Chapter VI Hydrologic Cycle and Ecosystem

Impact of interannual variability of meteorological parameters on vegetation activity over Mongolia

Introduction

This study is designed to elucidate the impact of interannual variability of meteorological parameters on vegetation activity over Mongolia using 10-day composite NDVI data set and surface meteorological data (precipitation, temperature and snow depth) for 97 meteorological stations from 1993 to 2000.

Impact of precipitation and temperature

The analysis is made on vegetation in two developmental stages; the rapid-growth stage (almost June to July) and the mature stage (almost July to August). Positive correlations at 99 % significant level between precipitation and vegetation activity are recognized for 29 % and 42 % of meteorological stations in the rapid-growth stage and the mature stage, respectively. Precipitation in June and July impacts vegetation activity in both stages.

The impact of air temperature on vegetation activity in the mature stage differs from season to season. The vegetation activity is negatively correlated with summer temperature over most area. Negative correlations are found over the western part of Mongolia with respect to temperature in early winter, and positive correlations are concentrated in the northeastern part of Mongolia with respect to temperature in midwinter.

Prediction possibility of vegetation activity

Vegetation activity at most meteorological stations were influenced by variability of meteorological elements prior to the maximum of the vegetation activity, which indicates that the vegetation activity may be predicted using routine observation data. Multiple regression

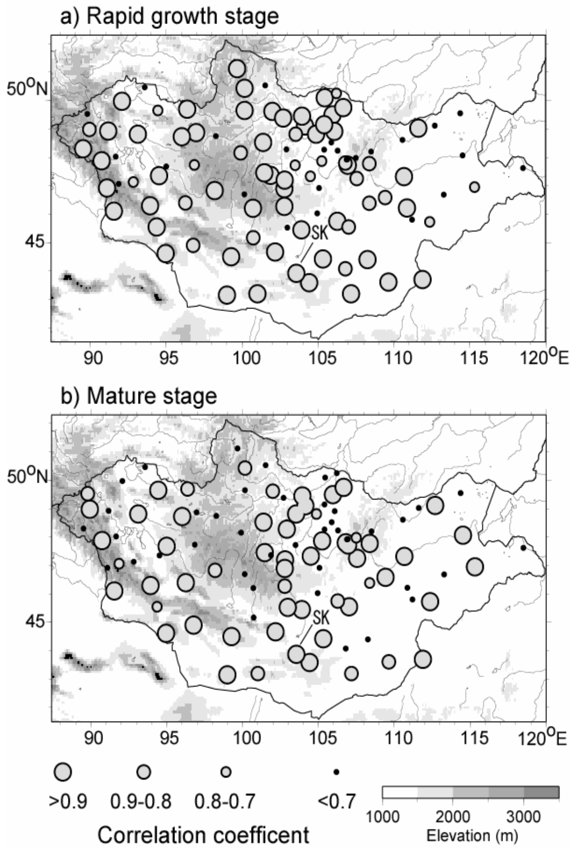

Fig. 1 Distribution of correlation coefficients between vegetation activity derived from NOAA NDVI and from multiple regression equations for the rapid growth stage (a) and the mature stage (b).

equations for the two stages are obtained by the Stepwise method for each meteorological station using monthly mean air temperature and precipitation amount.

Fig. 1 shows the distribution of correlation coefficients between observed vegetation activity and estimated vegetation activity from the multiple regression equations. Correlation coefficients at 73 % and 58 % meteorological stations for the two stages exceeds 0.7 and 65 % and 53 % stations are larger than 0.8. This prediction of vegetation activity would be available for these stations with high correlation. Furthermore, since correlation coefficients in desert steppe and desert are larger, this prediction method using regression equations is more effective over the drier rangelands.

References:
(1) Iwasaki, H., 2006a: Impact of interannual variability of meteorological parameters on vegetation activity over Mongolia, J. Meteor. Soc. Japan, 84,745-762.
(2) Iwasaki, H., 2006b: Study on Influence of Rainfall Distribution on NDVI Anomaly over the Arid Regions in Mongolia Using an Operational Weather Radar, SOLA, 2, 168-171.

Vegetation phenology refined

Introduction

Analyzing spatial and temporal change of vegetation over steppe and forest is of great importance for understanding present situation and predicting future change of desertification and sustainability of bio-resources. Earth observation satellites are especially designed to detect vegetation signals from the earth surface. Those signals are converted to an easily understandable parameters, normalized difference vegetation index (NDVI), which is almost proportional to the area of vegetation cover. There are a lot of polar orbital satellites, which circulate around the earth in about 100 minutes, observing every area of the earth surface more than once a day. That realizes obtaining daily change of NDVI if cloud covers do not intercept the surface signals. There is remaining problem that is the values of NDVI have some error which comes from satellite positioning, which makes difficult to analyze daily change of NDVI precisely, especially in Mongolia where there are frequent sudden changes of vegetation cover. In order to overcome this difficulty, we conducted a study developing a method for reducing the error and retrieving more exact values of NDVI.

