The impact of land cover change on patterns of zoogeomorphological influence: Case study of zoogeomorphic activity of *Microtus brandti* and its role in degradation of Mongolian steppe

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Abstract—**Earth's surface building and changing by endogenetic and exogenetic processes. Endogenous processes are large-scale landform building and transforming processes. However, The exogenetic processes are the processes that shape the land by forces coming on or above the Earth's surface (exogenetic forces), such as zoogeomorphic activity. Ecosystems in the Central Asian Plateau, which includes the Mongolian Plateau, are becoming increasingly sensitive to human interventions, leading to deterioration of already fragile ecosystems. Grassland ecosystems supply almost all of the forage needed for livestock production in the Mongolian Plateau, and support the livelihood of the region's herders and their primarily nomadic way of life. However, the grassland ecosystems are distributed over a vast region that ranges between forest and desert ecosystems, and negligent human activities have caused serious environmental consequences for human society. The degraded grassland is habitat of Brandt's vole (*Microtus brandti*). Does Brandt's vole make damage to the environment or it provides management? Therefore we analysing NDVI, soil temperature and soil hardness measurements at the Brandt's vole colony, to examine changes of land surface characteristics by activity of Brandt's vole. As conclusion, we suppose that Brandt's vole is might indicate the degradation of pasture and play important role in ecosystem recovery.**

***Keywords*— Zoogeomorphic activity; Brandt's vole, land cover change detection, overgrazing, grassland, Mongolia**

I. INTRODUCTION

The endogenetic and exogenetic processes are driving forces of the building and changing the Earth's surface. Endogenous processes are large-scale landform building and transforming processes. However, The exogenetic processes are the processes that shape the land by forces coming on or above the Earth's surface (exogenetic forces), such as zoogeomorphic activity. Biogeomorphology and zoogeomorphology are subfields of the discipline of geomorphology, the study of landforms and land-forming processes. Biogeomorphology encompasses the study of the effects of plants and animals on the landscape, as well as how geomorphic processes affect the distribution of plants and animals. Zoogeomorphology is a subfield of biogeomorphology that specifically focuses on the study of the geomorphic effects of animals. "Phytogeomorphology" is a term sometimes used for the study of the interaction of geomorphic processes and plants [1]. The role of ecosystem engineering activity of the Brandt's vole has been evaluated in degraded pasture of Mongolia. In recent years, degradation and desertification of pasture land of Mongolia is in progress under the influence of climate change and overgrazing. The climate change has become a worldwide problem. This problem is severe in Mongolia; the changes of climate in this country are manifest significantly in winter season [2]. According to climate change studies conducted in Mongolia, during the period between 1940 and 2005, the annual average temperature has increased by about 1.9 ℃ and winter temperature changes were even greater in the mountainous areas (2.0 - 3.7 ℃) [3]. Another cause of pasture degradation is overgrazing in surrounding of major cities (market) and around the watering places by the human activity. The country's economy significantly depends on livestock breeding. The subsector of animal husbandry employs 47.9 per cent of the total population, produces 34.6 per cent of agricultural gross production, and accounts for 30 per cent of the country's export: clearly, animal husbandry plays a major role in the national economy [3]. However, the grassland ecosystem is distributed over a vast region that ranges between forest and desert ecosystems, and negligent human activities have caused serious environmental consequences for human society [4]. For instance, about 90% of Mongolian grassland is now subject to desertification as a result of increasing human impacts [5].

This is also the same in Inner Mongolia, where even a slight intensification of grazing can remarkably reduce the grassland quality and sometimes even lead to the loss of productive grasslands [6]. The degraded grassland is habitat of

