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Monitoring the Growing Environment of Wild Licorice with Analysis of Satellite Data at a Semi-arid Area in Mongolia

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Abstract: Wild licorice (*Glycyrrhiza uralensis*) is an important medicinal plant. It is grown in Asia, most notably in semi-arid regions of China and Mongolia. Recently, overharvesting of wild licorice has caused land deterioration and/or desertification, and some countries have begun restricting the harvesting of wild licorice. The objective of this study is to research areas within semi-arid regions where wild licorice grows, both over the period of a year, and over several years, through satellite data. The study also seeks to investigate characteristics of the growing environment, such as soil temperature and water content. Monitoring results indicate that soil surface conditions were severe. However, a constant temperature is maintained in the deeper layer below 70 cm during winter months, and the layer below 30 cm has adequate water content to permit plant survival in summer. MODIS (MODerate resolution Imaging Spectroradiometer) data were used to calculate seasonal variation in EVI (Enhanced Vegetation Index) in 2011. This clearly indicated differences between vegetated and non-vegetated areas. No vegetation index was obtained for the winter season, but some plants were able to grow in specific areas during summer months. MODIS satellite data from 2000 to 2013 were used to analyze the water resources in the area. Results showed that the extent of Lake Orog (near the licorice habitat area) declined, and that the lake suffered water shortages on several occasions over the last eight years. These results will contribute to recovery of wild licorice in semi-arid regions, also indicating potential areas of growth for wild licorice.

Key Words: Desertification, Desert Vegetation, Licorice, MODIS, Remote Sensing

1. Introduction

Glycyrrhiza uralensis (L) (licorice) grows wild in Asia, most notably in semi-arid regions of China and Mongolia. Licorice is an important medicinal plant; 70% of traditional Kampo medicines contain glycyrrhizin (GL), which is derived from this plant. Recently, the overharvesting of wild licorice has caused land deterioration and/or desertification, and some countries have begun restricting the export of wild licorice. Yamamoto and Tani (2005) reported that, in 1984, the Chinese government restricted the collection of licorice by people living in areas other than the three northern regions. In 2000, the Chinese government restricted the collection of wild licorice nationwide (Yamamoto and Tani, 2002). Therefore, the exhaustion of medicinal plant resources is of concern. However, there is continuing high demand for licorice. Hayashi and Sudo (2009) summarized the economic importance of licorice extracts, which are used for cosmetics, food additives, tobacco flavors, and confectionery foods. Their suggested means to increase licorice supply is the cultivation of licorice in semi-arid regions of China and Mongolia, while also combating desertification. Abe *et al.* (2005) indicated that cultivation of medicinal plants in arid regions could provide an alternative income source. Yamamoto and Tani (2005) reported that licorice harvested in China in the fourth year after seeding conformed to the JP XV standard (The Japanese Pharmacopoeia XV, 2006) for GL content; in order to use licorice as a medicinal plant in Japan, the GL content must exceed 2.5%. In another study, Zhang and Xiong (2008) reported that N+ ion beam irradiation made licorice salt-tolerant.

However, there have been few reports concerning environmental conditions that characterize the habitat of wild licorice, although many studies have investigated its cultivation. The objective of this study was to obtain information concerning environmental characteristics of wild licorice habitat in semi-arid regions, including air temperature, relative humidity, precipitation, solar radiation, soil water content, and soil temperature. First, field monitoring of licorice habitat areas was conducted from June 2011 to June 2012 near Bogd soum, Bayankhongor, in Southern Mongolia. Second, satellite data were analyzed to investigate the extent of vegetated areas where the plant survives, and to detect available

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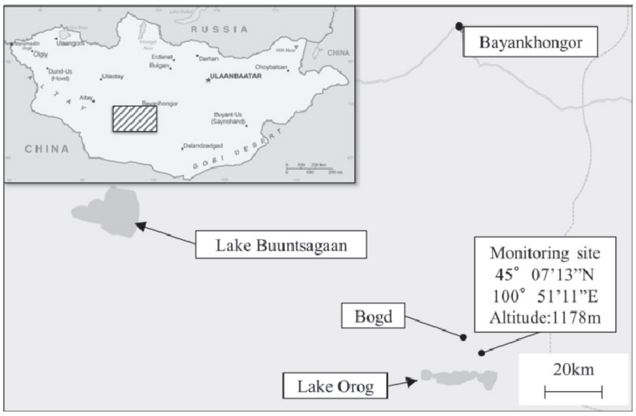

Fig. 1. Location of research area. Wild licorice is widely distributed between Lake Orog and Lake Buuntsagaan. The density of licorice is high around the lake. There are a number of mountains of over 3000 m height, in areas north and south, shown on the map.

water resources within this semi-arid region.

