Recent Findings From RAISE Project

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I. Introduction

Rangelands occupy some 40-50% of the earth's land area, and have a vital importance for the production of live stock. Among them, over 80% is in arid and semiarid zones, and is in possible danger of desertification. Given the large extent of rangelands and importance for us, it is imperative to understand the natural environments of the rangelands in general and the mechanism that maintains or changes the ecosystem in response to variation of the environments in particular. Since ecosystem is closely related to hydrology and climate, not only the vegetation but also other closely related factors must be studied at the same time. Although there have been attempts to study rangelands, most of them are limited to narrow scientific discipline such as ecology or micro-meteorology. Perhaps one recent exception is the Semi-Arid Land-Surface- Atmosphere (SALSA) program (Goodrich et al., 2000) which targets mostly land-surface interaction in semiarid region in upper San Pedro basin in the US-Mexico border region, but also includes some components of ecology and hydrology. Unfortunately, its special issue published in Agricultural and Forest Meteorology in 2000 does not yet fully cover all aspects of their studies.

Also one should note that the rangelands in northeastern part of Asia have not received enough attention in contrast to those in the US for example. There are general features that are common to any rangelands and at the same time there exist local characteristics which are relevant in certain rangelands only. Both aspects must be studied of course, and only through comparison and integration of the results obtained in geographically diverse rangelands, we can obtain understanding on the rangelands in general. One characteristic in northeastern Asia that is somewhat different from other rangelands is the presence of an ecotone and recent changes of climatic as well as human-induced factors. A climatic shift from humid condition in the northern part to arid condition in the southern part can be found in a relatively narrow, boundary zone, and as a result a distinct ecotone of forest-grassland-desert is formed. Such an ecotone area is very sensitive to even a small change of the external factors. In reality, it has already been reported that air temperature has increased and precipitation has decreased in the last four decade in this region. Also, overgrazing and inappropriate water use have been reported in the central part of rangelands of this region, i.e. Mongolia, because of a drastic recent changes from a planned economy under the communist regime to the market economy which resulted in sudden increase in the stocking rate. Thus there is a need to clearly understand the hydrologic processes in this area and its interaction with ecosystem and atmosphere.

In the light of above discussion, an integrated research project, RAISE (the Rangelands Atmosphere- Hydrosphere-Biosphere Interaction Study Experiment in Northeastern Asian) has been organized to evaluate the effects of environmental changes on the rangeland ecosystem with emphasis on the role of hydrologic cycle in northeastern Asia. In the northeastern Asia including Mongolia and the northeastern China, a climatic shift from humid condition in the northern part to arid condition in the southern part can be found in a relatively narrow, boundary zone. As a consequence of the steep gradient in climatic conditions, a distinct "ecotone" (i.e., forest-grassland-desert) is formed in the northeastern Asia. Such a ecotone is sensitive to changes in external environment (e.g., global warming) even though those changes are very small. For instance, changes in external environment may result in desertification in this region. In reality, it has been reported that air temperature in winter and spring gradually has increased and precipitation amount has decreased in the last four decade. A possibility can be pointed out that the warming and drying of the atmosphere induce drastic changes in plant growth and vegetation distribution through changes in hydrological cycle. In addition, changes in human activity as an external forcing can affect natural environments in this region. Overgrazing and inappropriate water use might have already disturbed ecosystem and hydrological cycle of this region.

The strategy of the project includes field observations for the understanding of the current status of the ecosystem and the modeling of the atmosphere, hydrosphere and biosphere in this area. The models to be produced and optimized for the area will then be used for the prediction of the possible changes of the area in response to likely scenarios of future climate and land use changes. In this article, some findings from RAISE project from activities in the past three and half years are summarized, and future directions will be discussed.

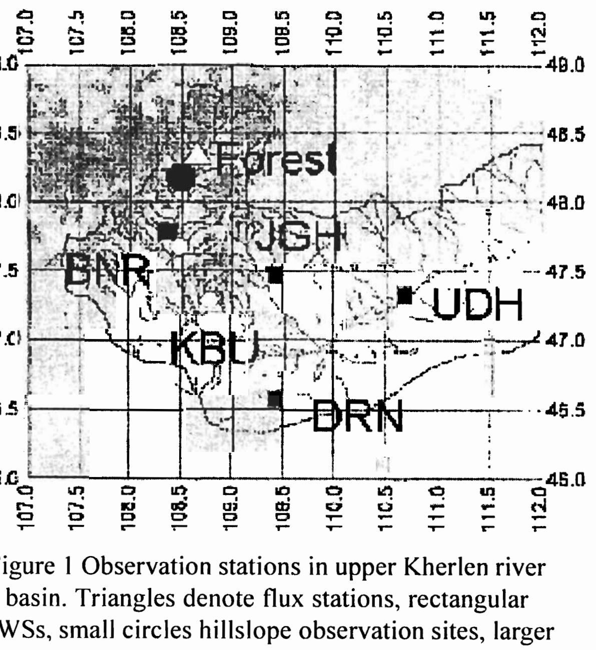

Figure 1 Observation stations in upper Kherlen river basin. Triangles denote flux stations, rectangular AWSs, small circles hillslope observation sites, larger circle the GPS station. JGH: Jargalthaan, BNR: Baganuur, KBU: Khereen Bayan-Ulaan, UDH: Underhaan, DRN: Darhan.

