G-1.1 Land Evaluation of Prevention and Remedies for Desertification

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Abstract To evaluate the effects of measures to prevent and reverse desertification with respect to natural environmental and socioeconomic conditions, we conducted a field survey in Naiman, Inner Mongolian Autonomous Region, with the following results: 1) Three types of soil were broken down into 5 subtypes based on physicochemical properties. Naiman vegetation was also classified into main 3 types corresponding to these soil types. 2) The optimal stocking rate in the surveyed region is about 4 sheep per hectare. Because continuous grazing eventually adversely affects grassland vegetation, rotation is advisable in sustainable grazing management. 3) The high correlation between red-band reflectance of Landsat TM (TM3) and measured biomass enabled us to estimate grassland biomass and to determine most districts in northern to central Naiman were overgrazed. 4) Nitrogen fertilizer is improves biomass production in this grassland most effectively. 5) After investigating a local farming system to reduce grazing intensity and restore grassland productivity in two villages, we confirmed that overgrazing could be remedied without reducing the present number of livestock with bare feeding. 6) Desertification and its prevention and recovery depend on natural environmental and socioeconomic conditions.

Key Words China, Desertification, Preventive Technology, Grazing Intensity, Land Use

1. Introduction

Desertification and land degradation in China is estimated to affect 148,000,000 km^2 (15%), where they affect all areas not just the Taklimakan and Gobi Deserts. China's annual desertification rate over the last 2 decards alone estimated at 43,000 km^2. Reasonable land use planning for sustainable production and the evaluation of useful prevention technology could solve desertification issues based on understanding the local production activities.

2. Research Objective

Our objective was to guage grazing intensity and evaluate the effects of measures to prevent and reverse desertification with respect to natural environmental and socioeconomic conditions, based on field survey of vegetation, soil and agricultural products, grazing and recovery experiments, and remote sensing analysis. Based on these results, we studied how to set up appropriate land use and farming that prevented and remedied grassland deterioration without reducing the present number of livestock. Our field of study was Naiman, Inner Mongolian Autonomous Region, China.

3. Research Method

(1) Region

Naiman, about 400 km northeast of China's capital Beijing, covers about 8,000 km^2. This semiarid region has an annual average rainfall of 372 mm and an annual average temperature of 6.4℃. A little rain falls in autumn and winter and a strong 5 m/s of wind often blows in the spring, making the ground surface almost bare and easily subject to wind and water erosion from spring to early summer.

(2) Land Use and Desertification History

We studied Naiman land use changes and desertification history using old agricultural documents and geological surveys, and also followed the desertification process using maps and Landsat images.

(3) Land Conditions and Desertification

We set 163 quadrates differing in topography and land use, and surveyed vegetation, conducting TWINSPAN and DCA for all samples to classify and ordinate floral data.

We surveyed 14 soil profiles to gather general information on soil characteristics and distribution, collecting soil samples from each horizon after examining morphological features of soil profiles and analyzing their physical and chemical properties. We generated a soil productivity map via computer after inputting soil map parameters (1/100,000) and physicochemical soil properties.

(4) Estimation of Grazing Intensity

1) Field experiments

A grazing experiment was conducted in Naiman to clarify the pasture grazing capacity. Four plots with different grazing intensities --6, 4, 2, and 0 sheep/ha-- were fenced with barbed wire on a homogeneous grazing pasture and changes in vegetation, soil, and topography were monitored.

2) Remote sensing analysis

We studied the relationship between measured biomass and red-band reflectance from Landsat data. Based on this relationship, we estimated the entire Naiman grassland biomass and grazing intensity in 32 of its districts.

(5) Effect of preventive technology

1) Grassland

Fertilization and irrigation experiments were conducted to evaluate grassland restoration and improvement measures.

2) Soil

We surveyed soil profiles to determine the effect of measures such as terrace cropping against water erosion, and windbreak forest against wind erosion, comparing two adjacent sites -- terraced and unterraced -- in south Naiman, and studying two types of windbreak forest -- wide and narrow -- in north Naiman.

