Project on "Strengthening Mongolia's capacity to monitor and warn Drought/Dzud"

Review of Drought monitoring system in Mongolia

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17 September, 2018, Ulaanbaatar, IRIMHE

Outlines

- Purpose of study
- Drought monitoring system in Mongolia
- Cooperation with RADI
- Drought monitoring systems used at international level
- DroughtWatch system review and evaluation
- Recommendations for further improvements

Purpose of study

- The main purpose of this study is to analyze and evaluate drought monitoring system used at IRIMHE
- Review the DroughtWatch system developed focusing its operation, data processing, output product, report, statistical data and how it responds to users demand.
- Compare with similar systems used in other countries
- Make recommendations for further improvement of the existing system.

Works done

- Field trip reports
- Validation reports
- User manual of DroughtWatch
- Review of Drought monitoring/information systems used at global level and in other countries
- Review of DroughtWatch system comparing with similar systems
- Outline recommendations for further improvements
- Report in English and Mongolian

Drought information needs and availability

Users

- MET
- MOFALI
- River Basin Adminstrations
- Insurance companies
- NAMEM
- NEMA
- MoH
- MoE
- Researchers
- Local governors
- Public, herders

Drought distribution and intensity map – 1
Drought forecast and outlook - 4
Deficit of soil moisture - 1
Crop and pasture productivity losses -3
Plant species resistant to drought - 4
List of drought affected soums - 2
Drought starting ending date, duration - 2
Drought frequency map - 3

Data needed	Data providers	Data availability
Drought duration, ntensity and distribution map	DroughtWatch	Available after little calculation and processing
Drought forecast and outlook	NAMEM	Not available Need methodology
Hydrological drought real time data	IRIMHE	Not available Need methodology
Hydrological drought forecast	IRIMHE	Not available Need methodology
Drought impact data (water shortage, pasture/crop losses, affected area and persons)	NEMA, MOFALI, RBA	Available after little processing
Drought indicators(precipitation, temperature anomaly, soil moisture)	IRIMHE	Available after little calculation and processing
Drought frequency map	IRIMHE	Available after more complicated processing

Drought information needs

Drought data need to

- **Report at international and national level**
  - **List of soums affected by drought -> national statistical report**
  - **Drought map, size of area -> SoE**
  - **Drought frequency -> Convention Desertification combating and Climate change**

- **Evaluate conventions and programs implementation**

  - **Number of Drought affected persons -> SDG -2030**
  - **Size of drought affected area -> Convention Desertification combating and Climate change**

where drought parameter is used as indicator to report and evaluate .

Drought index based on Ground data

	Index name	Type of drought	Formula, input parameters	Advantage	Disadvantage	Citation, creators
1	Aridity Anomaly Index (AAI)	M(Meterological)	$AAI = \frac{AET-PET}{PET}$ x 100 P - Precipitation T- Temperate AET, PET real and potential evaporation	Simple On 7-14 days based	Not avialble for season and long term data	Iidia, 1968
2	Deciles of precipitation	M	Precipation range is divided with 10 intrebvals. 1-st group precipitation much below average, 5-6 gropu near average, 10 th group much more than average.	Easy to use Calculation at	Only precipitation is considered. Long term range of data is needed	Gibbs and Maher, 1967 Australia
3	Keetch–Byram Drought Index (KBDI)	M	$W = W_c\ e^{-l/t}$ W_c – moisture holding capacity l – duration to loss soil moisture , t - evapotranspiration duration, in days	Based on moisture deficiency		1960s by Keetch and Byram, USA

Application of Drought indices

- There are 38 indexes; of which 10 - for agricultural drought, 7 - for hydrological drought and the rest is used for meteorological drought.
- 28 indices of total 37 indices based precipitation, 14 indices use moisture and evaporation and 14 indices use temperature indicators. Temperature data is mainly used for calculating evaporation.
- 76% of the world's 50 countries or 33 countries use SPI, 44% use PI and 25% use PDSI.
- India, Russia, China and the United States are the countries that uses 5-9 types of indexes, the highest number of drought index.
- In Mongolia 6 indexes were used for research and 3 indexes such as PDSI, SPI, Pedi indexes were used for research and operational service.
- SPI, AI are available from DroughtWatch system

Drought indexes based on Remote sensing

Drought index	Formula	Inputs	Reference
Ratio Vegetation Index (RVI)	$RVI = \frac{NIR}{R}$	NIR, R –NIR, R сувар дахь ойц	Pearson and Miller (1972)
Crop Water Stress Index (CWSI)	$CWSI = 1 - \frac{PET}{AET}$	AET, PET , actual and potential evapotranspiration	Idsoetal.(1981); Jacksonetal.(1981)
Normalized Difference Infrared Index (NDII))	$NDII = \frac{R_{850} - R_{1650}}{R_{850} + R_{1650}}$	R_{850}, R_{1650} surface reflectance at 850 and 1650 nm	Hardiskyetal, 1983
Vegetation Supply Water Index (VSWI)-	VSWI = 100*NDVI/LST	LST – land syrface temperature NDVI – normalized vegetation index	(Carlson et al.,1990):
Standardized Vegetation Index (SVI)	SVI =(NDVIijk – NDVIij)/σij.	Mean and current value of NDVI σij - standard deviation of NDVI	[Petersetal., 2002; Parketal., 2008]:
Vegetation Condition Index (VCI)	$VCI = \frac{NDVI_i - NDVImin}{NDVI_{max} - NDVI_{min}} x\ 100$	NDVImaxandNDVImin=themaximumandminimumNDVIs,respectively,intherecordforthespecificmonth/week;NDVIjistheNDVIforthemonthunderstudy	Kogan, 1990
Temperature Condition Index (TCI)	$TCI = \frac{LST_{max} - LST_i}{LST_{max} - LST_{min}}$	LST - land surface temperature, maximum and minimum landsurface temperatures of pixel sinthestudy region LSTNDVIi=landsurface temperature of pixel.	Kogan, F.N., 1995
Vegetation Health Index (VHI)	$VHI = aVCI + (1 - a)TCI$		Kogan, F.N., 1990
Weighted Difference Vegetation Index (WDVI)	WDVI = NIR –μR	NIR, R – reflectance at NIR, R band μ = slope of the soilline	Qietal, 1994
Normalized Difference Water Index (NDWI)	$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$	NIR, SWIR – reflectance at NIR, SWIR band	Gao, 1996
Normalized Difference Drought Index (NDDI)	$NDDI = \frac{NDVI - NDWI}{NDVI + NDWI}$	NDVI- normalized vegetation index NDWI - Normalized Difference Water Index	Guetal., 2007
Anomaly of NDVI (ANDVI)	$ANDVI = NDVI_{i\_} - NDVI_{mean}$	$NDVI_i$, $NDVI_{mean}$ - current value and long term mean value of NDVI	Anyambaal, 2001
Simple Ratio Water Index (SRWI)	$SRWI = \frac{R_{858}}{R_{1240}}$	R_{858} = MODIS band 4(858.5nm) R_{1240} = MODIS band 5(1240nm).	Zarco-Tejada and Ustin, 2001

