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Chapter VII: Future Prediction

著者	SATO T., KIMURA F., CHEN Y., LEE G., LEE P., OIKAWA T., LEE S.-G., URANO T., SUGITA M.
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Chapter VII Future Prediction

How change in rainfall in Mongolia after global warming

Climate change

By increasing of greenhouse gas such as CO_2, the climate in the world will change. The climate change means not only increasing of temperature but also changing in precipitation and evaporation, which are directly related to floods and droughts. Since Mongolia is located in the arid or semi-arid regions, the decreasing of precipitation will seriously affects the regional sociality.

Method

Climate change is generally predicted by huge computers by the methods called General Circulation Models (GCMs) which simulate the dynamics of the atmosphere, moisture and clouds in the world. However, precipitation change in the specific region is not easy to predict only by the GCM because precipitation strongly depend on place(1). By this study, precipitation change in the next 70 years is predicted by the method of RCM (Regional Climate Model). The RCM can estimate the climate change in the specific region based upon the prediction by GCM. The GCM prediction was provided by Meteorological Research Institute, Japan Meteorological Agency (2) assuming the SRES-A2 scenario for the greenhouse gas emission.

Results

Fig. 1 shows the predicted distribution of change in precipitation in summer (Jun, Jul, Aug) until 2070s. The color bar in the right of the figure shows the amount of precipitation change in the unit of mm per three months. Blue indicates increasing and red indicates decreasing of precipitation.

The figure shows that precipitation will decrease in the most part, particularly in the mountainous area. It will decrease by 10-20mm in the three summer months in the entire Mongolia, while temperature will climb up by 2.5 deg in average. These are the differences between ten years around 2000 and 2070s. Actually, the year-to-year variation of temperature and precipitation is so large that even declining of temperature or increasing of precipitation may occur in some years in 2070s.

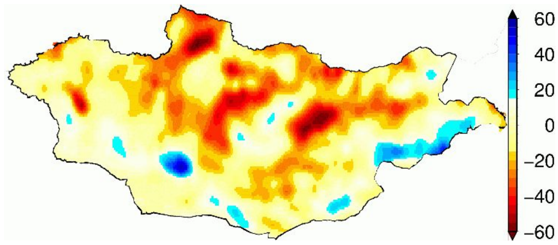

Fig.1 Change in precipitation in summer (Jun,Jul,Aug) until 2070s,blue:increase red: decrease Unit: mm/three month

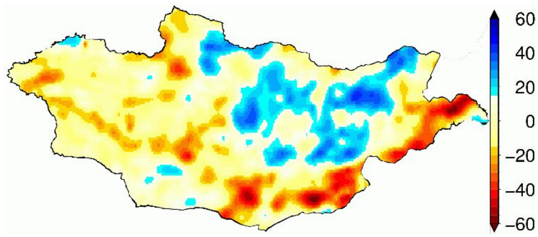

Fig.2 Change in precipitation after desertification as an assumption. The meaning of figure is the same as Fig.1

Comparison with desertification affects

The predicted climate change by the greenhouse gas is compared with that by the assumed desertification in Mongolia. In this estimation, we assumed that the all grass land becomes semi-desert and the semi-desert becomes desert caused by some human activities. Change in precipitation depends on place in Mongolia as shown in Fig. 2 and the total precipitation in this area will not much change. Temperature will go up but its range will not exceed 0.5 degree. These effects seem to be weaker than the effects of the greenhouse gas.

References:

(1) Houghton, J. T. et al., 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881p.

(2) Yukimoto, S., et al., 2001: A new Meteorological Research Institute coupled GCM (MRI-CGCM2) - its climate and variability -. Pap. Met. Geophys., 51, 47-88.

Grazing effect on above-ground biomass and above-ground net primary production of a Mongolian grassland ecosystem

Introduction

About 75% of the total land area in Mongolia is made up of grasslands and shrublands, which have been freely grazed by livestock all year round. Moreover, the number of livestock increased significantly in recent years. Grazing is the main activity in these grasslands. The effect of grazing on the ecosystem cannot be neglected. In this study, we have analyzed the productivity of a grassland ecosystem in Kherlenbayan-Ulaan

