# DROUGHT MONITORING AND ASSESSMENT USING MULTI SATELLITE DATA IN MONGOLIA

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**ABSTRACT:** In this paper have included some remote sensing based drought indices estimating drought situation over Mongolian pasture land.

The Remote Sensing Drought Index (RSDI) was developed based on 10 daily long term global coverage of NOAA/NDVI 8km coarse resolution data and Climatic Moisture and Evapotranspiration Drought Indices (EDI) based on FY-2 geostationary satellite data were applied in Mongolia.

The processed MODIS products as Normalized Difference Vegetation and Water Indices (NDVI, NDWI) can be used to indicate deficiencies in rainfall and portray meteorological and/or agricultural drought patterns both timely and spatially, thus serving as an indicators of regional drought patterns. NDWI holds considerable potential for drought monitoring because the two spectral bands (NIR and SWIR) used in its calculation are responsive to changes in the water content and inter-cellular air spaces of the spongy mesophyll layer of leaves in the vegetation canopy.

A new vegetation drought indicator, the Normalized Difference Drought Index (NDDI), is combines information from both the NDWI and NDVI data derived from MODIS data and NDDI was found to be more responsive and have wider dynamic range values than a simple NDVI-NDWI differencing through drought periods.
According to the NDDI categories many countries use these values as, extremely wet, very wet, moderately wet, slightly wet, wet, normal, dry, mild drought, moderate drought, severe drought and extreme drought.

**KEY WORDS:** drought monitoring, RSDI, NDWI, NDDI, EDI.

## INTRODUCTION

Drought is the single most important weather-related natural disaster. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply.

Satellite data processed into Normalized Difference Vegetation Indices (NDVI) can be used to indicate deficiencies in rainfall and portray meteorological and/or agricultural drought patterns both timely and spatially, thus serving as an indicator of regional drought patterns. NDVI is a measure or estimate of the amount of radiation being absorbed by plants.

Unlike earthquake, drought always has a slow onset, which is quite observable, but its consequences are quite immeasurable for Mongolia during coming harsh winter "dzud" condition. Recent droughts in Mongolia, resulting economic and environmental impacts and personal hardships have underscored the vulnerability of all societies to this "natural" hazard.

Many drought indices have been used over the globe to monitor drought and in case of Mongolia the drought estimation indices have been developed and applied. For example, the Remote Sensing Drought Index (RSDI, 2005) based on long term NOAA/NDVI data and Normalized Difference Drought Index (NDDI) based on MODIS/NDVI and NDWI data being used for estimation drought condition in Mongolia.

**STUDY AREA**

While the satellites are covering whole territory of Mongolia, there are needs to monitor over all Mongolia and estimating and mapping drought condition and informing the facts to the Ministry of Nature Environment and Tourism, National Agency of Emergency Management (NEMA) and other related organizations and to the aimags.
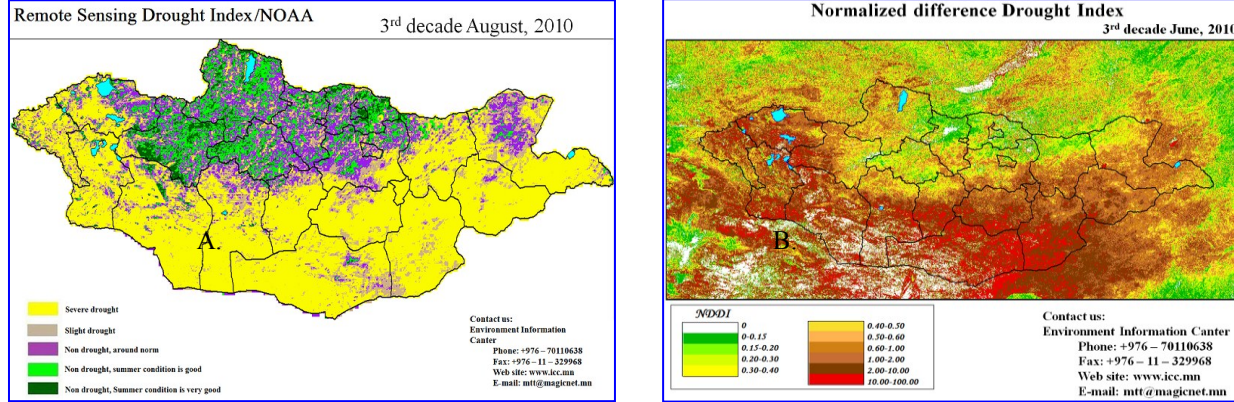