Application of remote sensing based Drought indices

- Totally 21 indexes have been developed by researchers and used around the world for drought.
- The VCI and VHI indexes are the most widely used index globally.
- In Mongolia, 9 indexes were used within the research study and 5 indexes are used for operational service.
- 6 indexes such as VCI, VHI, TCI, NDDI, NDWI,VSWI are provided by Drought Watch system

Cooperation with RADI

- Installed SatSee system
- Training
- Field trip
- Data validation
- Development of DroughtWatch system and running
- Capacity building

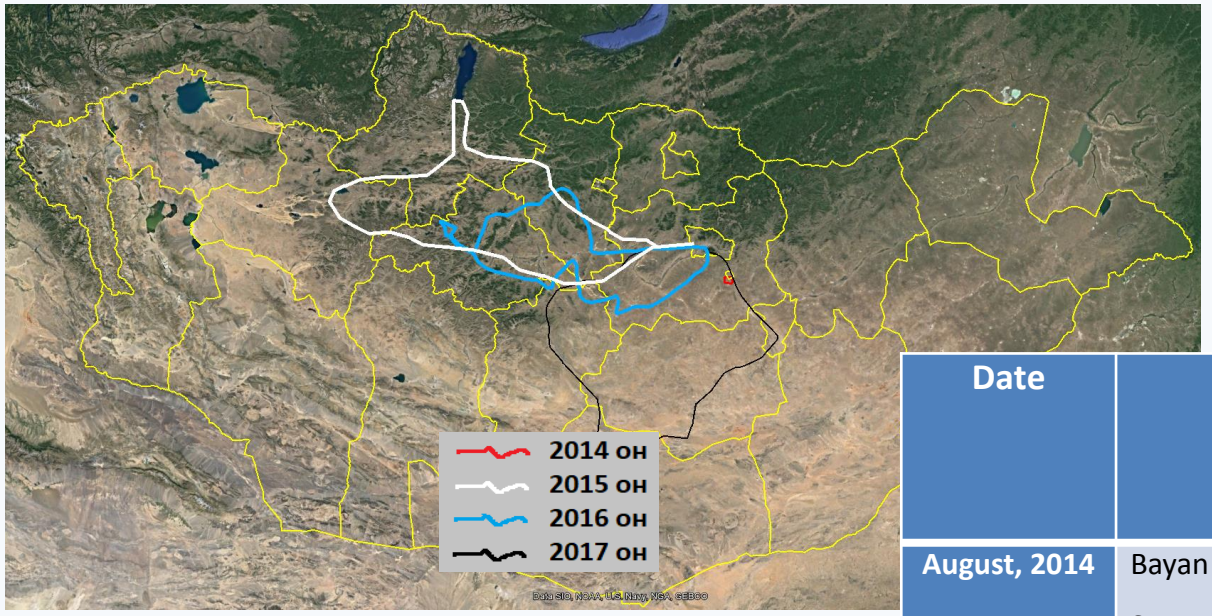
Installing of SatSee system

Under the collaboration with the Institute for Remote Sensing and Digital Earth (RADI) was installed SeeSat system enabling IRIMHE to use real-time high resolution data as Landsat and other satellite images received at RADI. It is important to increase number and quality of products and service delivered by IHMEMI. For example it allows early and accurate detection of forests and steppe fires.

Training, on the job training

Date	Place held	Topic	Number of participants
29 -30 Aug, 2013	Ulaanbaatar, EIC	ESCAP/Workshop	18
January - April, 2014	RADI, Beijing	On the job training, Remote sensing based drought monitoring system, Drought Watch system	2
14-17 Apr, 2014	RADI, Beijing	Workshop, Drought indexes evaluation	4
July, 2014	RADI, Beijing	On the job training, Data processing and validation	2
January, 2015	RADI, Beijing	On the job training, Data processing and validation	2
25 Nov – 24 Dec, 2016	RADI, Beijing	On the job training, Data processing and validation	2
20 Mar – 16 Apr, 2017	RADI, Beijing	On the job training, Data processing and validation	3
20 Dec, 2017 – 10 Jan, 2018	RADI, Beijing	On the job training, Data processing and validation	2

Field trip.



Date	Area of field survey	Number soil moisture measuremnts	Number of biomass measurement	Number of radiance temperature measurement
August, 2014	Bayan soum, Tuv aimag Steppe area. Summner condition and pasture growth were as normal.	9	810	9
27 July-5 Aug, 2015	Tuv, Uvurkhangai, Arkhangai, Zavkhan, Khuvsgul, Bulgan, Selenge. Forest and steppe area. Summer and pasture condition were as normal	234	78	78
24 July -13 Aug, 2016	Tuv, Uvurkhangai, Arkhangai, Bulgan. Forest and steppe area. Summer and pasture condition were as normal	168	168	-
22 July -10 Aug, 2017	Tuv, Uvurkhangai, Dundgvo, Gobi-sumvber. Steppe and desert steppe area. Summer condition and pasture growth were very bad.	2362	112	-

Validation works

Comparing or correlation analysis were done between

Ground indexes as

- ✓ standardized precipitation index(SPI),
- ✓ Pedi index (PED),
- ✓ ratio index of precipitation to evaporation(SPEI)
- ✓ biomass per one meter square area and its standardized value
- ✓ soil moisture at 3.5, 12, 20 cm depth

MODIS data derived indexes such as

- ✓ VCI,
- ✓ TCI,
- ✓ VHI,
- ✓ NDDI
- ✓ NDWI
- ✓ VSWI.

Review of existing drought monitoring and information system

At Global level

- Global Agriculture Drought Monitoring and Early Warning System
- Global Integrated Drought Monitoring and Prediction System
- The Global Drought Information System
- Drought and flood Monitoring system of Africa
- The South Asia Drought Monitoring System
- European Drought information system
- North American Drought Monitoring system