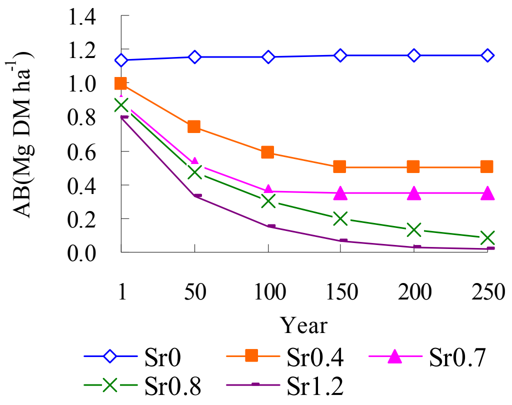

Fig. 1 Effect of grazing on *AB* simulated by Sim-CYCLE grazing

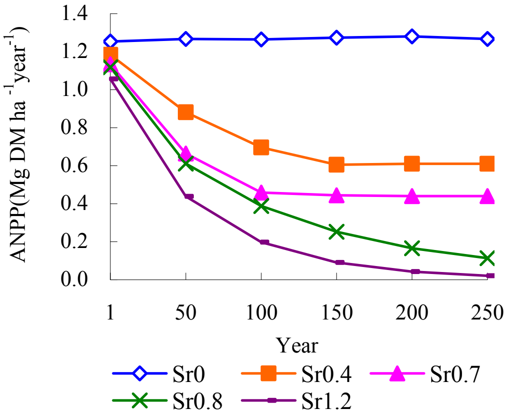

Fig. 2 Effect of grazing on ANPP simulated by Sim-CYCLE grazing

(KBU), Mongolia under non-grazing and grazing conditions using a new simulation model, Sim-CYCLE grazing.

Model description

Sim-CYCLE grazing was obtained by integrating the Sim-CYCLE (Ito and Oikawa, 2002) and a defoliation formulation (Seligman et al., 1992). The model time step is one month. Model inputs include meteorological and soil data, which were obtained from a local meteorological agency by RAISE project.

Grazing effect on biomass and net primary production

The results from the model have been

validated against a set of field data obtained at KBU. The simulated results show that both above-ground biomass (AB) and above-ground net primary production (ANPP) decrease with increasing grazing intensity (Chen et al., 2007). The simulated maximum AB for a year maintains a nearly constant value of 1.15 Mg DM ha^{-1} under non-grazing conditions (Fig. 1). The *AB* decreases and then reaches equilibrium under a stocking rate (S_r) of 0.4 sheep ha^{-1} and 0.7 sheep ha^{-1}. The *AB* decreases all the time if S_r is greater than 0.7 sheep ha^{-1}. A similar trend is also observed for the simulated ANPP (Fig. 2). The annual ANPP is about 1.25 Mg DM ha^{-1} year^{-1} and this value is also constant under non-grazing conditions. The annual ANPP decreases and then reaches equilibrium under an S_r of 0.4 sheep ha^{-1} and 0.7 sheep ha^{-1}, but the ANPP decreases all the time when S_r is greater than 0.7 sheep ha^{-1}.These results suggest that the maximum sustainable S_r is 0.7 sheep ha^{-1}.

References:

(1) Chen Y., Lee G., Lee P. and T. Oikawa, 2007. Journal of Hydrology, 333: 155-164.
(2) Ito, A., Oikawa, T., 2002. Ecological Modelling. 151, 143-176.
(3) Seligman, N.G., Cavagnaro, J.B.and Horno, M.E., 1992. Ecological Modelling 60, 45-61.

Root response to grazing of a Mongolian grassland ecosystem

Introduction

Grazing is the main activity in Mongolian grasslands. So the effect of grazing on the ecosystem cannot be neglected. In this study, we have analyzed the root response to grazing of a grassland ecosystem in Kherlenbayan-Ulaan (KBU), Mongolia under non-grazing and grazing conditions using a simulation model, Sim-CYCLE grazing. More detail about the model is in Chen et al. (2006).