Field observation

We conducted surface-based (Fig. 1) and airborne-based (Fig. 2) field observations of the surface reflectance and NDVI in steppe and forest in Khentii Aimag in 2003. These observations aimed for obtaining data of the technique of the bi-directional reflectance adjustment, which is applied to adjusting satellite data.

Fig. 1 A snapshot of a field observation in a steppe in Khentii Aimag.

Application to satellite data

Satellite data measured by MODIS operated by NASA (USA) is used this study. Daily change of NDVI in Kherlen-Bayan Ulaan, Khentii Aimag is illustrated in Fig. 3. In summer time, not adjusted values of NDVI are fluctuated because of error due to the satellite positioning. This fluctuation is attenuated after adjusting the values by the technique of the bi-directional reflectance adjustment, which makes clearer the correlation between the NDVI and the soil moisture. (1)

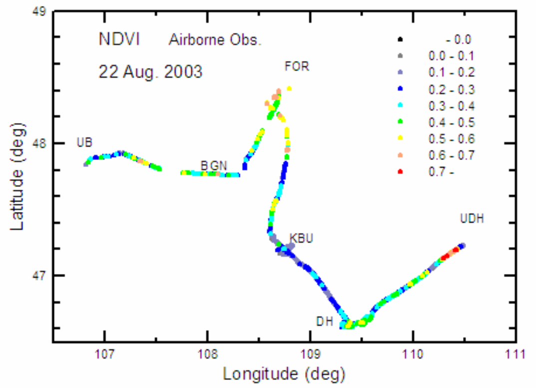

Fig. 2 NDVI values along the aircraft path from Undurkhaan (UDH) to UB (Ulaanbaatar) on 22 August 2003.

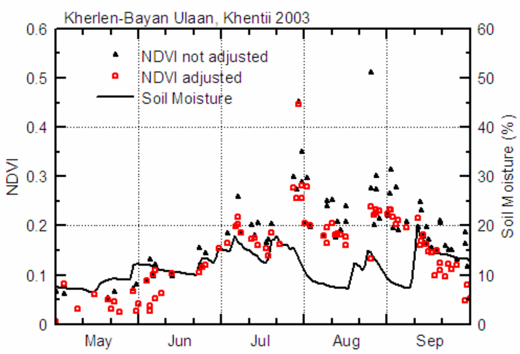

Fig. 3 Daily changes of NDVI and soil moisture in Kherlen-Bayan Ulaan, Khentii Aimag in summer time of 2003.

References:

(1) Matsushima et al., 2005: Proc. 1st Int'nl. Symp. Terre. Clim. Change in Mongolia, 137-140.

Larch trees use deeper soil moisture under water shortage

Introduction

The Kherlen River originates from the Khentii and Khyangan mountain ranges. At the upper reach (mountain catchment area) of the river is distributed larch (*Larix sibirica* Ledeb.) taiga forest, which plays a critical role in water cycling in the entire river basin. As a part of the RAISE project, this study used the isotopic technique to explore hydrological performance of this larch forest. The measurements of isotopic compositions of foliage water, stem water, soil water, and precipitation water were conducted in the 2003 growing season. One of our main objective is to identify the water use characteristic of the larch forest.

Methods

The measurement site was located in Mongonmorit, Tov province of Mongolia (lat. 48°21.112'N, long. 108°39.260'E) (1-2). There is an eddy covariance flux tower at the site, which was erected in March 2003 in a Siberian larch (*Larix sibirica* Ledeb.) forest on a southwest-facing gently-sloping hill of the Khentii Mountains. Within about 150 m proximity close to the tower, ten larch trees (five for sunny leaves and five for shady leaves) were tagged in June of 2003 for collecting leaf and stem water samples. Soil water samples at different depths were collected at the site near the tower by digging a 1 m × 1 m × 1 m pit. Precipitation was routinely collected with a standard rain gauge by the Mongonmorit Meteorological Station throughout the year.

Vegetation recovery

Measurements of water oxygen isotopic composition were conducted in the 2003 growing season for a montane larch (*Larix sibirica* Ledeb.) forest in northern Mongolia, a transitional area from the south Siberian taiga to the Asian steppe. Oxygen isotopic composition of foliar water and its daily variability were found to be sensitive to atmospheric evaporative demand. During most of the growing season, water sources used by larch trees were from the upper 30-cm surface layer of the soil when precipitation input was large, and were from the deeper layer when the water supply at the upper soil layer was limited (Fig. 1). The Keeling plot method suggested that the forest returned soil water to the atmosphere predominantly by means of canopy transpiration during the peak growth period (in August) (Fig. 2).