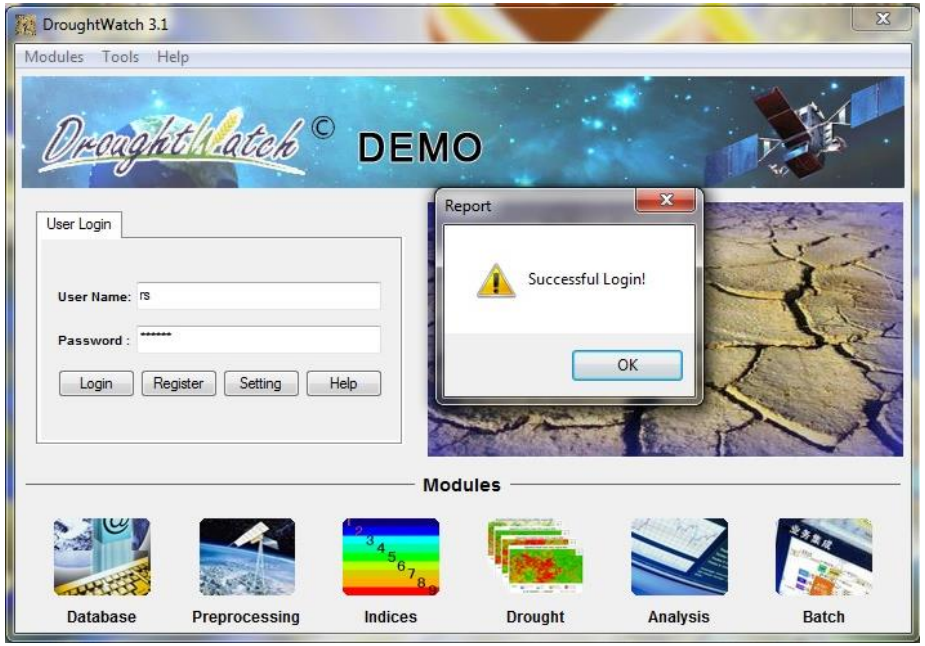
At country level

- USA
- China
- India
- Russia
- Australia

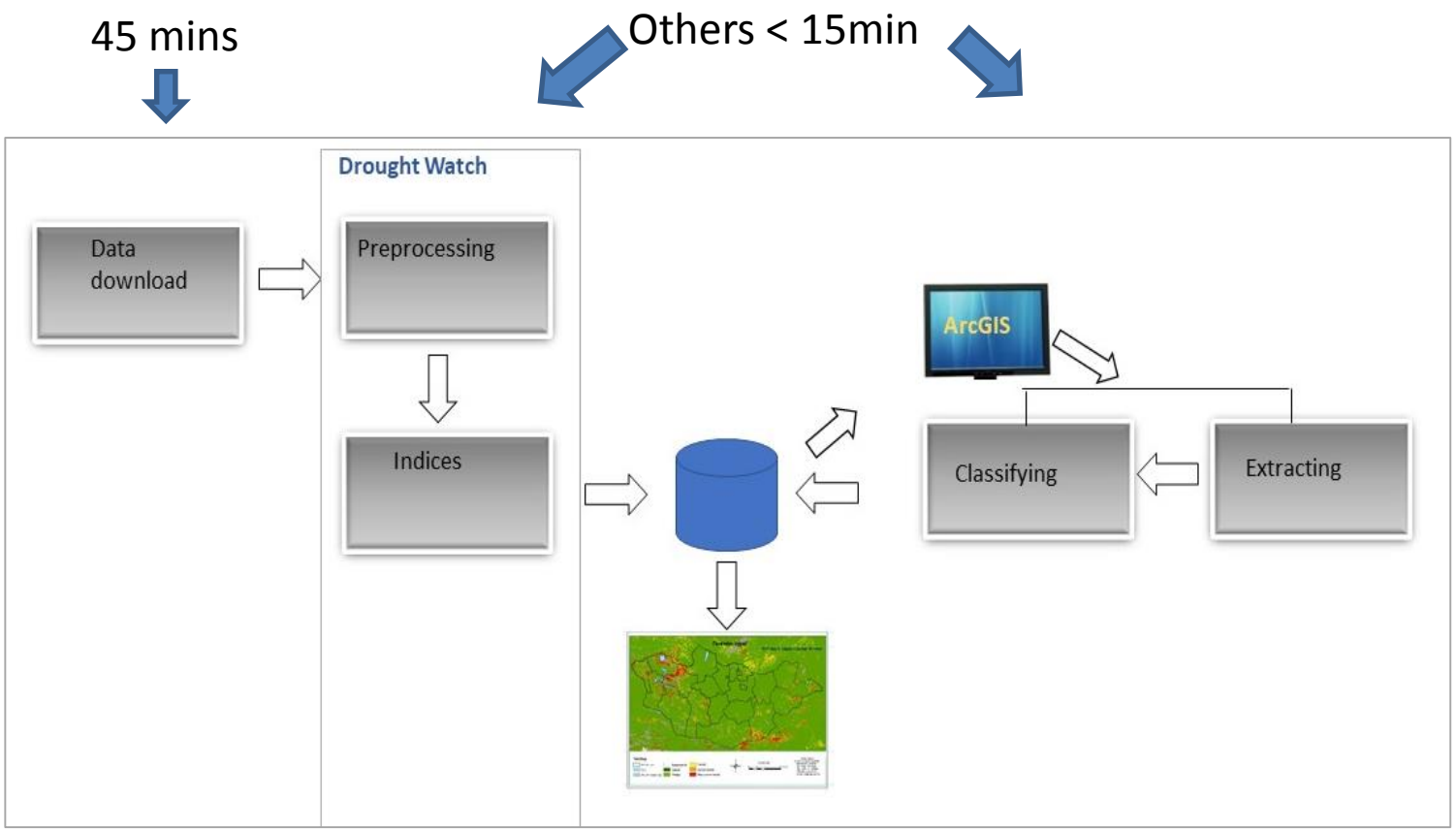
DroughWatch System

The DroughtWatch system consists of basic 6 modules.

- **Database-** database module. This module provides input, display, browse and selection(query) of data of satellite and ground data.
- **Preprocessing – primary processing**. This module includes standard functions for preprocessing of satellite raw data such as georeferencing(GEO), atmospheric correction(ATC), radiometric correction(RAD), cloud masking(CLD), composite image (MOS) and calculation of NDVI and LST.
- **Indices** module calculates drought indexes such as VCI, TCI, VHI, NDDI, VSWI from MODIS data and ground based indexes as SPI, AI
- **Drought** modules is used to output statistics after selecting interested date, frequency and index.
- **Analysis** module help to analyse and view drought dynamics over time and space of the wanted administrative unit, frequency and date, results can be presented in graphs, spreadsheets and files.
- **Batch** module helps to run automatic processing of multi staged procedures and repeated workflows from the processing of source data to the drought mapping without human intervention.



Mapping workflows & performance by system



Indexes calculated by DroughtWatch

Remote sensing based

Vegetation condition index - VCI

$$VCI = \frac{NDVI_i - NDVI\,min}{NDVI_{max} - NDVI_{min}}\ x\ 100$$

Temperature Condition index -TCI

TCI = (LSTmax− LSTi) / (LSTmax− LSTmin)× 100

Vegetation health index (VHI)

VHI = 0.5VCI + 0.5TCI

Normalized difference vegetation index-NDDI

NDDI = (NDVI − NDWI) / (NDVI + NDWI)

Normalized difference water index - NDWI

NDWI = (NIR − SWIR) / (NIR + SWIR)