Figure 1. RSDI (A) and NDDI (B) maps of Mongolia

**USED DATA and METHODS**

The drought estimation methodology using long term NOAA – NDVI data was developed in 2005 (M.Bayasgalan, 2005) and this technology was upgraded and applied by MODIS data.
Each TERRA and AQUA satellites with MODIS sensor are covering Mongolian territory 2 times a day. The MODIS sensor has 36 channels with 250m, 500m and 1 km spatial resolution and generates some standard products such as, cloud mask, NDVI, snow and fire hot spot. The drought products are generated based on NDVI and NDWI.
The FY-2 geostationary satellite data was used for drought monitoring system based on Climatic Moisture and Evapotranspiration Drought Indices (EDI).

**Normalized Difference Vegetation Index (NDVI)**

The NDVI formula in particular was originally termed the VI (Vegetation Index) and devised by Rouse et al. in 1973 and applied to Landsat MSS data (Tucker 1979).

$$\text{NDVI} = (\text{NIR - RED}) / (\text{NIR + RED}) \qquad (1)$$

The intensity or digital number (DN) value, of each visible red band is subtracted from the infrared band on a pixel-by-pixel basis. That value is then divided by the sum of the two. The result of NDVI is a theme consisting of continuous floating-point data that ranges from -1 to 1. Floating point data includes decimal and negative values.
In the case of AVHRR and MODIS data, the Near Infrared Layer is Band 2 and the Visible Red Layer is Band 1 (AVHRR & MODIS). The near infrared band of the spectrum emphasizes the contrast between vegetation and water. In the Visible Red Layer, vegetation appears darker than man-made structures.

**Remote Sensing Drought Index (RSDI) based on NOAA/NDVI data**

The Remote Sensing Drought Index (RSDI) was developed based on 10 daily long term global coverage of NOAA/NDVI (M.Bayasgalan, 2005) 8km coarse resolution data and applied for Mongolia.

$$\text{RSDI} = (\text{NDVI}_{cur} - \text{NDVI}_{min}) / (\text{NDVI}_{max} - \text{NDVI}_{min}) \qquad (2)$$

Here,   $\text{NDVI}_{cur}$ – current 10 daily NDVI image
        $\text{NDVI}_{min}$ – long term minimum NDVI image
        $\text{NDVI}_{max}$ – long term maximum NDVI image

**Normalized Difference Water Index (NDWI) and Normalized Difference Drought Index (NDDI) based on MODIS/NDVI data**

The Normalized Difference Water Index (NDWI), which is calculated from the 500 meter near-infrared (NIR) and shortwave-infrared (SWIR) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) (Equation 3), is being investigated for large-area drought monitoring.

$$NDWI = \frac{\rho_{NIR} - \rho_{SWIR}}{\rho_{NIR} + \rho_{SWIR}} \qquad (3)$$

NDWI holds considerable potential for drought monitoring because the two spectral bands used in its calculation are responsive to changes in the water content (SWIR band) and inter-cellular air spaces of the spongy mesophyll layer of leaves in the vegetation canopy. As a result, NDWI is influenced by both the desiccation and wilting of vegetation and may be a more sensitive drought indicator than traditional remote sensing-based indices such as the Normalized Difference Vegetation Index (NDVI), which do not account for changes in the vegetation's water content.

A new vegetation drought indicator, the Normalized Difference Drought Index (NDDI), is also being researched. The NDDI combines information from both the NDWI and NDVI data derived from MODIS as shown in equation 4.

$$NDDI = \frac{NDVI - NDWI}{NDVI + NDWI} \qquad (4)$$

Initial research investigated the potential of the NDDI, NDWI, and NDVI for drought monitoring over the Flint Hills region in eastern Kansas and northeast Oklahoma and the results were encouraging. NDWI was found to be more sensitive that NDVI to the onset of drought conditions. NDDI was also found to be more responsive and have wider dynamic range values than a simple NDVI-NDWI differencing through drought periods.

**Climatic Moisture and Evapotranspiration Drought Indices (EDI) based on FY-2 satellite data**

The Energy, Water Balances Monitoring System (EWBMS) consists of a set of software programs that comprises three steps, which have to be followed sequentially to obtain information on winter grazing conditions, drought indices and pasture yield forecast. The EWBMS software needs two primary input products: specially prepared FY-2C satellite images and GTS (Global Telecommunication System) rainfall data.