3) Agricultural Management

We analyzed current land use and farm management and studied desertified land recovery based on the relationship between development of the rural economy and desertification recovery measures, determining how to relieve grazing intensity without reducing the present number of livestock by bare feeding.

4. Results and Discussion

(1) Land Use and Desertification History

Grazing and cultivation have been continued alternately from 7,200 years ago in Naiman, with cultivation leading to desertification and grazing leading to recover of the grassland ecosystem. The rapid population increase and livestock expansion since 1947, however, have caused severe desertification. Desertified area was also expanded by the reclamation of fixed sand dunes in the 1960s --facts confirmed by our study of desertification maps and Landsat images. Desertified area has shown little change following the 1980s, however.

(2) Land Conditions and Desertification

Soil was classified into the following 5 types by morphology and physicochemical properties: Type A: soils derived from loess in southern Naiman; Type B: eolian sandy soils in the Horqin sandy land, divided into 2 subtypes of eolian sandy soil -- moving and fixed or semi-fixed; Type C: alluvial soils distributed along rivers and in interdune lowland, divided into 2 subtypes -- saline and nonsaline.

To make a soil productivity map, we divided soil productivity into five classes. Productivity is high in alluvial soil along rivers and in interdune lowland, and low in eolian sandy soils, especially moving dunes.

Naiman vegetation was classified into 3 main types corresponding to soil types. The TypeA area supported *Stipa bungeana* and *Thymus mongolicus*. TypeB area vegetation type was characterized by annual grasses such as *Setaria viridis* and *Chloris virgata*. The TypeC area was dominated by hygrophytes such as *Phragmites australis* and *Carex duriuscula*.

(3) Estimation of Grazing Intensity

1) Field experiments

In the grazing experiment, biomass production changes closely related to livestock production were measured by movable cage. Biomass production decreased with increased grazing intensity, but marked changes did not occur, even in heavily grazed plots (6 sheep/ha) (Fig. 1). The proportion of less palatabe, lower nutrient speicies such as *Aristida adscensionis* and *Artemisia scoparia* increased, however, indicating that forage quality deteriorated as grazing intensified (Fig. 2). Sheep weight decreased by 10% starting into the experiment's third year. These results suggest that a qualitative change in biomass production would greatly influence dietary consumption and productivity among sheep.

Changes in vegetation cover, soil, and topography relating to microlandform were also analyzed using a transect, which indicated that the vegetation degradation and grazing sustaine in surveyed regions varied with microtopography.

2) Remote sensing analysis

We divided the grassland from other land use and land cover by the supervised classification. Accuracy exceeded 90%.

Measured biomass correlated highest with red-band reflectance(TM3) (Fig. 3). We thus estimated the overall Naiman grassland biomass using the following equation:

$$\text{Biomass} = -3.99 \times \text{TM3} + 388.47$$

We then estimated grazing intensity versus grassland in 31 districts as follows:

Biomass for feed (g/m^2)=livestock density ($sheep/m^2$) $\times$1500 g$\times$grazing days

Biomass production (g/m^2)=biomass at end of grazing - biomass at beginning of grazing + biomass for feed

Load factor by grazing (%) (Fig. 4)=biomass for feed / biomass production × 100

North to central district had a load factor exceeding 35%, higher than southern districts. According to the grazing experiment, appropriate grazing intensity of the northern to central area is less than 4 sheep per hectare, for a load factor of 35%, indicating overgrazing.

(5) Effect of Preventive Technology

1) Grassland

Our results showed that fertilization had no effect on species composition, with *Gramineae* (annual) and *Chenopodiaceae* dominating all plots. Above-ground dry weight increased significantly with increasing applications of nitrogen and phosphorus (ANOVA, $p<0.05$) --particularly in nitrogen effects on the growth of annual grasses ($p<0.05$) and *Chenopodiaceae* ($p<0.02$). Nitrogen and phosphorus interaction was not significant. Irrigation had little effect on growth, perhaps due to inappropriate timing and rapid irrigation water due to the sandy soil's low water retention (Fig. 5).

