theme 2 was used for trend analysis. It was found that wind erosion increased around the Gobi-steppe region in the Monglian Plateau (Figure 7), while water erosion increased around Khangai Mountains and a belt of steppe region in Mongolia (Figure 8). Then, from the benchmark grazing pressure from sub-theme 3, the corresponding benchmark soil erosion rate was calculated. Then, we counted how many years the erosion rate was greater than the benchmark, and the number of counts was mapped as desertification status (Figures 9 and 10). A small number of counts mean that the erosion rate is over the benchmark only in the humid years. A large number of counts mean that the erosion rate is always over the benchmark, which means more desertification risk.

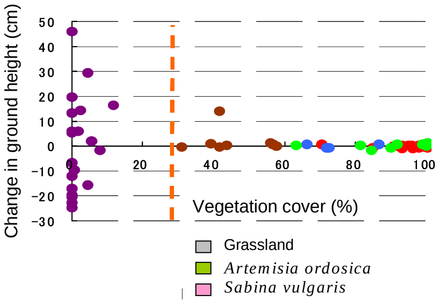

Figure 11 Vegetation cover effect on wind erosion

For scenario assessment, a model area was selected from 3 regions of steppe, Gobi-steppe and sandy land, namely Delgerkhaan (DK hereafter) in Mongolia, Mandalgovi (MG) in Mongolia and Naiman (NM) in China, respectively. Then, we (a) developed a process model that can simulate the effect of human impact on a rangeland ecosystem, and (b) quantified the cost and effect of desertification countermeasures, then (c) proposed optimized land-use plans combining grazing control and desertification measures, by mathematical programming.

a. Developing an ecological model. First, we developed a model which can simulate desertification processes in various geographical conditions found in sub-theme 3. Because there is no ecological model which can explicitly deal with soil erosion, we coupled Mosaic Arid Land Simulator (MALS) with WEAM and RUSLE. The physiological data was derived from sub-sub-theme 2 of sub-theme 3. Vertical root distributions and soil characteristics were derived from sub-sub-theme 1 of sub-theme 3. In cooperation with the local research institutions, weather and statistical data was collected. The simulation results were validated with the survey results in sub-theme 3.

b. Quantifying the cost and effect of desertification countermeasures. We considered 3 options. The first option is grazing control. The effect of this option was quantified as the modification of grazing parameter in MALS, and the cost was the loss of expected income due to the decrease in livestock number (or, gain of income due to the increase in livestock number). Because of the computation resource, the grazing pressure can be changed to 0, 0.5, 1.5, 2, and 3 times the current grazing pressure. The second option is a soil fixation method, straw checkerboard, which is the most common method in China. In this method the dead stems of crops are inserted into the soil manually, therefore this method was assumed to be applicable only in soft sandy soil. The effect of this option was quantified as the modification of surface roughness length, an atmospheric parameter, of WEAM. The cost of the materials and labor was taken into account. The third option is shrub planting. Because there is insufficient evidence on the relationship between shrub cover ratio and erosion rate, we carried out field experiments by using an erosion-pin, to observe the change of ground height in relation to shrub cover. We found that 30 % shrub cover was enough to suppress wind erosion (Figure 11). The erosion parameters were tuned to be made consistent with this result. The cost of the materials and labor was taken into account.

MG: Only grazing control

MG: Grazing control, destocking on drought and shrub planting when shrub degraded

Figure 12 Various management options and corresponding edible plant productivity in MG

c. Proposing the optimized land-use plans combining grazing control and desertification measures, by mathematical programming. We carried out scenario assessment, by combining the ecological model developed in a and b, as well as the geographical condition maps cooperatively developed with local research institutions. Here we assume 3 cases: In the first case, only grazing control is available. The second case is destocking during drought and shrub planting when shrubs decrease, in addition to grazing control. The third case is the same as the second, except that the straw checkerboard was used instead of shrub planting, only in NM.