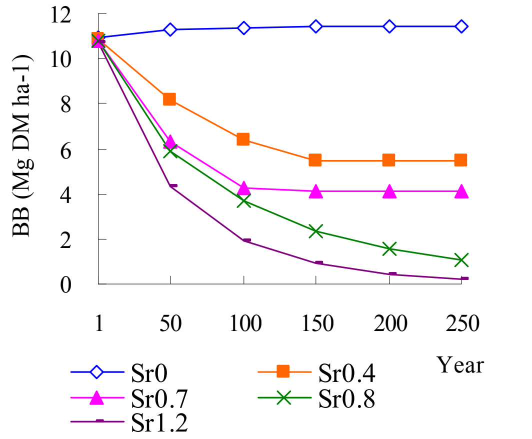

Fig. 1 Below-ground biomass at different stocking rates

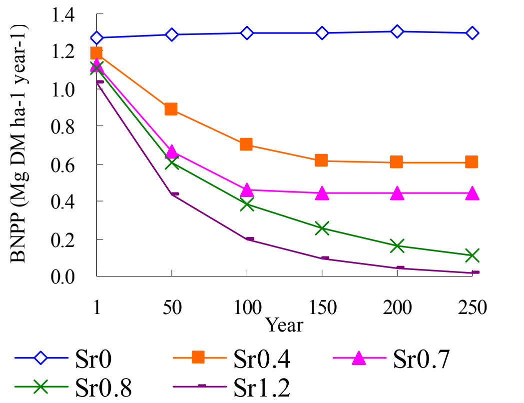

Fig. 2 Below-ground net primary production at different stocking rates

Root response to grazing

The simulated results show that both that both below-ground biomass (BB) and below-ground net primary production (BNPP) decrease with increasing S_r. However, if S_r is not higher than 0.7 sheep ha^{-1}, a sustainable state of the grassland ecosystem can be achieved, which also suggests that the maximum sustainable S_r at KBU should not be higher than 0.7 sheep ha^{-1}. At the sustainable state, the maximum BB in a year is about 11 Mg DM ha^{-1} under non-grazing condition, 5 Mg DM ha^{-1} under 0.4 sheep ha^{-1} S_r, and 4 Mg DM ha^{-1} under 0.7 sheep ha^{-1} S_r (Fig. 1); the BNPP is 1.3 Mg DM ha^{-1} year^{-1} under non-grazing condition, and 0.6 Mg DM ha^{-1} year^{-1} under 0.4 sheep ha^{-1} S_r, and 0.4 Mg DM ha^{-1} year^{-1} under 0.7 sheep ha^{-1} S_r (Fig. 2). Root turnover rate decreases with increasing stocking rate. The rate is 12% each year under non-grazing conditions, and 11% each year under 0.7 sheep ha^{-1} S_r. Form this study, the *Sr* at KBU should not be higher than 0.7 sheep ha^{-1} in order to maintain sustainable grassland ecosystem.

References:

(1) Chen Y, Lee P., Lee G., Mariko, S. Oikawa, T. 2006. Plant Ecology, 188(2): 265-275.

Estimation and forecast of carbon/water cycles in a Mongolian Ecosystem

Introduction

The climate of northeast Asia has undergone significant changes over the last 20 years (1979-1997, +1.5℃). The climate change may considerably affect Mongolian steppe in the future while it in turn may have the potential to feedback to regional and possibly global climate. This study was conducted to understand the present and future carbon/water cycles of a Mongolian steppe under the natural condition.

Model and site description

A process-based model, *Sim-CYCLE* [1] simulates ecosystem-scale carbon and water dynamics (Fig. 1). The research site is located in Kherlenbayan-Ulaan (KBU: 47°12N, 108°44E). Meteorological data to forecast future climate are from a local meteorological station of the Institute of Meteorology and Hydrology of Mongolia and provided for ***RAISE***.

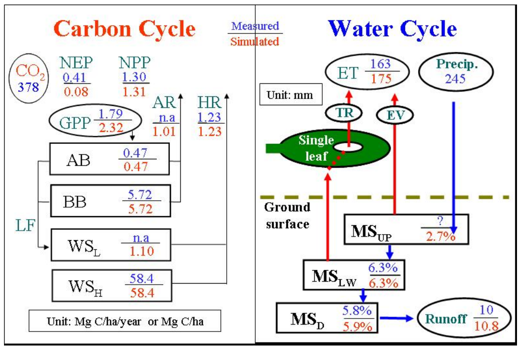

Fig. 1 The schematic of *Sim-CYCLE* and the validation results between the measured and the simulated annual carbon/water cycle in 2003.

Results and discussion

Fig. 1 shows that the comparison between measured and simulated carbon and water dynamics. Annual average and monthly results of this calibrated *Sim-CYCLE* showed a high consistence with measured data in 2003, such as ecological data (ex. *AB, BB, WS*) and micrometeorological data (ex. *NEP*, *HR, ET*).

The combination effects of precipitation, temperature, and atmospheric CO_2 changes had synergistic effects on carbon and water cycles. Decreases in precipitation (net primary production and transpiration are decreased 52 and 71%) and increases in temperature (*NPP* and *TR* are decreased 32 and 47%) had great negative effects on carbon cycles due to water and temperature stress to plant, while increases in atmospheric CO_2 (*NPP* and *TR* are inversely increased 55 and 22%) had positive effects on them due to increase of water use efficiency by CO_2 fertilization effect. Here, the carbon and water cycles of KBU were most sensitive to change in precipitation as time passes.

References:

(1) Ito, A. and T. Oikawa, 2002: Ecol. Model., 151, 147-179.