2. Materials and Methods

2.1. Monitoring of licorice habitat

Wild licorice is distributed around Bogd soum in the Bayankhongor prefecture, located in Southern Mongolia. **Figure 1** shows the location of the monitoring site and of Lake Orog. This location has the highest density of wild licorice in Mongolia.

Environmental parameters of the licorice habitat area were monitored between June 2011 and June 2012. Air temperature, relative humidity, precipitation, wind speed, and wind direction were measured at a height of 1.5 m using a Weather Transmitter (WXT520; VAISALA Inc.) at 60 min intervals. Solar radiation was measured by means of PCM-01 (PREDE co.) at 30 min intervals. Soil water content and soil temperature were measured at depths of 10 cm, 20 cm, 30 cm, 40 cm, 50 cm and 70 cm, using a soil moisture sensor 5TE (Decagon Inc.) at 60 min intervals. The moisture sensors were calibrated using a three point method. As equipment was being placed on site, we confirmed that the groundwater level was 160-180 cm below the surface, and that the root length of licorice was over 160 cm.

2.2. Detection of vegetation index and water area

Seasonal variation of EVI (Enhanced Vegetation Index) in 2011 was calculated using MODIS (MODerate resolution Imaging Spectroradiometer) data. MODIS data set MOD13Q1 (250 m 16-days-composite) was downloaded from USGS, and the EVI was calculated, with removal of noise. Furthermore, analysis was conducted for MODIS data sets MOD09Q1 (250 m 8-days-composite) and MOD09A1 (500 m 8-days-composite), from 2000 to 2013; analysis was intended to detect changes in water areas, based on the method of Sakamoto *et al*. (2007). The confidence level of calculated results was confirmed in order to enable comparison with Landsat data.

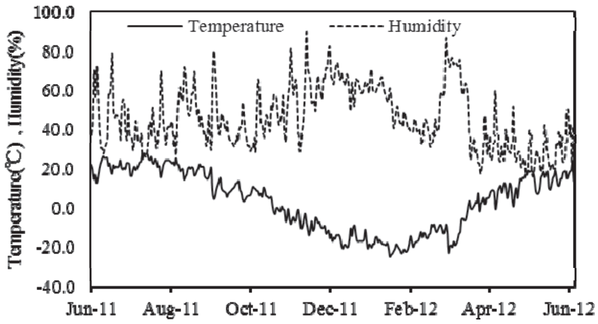

Fig. 2. Air temperature and relative humidity at monitoring site.

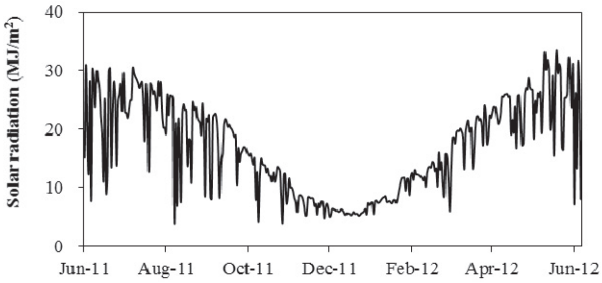

Fig. 3. Daily solar radiation at monitoring site (sum of 30 minutes solar radiation).

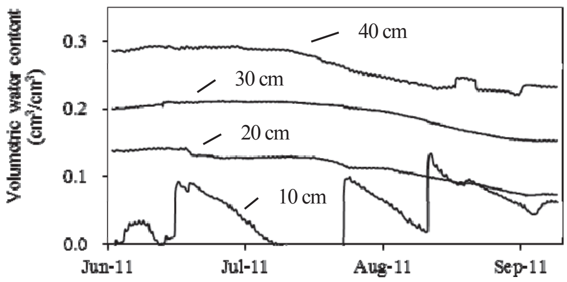

Fig. 4. Soil water content at monitoring site during summer season (on some occasions, the limit of measurement at 10 cm was exceeded).