2) Soil

The effect of a wide windbreak forest on surface soil properties showed soil organic carbon content and fine soil particle content of surface soil to be higher in forests and leeward than to windward (Fig. 6). Subsoil properties were almost the same at all sites, indicating surface soil property differences were due to afforestation. Windbreak forest thus effectively prevented the loss of fine particles to wind erosion and also caused fine particles to be deposited and organic matter to accumulate. Narrow windbreak forest also effectively prevented leeward soil from deteriorating by depositing coarse sand from windward.

The effect of terrace cropping on soil properties revealed organic matter and clay content of terraced fields to be almost the same as that of subsoil, but less in the surface than subsoil in nonterraced fields. Fine particles and organic matter were selectively lost at the surface by water erosion in nonterraced fields. Terrace cropping effectively prevented this selective water erosion in sloped fields.

3) Agricultural Management

Land use and farm management were diversified. In the Hans region of which Yaoledianzi village is representative farmers attach importance to the key sector of upland cultivation with subsidiary livestock grazing, and in the Mongolian region of which Sharitala village is representative, pasturage and upland cultivation polyculture is conducted emphasizing the key sector of livestock grazing.

In contrast to the grazing experiment results, current grazing intensity in both Yaoledianzi and Sharitala is 4 sheep per hectare, which will probably degrade grassland vegetation in undulating plots. In Yaoledianzi, feeding maize shoots to domestic livestock would decrease grazing intensity to 2.85 sheep/ha, enabling grassland vegetation to recover. If all parts of maize were used to feed domestic livestock, all current grazing animals could be raised on maize produced upland. In Sharitala, feeding all parts of maize to domestic livestock would make grazing intensity 2.25 sheep/ha, controlling grassland vegetation degradation (Fig. 7).

5. Conclusion

Based on the above results and discussion, we arrived at the following conclusions:

1. Three types of soil were broken down into 5 subtypes based on physicochemical properties.

2. The optimal stocking rate in the surveyed region is about 4 sheep per hectare. Because continuous grazing eventually adversely affects grassland vegetation, rotation is advisable in sustainable grazing management.

3. The high correlation between red-band reflectance of Landsat TM (TM3) and measured biomass enable us to estimate grassland biomass and to determine that most districts in northern to central Naiman were overgrazed.

4. Nitrogenous fertilizer improves biomass production in this grassland most effectively. We also confirmed the effectiveness of desertification remedies.

5. After investigating a local farming system to reduce grazing intensity and restore grassland productivity in two villages, we confirmed that overgrazing could be remedied without reducing the present number of livestock through barn feeding.

6. Desertification and its prevention and recovery depend on natural environmental and socioeconomic conditions (Fig. 8).

6. Reference

1) Zhu, Z., Wang, X., Wu, W., Kang, G., Zhu, C., Yao, F., & Wang, T.(1992):China: Desertification mapping and desert reclamation. In "World Altas of Desertification", UNEP: 46-49.

2)Shi, M., Tanaka, Y. & Zhao, H.（1998）：Land use and desertification in interlacing agropastral area of north China -A case study on Korqin Sandy Land. Men. Inst. Agr. & For. Univ. Tsukuba(Rural Econ. & Socio.), No.15, 1-26.

3)Liu, X., Zhao, H. & Xu, B.(1993):Mechanism of Destruction and Restoration of Korqin Steppe Ecosystem. Liu, X. & Zhao, H.(eds.)『Study on integrated rehabiritation of ecological environment in Korqin Sandy Land』, Gansu science & technology press, 12-26.

4) Hill, M.O.(1979a)：TWINSPAN －A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University Press, Ithaca, New York, 60pp.

5) Hill, M.O.(1979b)：DECORANA －A FORTRAN program for Detrend Correspondence Analysis and Reciproca l Averaging. Cornell University Press, Ithaca, New York, 36pp.

6) Agriculture Bureau of Naiman Qi(1984):The secondary soil survey report in Naiman Qi, Inner Mongolia, China. 125pp.

7) Zhu, Z., Zou, B., Di, X., Wang, K., Chen, G. & Zhang J.(1988):Desertification and Rehabilitation -Casse Study in Horqin Sundy Land: Institute of Desert Research Academia Sinica, Lanzhou, 113p.