Vegetation supply water index- VSWI

VSWI = LST / NDVI

Ground based

Standardized precipitation index-SPI

$$SPI = \frac{P - \bar{P}}{\sigma}$$

Aridity index - AI

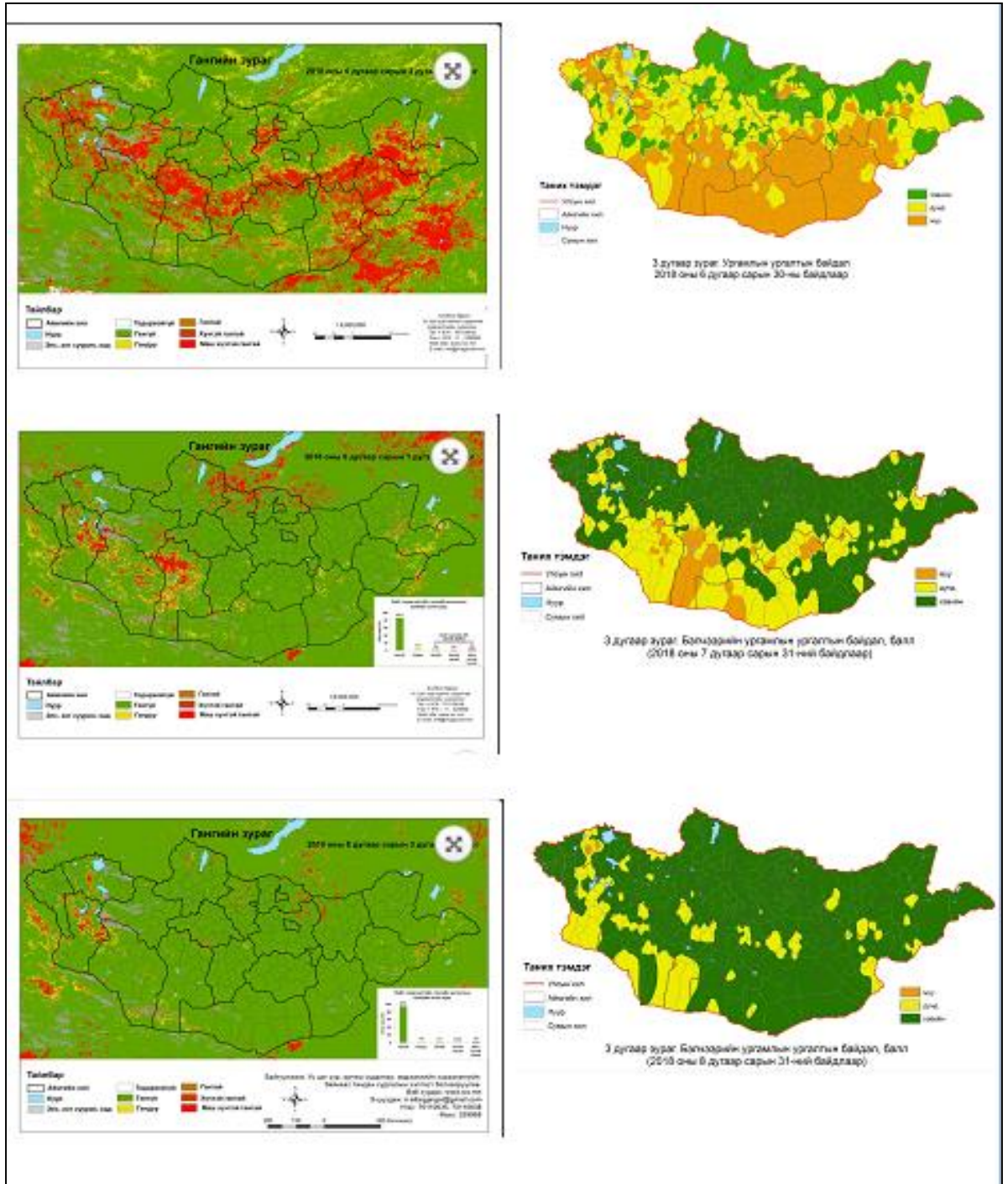
$$SPI = \frac{P}{T + 10}$$

Output drought maps

Main product of Drought Watch system is drought map based on MODIS/ NDDI, VSWI, TCI, VCI, VHI indexes.
Drought is classified by values of indexes selected depending on zones as no drought, weak, moderate, severe and very severe.

Drought maps can be produced for 5 days, 10 days, and months. The spatial resolution is 250 meters.

In general, the summer and drought situations has been well assessed in the maps of DroughtWatch system gives good results, similar picture as ground observation based map.



Output drought reports

DroughWatch can provide reports over spatial and time such as size of drought affected area by aimag, soum and each class of drought over selected period. The NRSC submits some reports from the end of this year.

Гангийн ангиллын талбайн эзлэх хувь,
2018 оны 7 дугаар сарын 3 дугаар 10 хоног

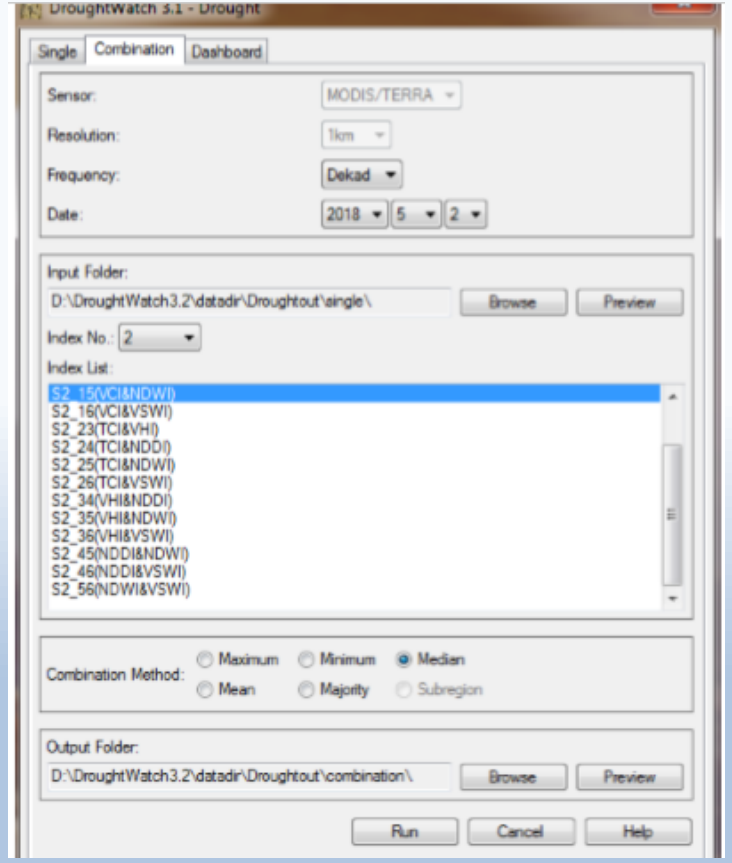
	Аймгийн нэр	Архангай	Баян-Өлгий	Баянхонгор	Булган	Дорноговь	Дорнод	Дундговь	Говь-Алтай	Говьсүмбэр	Завхан
Гангийн ангиллын эзлэх хувь, %	Гангүй	99.7	96	44	96	68	89	67	54	40	92
	Гандуу	0.1	2	9	1	11	6	18	16	25	3
	Гантай	0.1	1	12	1	10	3	11	14	20	2
	Хүчтэй гантай	0.03	0.3	19	0.4	7	1	4	8	11	1
	Маш хүчтэй гантай	0.05	1	15	1	5	1	0.3	8	4	1
	Аймгийн нэр	**Өвөрхангай**	**Өмнөговь**	**Ховд**	**Хөвсгөл**	**Хэнтий**	**Сэлэнгэ**	**Сүхбаатар**	**Төв**	**Увс**	**Дундаж**
Гангийн ангиллын эзлэх хувь, %	Гангүй	85	75	81	98	92	87	91	90	90	80
	Гандуу	6	15	7	0.4	3	5	5	3	1	7
	Гантай	5	6	5	0.3	2	3	2	2	1	5
	Хүчтэй гантай	2	2	2	0.1	2	1	1	1	0.3	3
	Маш хүчтэй гантай	1	2	4	2	1	4	0.5	3	8	4

Percent of area of the drought affected area by aimag

System advantage

The interface is well designed and easy to use.

