A summary of doctoral dissertation

Laboratory of Forest Hydrology and Disaster Mitigation Sciences
Department of Biosphere Resources Sciences
Division of Regional Resources Management
Graduate School of Bioagricultural Sciences
Nagoya University

Wang Lusha

Title: Assessment of drought in Inner Mongolia based on remote sensing drought severity index and its improvement

Inner Mongolia is an autonomous region located on the southern Mongolian Plateau in northern China, which presents a diverse ecosystem environment including forest, grassland, desert, etc. Most of Inner Mongolia belong to arid and semi-arid areas, with little and unevenly-distributed precipitation, hence drought is the major natural disaster. The traditional industries of Inner Mongolia are agriculture and cattle breeding, and drought directly undermines agriculture and animal husbandry. To characterise the status of drought, various types of drought indexes have been proposed and tested. The Remotely Sensed Drought Severity Index (DSI), which integrated the operational MOD16 ET/PET (ratio of evapotranspiration to potential evapotranspiration) and MODIS NDVI (the Normalized Difference Vegetation Index) were selected to assess the drought situation of Inner Mongolia, as satellites have been recognised as an excellent means for drought monitoring. In this thesis, at first the Remote Sensing DSI was used to evaluate drought in Inner Mongolia in the growing season (May-September) from 2001 to 2010, and then the deficiencies of DSI was found, and more suitable improvements were made. Evaluation of the drought situation in Inner Mongolia through DSI and its improved index, as a past drought monitoring experience, plays an early warning role in the future drought monitoring of agricultural and animal husbandry in Inner Mongolia.

In Chapter 2, DSI was applied to evaluate the monthly drought situation in the growing season in Inner Mongolia during the 10 years. Because the soil moisture as an important drought measure has not been used in the calculation of DSI, the relationship between DSI and soil moisture was investigated with correlation coefficient and regression analysis. The soil moisture data of the

Global Land Data Assimilation System (GLDAS) coupled with Noah model was used in this chapter. The depth of soil moisture were 0-10 cm and 10-40 cm. Using DSI to examine the drought in the growing season of 10 years, different seasonal and spatial patterns of drought occurrence were found in the notable drought years of 2001, 2007, and 2009. The largest correlations between DSI and soil moisture were attributed to the links between evapotranspiration and soil moisture. The spatial distribution of the correlation coefficients between DSI and soil moisture varied seasonally, tracking closely with the movement of rainfall belt. DSI could not reflect the variation of soil moisture in woodland. In grassland, DSI correlated with surface soil moisture in the east at the beginning of the growing season. As the rainfall belt expands to the west in the second half of the growing season, DSI reflected apparently deeper soil moisture conditions because of the spatial difference of soil properties, that is, the water-holding capacity becomes larger from west to east. However, evapotranspiration and NDVI are not independent of each other, and the drought situation will be repeatedly superimposed and become difficult to assess.

In Chapter 3, the ET/PET item was replaced with soil moisture (0-10 cm) to establish a new improved DSI drought index (IDSI). Using monthly IDSI data during the same period as DSI to re-assess the drought conditions in Inner Mongolia, then clarified the relationship between the new IDSI and precipitation. Precipitation data is obtained from a gridded daily precipitation dataset, compiled by the Asian Precipitation - Highly Resolved Observational Data Integration Towards Evaluation (APHRODITE). In IDSI, the two items are independently derived, and the effects of evapotranspiration are still contained in the soil moisture, even the changes of precipitation could be reflected. The confidence interval estimation analysis to determine the interval of the IDSI and also got 11 classification intervals. IDSI also pointed out that 2001, 2007, and 2009 were drought-significant years. The areas for extreme droughts were less than those assessed by DSI because the ET/PET item, which contains the effects of NDVI, were removed. The Z_{NDVI} (the normalised values of NDVI) and Z_{SM} (the normalised values of soil moisture) in IDSI have the same contribution to IDSI at all times. IDSI not only contained the degree of change of precipitation in the current month through soil moisture but also reflected the influence of water and heat in the previous month through NDVI. IDSI had better applicability except for the west grassland areas and areas without vegetation and was generally consistent with agricultural drought disaster records.

In Chapter 4, it could be considered that if the depth of the soil is changed, IDSI's evaluation of the drought situation will also change accordingly, the improved drought severity index with different depth of soil layer (0-40 cm, IDSI-D) was applied to evaluate the drought situation in Inner Mongolia. Compared the results with IDSI, the dry and wet condition classification of IDSI-D by the confidence interval estimation analysis was almost not different from IDSI. The Z_{NDVI} and Z_{SM} in IDSI-D also had the same level contribution to IDSI-D at all times. The drought

conditions of the regions from central to west characterized by IDSI-D were quite different from IDSI in May and June of the early growing season because of smaller fluctuation of soil moisture and seasonal lag in precipitation.

From the above results, for the drought in the growing season of Inner Mongolia from 2001 to 2010, comparing the DSI, IDSI, and IDSI-D, it is more appropriate to choose IDSI to guidance for agriculture and animal husbandry. The suitable points for IDSI to evaluate the drought situation are the follows: (1) The soil moisture and NDVI terms in IDSI are independent of each other. (2) IDSI can reflect the change of precipitation in each month of the growing season, which was also not included in DSI, and the change of precipitation is an important indicator in the record of drought disasters in China. (3) IDSI is robust for drought situations in grassland areas, in which plant growth is more sensitive to water and heat than woodlands.

The points to be noted when using IDSI to evaluate the drought is applicability for areas close to the west. (1) The closer to the west of Inner Mongolia, vegetation has decreased, rocky deserts have increased, so the NDVI value is small, the change of NDVI is not significant, and the Z value (the normalised value) will change greatly. Therefore the Z_{NDVI} needs to be examined carefully. (2) Since the soil moisture fluctuation in the west is small, the standardized value, Z_{SM} will fluctuate greatly, and there is a possibility of excessively reflecting the drought situation. It can also be considered that the accuracy of GLDAS soil moisture data in the west is not enough. (3) There are few agricultural and animal husbandry activities in the west, and it is difficult to compare the drought conditions represented by the drought index with the agricultural and animal husbandry data. In addition, it should also be noted that IDSI contains the water and heat effects of the current month and the previous month. When their values are opposite to each other, there may be drought situation that cannot be correctly reflected by IDSI. Under such circumstances, it may be necessary to change the month-scale to short-scale. When investigating drought conditions on a month-scale, IDSI may consider more suitable for continuous monthly drought.

Through this thesis on the drought assessment of the growing season in Inner Mongolia from 2001 to 2010, it was found that soil moisture was very important for drought monitoring in Inner Mongolia. The drought index containing soil moisture did not only include the effects of precipitation and evapotranspiration but also fully reflected the regional drought characteristics of Inner Mongolia. Therefore, the IDSI with shallow soil moisture (0-10 cm) is the most suitable for evaluating the drought conditions in Inner Mongolia, especially for the grasslands from the central to the east.