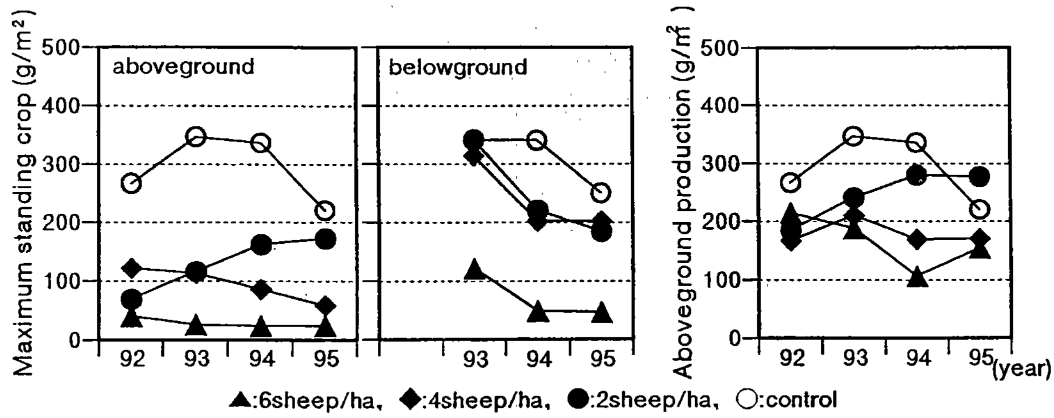

Fig.1 Changes in the maximum standing crop and abovegound production

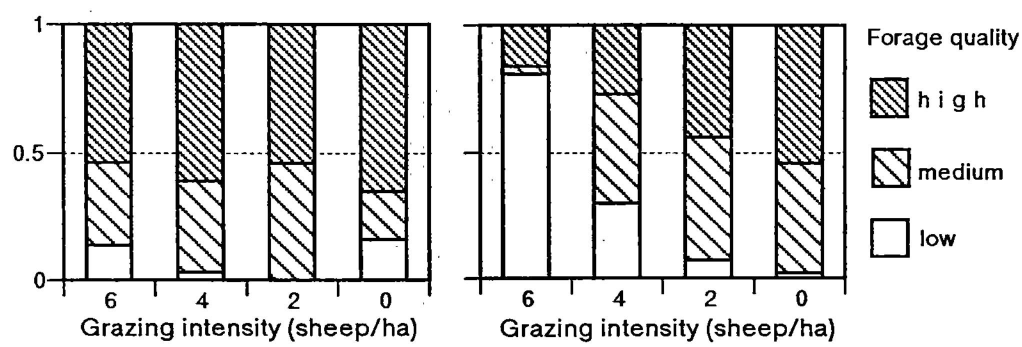

Fig. 2 Changes in the aboveground production by forage quality
(left; 1992, right; 1995)

