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# Effects of grassland degradation on air and soil temperature in Songnen plain of northeast China

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**Grassland degradation due to human activities is a critical problem in Songnen plain of northeast China, but the possible regional climate changes, especially air and soil temperature changes because of grassland degradation, are still not clearly known. From May to September of 2014, we simulated a *Leymus chinensis* degradation experiment in Songnen plain to study the effects of grassland degradation on air temperature, soil temperature and the difference between soil and air temperatures. The results demonstrated that grassland degradation will increase both the growing season surface air and soil temperature by 0.49–1.49°C and 0.6–2.27°C respectively. The difference between soil and air temperatures also increases with the reduction of *L. chinensis* vegetation cover, implying that the increase in soil temperature will be much faster than air temperature with the degradation of the grassland in Songnen plain.**

**Keywords:** Climate change, grassland degradation, *Leymus chinensis*, surface air temperature, soil temperature.

IN the background of global warming, both surface air and soil temperatures have increased rapidly in the last few decades[1,2]. The increase in air and soil temperatures will have a significant effect on plant growth by influencing the growth of overground and underground parts. Vegetation changes, in turn, could also change surface air and soil temperatures by affecting the land surface water and energy balance[3]. Studying the effects of vegetation change on air or soil temperature is critical for understanding the interactions between vegetation and climate[4,5], and becomes an interdisciplinary research effort[6].

Due to human disturbances, grasslands in arid and semi-arid regions of North China are facing degradation[7]. Grassland degradation not only affects the carbon cycle and regional economy, but also has a significant impact on climate[8]. Many researchers have studied the effect of grassland degradation on evapotranspiration[9–11] and surface water balance[12] in these regions of North China. However, the effects of grassland degradation on surface temperature, especially soil temperature, have received little attention.

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In the present study, by simulating a degradation experiment, we study the effects of *Leymus chinensis* degradation in Songnen plain (where the grassland is one of the primary grasslands in North China) on soil temperature, air temperature and the difference between soil and air temperatures. We also study the influence mechanism by evaluating the energy balance and partitioning for *L. chinensis* ecosystems.

The study was conducted at the Changling Station of Grassland and Agroecology, Chinese Academy of Sciences, Songnen plain, northeast China (44°33′N, 123°31′E). The mean annual temperature and annual total precipitation in this region have been 5.6°C and 428 mm in the past 50 years.

The controlled experiment was conducted to simulate different degradation intensities in an artificial *L. chinensis* grassland (200 m × 200 m, all the existing vegetation was mowed before planting *L. chinensis*). There were four treatment combinations, i.e. undegraded (UD, *L. chinensis* grow naturally), slightly degraded treatment (SD, reduce about 30% of the biomass production of *L. chinensis* compared with UD), heavily degraded (HD, reduce about 70% of the biomass production of *L. chinensis* compared with UD), and a bare plot used as control (CK, remove all the grasses). There were seven replicates for each treatment, with six groups of small plots (10 m × 10 m, 1 m buffer between two sites), and a group of large plots (20 m × 20 m, 1 m buffer between two sites). Except for the UD treatment, all the other treatments were maintained (reduce vegetation height and density, and remove weeds) semimonthly.

In each small plot, soil temperature, water content and heat flux were measured at a depth of 5 cm, and surface air temperature was measured at the height of 150 cm. In four large plots, we also measured air temperature and humidity (at two heights of 50 and 150 cm) and solar radiation (at a height of 2 m), including the incoming and reflected short-wave radiation, and incoming and outgoing long-wave radiation. All the data were sampled every 60 min and recorded by separate data-logger. In addition, we measured the leaf area index ($A_L$) using a Plant Canopy Analyzer (LAI-2200) once a week in each plot. Precipitation in the station was measured with a tipping bucket rain gauge 4 m above the ground.

We used the Bowen ratio-energy balance (BREB) method to calculate the energy partition for *L. chinensis* ecosystems[13]. This method is based on the energy balance at the surface

$$R_n = H + LE + G, \tag{1}$$

where $R_n$, $H$, $LE$, $G$ are net radiation, sensible heat, latent heat and soil heat flux respectively. The net radiation was calculated from the measured downward and upward, long- and short-wave radiations[14]. $G$ was directly measured by a soil heat plate at 5 cm depth without accounting for the heat storage in the thin layer above[15]. The storage of heat in the canopy was not included in the study as it is expected to be negligible in short canopies with minimal biomass[7]. Therefore, $H$ and $LE$ can be calculated based on the available energy (the difference between $R_n$ and $G$) and the Bowen ratio (the ratio of $H$ and $LE$).

The Bowen ratio $\beta$, is

$$\beta = \frac{H}{LE} = \frac{C_P \mathrm{d}\theta}{L \mathrm{d}q}, \tag{2}$$

where $C_P$ is the specific heat of air at constant pressure and $\mathrm{d}\theta$ and $\mathrm{d}q$ are the vertical gradients of potential temperature and specific humidity respectively. In our experiment, the vertical gradients of potential temperature and specific humidity were calculated from air temperature and humidity at two heights of 50 and 150 cm.

