論文の内容の要旨

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論 文 題 目　Effects of crop abandonment on vegetation and soil properties in Mongolian rangelands
（モンゴルの放牧草原における耕作放棄が植生および土壌に与える影響）

1. Introduction

Land transformation of rangelands to croplands and their subsequent abandonment is a significant ecosystem change that causes land degradation in dryland. In Mongolia, cropping was initiated in the 1950s under the Soviet regime; however, crop abandonment has increased since 1990 because of the shift from socialism to a market economy caused by dissolution of the Soviet Union.

Dominant species, such as *Stipa krylovii*, of a typical perennial grass are not found in abandoned croplands even decades after abandonment. In addition, changes are observed in soil physicochemical properties, decreasing organic nutrients, particle size distribution, and hydraulic properties. The biotic and abiotic legacy of crop abandonment results in poor adaptation of the regional species pool and lead to areas remaining in a degraded state for decades. Since grazing has been practiced for many years in Mongolia, the regional species pool is completely adapted to grazing disturbance. Therefore, it is important to clarify the altered physicochemical properties that are acceptable and not acceptable for plant species in Mongolian rangelands.

Many studies have reported that plant growth is highly associated with precipitation and soil water stress; however, studies on unsaturated hydraulic properties in semi-arid regions are few. In particular, the hydraulic properties of the soil profile under different climatic conditions are required to clarify how degraded the conditions are in abandoned croplands.

In addition, drought, due to sparse rainfall, and salinity (nutrient), due to excess fertilizer use,

are two serious plant stressors in the semi-arid ecosystems of abandoned croplands in Mongolia. However, previous evaluations of drought and salinity stresses for plants have been based on individual static treatments, such as continuous wet or dry conditions, even though drought and salinity stresses vary continuously *in situ*. Hence, information on stress tolerance under various drought and salinity stresses is required for typical species in the Mongolian rangelands. An understanding of how these drought and salinity stresses affect altered soil hydraulic properties under different climatic conditions is also required.

Therefore, the objective of this study was to evaluate the effects of crop abandonment on vegetation and soil properties, and to provide vital knowledge on species adaptation for soil properties (Chapter 2), in particular soil hydraulic properties (Chapter 3), with stress tolerance (Chapter 4) under altered soil hydrological processes following crop abandonment (Chapter 5) in semi-arid Mongolian rangelands.

Study sites were croplands that had been abandoned for 18 years (CA18), 9 years (CA9), and 2 years (CA2), and a grazed semi-natural grassland (SNG) with a grazing gradient (10, 50, 100, 200, and 500 m from the center of a livestock holding) provided representative sites of a grazing-disturbance regime of semi-arid grasslands in Mongolia. Each study site was a moderately grazed grassland situated in the buffer zone of Hustai National Park, where the livestock number is strictly controlled.

2. Response of plant functional traits to crop abandonment in rangelands

Functional traits are a consequence of historical selective pressures. I therefore used the change in composition of functional traits along a grazing gradient as representation of vegetation and soil variation due to adaptation to livestock grazing. I then examined croplands abandoned at different times to investigate the differences in the composition of functional traits and soil properties from those of rangelands.

Moderate grazing (100, 200, and 500 m, and SNG) and the late successional trajectory of abandoned croplands were represented by an increase in zoochorous species and fine sand content. *S. krylovii* was the most frequently found zoochorous species. Rhizome-forming species were common on intensively grazed rangeland (10 and 50 m) and during the early successional trajectory of abandoned croplands (CA9). The main rhizomatous species was *Leymus chinensis*. *S. krylovii* and *L. chinensis* were considered important species during the late and early successional trajectories of abandoned croplands, respectively. The CA2 site, where there was a higher content of coarse sand, was characterized by an absence of zoochorous and rhizomatous

perennial species. The plant functional traits, which differed from those of the rangelands, were apparent in the abandoned croplands, where a difference in particle size distribution influences soil hydraulic properties.

3. Effects of changes of soil hydraulic properties on plant transpiration following crop abandonment in semi-arid Mongolian grasslands

To investigate changes in the hydraulic properties of a soil profile under different climatic conditions following crop abandonment, I measured the unsaturated hydraulic properties of undisturbed core soil samples from different depths (i.e., 0–5, 10–15, and 30–35 cm) at abandoned croplands (CA2, CA9, and CA18) and the SNG site. The hydrological properties of soil profiles were simulated with soil hydraulic properties at the study site under drought and non-drought conditions. I selected data from non-drought (1999) and drought (2004) summers as a typical climate range. The amounts of precipitation during the period considered were 158 and 81 mm, respectively.

Although the difference in volumetric water content was not large, there were differences in the pressure head at the soil surface among sites in drought and non-drought years. The present study suggests that the pressure head at the soil surface indicated the soil hydraulic condition more clearly than volumetric water content. The pressure heads at the soil surface at the CA9 and CA18 sites were lower than those of the CA2 site because of the high fine sand content. In drought conditions, the soil pressure head at CA18 was lower than that at CA9 for subsurface soil. This suggests that a change in soil hydraulic properties under a successional trajectory of abandoned croplands readily occurs in drought years. In addition, this change may contribute to preventing the growth of plants such as annual species, which rely on soil water in the surface soil for growth.

4. Comparing the drought and salinity tolerances of two dominant perennial grasses in Mongolia

Pot experiments were conducted in a greenhouse to compare the tolerance of two dominant perennial grasses to drought and salinity stresses in continuously changing drought and salinity conditions. The tolerances are evaluated in terms of parameter values of a root water uptake model.

The drought and salinity tolerances of these species appeared to depend on the degree of matric and osmotic head. *L. chinensis* had a higher tolerance to relatively low drought and salinity stresses than *S. krylovii*. On the other hand, *S. krylovii* had a higher tolerance to relatively high drought stress than *L. chinensis*. For high salinity stress, the measured osmotic head in the pot

experiment was extremely extended, so the osmotic head was estimated from the electrical conductivity of field data. I therefore simulated only the effect of drought stress tolerance with soil hydraulic properties on cumulative transpiration in Chapter 5.

5. Effects of invasion of perennial grasses on soil hydraulic properties in abandoned croplands

A numerical simulation was developed to clarify the effects of drought tolerances of *L. chinensis* and *S. krylovii* on transpiration and soil hydraulic properties at different times after fields had been abandoned under drought and non-drought climatic conditions. The effect of drought tolerance of each species was evaluated by cumulative transpiration.

The cumulative transpiration of *L. chinensis* was higher than that of *S. krylovii* at each site in non-drought years with a relatively high pressure head. On the other hand, the cumulative transpiration of *S. krylovii* was higher than that of *L. chinensis* at each site in drought years with a relatively low pressure head. In addition, *S. krylovii* seemed to make conditions less favorable for other plants in terms of the pressure head; that is, a low pressure head was created as *S. krylovii* grew. This may indicate the competitive superiority of *S. krylovii* in dry Mongolian rangelands. In addition, drought would create an opportunity for the replacement of *L chinensis* by *S. krylovii* in abandoned croplands. This implies that substantial annual variability in climatic conditions may contribute to plant species replacement in Mongolian rangelands.

6. Conclusion

The present study finding that the typical dry conditions of the soil surface and climate can play an important role in the successional trajectory of abandoned croplands. Crop abandonment seemed to lead to a high-pressure head condition at the surface of the soil, particularly immediately after crop abandonment, which decreases the advantage of drought tolerance of typical perennial grass species. The results of the present study imply that hydraulic conditions, which promote infiltration to the subsurface soil where typical perennial grass species may have an advantage of root water uptake, are a cause for the successional trajectory in rangelands.