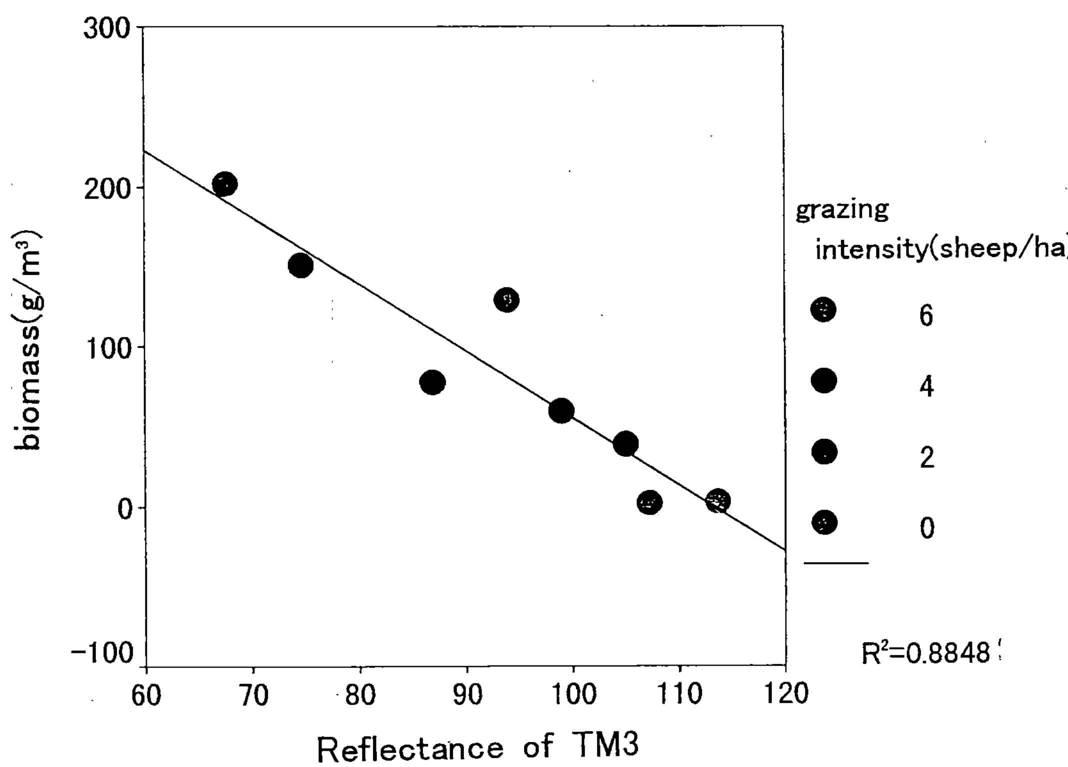

Fig. 3 Relationship between reflectance of TM3 and biomass

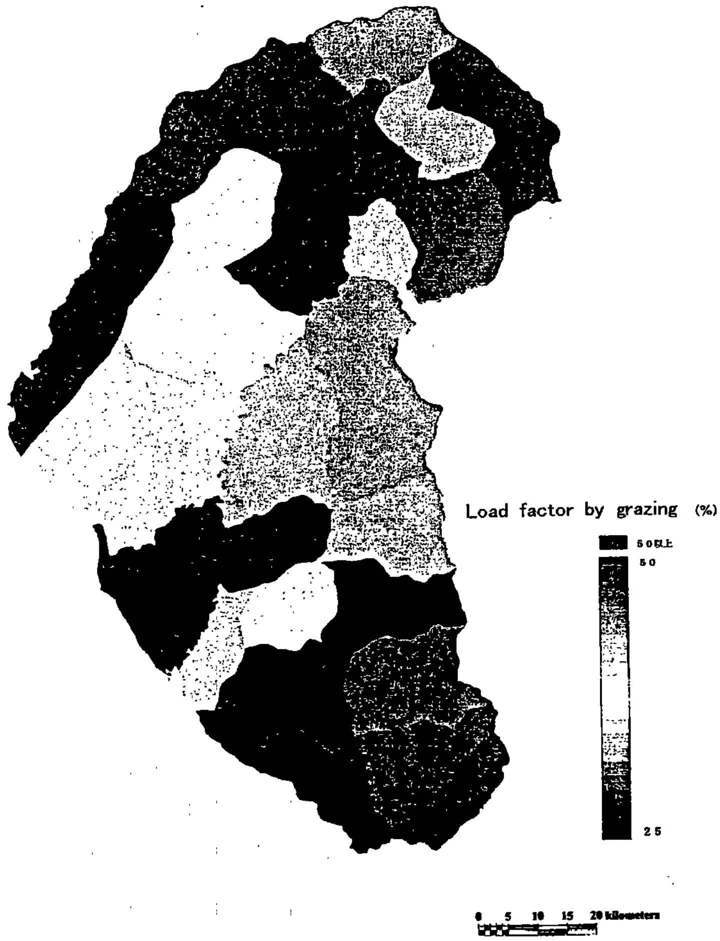

Fig. 4 Load factor by grazing (1996)