- The interface is grouped and separated as layout.
- Input parameter to the system is easy by selecting from the drop-down list as below.

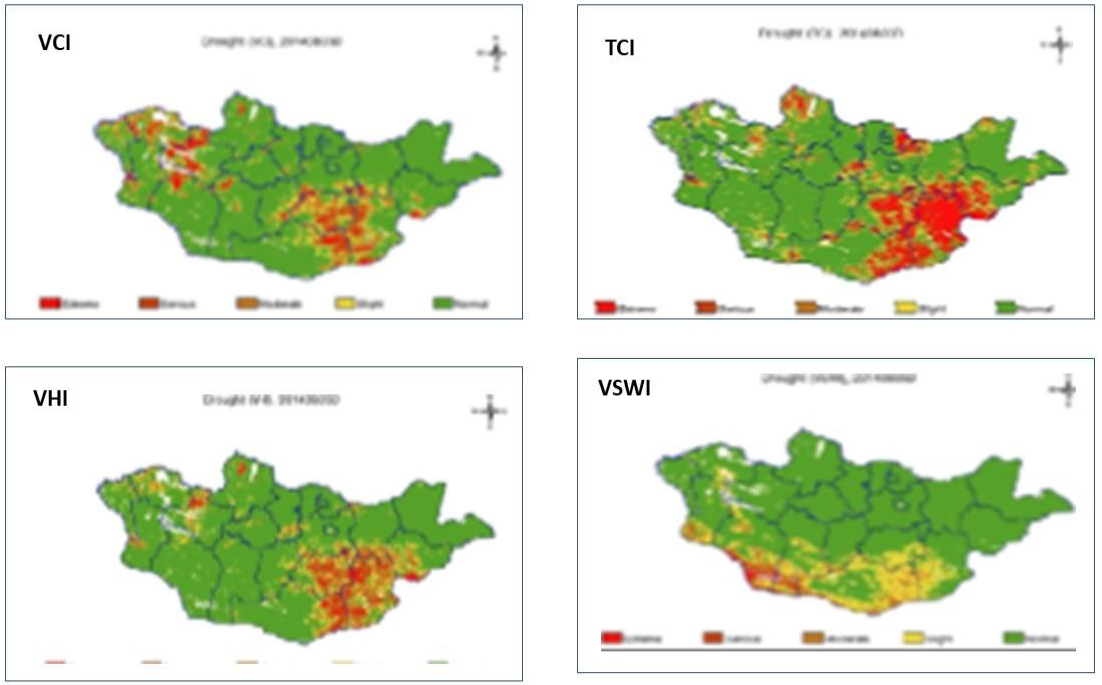


System advantage

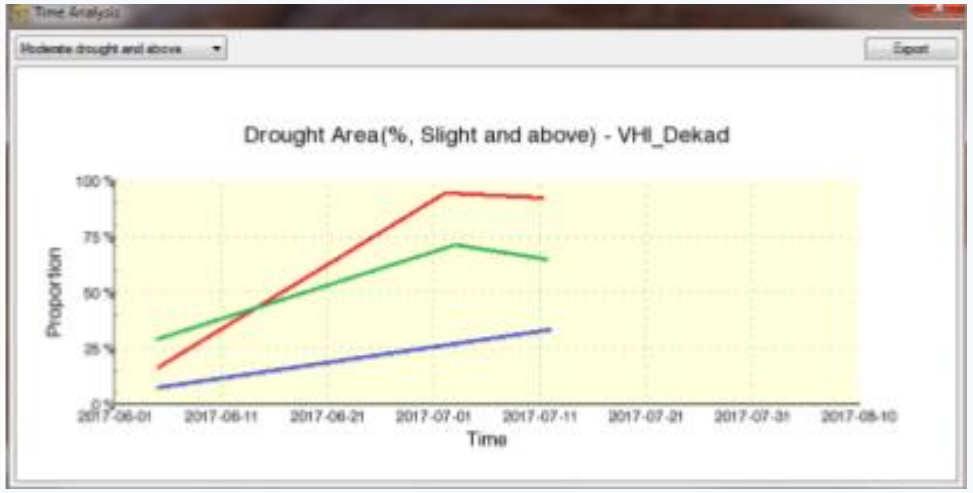
Analysis tools are powerful.

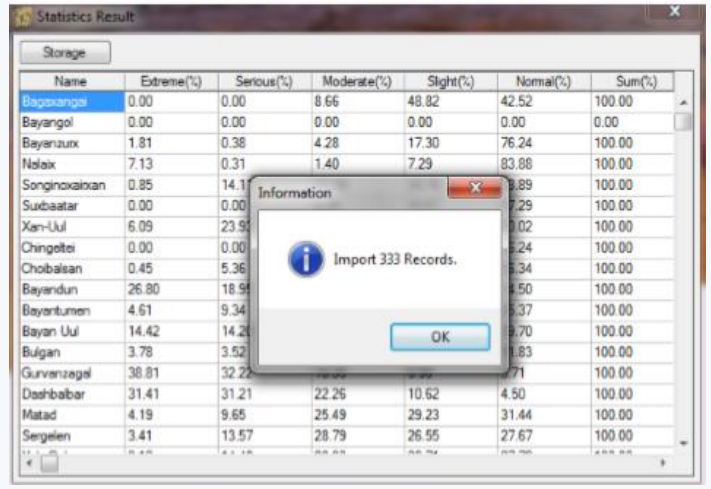
The system has tool ”Dashboard” to simultaneously view multiple images or maps displaying several maps in one window

It helps to analyze and compare maps derived from different indices.



System advantage





The system has tool ”Analysis” to analyse drought over time and spatial coverage.

It is so useful to track and analyze drought between selected dates and calculate statistics over country or selected administrative unit.