The EWBMS provides hourly cloud duration, rainfall, radiation, sensible heat flux and actual evapotranspiration data for whole Mongolia at 5 km spatial resolution and using those basic products running Drought monitoring system, Pasture monitoring system and Winter grazing condition monitoring system to monitor both summer and winter condition in order to prevent the natural disasters such as, drought and dzud.

**The Drought Monitoring System** is capable of calculating three desertification indices as, the climatic moisture index (CMI) indicates a climatic condition, the soil moisture index (SMI) characterizes the actual drought or desertification status the Evapotranspiration Drought Index (EDI) defines the agricultural drought and on a pixel by pixel basis.
CMI-Climatic Drought Indicator (1 YEAR)

$$\textbf{CMI=P/LE}_{pot} \qquad (5)$$
where,

      P:     precipitation, $LE_{pot}$ : potential evapotranspiration

SMI- Ecological Drought Indicator (1 YEAR)

$$\textbf{SMI = LE/LE}_{pot} \qquad (6)$$
where,

      LE :    Evapotranspiration, $LE_{pot}$ : potential evapotranspiration

The amount of water that is available to the vegetation is also quantified in terms of plant available water (PAW in mm), here defined as soil moisture (SM) minus wilting level (WP):
$$\textbf{PAW = SM – WP} \qquad (7)$$

The wilting point or wilting level is the amount of water left in the soil that cannot be taken up by the roots of vegetation due to strong capillary forces of the soil matrix. We assume the soil moisture content never exceeds field capacity.

EDI-Agricultural Drought Indicator (2 monthly)

$$EDI = \Sigma \ (LE/LE_{pot})/ \ n \qquad\qquad (8)$$

where,

LE : Evapotranspiration, LEpot : potential Evapotranspiration, n : time period (2 months)

## RESULTS AND DISCUSSIONS

The RSDI maps were calculated and the values ranged between -1 to +1 and the values are classified in 5 categories such as, < 0.2 – severe drought, 0.2 – 0.4 – slight drought, 0.4 – 0.6 – normal, 0.6 – 0.8 – non drought good and > 0.8 – non drought very good summering condition.
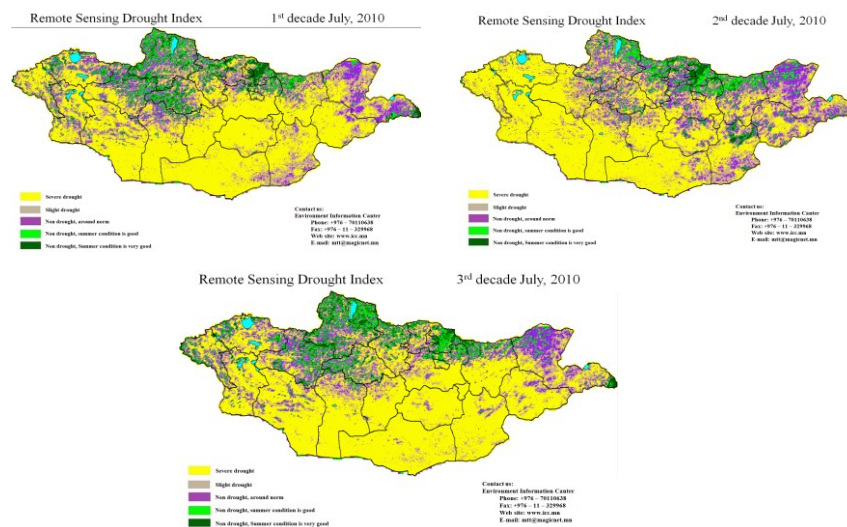


Figure 2. RSDI maps of Mongolia

Based on 10 daily RSDI maps we tried to generate yearly drought map for whole territory of Mongolia using remote sensing and GIS techniques.
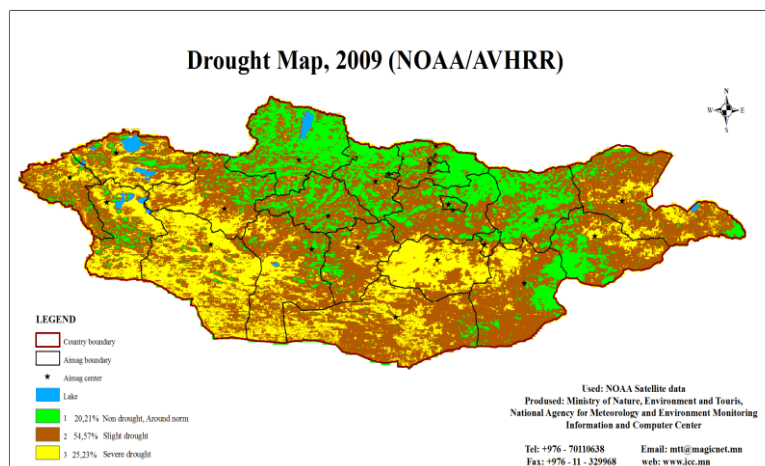


Figure 3. Yearly drought map of Mongolia, 2009

In 2009, during growing season the summer condition of Mongolia can be estimated as droughty or slightly drought condition in more than half territory (54.6%) and the severe drought condition counted as 25.2% and only 20.2 percentage of whole country was estimated as none drought condition.