3. Results and Discussion

3.1. Monitoring results

Figures 2, 3 and **4** show air temperature and relative humidity, solar radiation, and soil water content, respectively. During the winter season, temperatures less than -20°C were recorded. Highest values for solar radiation were recorded during the summer season; conversely, solar radiation was very low during winter. In summer, soil water content at a depth of 10 cm presented severe constraints to plant growth, while at a depth of 20 cm, water content was constant. Water content at 20 to 40 cm depth corresponded to suction of 100-300 cm H_2O (Marui *et al*., 2012). This is not adequate for plant

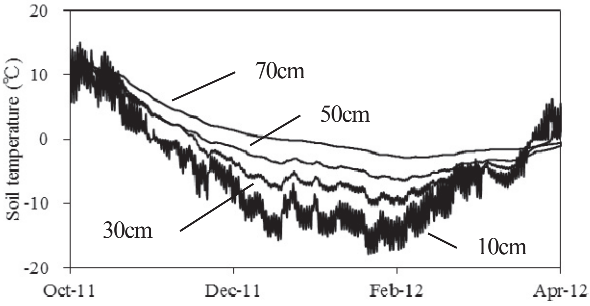

Fig. 5. Soil temperature at monitoring site during winter season.

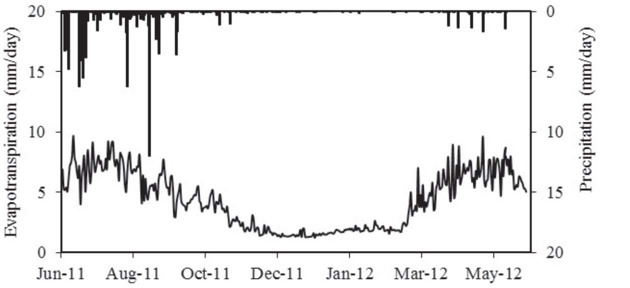

Fig. 6. Estimated evapotranspiration and precipitation at monitoring site. Evapotranspiration was estimated using the Penman method. There was snow during the winter season.

growth but enough for survival. The ground water level was considered to possibly be high between 1.0 and 2.0 m soil depths. **Figure 5** shows soil temperature at different depths. Conditions at the soil surface presented severe constraints to plant survival, with temperatures of -15°C at a depth of 10 cm. During winter, temperatures were below freezing from the surface to 70 cm soil depth. This indicates that short-rooted plants face severe constraints to survival during this season. **Figure 6** shows precipitation and estimated evapotranspiration using the Penman method. In summer, evapotranspiration was very high because of strong winds, high solar radiation, and low humidity.

Based on the above, it can be concluded that during the winter season, there are severe constraints to the survival of short-rooted plants, owing to low temperatures. However, during summer, water content in the root zone is adequate for plant growth, even though water conditions at the soil surface remain severe.

3.2. Results of remote sensing

Figure 7 shows seasonal EVI around the licorice habitat area. There is a clear difference between vegetated and non-vegetated areas, although the confidence level of data obtained in winter is low due to snow and cloudy weather. No vegetation index was obtained for the winter season, but there were indications that some plants could grow in specific areas during the summer season. EVI results indicate a large vegetation area during the summer season, located around water resources, such as rivers and lakes.