Brandt's vole (*Microtus brandti*). Until recently, burrowing rodents had been considered to be pest damage to the pastureland and the cause of decline of grassland around the world [7]. The impact of rodents in ecosystem of Mongolia is heavy; herders are considering it as major cause of degradation of pastureland [8]. Brandt's vole has habitat to over a wide range in Mongolia, and its role in modifying soil's physical properties is high through such as increasing aboveground biomass, urinating and defecating. Their roles in ecosystem functioning are now reconsidered [9]. The Brandt's vole is said to be the "Keystone" species that acting as an ecosystem engineer. The Brandt's vole prefers grassland habitat with shorter plants, and easily expanding through pastures that have been heavily grazed by livestock [10]. According to several researches [11] the Brandt's vole dislikes tall grass steppes and its expansion occurs usually in degraded pastures. Colonies of Brandt's vole significantly changes vegetation, soil and landscape of steppe in Mongolia. However, to our knowledge, the influence of the Brandt's vole activity on land surface temperature (LST) and soil hardness at broad areas remained unclear. The goal of the present study is to clarify the effect of Brandt's vole on the grassland by studying the differences in surface characteristics, plant and soil of each landscape. On the basis of these evaluations, we hope to provide good approaches to the management of Brandt's vole in Mongolia.

II. MATERIALS AND METHODS

A. Study Sits

Five locations with different livestock grazing pressure in Mongolia were selected. Site 1 is characterized by low grazing pressure, site 2 and 3 are by medium, Site 4 and 5 are by high grazing pressure, respectively. To classify sites the distance from river and the number of yurt was also considered. Geographic locations of each site are as follow: Site 1; the latitude was 47°25'N and the longitude 106°38'E, at an elevation of 1620m; Site 2; the latitude was 47°38'N and the longitude 106°52'E, at an elevation of 1360 - 1530m; Site 3; the latitude was 47°37'N and the longitude 106°25'E, at an elevation of 1381m; Site 4; the latitude was 47°40'N and the longitude 106°40'E, at an elevation of 1290m; Site 5; the latitude was 47°35'N and the longitude 106°38'E, at an elevation of 1345m. In each site the plots were established on colony and no colony places (shows in Fig.1).

B. Field survey

At each site (1×1)-m quadrates were used for the vegetation survey. This survey included measurement of the plant height, cover, and richness for each species found in the quadrate (Plot number is 20 quadrates in site 1, 30 quadrates in site 2, 12 quadrates in site 3, 11 quadrates in site 4, 12 quadrates in site 5.). We measured soil hardness at 5 cm depth from surface soil and temperature inside colony hole at surface soil on colonies and no colonies.

C. Estimation of land surface temperature (LST)

LST was calculated using the satellite data from Landsat 5 Themaitic Mapper (TM) (2011/07/2, pixel size 30 m). LST is expressed as follows equation (1) and (2):

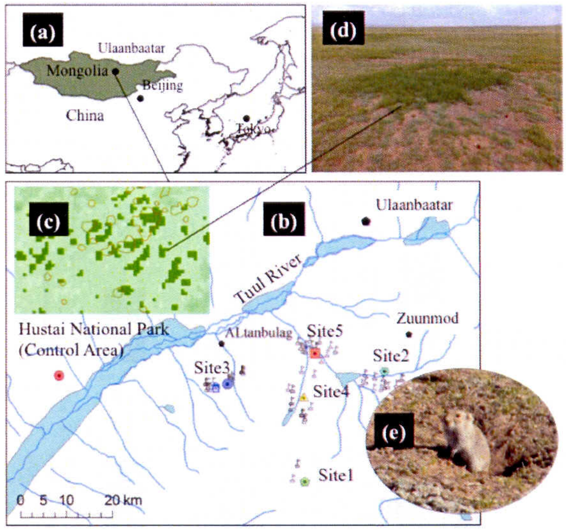

Fig. 1 Location map of the study sites (where, (a): Mongolia; (b): Study sites of Tuul River Basin. Site 1is located in low grazing pasture; Site 2 and 3 are located in medium grazing pasture; and Site 4, 5 are located in over-grazing pasture; (c): NDVI image of Quick Bird satellite; (d): picture shown colony of Brandt's vole; (e): Brandt's vole)

$$T = \frac{K_2}{\ln\left(\frac{K_1}{CV_{R2}} + 1\right)} \quad (1)$$

$$LST_{TM5} = [1260.56 / \text{alog}(607.76 / B1 + 1)] \quad (2)$$

Where, T is degrees Kelvin, CV_{R2} is the atmospherically corrected cell value as radiance, ε is emissivity (typically 0.95) and K_1 is 607.76 and K_2 is 1260.56 in TM5; B1 is value of with the atmospherically corrected radiance of thermal band.