Results can be presented in graph and table form

Week	гангүй	гандуу	гантай
2018-05-29	57.44	42.56	26.42
2018-05-22	56.68	43.32	26.72
2018-05-15	54.36	45.64	28.28
2018-05-08	55.56	44.44	27.67
2018-05-01	57.24	42.76	28.60
2018-04-24	57.51	42.49	28.99
2018-04-17	57.19	42.81	28.85
2018-04-10	53.50	46.50	29.69
2018-04-03	52.45	47.55	29.42

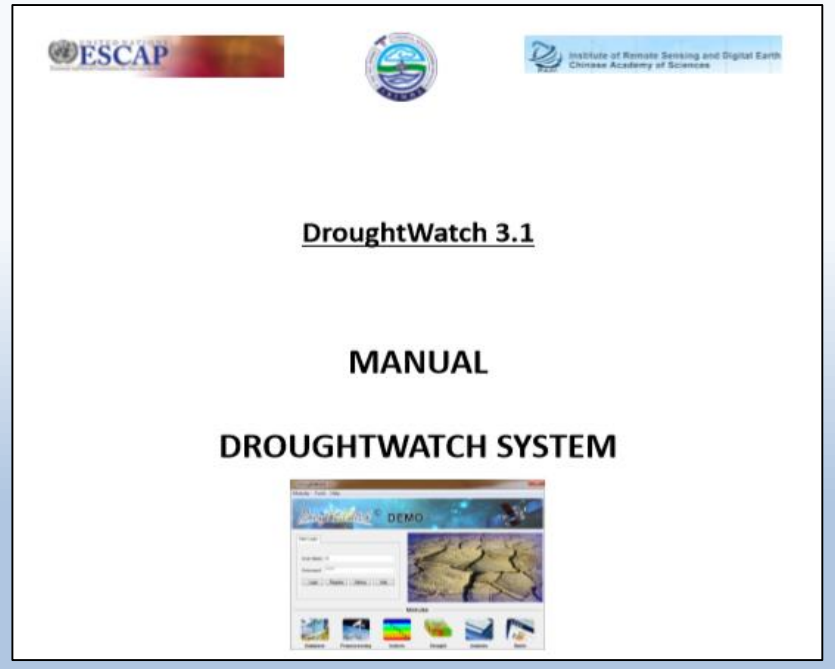
DroughtWatch system advantage

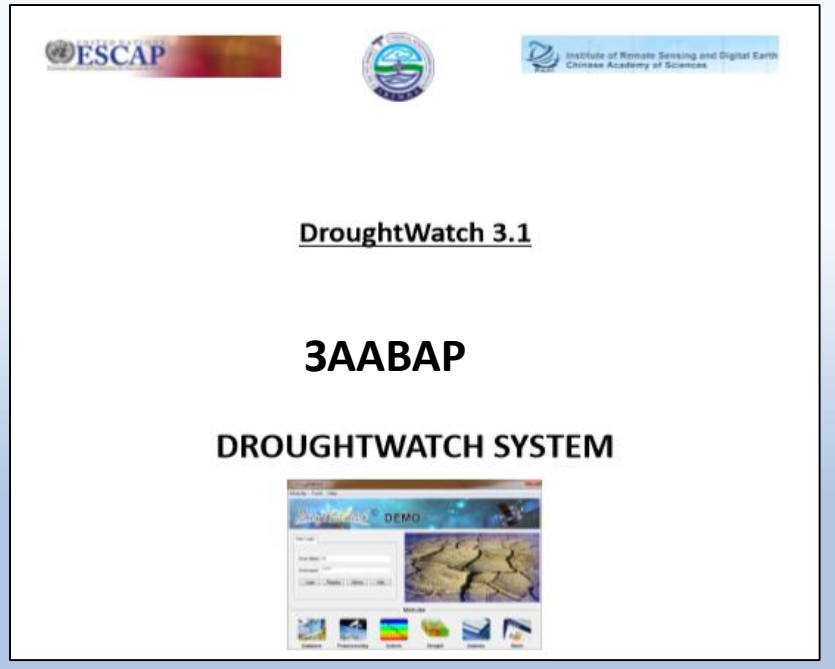
More automated.

A tool “Batch” helps to process a series of data in any time program automatically without intervention. It is very useful tool to save your time and increase computer use efficiency

DroughtWatch system advantage

System user manual existed in Mongolian and English





System disadvantage

- System is not server based
- System has limited licences
- System is only in English
- System not open to public

1. Recommendations to improve DroughtWatch system

Methodology

- ✓ To use MODIS/NDVI received and processed at IHMESI/NRSC instead to download data.
- ✓ Test indexes reducing soil background effect such as SAVI, TSAVI, MSAVI for drought assessment where vegetation is sparse.
- ✓ Create file containing dates of NDVI maximum selected to composite images over 10 days. Such data are useful to compare remote sensing and ground data ensuring to select the closest dated data.
- ✓ To extend length data range using high correlation between NOAA/NDVI and MODIS/NDVI

  MODIS data since 2000, NOAA since 1981

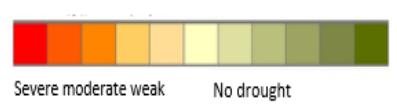
Data

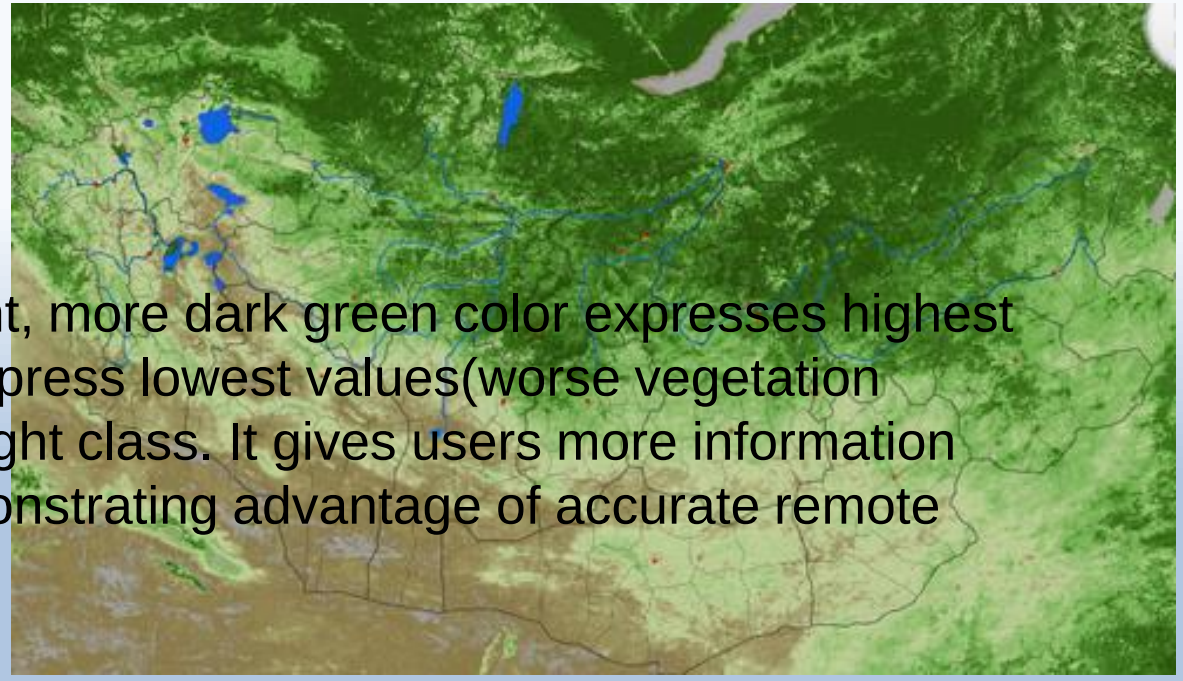
- ✓ Enter the following maps and data needed to check and make comparison analysis such as
  - Temperature and precipitation anomaly from long term average
  - Pasture and drought condition map based on ground agrometeorological data