II Method

1) Study Area

Kherlen river basin in northeastern part of Mongolia, and its surrounding regions have been selected as the observation target. The basin has the area of 122,500 km2 (total area in Mongolia), 71500 km2 (upriver part of Choybalsan) or 39400 km2 (upriver part of Undorhaan). Khelren River has its headwater source at Henty mountain in the northeast of Ulaanbaatar and runs eastward through moderately hilly plane.

2) Observation Stations

Within Kherlen river basin, two flux stations, four automatic weather stations (AWSs), two GPS stations, two hillslope observation sites have been set up (Figure 1). Most of the stations have been in operation since March of 2003. In addition, an intensive observations were carried out in the following schedule (1) 6/13-29, (2) 7/16-8/1, (3) 8/18- 9/1, (4) 9/25-10/12 to make special measurements (e.g., leaf area index, multi-spectral radiance data, etc.) that are not available from routine observations by AWSs and flux stations.

3) Aircraft Observations

In addition to the surface observations, special observation by means of MIAT aircraft AN-2 was carried out. The sensors and equipment for the special observations on board include (1)

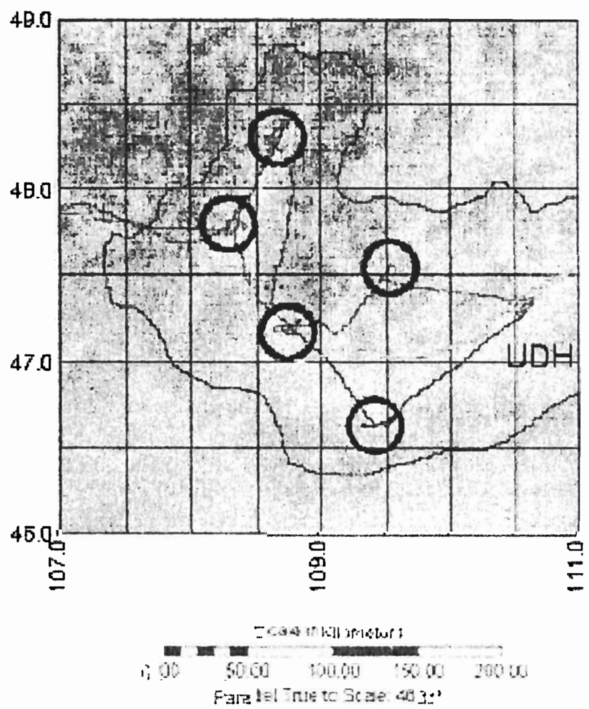

Figure 2 Flight pattern by AN-2 aircraft

turbulence sensors of humidity and temperature, (2) a multi spectral radiometer, (3) an infrared radiometer, (4) an air sampling device, (5) digital video camera. A GPS system allowed a determination of the exact position. Figure 2 indicates typical flight pattern during the observations. From June 17 through October 4, a total of 11 flights with total flight hours of 66 was carried out.

III Results

Based on the analysis of the observed results, some interesting findings have emerged. Details will be presented as a separate paper in this workshop and other publications, but briefly, the following list hight some of the results.

1) Surface and Ground Water Hydrology

- Water of the Khelren river originated from precipitation mainly at upper part of the watershed.
- River water flows Khelren river with only a limited water exchange between groundwater. The horizontal extent of such region is limited within 101 km scale from the river. In these areas there is a flow from groundwater to river. At the same time river loses water through evaporation. Net result is more or less same discharge from upper stream to downstream.
- Shallow groundwater is mostly circulated within a relatively small local watershed. As a result, continued aridity and/or extensive use of well water would result in loss of well water.
- Watershed under grazing pressure produced more sediment output as a result of active erosion.