The NDDI map can be generated 10 daily based on daily NDVI and NDWI images obtained from corresponding channels of MODIS data and its values are ranging between 0 to 100 and these values were classified into 10 categories and nowadays we are not giving legends for the map as using in many foreign countries.

According to the NDDI categories many countries use these values as, extremely wet, very wet, moderately wet, slightly wet, wet, normal, dry, mild drought, moderate drought, severe drought and extreme drought.
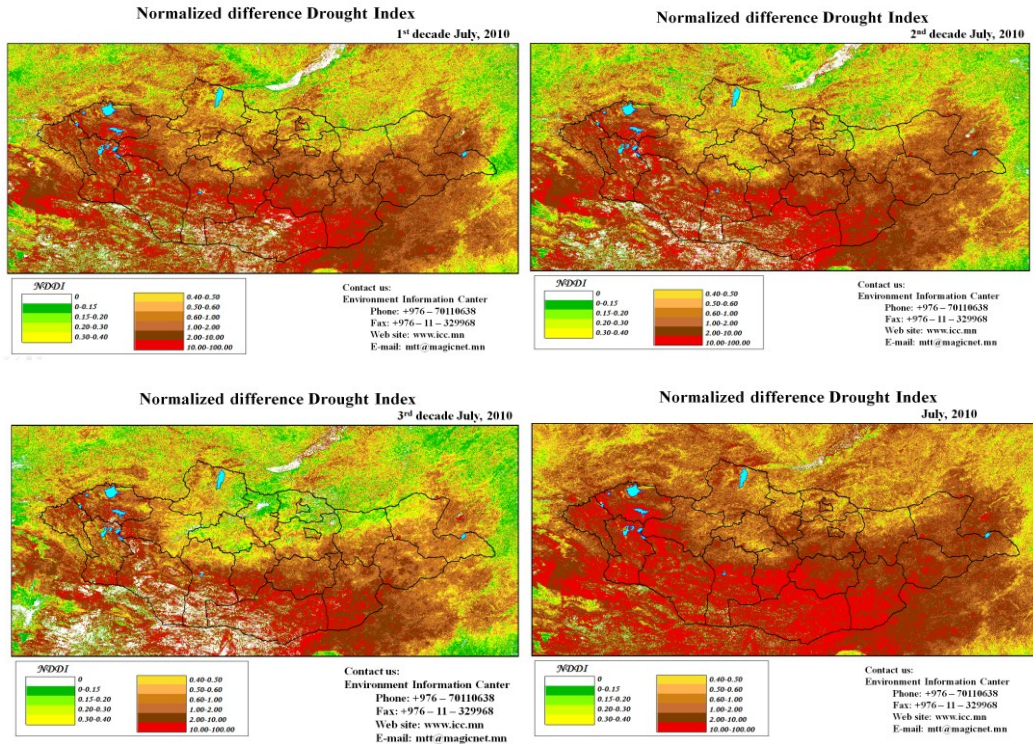