1. Recommendations to improve DroughtWatch system

Drought map

- ✓ Legend. Drought class name as “weak or severe” should be clear to public. Select colors more close to natural color and meaning. For example no drought area can be presented by dark green, severe drought by brown or grey color.
- ✓ Harmonize drought class name, scale and color of both maps based remote sensing and ground data.
- ✓ Value quantitative difference inside one class can be distinguished by a graduated color as shown bellow.



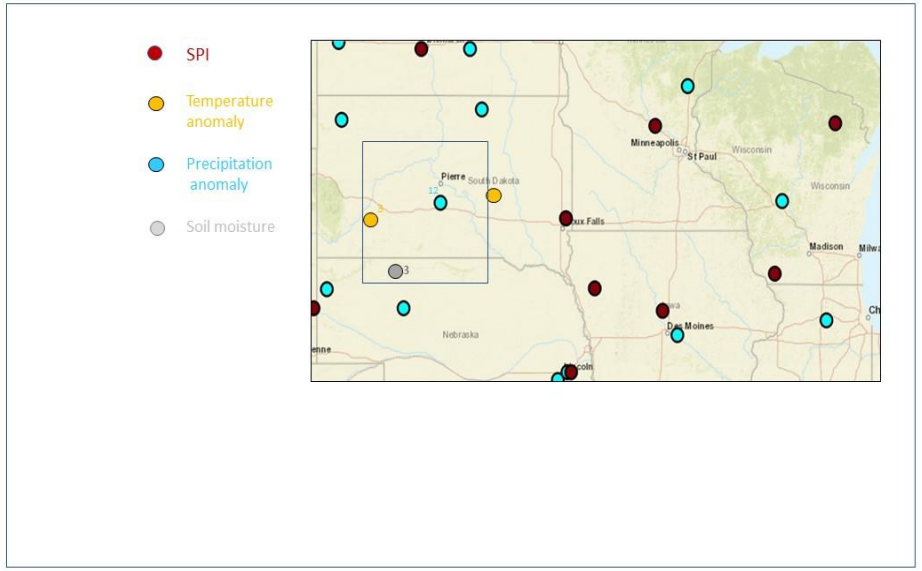


In this example green means generally no drought, more dark green color expresses highest value(vegetation is very good) more light color express lowest values(worse vegetation within no drought class) of green colored no drought class. It gives users more information and enhances map quality and visualization demonstrating advantage of accurate remote sensing quantitively data.

1. Recommendations to improve DroughWatch system

Interface, tools and modules

- ✓ Customize system into Mongolian language
- ✓ Add temperature and precipitation anomaly to ground data list. This tool will be more convenient, if distinguish the parameters in different colors as shown below. There need display values on the ground points by selected area of interested rather than select one by one.

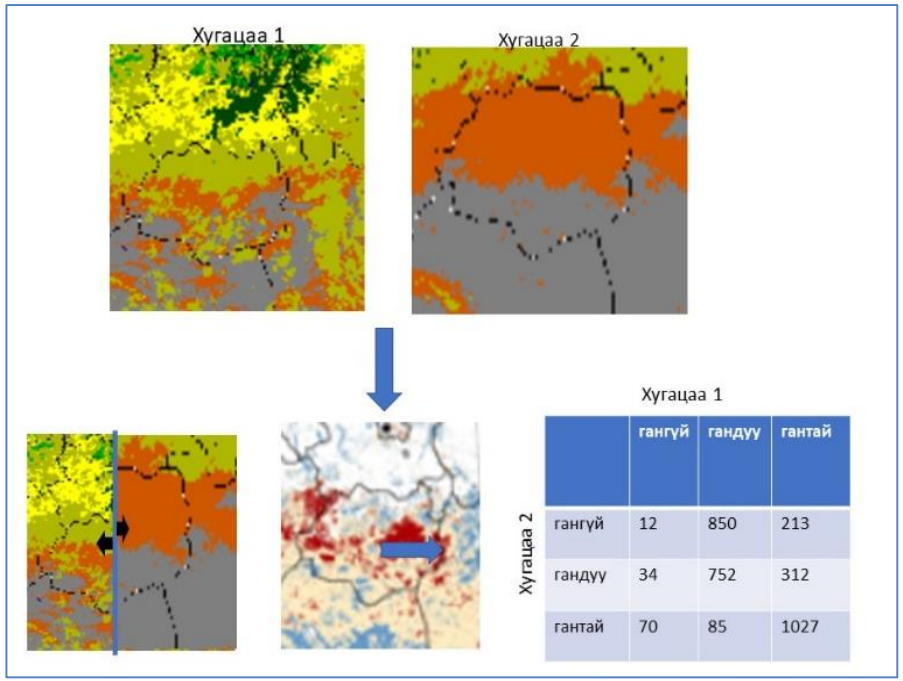


1. Recommendations to improve DroughWatch system

- ✓ Develop data extraction tool. It is needed to extract values of remote sensing indexes(NDI, LST,VCI, etc.,) within a given box(N x N pixels) or radius around each ground measurement point and then calculate statistics as mean maximum, median, minimum, sum of involved pixels. Such tool is quite useful to make validation analysis and compare both ground and remote sensing values.
- ✓ Develop overlapping tool. This tool is to see overlapped layers in the viewer by swiping the top layers out of the way. It allows to detect even small changes.