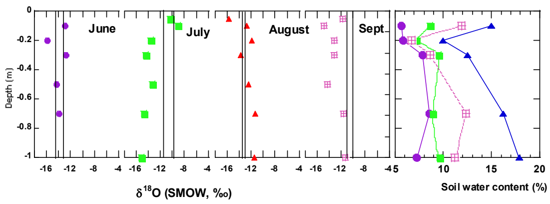

Fig. 1 Profiles of soil water and its $\delta^{18}O$ values. Vertical lines represent the $\delta^{18}O$ values of larch stem water and the wideness between two neighboring lines represents the standard deviation.

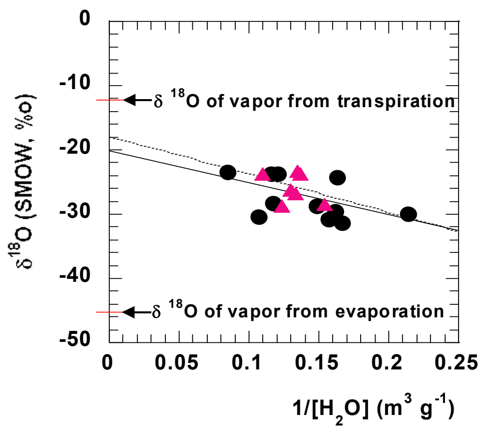

Fig. 2 An example of the Keeling plot describing the daytime relationship between the water vapor $\delta^{18}O$ value and the inverse of the air water vapor concentration at different heights (circles above the canopy, triangles within the canopy). Samples were collected in 21-23 Aug 2003 (Table 1). Curves are best fits by the linear regression for the within-canopy samples (broken line) and the above- and within-canopy samples (solid line), respectively.

References:

(1) Li S.-G. et al., 2006a: J. Hydrology (in press).

(2) Li S.-G. et al., 2006b: Trees-Structure & Function 20, 122–130.

Ecosystem function and water condition in a semi-arid grassland

Introduction

World's grasslands covering more than a half of terrestrial part of the earth[1] and containing high soil organic carbon are a potential sink or source of carbon. Therefore ecosystem function of grasslands influences global carbon budget. In general, carbon fluxes in grassland ecosystems are controlled by precipitation. In particular, a small amount of annual precipitation in Mongolian semi-arid grasslands will affect ecosystem carbon fluxes. In this study, we measured a CO_2 budget of ecosystem (Net Ecosystem Production: NEP), CO_2 assimilation by plants (Gross Primary Production : GPP), and CO_2 release from ecosystem (Ecosystem Respiration: Re) before and behind rainfall event.

Measurement method

A dynamic-closed chamber (Fig. 1) was used for CO_2 flux measurements. The transparent chamber was put on the grassland vegetation and sealed. We calculated NEP from the temporal change in CO_2 concentration in the chamber. Next, the chamber was covered with a black box for measuring Re. GPP was calculated from NEP value plus Re value. The effects of rainfall events on CO_2 fluxes were assessed by comparing between flux measurements before and after rainfall events

Fig 1 Measurement system Chambertop was made of acrylic resin, color was made of PV. Temperature sensor and PPFD sensor were installed. 10 chambers were set on randomly.

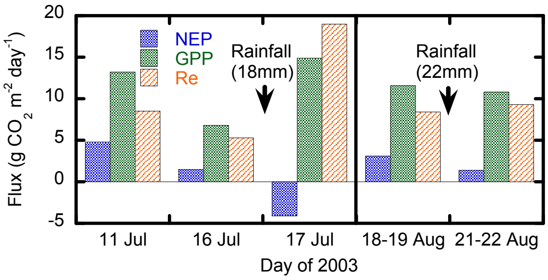

Fig. 2 Changing of CO_2 flux before and after rainfall.

in July and August (Fig. 2). The responses of CO_2 fluxes to rainfall events differed between July and August. Rainfall events occurred in a large increase in GPP and Re in July, and a slight decrease in GPP and a slight increase in Re in August. However, an increasing rate in July was higher in Re than in GPP. As a result, NPP was a minus value (CO_2 emission from the ecosystem) in July and slightly decreased in August.

Soil water content before the rainfall event was lower in July (5%) than in August (9%). The difference in soil water content between July and August would result in the different responses of CO_2 fluxes to the rainfall events. The extremely dry condition causes a significant response of Re and a resulting decrease in NEP. Previous studies have suggested positive effects of rainfall events on carbon dynamics in semi-arid grasslands. However, the present study indicates that rainfall effects should be reconsidered.

References:

(1) Chapin, F.S., 1995: Rangelands in a changing climate, in Climate Change. Springer.