Figure 4. Three decades and monthly NDDI maps of Mongolia, July 2010

The CMI was adopted by UNCCD (1994) as an index defining climatic drought condition and process drought itself defined by the UNCCD that, "Drought is the regional stable precipitation deficite that cause hydrological inbalance due to long duration of abnormal dry weather".
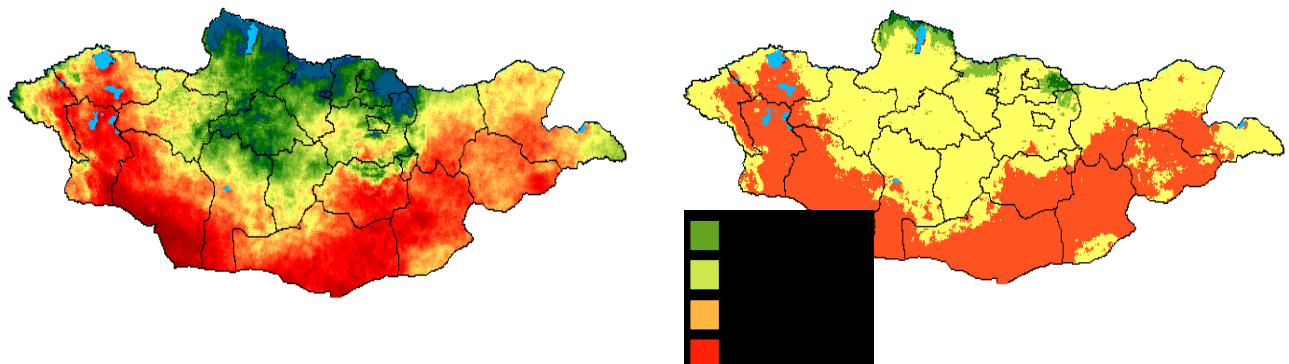
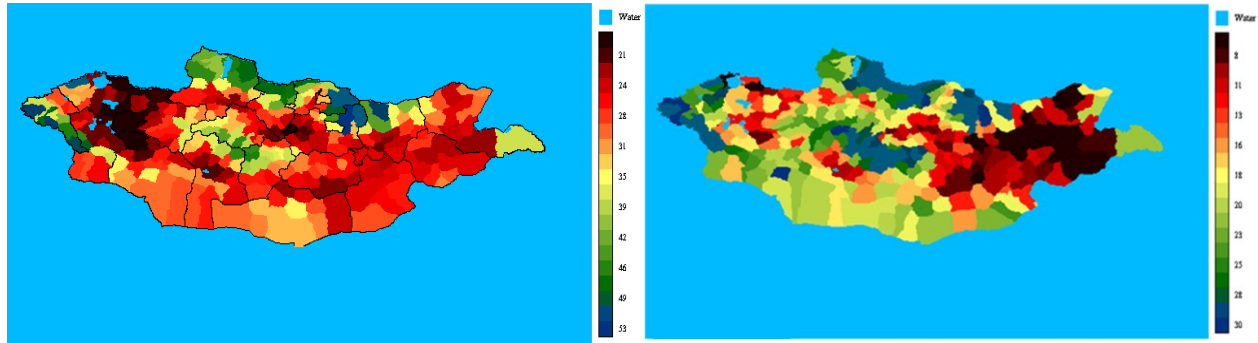

Figure 5. CMI and Aridity zone maps of Mongolia, 2007

Figure 6. SMI and EDI maps, July – August 2007

All above mentioned NOAA, MODIS and FY-2 satellite products are served through www.icc.mn websites 10 daily based and at the same time information of these products are included in metadatabase at http://geodata.mne-ngic.mn:8080/geonetwork/srv/en/main.home and in Disaster Information Service as part of National Environmental database of Mongolia is included at http://geodata.mne-ngic.mn/index_disaster.html websites.

**CONCLUSIONS**

1. Based on drought estimating experiences, the NRSC is willing to replace drought monitoring techniques with use of coarse resolution RSDI maps by moderate resolution MODIS NDVI data from 2000 to 2010 for calculation of long term minimum and maximum NDVI data.
2. The NDDI is considering not only changes of vegetation and also its water contents using SWIR, RED and NIR bands together.
3. The NDDI and EDI maps would be validated by ground measurements and need to be operationalized.

**REFERENCES**

1. "Application of Perpendicular Drought Indices as a Dynamic Drought Monitoring Method" Institute of Meteorology, University of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria.
2. Bayasgalan M. "Drought monitoring in Mongolia", Dissertation, UB 2005.
3. Huete A. and Didan K. "MODIS Seasonal and Inter-Annual Responses of Semiarid Ecosystems to Drought in the Southwest U.S.A" Department of Soil, Water and Environmental Science University of Arizona, U.S.A.
4. National Drought Mitigation Center (NDMC), USGS Center for EROS, USDA Risk Management Agency (RMA), and High Plains Regional Climate Center (HPRCC)
http://www.drought.unl.edu/vegdri/experimental.htm
5. Tucker C.J. Red and Photographic infrared linear combinations for monitoring vegetation. Remote sensing of Environment, 1979, Vol. 8, pp. 125-150.
6. Tucker C.J., Sellers P.J. Satellite remote sensing of primary production. Int. Journal of Remote Sensing, 1986, Vol. 7, pp. 1395-1416.
7. Verdin J., Aguilar L., Brown J., Pedreros D., Budde M., and Rowland J., "Application of Remote Sensing to Drought Monitoring".