2) Atmosphere-surface Interaction

- There is a distinctive difference of the interaction features between the larch forest in upper watershed and the steppe grassland, although the general seasonal trend is essentially the same with active fluxes observed in vegetation season and dormant flux rest of the seasons.
- In general fluxes are larger in forested area, with annual evaporation 225 mm in forest and 163 mm in grassland. Similarly, CO2 fluxes amount to 164 g/m2 at forest and 40 g/m2 at grassland
- At forest evaporative fluxes are essentially controlled by the amount of foliage. i.e., leaf area index, while in grasslands soil moisture play more dominant role. This is because the LAI of the grass land is generally very small (<1.0) and thus soil evaporation is more important.
- The amount of transpiration that constitute the total evapotranspiration has been determined by means of the Keeling plots as 60-70% at forest while 30-60% at grassland.
- At grassland amount of biomass is highly influenced by grazing activity although the primary factor appearsto be precipitation in spring.
- LAI is variable within the watershed both in time and space.
- The mixed layer variance methods have been improved by inclusion of such parameters as advection, Colioris effect, etc. The methods were applied to estimate area averaged fluxes with the data obtained by an aircraft.
- Satellite data together with linear energy balance model produced evaporation map of the watershed.
- Scintillometer produced fluxes averaged around 500 m horizontal scale.
- Mixed layer variance methods by means of

3) Soil and Plant Ecology

- Difference of the amount of precipitation produced different level of Ca layer within the soil profiles, with deeper level in northern watershed with more precipitation.
- In general surface soil has smaller permeability due to higher solid ratio and smaller amount of C within humus.
- There is a clear difference in the soil profiles between natural area and abandoned cultivated area even after some 30 years.
- Protected area of the size of 200 by 170 m yielded different surface features as well as resulting fluxes. After one year, LAI and above-ground biomass become somewhat larger than outside the fence, the amount of litter is clearly different, and the belowground biomass doe not show significant difference. In the second year, the difference becomes more pronounced with the LAI inside about twice than that outside. As a result, evaporation and sensible heat flux became larger inside. This was not because of net radiation but because of decreased soil heat fluxes.
- The net ecosystem production (NEP) is larger with C3 plants than C4 with clear increase after the rainfall. Diurnally, NEP decreases in the afternoon due to the decrease of the C3 plants NEP.

- Soil respiration depends not only the soil temperature but also soil water content.

4) Meteorology and Climatology

- Regional climate model has shown that the aridity in the northern part of Tibet and surroundings is caused by the heating effect of the Tibet plateau which produces downward atmospheric movement in the north.

- The amount of precipitation and NDVI is correlated well in some areas and it appears that some parameters such as temperature and precipitation in the earlier seasons can be used to predict amount of grass of the later part of the same year.

- There is a "break" in Mongolian rainy season.

IV Future Prediction

Currently, a possibility to make future predictions by means of three RAISE models is being investigated. The approach includes the evaluation of the difference between the averages of the current 10-year simulation and those of future 10-year simulation. This will be carried out for regional climatology, hydrology and ecosystem modeling. At this point, a 10-year regional climate around 2003 has been created and some of the future simulation have also been completed. The result will be presented by Sato (2005) in this symposium. The current reanalysis product of the regional climate model has been used as inputs to the hydrologic model. Kamimera and Lu (2005) will discuss this topic in this symposium. For ecosystem model, the outputs of regional climate model have been found problem as it is very sensitive to the amount of precipitation and the climate model appear to produce precipitation that is slightly too large. Thus at the moment inputs from NCEP/NCAR reanalysis data are used for the ecosystem modeling. This will be presented by hen et al. (2005) in this symposium.

V. Concluding Remarks

The scientific findings from the RAISE project are currently being put together as a special issue of Journal of Hydrology. If everything goes well, publication is expected sometime in year 2006. In the appendix, a list of proposed paper for this special issue is attached for references.

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3) Asanuma, J. and Li, S-G.:Multiresolusion analysis of surface heat, water, and carbon dioxide over a grassland and forest in Mongolia

(4) Sugita, M, Kojima, S, and Kotani, A.: A concise functional relation between soil moisture and evaporation.

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(6) Mariko, S. Urano, T. Sugita, M., Kawada, K., Lee G., and Oikawa, T.: Temporal variability of CO2 emission and CH4 uptake in grazed and ungrazed soils in a Mongolian grassland

(7) Asanuma, J.: Temperature variance budget over Mongolian grassland using laser scintillation techniques

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(10) Matsushima, D., Matsuura, Y., Byambakhuu, I., and Adyasuren, Ts. : An estimation of spatial distribution of evapotranspiration over Kherlen River Basin using a combination of satellite data and a heat budget model

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(23) Tanaka, Y., Kato, H., Onda, Y., Nishikawa, T., Tsujimura, M., Davaa G., and Oyunbaatar, D. : Difference in runoff process between steppe and forest-steppe sites in Mongolia

(24) Adachi, S. and Kimura, F.: The generation of the dust storm and transport process of particles in northeastern Asia