Figure 1 shows the variations in mean daily air temperature ($T_a$) and soil temperature ($T_s$). It can be seen that $T_a$ increases gradually at the beginning in May, fluctuates from June to August and then gradually decreases (Figure 1). The daily variation of $T_a$ in four different treatments shows similar pattern, but $T_a$ increases with degradation of *L. chinensis*. The large differences in $T_a$ between the four treatments mainly occur from late July to late August. For the whole growing season, the mean $T_a$ of four different treatments is about 20.33°C (UD), 20.82°C (SD), 21.33°C (HD) and 21.75°C (CK) respectively.

Similar to the temporal variation in $T_a$, $T_s$ continues to increase at the beginning of the growing season, fluctuates slightly from late June to late August, and declines in

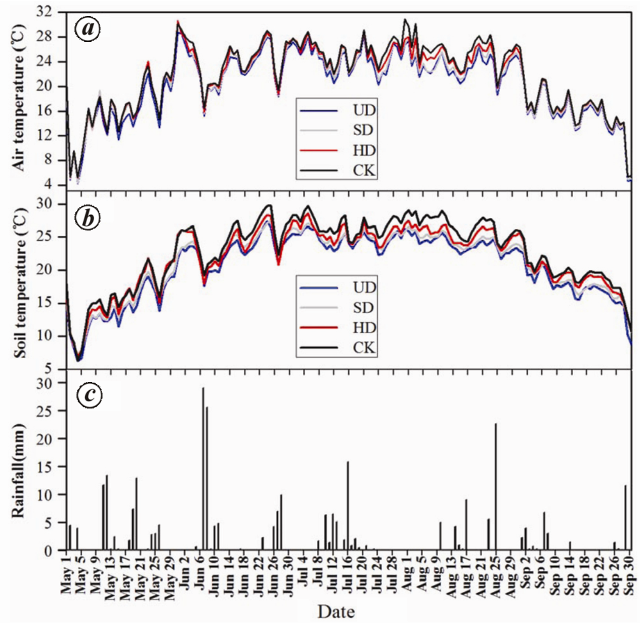


**Figure 1.** Temporal variation in daily air temperature, soil temperature and rainfall from 1 May to 30 September 2014 (undegraded (UD), slightly degraded (SD), heavily degraded (HD) and bare land (CK)): ***a***, Daily mean air temperature; ***b***, Daily mean soil temperature; ***c***, Daily sum of rainfall at the Changling Station of Grassland and Agroecology.

**Table 1.** The growing season (May–September) average of net all-wave radiation ($R_n$), soil heat flux at the depth of 5 cm ($G$), Bowen ratio ($\beta$), sensible heat flux ($H$), latent heat flux ($LE$) and volumetric soil water content at 5 cm depth (SWC) for different treatments

| Treatment | $R_n$ (MJ $m^{-2}$) | $G$ (MJ $m^{-2}$) | $H$ (MJ $m^{-2}$) | $LE$ (MJ $m^{-2}$) | $\beta$ (dimensionless) | SWC (%) |
|---|---|---|---|---|---|---|
| UD | 1554.28 | 120.92 | 556.22 | 877.14 | 0.63 | 50 |
| SD | 1508.44 | 124.35 | 582.63 | 801.46 | 0.73 | 42 |
| HD | 1460.40 | 126.74 | 607.14 | 726.52 | 0.84 | 34 |
| CK | 1417.81 | 131.96 | 630.43 | 655.42 | 0.96 | 30 |

UD, Undegraded; SD, Slightly degraded; HD, Heavily degraded; CK, Bare land.

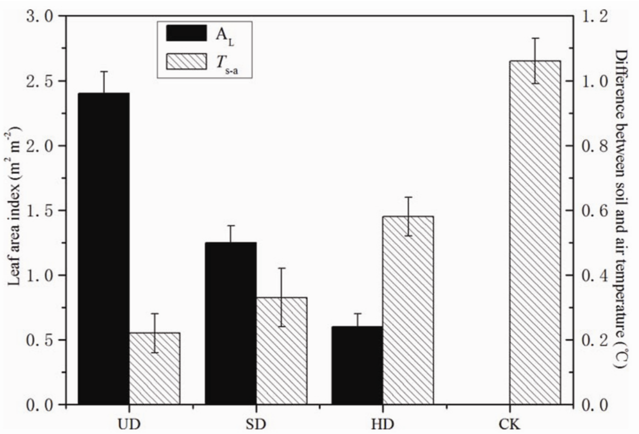


**Figure 2.** The mean growing season leaf area index ($m^2$ $m^{-2}$) and difference between soil and air temperature (°C) for different sites.

September (Figure 1). Compared with $T_a$, mean daily $T_s$ of the four treatments also shows a similar pattern, but the difference in $T_s$ between four treatments is more obvious than $T_a$ (Figure 1). The mean growing season $T_s$ of the different treatments is about 20.55°C (UD), 21.15°C (SD), 21.91°C (HD) and 22.82°C (CK) respectively.

In this study, we also compared the temperatures between the rainy and rain-free periods. It is obvious that both $T_a$ and $T_s$ decrease abruptly during the rainy periods, and the differences of air or soil temperatures between four treatments became smaller during or immediately after the rain events (Figure 1).