D. Maximum Entropy (Maxent) Model

Maxent Model is based on a machine learning response that is designed to make predictions from incomplete data. This approach estimates the most uniform distribution (maximum entropy) of sampling points compared to background locations given the constraints derived from the data [12]. The approximation of an unknown probability distribution should satisfy any known constraints, and subject to those constraints should have maximum entropy [13]. The distribution and habitats of the Brandt vole were studied using satellite and fieldwork data, aimed to clarify the influence that the habitation of the Brandt's vole gives on the degenerated pastureland. During fieldwork the geo-botanical studies (such as plants coverage, species richness, plants height and dry matter productivity (DMP)), landscape and habitat observations (such as elevation, land cover, colony sizes, population density) were done. Maxent modeling has great potential for identifying distributions and habitat selection of wildlife given its reliance on only presence locations. Estimation of potential habitat selection of B Brandt's vole was analyzed using Maxent Modeling method.

III. RESULT AND DISCUSSION

A. Change of plants richness, soil hardness, biomass and vegetation cover by burrowing activity

Of the sites are investigated, measurements done on all site showed clear differences in plant coverage, dry biomass and bare area of coverage on colony and outside areas (Fig.2 A). Plant coverage on colony ground was higher than that in outside areas, except site 5. Dry biomass on colony ground was less than in outside area. Bare area on colony ground also has increased, showing response of vegetation to soil disturbance by borrowing activity of Brandt's vole. Because, site 5 is a new habitat area of Brandt's vole, such changes are thought to be primarily a consequence of borrowing activity of Brandt's vole. Measurements done on site 3 and 4 are showed clear differences in soil hardness on colony and outside areas (Fig.2 B). Soil hardness on colony ground was softer than that in outside area. The differences in soil hardness were not significant in other sites. The difference of soil hardness was highest in Site 4 (about 6.7 mm). This site has a highest burrowing activity by Brandt's vole. The difference of soil hardness was lowest at site 2. However, the soil character in that site was entirely stony. Also, differences in soil hardness were high at the sites with higher grazing pressure. Thus, we can suggest that Brandt vole digging activity softening the soil on its colony ground and that is providing good condition for the plant growth, especially those species that prefer soft soil.

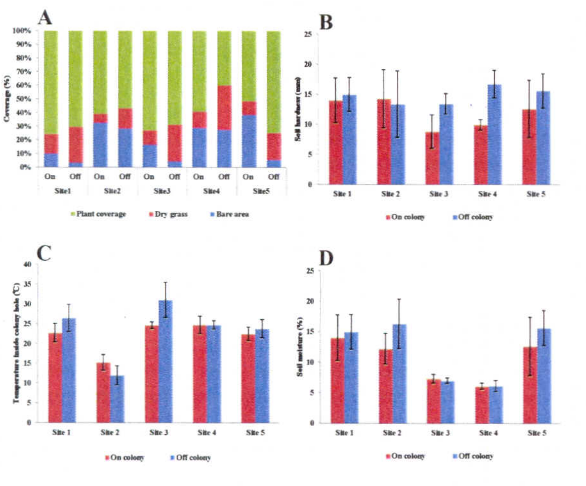

Fig. 2 (A, B, C, D). The **A**: Rate of **plant coverage**, dried grass and bare area compared at the on colony and outside area in site 1, site 2, site 3, site 4 and site 5; the **B**: **soil hardness**; the **C**: **LST** inside colony hole; the **D**: **soil moisture**.

The LST inside colony hole in general has no differences between outside area and colony territory. However, at site 3, the LST was lower at colony ground than that on outside area (Fig.2 C). Difference of LST inside colony hole was 6.4℃ in Site 3. Site 3 has also high burrowing activity of Brandt's vole. The soil moisture showed no clear differences in on colony and outside area. However, soil moisture inside colony hole well high than outside area (Fig. 2 D).