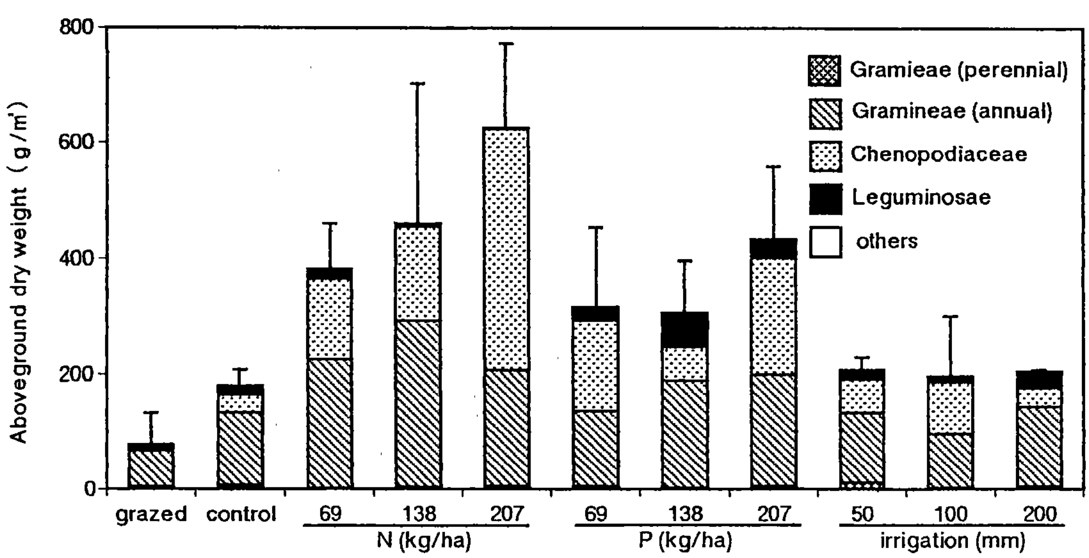

Fig. 5 Aboveground dry weight in each treatment of fertilization and irrigation

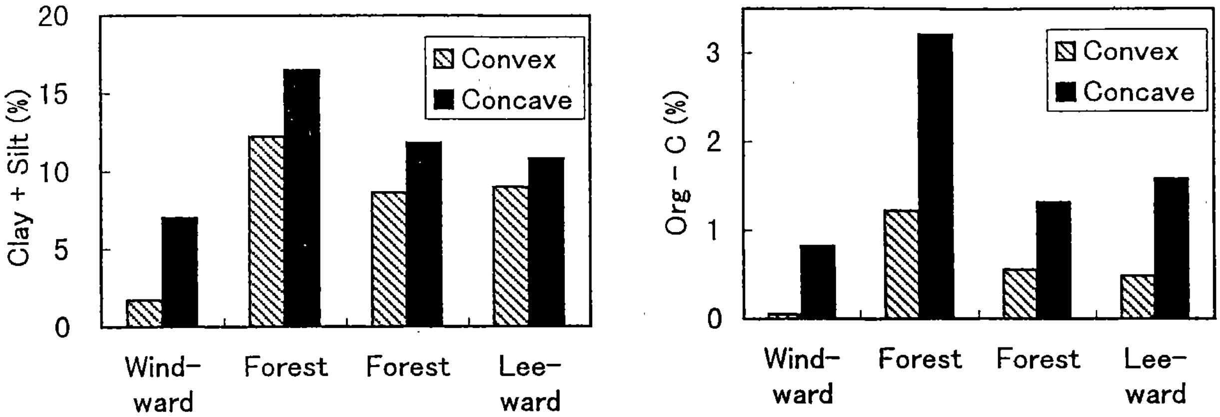

Fig. 6 Effect of windbreak forest on surface soil properties