1. Recommendations to improve DroughWatch system

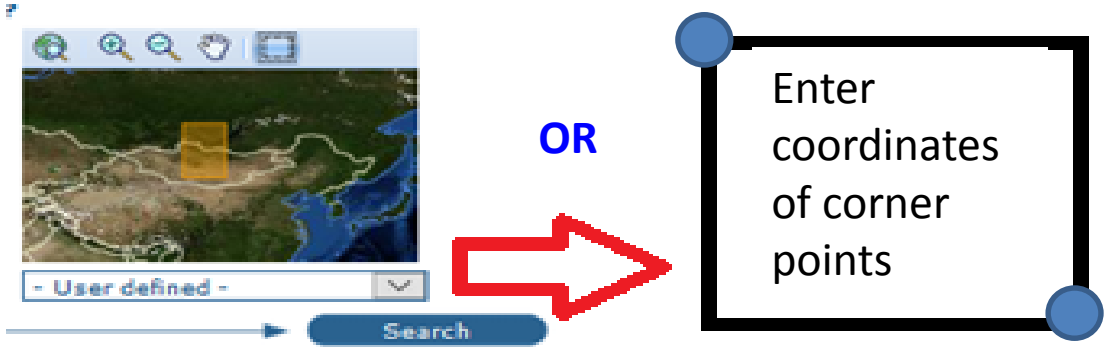
- ✓ Develop animation tool. It is very good visualization tool for detecting changes from time to time and drought dynamics among of satellite time-series images. Remote sensing images is most suitable data for animation because it’s temporally and spatially continuous.
- ✓ Develop change detection tool. This type of tools is required to identify changes compared to the previous image and to detect changes at same place present results in image and matrix form as shown below



	гангүй	гандуу	гантай
гангүй	12	850	213
гандуу	34	752	312
гантай	70	85	1027

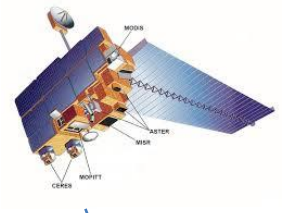
1. Recommendations to improve DroughtWatch system

- ✓ Develop tools to select the area of interested by drawing the box on the map or entering coordinates of corner points.



- ✓ Develop tools required for data preprocessing, mask, mosaic, classification recently are provided by external systems such as MRTSWATH, ArcGIS to ensure the reliability of the system.
- ✓ Improve export tool. Export maps to formats as KML, SHP or WMS service, table to formats as CSV, XLS, XML, JSON.
- ✓ Develop simplest and commonly used mapping tools.

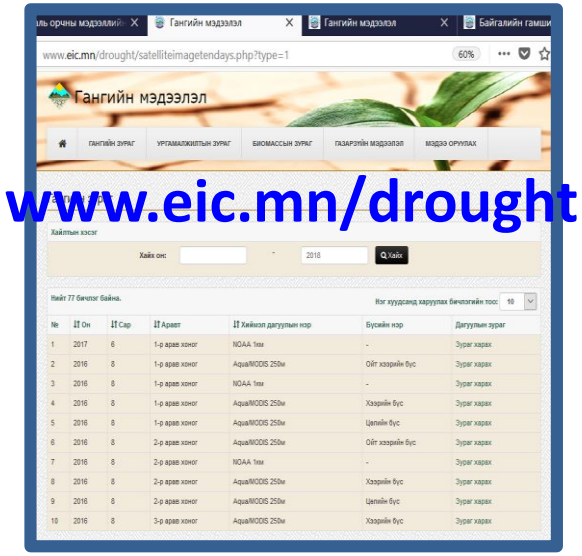
Drought data cycle

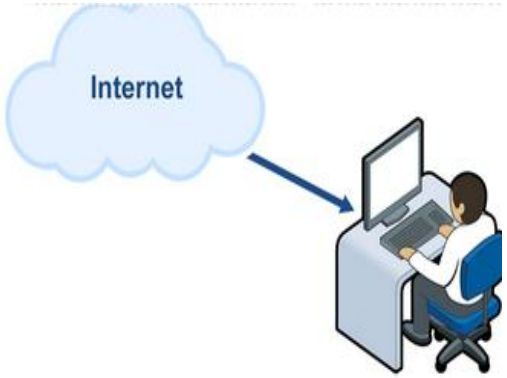


Data collection

DroughtWatch

Data information system





2. Recommendation to improve data collection

1) Increase the number of observation stations in the prone area drought and increase the number of instruments to measure evaporation, soil moisture and other drought indicators
2) Introduce latest advanced instruments to measure drought indicators such as precipitation intensity, soil moisture, soil and plant evaporation, water level and flow
3) Develop national database on Drought that could be shared integrating and harmonizing data produced by MET, MOFALI, NAMEM, Institute of Geography and Geoecology and other organizations supporting the one point service principle of Government.
4) Identify data provider organization, clarify obligation and strengthen capacity
5) Update data such as drought frequency and long-term averages on regular basis
6) Increase the temporal and spatial frequency of soil moisture measurements from April and May prior to planting starting

2. Recommendation to improve data collection

7) Use pastoral plant indicators and animal weight as drought indicators and take measures to compile these data
8) Compile data on soil and vegetation hydro moisture parameters such as soil texture, plant and soil evaporation, moisture holding capacity, leaf area size, moisture distribution with depth, vegetation stress, soil erosion.
9) Develop method and build capacity for the early warning of drought.
10) Collect data needed for estimating of impact of drought

3. Recommendations on the improvement of the drought information system

1) Establish drought data working group consisting of remote sensing, agrometeorological, water experts and representatives of key users on drought information. The working group tasks are to ensure timely and accurate data on drought, review information needs and gaps, harmonize drought products and maps based on different indicators with different results, review current infrastructure and systems used for drought monitoring, data collection and processing and develop recommendations on improvement and measures to be taken.
2) Develop regulation on national drought information system clearly identifying roles and functions of various stakeholders. For example, MOFALI shall supply data on crop yield, NEMA data on drought impact, River basin administrations data water shortage.

3. Recommendations on the improvement of the drought information system

3) Develop the drought system as Web-based information system or geoportal and identify host organization. Recently IRIMHE/EIC is the most suitable organization to host.
4) DroughtWatch system should be connected by the network to the database server to efficiently and easily transfer output data. There is needed to develop data conversion tool.
5) The drought information system should have commonly used the simplest minimum analysis tools to report and analyze drought data such as:
    - Mapping tools
    - Tools to detect changes over time and comparing with long-term statistics
    - Tools to select an area of interested by administrative units, box, and coordinates of corner points
      and output map with statistics
    - Tools to display series of maps in one window and show as animation and showing changes and trends in the graphical form

3. Recommendations on the improvement of the drought information system

The information system should contain the following data at the minimum:

- ❑ Drought maps produced by remote sensing and ground data, maps of temperature and precipitation anomalies, soil moisture, surface water level
- ❑ Drought frequency map using remote sensing
- ❑ List of drought affected area and soums with size, drought assessment reports, recommendations, starting, ending date, duration, statistical reports
- ❑ Forecast and outlook
- ❑ Data on drought impact on drought impact on the environment, social and economic such as the growth of pasture and crop plants, reduction of crop yields, surface water level, livestock weight, crop yield, and surface water level, distribution of pests and fires
- ❑ Data about measures and best practices to reduce drought impact as weather modification activity to increase precipitation, planting of plant resistant to drought, irrigation system, technology to reduce moisture losses.
- ❑ Other data necessary for drought management. For instance, cropland map, pasture/hayland map, livestock, population, desertification, SPA, tourist sites
- ❑ Facts, photo video demonstrating real picture of drought events
- ❑ Other data needed for drought management.

Acknowledgement

Finally I would like to express my special thanks

- *to project team for excellent works done*
- *to ESCAP for implementing this project and financial support*


Thank you for your attention