Drought Studies in Kazakhstan:
Response of Plant Growth to Surface Water Balance

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Abstract

In mid-latitude semiarid grasslands, water is the primary factor limiting plant growth. Water resources for plant growth in the grasslands of central Asia comprise snowmelt water in the spring and rainfall during the growing season. The Kazakhstan steppe is well-known as one of the largest granaries in the Eurasian continent. Soil (Chernozem) in this region is fertile, and has the potential to produce high-yielding crops. However, since the hydro-climatic conditions in the region are generally severe due to low levels of precipitation and frequent drought, water deficit is a major abiotic stress impacting on plants in this region. Therefore, crops are cultivated using not only rainfall during the growing season, but also spring snowmelt water. In the central Asian semiarid region, snow has melted entirely by early to mid-April, and the effect of snowmelt water on soil moisture can be clearly observed during May. This coincides with the period when evapotranspiration exceeds precipitation due to the wet soil conditions. The seasonal nature of water availability means that the dominant crop and natural grass species in the region have similar patterns of water use and limitations on their growth. In particular, droughts have severe negative effects, not only on immediate plant production, but also on interannual yield. Thus, the changes in plant growth, water use and limitations on plant growth that occur in the central Asian steppe on a seasonal and annual basis need to be clarified based on both in-situ and experimental observations. In order to evaluate the impact of hydro-climatic conditions on local surface energy balance and plant growth on a seasonal time scale, several measurements of surface energy and water balance components and plant biomass have been conducted at a natural grassland in northern Kazakhstan. In this presentation, we describe the changes in evapotranspiration and biomass, focusing on seasonal variations in the surface heat balance and soil moisture deficit.

Drought Studies in Mongolia: Pasture Monitoring Indices

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Abstract

Droughts have become widespread in the Northern Hemisphere, including Asia, notably in Mongolia. Mongolia has a cold and arid climate that creates an extensive area of pastureland and approximately 40% of the rural population derive their livelihood from climate-dependent pastoralism. Drought is the key factor driving livestock dynamics and human subsistence in the country; it has caused a significant amount of damage to the economy and society. Furthermore, the increasing drought frequency has led to problems in the farming of livestock and pasturing, and it may accelerate pasture desertification and threaten nomadic pastoralism, therefore understanding drought processes are of particular concern. A number of drought indices such as Dryness index (Ped), Palmer drought severity index (PDSI), standardized precipitation index (SPI) have been used to measure drought processes in Mongolia. The Ped index was the commonly used index for drought assessments in the country; however, it is based only on air temperature and precipitation. On the other hand, less attention has been given to detect agricultural (pasture) drought and its monitoring index regardless of its negative impact on the country. Determining an appropriate and user friendly index that reflects the direct impact of drought on the pastureland is crucial in the country. Soil moisture is a good candidate for drought index, reflecting recent precipitation and antecedent conditions and indicating agricultural potential and available water storage. In this study, drought analyses based on simulated soil moisture (W_m) derived from simple water balance model, which was developed for application in the cold, arid regions such as Mongolia, by considering soil freezing and snow melting, was discussed. The model performance was validated using long-term soil moisture observations (W_o), and its efficiency was evaluated with the performance of widely used PDSI and Ped indices. W_m was more strongly correlated with W_o ($r = 0.91$, $p < 0.05$) than PDSI ($r = 0.65$, $p < 0.05$) and Ped ($r = 0.81$, $p < 0.05$) indices. Drought defined when W_m values (percentiles) fall continuously below a threshold value in time over a contiguous area. During the last multi-decades, drought has been found increased over the country. It was significantly ($p < 0.05$) increased particularly after 1995, in conjunction with a significant decreasing trend in P and an increasing trend in potential evapotranspiration and resultant decrease in pasture vegetation. Interannual anomalies of W_m and vegetation due to P during a given summer are maintained through the freezing winter months to the following spring, and acting as an initial condition for subsequent summer land-surface. In the interannual basis; the vegetation activity is primarily controlled by the current year soil moisture and slightly affected by underground structures stored in the root system. This concept of soil moisture and root memories would provide practical information that can be used as an early warning system for the pasture production. In terms of applications, the present model is a useful tool for a reliable and timely monitoring of pasture drought, thereby providing valuable information for decision-makers and herders in the country.

Drought Studies in China

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Abstract

Drought is the greatest threat to agricultural production in China. Chinese agricultural production is a crucial issue not only for China but also for the world. Therefore, studies on agricultural droughts have been promoted in many academic fields. Chinese drought studies are mainly classified based on four aspects: (1) drought history, (2) drought index, (3) drought monitoring system, and (4) drought mitigation. Previous research shows that the spatiotemporal pattern of drought disasters from 1949 to 2000 differs between the east and west of China. These papers also show that heavy disaster areas mainly lie in the north, especially to the west of Heilongjiang, the center of Inner Mongolia, and the north of Hebei, Shaanxi, and Ningxia, and that in the south of the country, drought disaster areas mainly lie in five provinces (Anhui, Hubei, Hunan, Jiangxi, and Henan), Guizhou, the east of Sichuan, and the east-central Yunnan. The distribution of drought disasters in China tends to extend toward the west. The number of drought disasters to the north of Changjiang River has been increasing, while those in the south have generally been decreasing. Regarding studies on agricultural drought index in China, various methods and indices are used in evaluating rainfall, soil moisture, crop drought, crop water requirement, and their combination. The shortage of water stored in various reservoirs is expected to help provide a more precise index. As for the drought monitoring system, the current remote sensing approaches to drought monitoring in China adopt several methods for effective drought monitoring of large land areas, including thermal inertia, evapotranspiration, and the vegetation index. To mitigate the impact of drought, China has implemented irrigation, water-saving measures, and migration regulations.