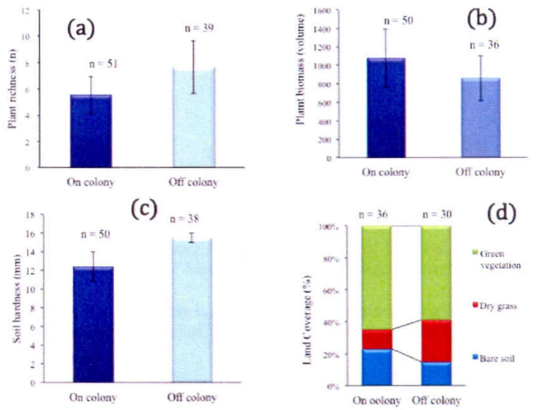

Fig. 3 The richness, biomass, soil hardness and grass cover different for on colony and off colony area (where, (a): plants richness; (b): biomass; (c): soil hardness; (d) land cover (grass cover)).

The average value of plant richness, biomass, soil hardness and grass coverage on the colony inside and outside of each sites shown in Fig. 3. The figure shows that the Brandt's vole activity softens soil at colony places; increases the green grass cover and increased the aboveground biomass amount in degraded pastureland.

B. Result of estimated habitat selection of Brandt's vole

Heavily overgrazed pastures are became suitable habitat for the colonies of the Brandt's vole [14]. The rodent pest is prefer short grass steppe habitat with sparse vegetation and readily colonizes degenerated pastureland. Analysis of the habitat selection by this rodent on Maxent Model showed that habitat most preferred by voles are degraded grassland along roads, "ger" (yurt) and watering sites with percent contribution varying from 5.5 to 47.9, and permutation importance of 25.1; 48.7 and 20.9, respectively (Table 1). So far, the more denser distribution of voles around water sources is not related with the need of water. The livestock watering sites are tramped and overgrazed at most and became suitable habitat for the voles. Voles are abundant in degraded grassland along rivers, around wells and springs.

Table 1 Analysis of the variable contribution for the habitat selection by *Microtus brandti*.

Variable	Percent contribution	Permutation importance
Distance from the roads	**47.9**	**25.1**
Distance from the Yurt (home)	**35.4**	**48.7**
Digital elevation	7.3	2.8
Distance from the river (watering places)	**5.5**	**20.9**
Effective brightness temperate	2.8	1.2
Heat Load Index	0.7	0.6
Hill shade	0.3	0
Slope	0.2	0.5
NDVI	0	0.2

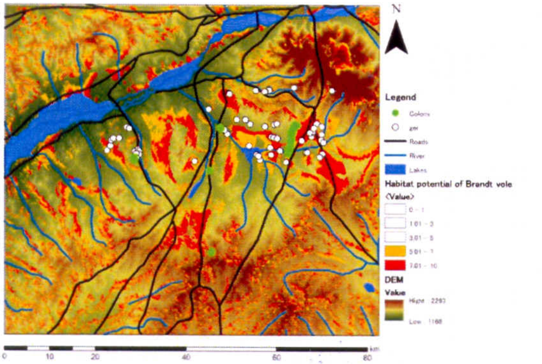

Fig. 4 Estimated colonies area of Brandt vole using Maxent Model (white, the O is ger (yurt); and green● is Brandt's vole colony; the vole colonies are concentrated in places with degraded vegetation close to ger, wells, and along the roads).

IV. Conclusions

Our result shows that these Brandt's vole invasion to degraded pastureland and this ecosystem engineering activity softens soil at colony places; increases the soil moisture; and increased the aboveground biomass amount in degraded pastureland. We suggest that increase of bare area by borrowing activity of Brandt's vole coincides with higher values of LST. The heat is absorbed by barren surface area on colony grounds, and LST has increased. As of consequences, these will help early melting of snow, and also early grow of plants. In this way, borrowing activity of Brandt's vole might increase the plant coverage and decrease of dry mass. The disturbances of the soil moisture, temperature and soil hardness, as well as soil mixing made by burrowing activity of Brandt's voles are have a great impact on Mongolian steppe ecosystems.

So far, this rodent species is not only consuming the plants in large volumes and harms pastures, but also its activity makes environment more better for various plant species. The Brandt's vole rightly can be called grassland ecosystem manager. To understand the mechanism, further detailed studies needed to be done.

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