Then, simulation was carried out for the periods where all input parameter were available (1997-2004 for DK, 1994-2004 for MG, 1990-2000 for NM), for all possible combinations of options. An example of the case in MG is shown in Figure 12. Then the relationship between income gain/loss and edible plant productivity was plotted (Figure 13). Finally, the spatial arrangement of maximum grazing pressure on the condition that no desertification occurred was found (Figure 14). For DK and MG, the case of only grazing control was

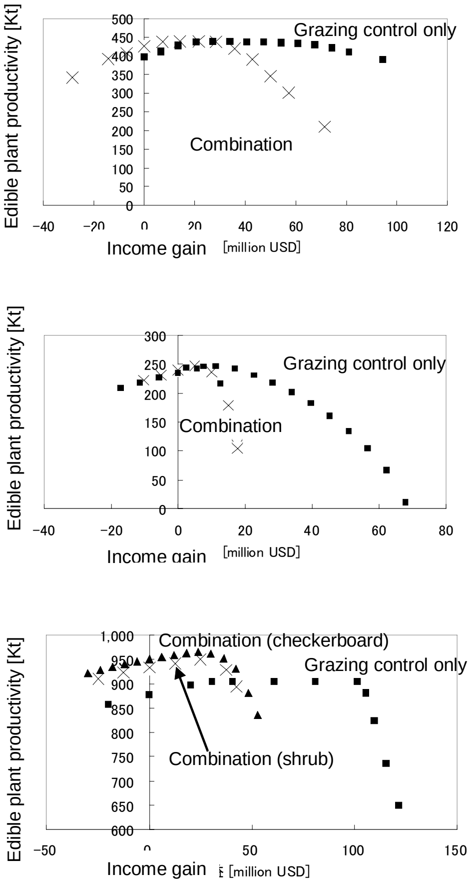

Figure 13 Relationship between income gain and edible plant productivity. From the top, DK, MG, NN

shown, because there was no clear benefit of shrub planting there, and for NM, the case of straw checkerboard was shown.