Satellite Monitoring of Drought in Central Asia and North America: Focus on Surface Temperature Indices

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Abstract

Central Asia and North America as part of arid regions that characterized by coupled cold and arid climate. Over these regions drought occurs on an average of once every two or three years. The drought dynamics in an arid, cold climate are unique in that the large amplitude of seasonal cycle in climate/vegetation and the soil freezing/snowpack during a cold winter profoundly affect the persistence of drought. Satellite data are widely used to monitor vegetation cover and drought episode throughout the world. Normalized difference vegetation index (NDVI), which provides a general measure of the state and health of vegetation, is one of the first remote sensing-based indicators used for drought detection and monitoring. Beside the conventional NDVI index Land Surface Temperature (LST) derived from thermal infrared (TIR) information serves as a proxy for assessing evapotranspiration, vegetation water stress, soil moisture, and thermal inertia. A large number of vegetation health and drought indices are based on the LST-NDVI space. Because droughts occur mostly in low latitudes, several vegetation health and drought indices were developed rely on the existence of a negative slope between the two variables (LST/NDVI). In low latitude areas, water is ultimately the limiting factor for vegetation growth throughout the year, making this assumption correct. Research carried over Gobi desert and Desert Steppe regions of central Asia points out that the correlations between LST and NDVI vary throughout the dryness zones. For arid zone, characterized by negative relations of the LST and NDVI, while for other dryness zone (Semi-Arid, Sub-Humid, and Humid), a relations of LST and NDVI are positive and increases from semi-arid (low latitude) to humid zone (high latitude).For North American continent (up to 60o N) previous research indicates that during the summer growing season (April-September) when water is the limiting factor for vegetation growth (the typical situation of low latitudes of North American content and during the midseason), the LST-NDVI correlation is negative. However, when energy is limiting factor for vegetation growth, as the case at higher latitudes and elevation, positive correlation exists between LST and NDVI. It is concluded that there is a need to use empirical LST-NDVI relationships with caution and to restrict their application to drought monitoring to areas and periods where negative correlations are observed, namely, to conditions when water-not energy- is the primary factor limiting vegetation growth. This review will examine available literature and new data from field and modeling studies to evaluate performances of drought indices for further utilization of this information.

Drought Early Warning System in Asia: A Case of Mongolia

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Abstract

In countries where dryland farming is part of large-scale commercial agricultural systems, i.e. Australia, South Africa and USA, drought disaster management has been developed for decades. Meanwhile, Asian countries, e.g. India and China, produce food in small-scale subsistence/commercial farming systems, and their food security is not as high as that of the large-scale farming countries. Drought is one of the most influential factors on the small-scale farming countries, so those countries need to develop an operational system for drought management, i.e. drought early warning system (DEWS), to improve agricultural productivity. The DEWS consists of (i) monitoring (nowcast) of crop status, (ii) forecast of crop yield and (iii) issue of drought warning. Recent satellite remote sensing technology allows us to monitor crop status during the growing season, and seasonal rainfall outlook is linked to yield forecasting. Farmers in most Asian countries make their livelihoods by carrying on crop-based/crop-livestock-mixed farming, while Mongolia is mainly pastoral with a long history of livestock grazing. For Mongolian nomads, grassland (steppe) is the most important natural resource, and its productivity highly depends on precipitation. Their interest is therefore information on feed availability (plant biomass production) from season-to-season. For example, when severe drought occurs, where should the nomads take their livestock for grazing? How much summer pasture production do the nomads need to leave for winter feeding? Moreover, the pasture production changes from year-to-year in association with inter-annual rainfall variability. How do we estimate grazing capacity? Is it based on long-term average pasture production? How about the quality of vegetation in overgrazed grassland? These questions need to be answered to improve the current DEWS for livestock management in Mongolia.

Future Projection of Drought in Central Asia

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Abstract

The 2007 Intergovernmental Panel on Climate Change report (IPCC AR4) stated that in many regions extreme climate events are becoming increasingly frequent and that this trend will continue. However, there is significant regional difference and it depends on which kind of (e.g., climatic, agricultural or hydrological) drought is the target. The presentation will start with looking at the trends in the recent past, which is helpful for estimating future risk. The previous studies revealed that in major part of the study area (i.e., China, Mongolia and Kazakhstan) precipitation does not have significant trend but because of increasing temperature the aridity has been intensified. It was also presented that the frequency of droughts in eastern China has slightly increased recently, but in 15-16th centuries they had a similar level of drought frequency to that of present day. For future, the IPCC AR4 presented that ensemble mean of climate models projected increasing precipitation and evaporation in the study area except the western part of Kazakhstan, while soil moisture will increase in Kazakhstan and West China but will decrease in Mongolia and East China. With these backgrounds, we are now studying future drought risk, with special focus on the social impact, in Mongolia using process models. We have revealed that in an earth system model (a climate model coupled with ecosystem models) in most of 21st century vegetation activity is enhanced by increasing temperature and precipitation, but in the end of the century the temperature will excess the optimum value for photosynthesis and will constrain the vegetation activity in the south part of Mongolia, inducing severe droughts. We also have a future plan to study whether the result is robust for other models, as there is large inter-model uncertainty among the climatic and vegetation models.