During the growing season, *L. chinensis* degradation will increase both the surface air and soil temperatures. It is interesting that the difference between soil and air temperatures ($T_{s\text{–}a}$) also increases with the reduction of *L. chinensis* vegetation cover, with the mean growing season $T_{s\text{–}a}$ ranging from 0.22°C (UD) to 1.06°C (CK) (Figure 2). In addition, $T_{s\text{–}a}$ also decreases in all the four treatments after the rain events (data not shown).

In recent decades, intense human activities such as over-grazing, mowing and crop cultivation have led to severe degradation in Songnen grassland of China[16]. By simulating a degradation experiment, we studied the effects of *L. chinensis* degradation in Songnen plain on soil temperature, air temperature and the difference between soil and air temperatures.

In the case of $T_a$, *L. chinensis* degradation results in changing the land surface albedo and soil water content (SWC). First, degradation exposes more soil surface and increases the land surface albedo, which reduces net radiation by reflecting more short-wave radiation (Table 1). Secondly, degradation reduces SWC, and SWC in UD treatment is relatively higher than other treatments (Table 1). This may be because root baffle and interception by plants at the UD site could retain more soil moisture, whereas less vegetation at the degradation sites increases the infiltration velocity of water[17]. As the energy partitioning of net radiation is mainly controlled by soil moisture conditions[15,18], SWC reduction will decrease the proportion of energy partitioned into $LE$, resulting in an increase Bowen ratio (Table 1). Although the net radiation is reduced, sensible heat flux increases with the degradation of *L. chinensis*, which explains the warming effect of degradation on air temperature. During or immediately after the rain events, water is relatively abundant and the partitioning of surface energy is similar in different treatments due to the limited vegetation-reduced SWC changes. This explains why the differences of air or soil temperatures between the four treatments are the smallest during the rain events (Figure 1).

*L. chinensis* degradation also increases both $T_s$ and $G$. The higher $T_s$ and $G$ can be explained by the fact that *L. chinensis* degradation results in larger proportion of exposed soil, which has smaller heat capacity than the vegetation[19]. In addition, due to high SWC, the higher heat capacity of wet soil and larger proportion of $LE$ partly explain the low soil temperature for UD treatment.

The results of the present study also show that the difference between soil and air temperatures increases with the reduction of *L. chinensis* vegetation cover (Table 1), indicating the larger warming effect of grassland degradation on soil temperature than air temperature. With the degradation of *L. chinensis*, increase in soil temperature will be faster than air temperature. Therefore, if degradation in Songnen grassland continues, the asymmetric warming pattern in two different interfaces (aboveground and underground) could change the microenvironment and alter the adaptive strategies of grassland plants.

Our results indicate that *L. chinensis* degradation will increase both the surface air and soil temperatures. In addition, the increase in soil temperature will be faster than air temperature with the degradation of *L. chinensis*. This needs further attention, as it may change the adaptive strategies of grassland plants due to the asymmetric warming between aboveground and underground.


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# Monogenoidea on exotic Indian freshwater fish. 3. Are Indian guidelines for importation of exotic aquarium fish useful and can they be implemented; The case of Neotropical *Gussevia spiralocirra* Kohn and Paperna, 1964

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***Gussevia spiralocirra*, a Neotropical parasitic monogenoid (Platyhelminthes), has been recorded from the type host, freshwater angelfish *Pterophyllum scalare* (Cichlidae), collected from the post-quarantine populations in local aquarium markets of Lucknow and Itanagar, India. The finding establishes India as a geographical distribution record for *G. spiralocirra*, and more importantly, reveals a potentially serious breach of quarantine regulations of the country. The present communication provides a summary assessment of existing Indian guidelines for importation of exotic aquarium fish and highlights some of its major shortcomings.**

**Keywords:** *Gussevia spiralocirra*, exotic aquarium fish, *Pterophyllum scalare*, quarantine regulations.

AQUARIUM trade is a potential pathway for the global translocation of exotic aquarium fish[1,2] and their parasites[3,4], especially the monogenoids (Platyhelminthes)[5]. Should these fish escape from the culture facilities and establish self-sustaining populations in the wild waters of an importing country[6,7], they can pose a serious threat to the native aquatic biodiversity and economy[8,9]. Not surprisingly, the aquarium species, dominated by freshwater fish, comprise one-third of the world's 100 worst aquatic invasive species[10].

The freshwater angelfish *Pterophyllum scalare* (Schultze, 1823), which originates from the river basins of tropical South America, is one of the most treasured of all the aquarium fish. Kohn and Paperna[11] established the monogenoidean genus *Gussevia* and designated *G. spiralocirra* from the gills of *P. scalare* 'raised in aquariums in various places in Israel' as its type species. Kritsky *et al.*[12] emended the generic diagnosis of *Gussevia* and restricted the genus to member species parasitizing the gills of Neotropical cichlid fish. Further, these authors redescribed *G. spiralocirra* based on specimens collected from the type host, but in a new locality in Peru, South America. The species has not been recorded since then.

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