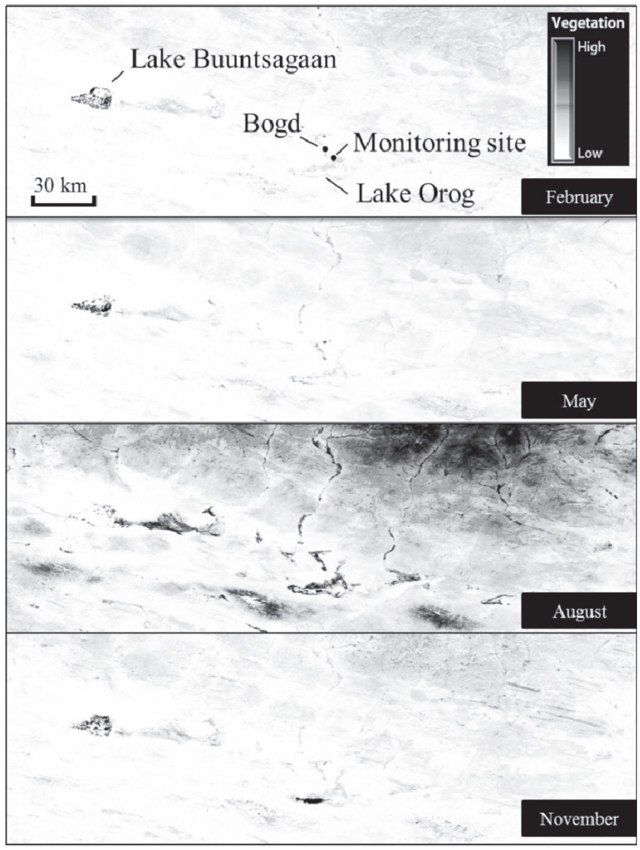

Fig. 7. Seasonal EVI calculated from MODIS data (250 m 16-days-composite). The confidence of data obtained in winter is low, due to snow and cloudy weather.

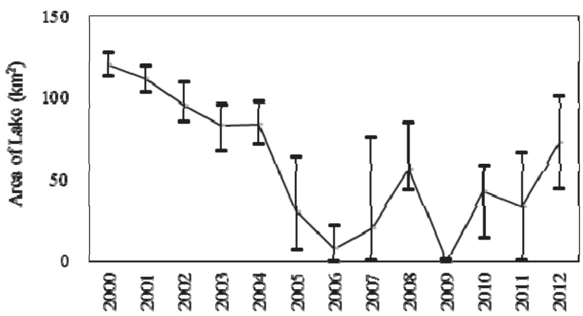

Fig. 8. Estimated water area of Lake Orog during summer season. Winter season data (from middle of Sep. to middle of May) were excluded, due to low confidence. This figure shows average line, and minimum/maximum values.

Figure 8 shows the estimated water area of Lake Orog. This indicates that the area of the lake decreased, with the range of vibrations increasing over the last eight years. In particular, the average lake area was almost 0 km^2 in 2006 and 2009, while minimum values of 0 km^2 were also recorded in 2006, 2007, 2009 and 2010. **Figure 9** shows precipitation at Bogd soum. Little rain was recorded in 2004, 2005, and 2009. Changes in the area of the lake are considered to be related to trends in precipitation.

The vegetation index derived through remote sensing indicates that plants only grow in specific areas near water

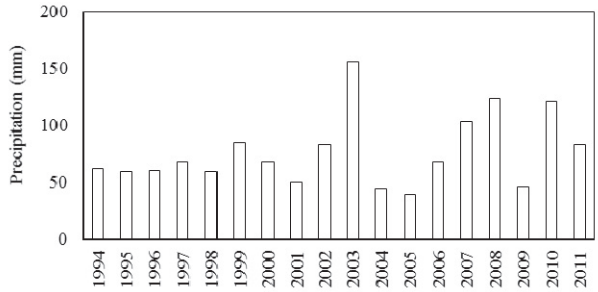

Fig. 9. Annual precipitation at Bogd soum. The distance to Lake Orog from Bogd soum is approximately 10 km.

resources. A decrease in the area of Lake Orog (near the licorice habitat area) was also noted.

The decrease in lake area, combined with trends of minimal precipitation, will affect the ground water level. Desertification is thus a possibility, as licorice survival and growth depend on groundwater availability.

4. Conclusion

Monitoring results indicate that, during the winter season, there are severe constraints to survival of short-rooted plants, due to low temperatures. During the summer season, available soil water below a depth of 20 cm is adequate for plant survival, although severe water constraints occur at the soil surface.

Vegetation index results based on remote sensing indicate that plants only grow in specific areas near water resources. A tendency towards a decrease of the water area at Lake Orog (near the licorice habitat area) was noted. The decrease in lake area will affect ground water level, as will precipitation; this will in turn influence the licorice habitat area.

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