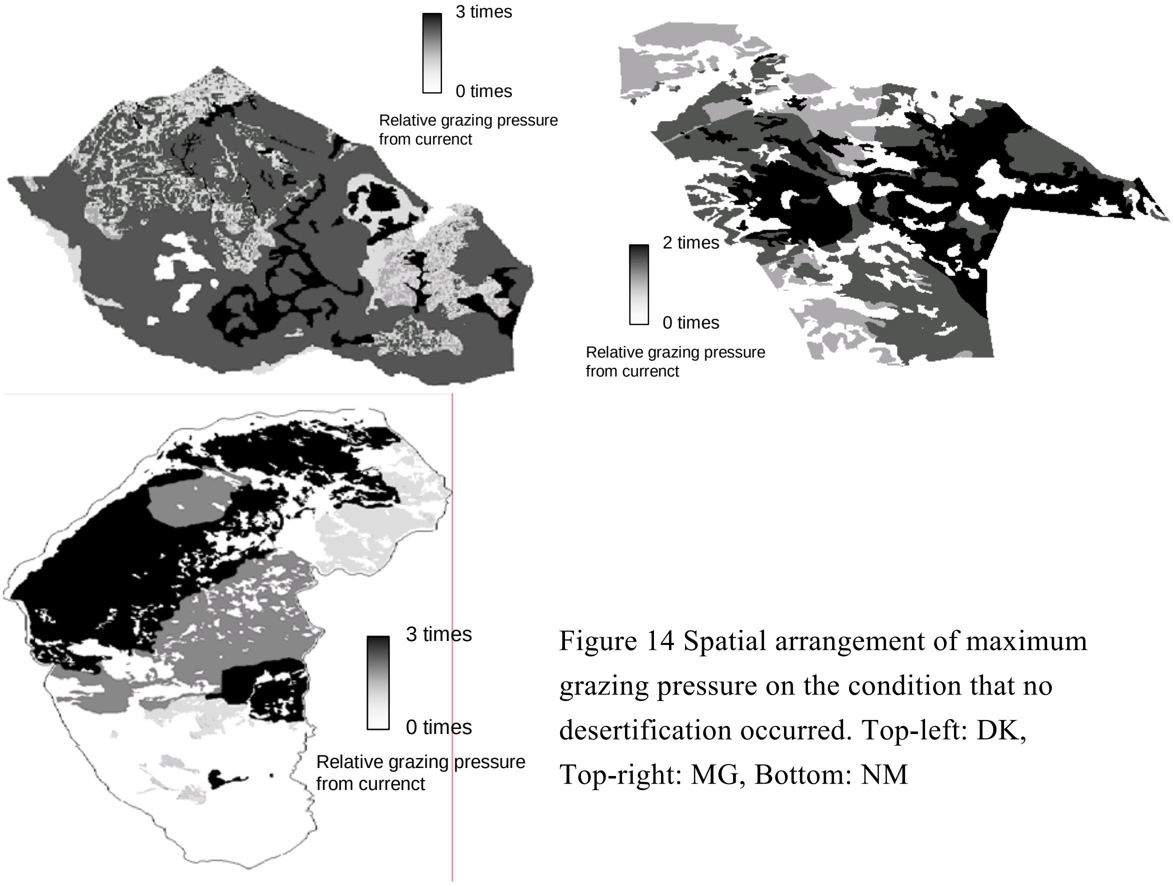

Figure 14 Spatial arrangement of maximum grazing pressure on the condition that no desertification occurred. Top-left: DK, Top-right: MG, Bottom: NM

5. Discussion

Although some areas were endangered by desertification, we found that desertification is relatively unserious in North-East Asia by large scale assessment. This result is consistent with a report of the Institute of Meteorology and Hydrology of Mongolia, which says that although in several areas the grazing pressure is over the carrying capacity, grazing pressure is generally under the optimum grazing pressure. In China also, in contrast to the period 1960 to 1980 when desertification was active, some reports claim that desertification has become suppressed due to intensive desertification counteractions.

However, economic reform in Mongolia caused a disordered increase in grazing pressure in its initial stage, resulting in the migration of pastoralists to the slums of the capital city Ulaanbaatar. In China, conversely, over-strict control such as overall prohibition of grazing caused drastic change and insecurity in the lives of pastoralists. Therefore, the current situation is far from an optimum balance of sustainable pasturage. From the results of this project we found that by controlling grazing pressure according to land vulnerability, pastoralists can pursue income gain and sustainable pasturage harmonically.

Therefore, we proved that our objective, which is the constructing of an Early Warning System integrating benchmarks and indicators whilst taking land vulnerability into account, can provide a concrete land-use policy, which can contribute to the sustainability of drylands in North-East Asia.

Major Publications

1) Asano M, K. Tamura, Y. Maejima, H. Matsuzaki, T. Higashi: Nuclear Instruments & Method in Physics Research, Section B (in press)
“The Δ 14C variations of pedogenic carbonate in steppe soils under vegetation sequence in Mongolia”
2) Okayasu T, M. Muto, Undarmaa J, K. Takeuchi: Land Degradation and Development (in press)
“Spatially heterogeneous impacts on rangeland after social system change in Mongolia.”
3) Sasaki T, T. Okayasu, Y. Shirato, Undarmaa J, S. Okubo, K. Takeuchi: Plant Ecology (in press)
“Can edaphic factors demonstrate landscape-scale differences in vegetation responses to grazing?”
4) Kotani, A. and M. Sugita: Journal of Hydrology, doi:10.1016/j.jhydrol.2006.07.029. (2007)
“Variance methods to estimate regional heat fluxes with aircraft measurements in the convective boundary layer.”
5) Li, S., Romero-Saltos, H. Tsujimura, M. Sugimoto, Sasaki, L., A., Davaa, G., and D. Oyunbaatar: Journal of Hydrology, 333, 109-117, doi:10.1016/j.jhydrol.2006.07.020. (2007)
“Plant water sources in the cold semiarid ecosystem of the upper Kherlen River catchment in Mongolia: A stable isotope approach.”
6) Iwao, K. and M. Takahashi: Geophysical Research Letters, 33, L16703, doi:10.1029/2006GL027119 (2006)
“Interannual change in summertime precipitation over northeast Asia”
7) Ishii, Y., K. Sakamoto, N. Yamanaka, L. H. Wang and K. Yoshikawa: Journal of Arid Environments 67, 403-415 (2006)
“Light acclimation of needle pigment composition in Sabina vulgaris seedlings under nurse plant canopy.”
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with sand-fixing measures in Horqin Sandy Land, Northern China”

10) Zheng Y.R., Xie Z.X., Gao Y., Yu Y.J., Shimizu H.: South African Journal of Botany 71(2), 167-172 (2005)
“Influence of light, temperature and water stress on germination of Hedysarum fruticosum.”

11) Zhang, T. H., H. L. Zhao, S. G. Li, F. R. Li, Y. Shirato, T. Ohkuro and I. Taniyama: Journal of Arid Environments, 58, 202-213 (2004)
“A comparison of different measures for stabilizing moving sand dunes in the Horqin Sandy Land of Inner Mongolia, China”