Grasslands of Asia and North America: Distribution of Soil Organic Carbon and Stable Isotopes in Grasslands of the Mongolian Steppe

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Purpose

The grasslands in temperate east Asia share many features with comparable grasslands in North America, including the strongly continental climate characterized by rainfall which occurs during the warmer months of June, July and August and monthly temperatures which range from 100 to 500 mm during these months. The grasslands of Asia and North America (GANA) share some floristic similarities, often at the genera level. These grasslands have evolved under a long evolutionary history dominated by grazing.

The grasslands of Inner Mongolia, China, have undergone changes in the extent of grazing systems due to increased cropland conversion and intensification. The Mongolian portion of the region has undergone less intensive changes in land use, and is noted for its greater reliance on indigenous pastoral systems, including continual seasonal nomadic pastoral patterns.

The purpose of this study was to examine the effect of climate and grazing on distributions of photosynthetic types, and to test whether the SOM isotopic signal reflects current vegetation inputs or whether plant community shifts have taken place. This paper presents information on soil organic matter (SOM) C and isotopic composition at several collection sites in the Mongolian steppe region.

Methods

Our research to compare ecosystem dynamics in grasslands of Asia and North America relies upon a detailed floristic analysis of distribution, the use of stable isotopes to quantify productive patterns and soil organic matter dynamics, and remote sensing to assess geospatially explicit land cover performance. Research sample sites and nearby cities are shown on seasonal land cover map of grasslands in the Temperate East Asia (Figure 1). The isotopic ratios not only characterize carbon from C_3 and C_4 sources, it is fractionated during transfer through trophic levels and is recorded in the SOM carbon, thereby allowing us to re-establish past carbon sources into the SOM pool resulting from community shifts between C_3 and C_4 plants.

Carbon isotopic analysis followed procedures in standard use. A soil subsample was de-carbonated with 0.5 N HCl and continuous stirring until no effervescence under vacuum was detected. The treated sample was centrifuged, re-suspended in distilled water, and re-centrifuged before the pellet was dried, pulverized and loaded into tin cups for combustion under pure oxygen and at high temperatures in the Carlo Erba CHN analyzer. Sample sizes were of variable size to provide adequate carbon for isotopic analysis. The combusted sample was separated into CO_2 and N_2 gases and quantified with a gas chromatograph.

The combusted products were passed through a drying column, and CO_2 was trapped at liquid nitrogen temperature in the triple trap of a VG SIRA-10 Isotope Ratio Mass Spectrometer (IRMS). Remaining gases were removed under high vacuum, and the CO_2 was analyzed by the IRMS.

Results

The typical grassland C_3 values for the Mongolian Steppe are clustered around -26.5% and C_4 around -12.5% (Table 1). Soil carbon isotope values in the Mongolian Steppe ranged from -25 to -20 which indicate a greater C_3 input compared to estimates based on the North America regression (-21 to -17) (Figure 2). The Mandolgovi, Mongolia and Donsheng sites (Figure 3a and d) indicate a greater C_4 contribution, perhaps due to the impact of grazing on plant community characteristics. The soil carbon levels of these two sites also reflect greater grazing removal of plant material, and both had low percent carbon values (approximately 1.5%). The Stipa grasslands tend to be more prevalent in Mongolia, and the values of d13C and soil carbon levels (Figure 3b and f) are typical of well-managed Stipa grasslands of this region. In the more mesic portions of the Mongolian Steppe, Leymus grasslands become an important community. The Leymus grasslands sampled at the Inner Mongolian Grassland Ecosystem Research Station (IMGERS) at Xilingole, China are indicative of d13C and soil carbon levels for this community (Figure 3c).

Analysis of climate relationship to d13C patterns in the Mongolian Steppe indicate that July wind speed (positive), June precipitation (negative), and June-July ratio of potential evapotranspiration to precipitation (positive) were the best predictors for soil carbon isotopes. All these factors support the assertion that C_4 plant species respond more favorably to water stress conditions than C_3 species. Soil carbon levels were sensitive to the same factors as the d13C isotopic content, but responded in an opposite fashion. These relationships for soil isotopic composition (d13C) and soil C based on climate data only are:

d13C = -23.979 + 1.326*(Wind/July) - 0.525*(Prec/June); (r2 = 0.837)

and

C = 6.224 - 1.446*(Wind/July) + 0.38*(Prec/June), (r2 = 0.58).

where wind/July = mean of daily wind speed for July, m/s and prec/June = mean of daily precipitation for June, cm.

Soil carbon levels better correlated with growing season wind speed and precipitation in grasslands of Mongolia, but annual mean temperature and growing season precipitation better explained soil carbon content for grasslands in Inner Mongolia. The soil carbon content decreased with precipitation in Inner Mongolia which appears to be related to land use intensity.

Change of land use impacted ecosystem structure and functions in a number of ways, altering plant composition, soil carbon, and soil isotopes. Relative C_4 plant cover increases with grazing relative to control in all research sites (Figure 4). Soil carbon at the depth 1-6 cm was more sensitive to grazing management, increasing by about 10% with light grazing, and decreasing by 25% with heavy grazing.

Conclusions

- The predominant plant community of the Mongolian Steppe is characterized by C_3, cool season community.
- Isotopic soil carbon values reflect the long-term stability of this cool season C_3 community.
- Soil d13C values and soil organic matter are predicted by summer precipitation and wind speed. Relationships derived from North American analysis over-predicts the amount of warm season C_4 plant inputs into these ecosystems.
- Warm season communities do exist in the Mongolian Steppe in the more arid regions of the steppe and in areas more heavily grazed.

Click here to view photos of Tumentsogt, Mongolia; Xilingole, Inner Mongolia; Mandalgovi, Mongolia; and Donsheng, Inner Mongolia.

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