Soil erosion rate on Mongolian grassland

Background

In Mongolia, the number of live stock has been increasing drastically in the last decade, which is considered to be the cause of intensive soil erosion. However the state of soil erosion on the grassland has not been assessed quantitatively because very few field data on soil erosion is available in this region. This study estimates soil erosion rates of the grasslands with different grazing condition.

Site Description

Two experimental catchments were selected in Kherlen river basin in north-eastern Mongolia. One site is Kherlen-bayan Ulaan (KBU; 6.9 ha), where has been exposed to intensive grazing as wintering ground for livestock. The other site is Baganuur (BGN; 7.6 ha), where the number of livestock has been increasing in the last decade.

Estimation of Soil Erosion Rate

Caesium-137 is an artificial radionuclide with half-life of 30.2 years, which derives from atmospheric nuclear-weapons tests in 1950s and 1960s. When Caesium-137 reaches the soil surface, they are strongly absorbed by soil particles. The amount of Caesium-137 in the soil of unit area (inventory) is equivalent with a local fallout amount from atmosphere, which varies with reflecting soil redistribution such as soil erosion and sediment deposition. The soil erosion rate can be estimated from the reduction rate of Caesium-137 inventory to atmospheric fallout input at the site.

To determine the spatial distribution of Caesium-137 in the experimental catchment, soil core samples (30 cm depth) were collected then the activity of Caesium-137 was measured by Ge γ ray detector in the laboratory.

Soil Erosion Rate on the Grassland

The spatial distributions of soil erosion rate in the experimental catchments are shown in Fig. 1. Red color represents erosion area and gray color represents depositional area. In BGN catchment, intensive soil erosion was detected at middle slope of the basin and depositional area was located at the lower slope directly below them. In KBU catchment, intensive soil erosion was detected over the whole basin. Sediment budget of the experimental catchments are shown in Fig. 2. The net erosion rate of KBU catchment was approximately three times greater than that of BGN. The high sediment delivery ratio in KBU catchment (97 %) indicated that eroded soil is easily removed from the basin.

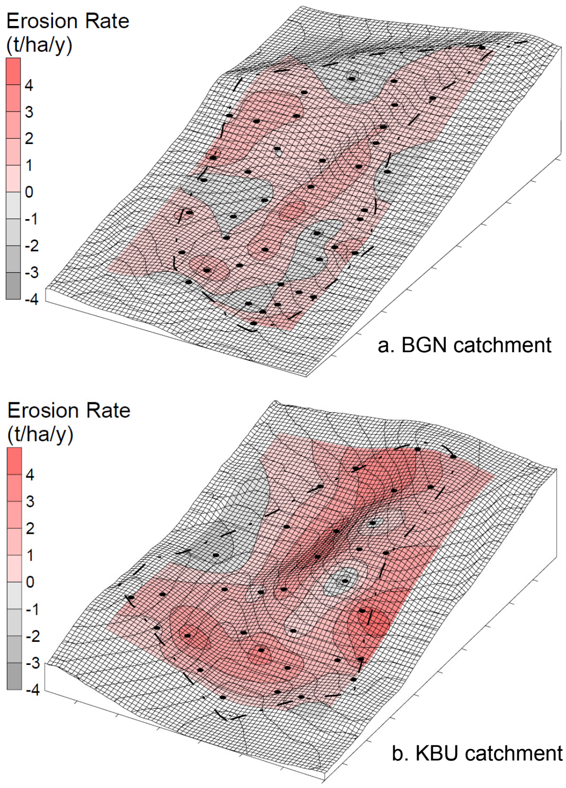

Fig.1 Spatial distribution of soil erosion rate in the experimental catchment based on ^{137}Cs analysis. Solid circle represents soil sample collection site. Broken line delineates the boundary of the experimental catchment.

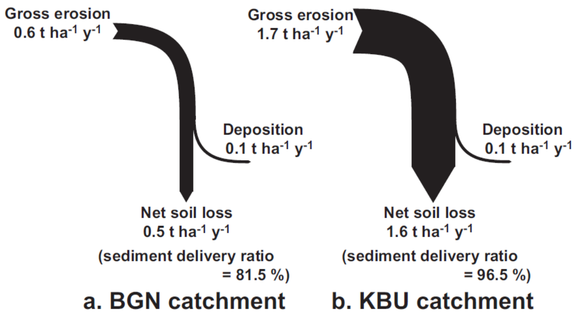

Fig.2 Sediment budgets of the experimental catchments derived from Caesium-137 analysis. Net soil loss represents sediment yield from the basin, which is calculated by subtracting deposition rate from gross erosion rate. Sediment delivery ratio is a percentage of net erosion rate against gross erosion rate.

References:

(1) Nishikawa et al., J. JSECE, 58 (3), 4-14, in Japanese.
(2) Onda et al., Journal of Hydrology, doi:10.1016/ j.jhydrol.2006.07.030