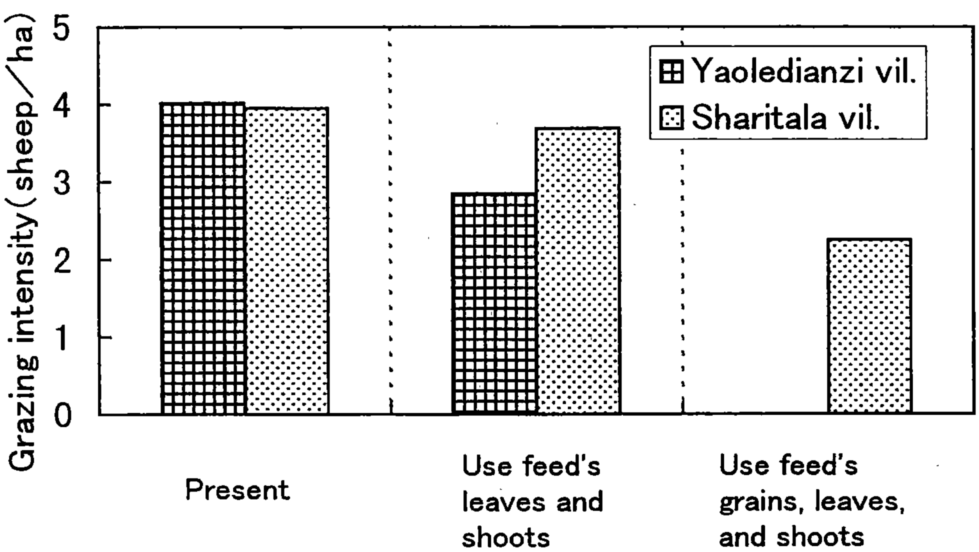

Fig. 7 Estimation of grazing intensity by breeding methods.

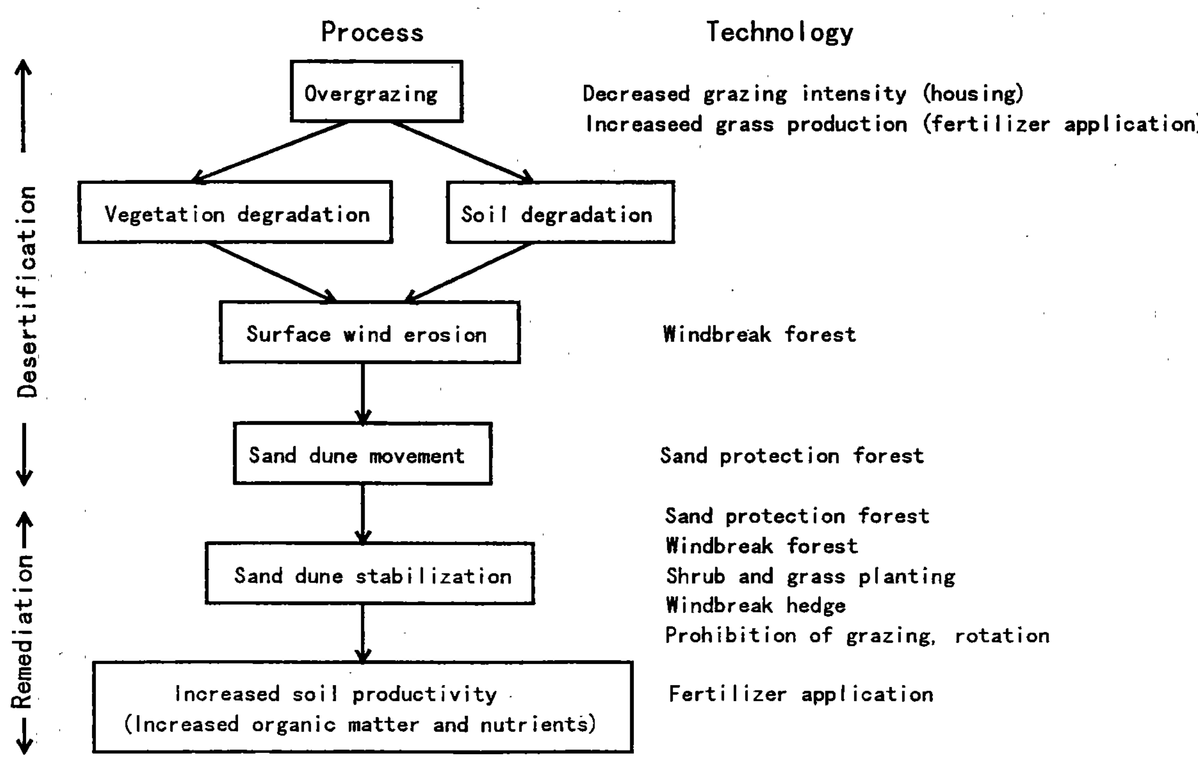

Fig. 8 Desertification process and prevention technology in Naiman.