International Conference on:
Climate Smart Agriculture, the Way of Farming for 21st Century

Advanced Tools for Drought Monitoring and Adaptations

Lecturers:
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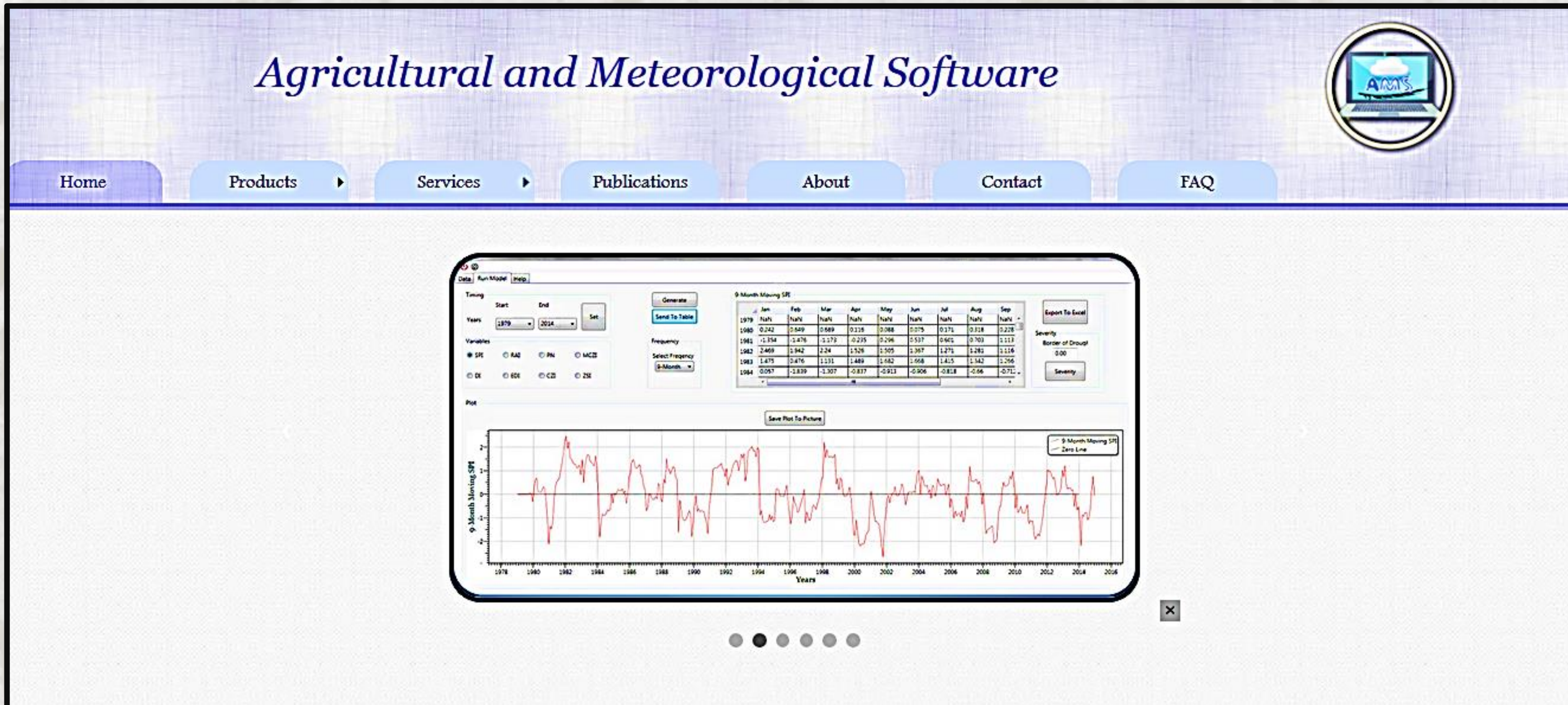
Oct. 10, 2018

Who am I?

- BSc. is in computer - software engineering (2002-2006).
- M.S. in Agrometeorology (2009-2011).
- Ph.D. in Agrometeorology (2013-2017).
- Visiting scholar in Florida University/USA.

Agrimetsoft Lab



Schedule Table

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Time	Agenda	Description
Day: 10 Oct. 2018		
9.30 AM – 10.00 AM	Registration	
10.00 AM – 10.20 AM	Welcome remarks by Vice Chancellor, Prof. Dr. Asif Ali, MNS-UAM	
10.20 AM – 10.40 AM		* Introductions and present the goals of the workshop
10.40 AM – 11.20 AM	Introduction and clarifications of drought event	* Descriptions of Drought Concept * Introduction of Drought indices and Agricultural droughts * Review the Drought papers in Pakistan * Present main indices and calculations of each components * How can present a Drought research? What is the best topic?
11.20 AM – 1.00 PM	Introduce of WD (Weather Data Tool (Excel add-ins)) and MDM (Meteorological Drought Monitor) Tools	* Installation steps * Sort data with WD tool * Present Examples with run the tools * Run and work with MDM tool * Present outputs and save the data
1.00 PM- 1.30 PM		break
1.30 PM – 2.30 PM	Introduce of KBDI (Keetch-Byram Drought Index)	* Descriptions of KBDI and related equations * Installation steps * Run KBDI tools * Save outputs and draw graphs * Give ideas to start a paper in this regard
2.30 PM – 4.30 PM	Exercise	* The attendees would run the tool in their systems * They would get examples of three tools * Solve the problems and discussion about them

What will we do in the workshop?

10.20 AM – 10.40 AM

- Introduction and clarifications of drought event (indices, types, research in this field, and etc.).
- Introduce of WD (Weather Data Tool, Excel add-ins) and MDM (Meteorological Drought Monitor) Tools.
- Introduce of KBDI (Keetch-Byram Drought Index) Tool.
- Do exercises and run the tools.

Introduction

☼ Drought, in contrast to aridity, affects almost all climates in the world (WMO, 2006).

☼There is no universal definition of drought.

☼Drought is a deficit in normal precipitation for a region over a period of time.

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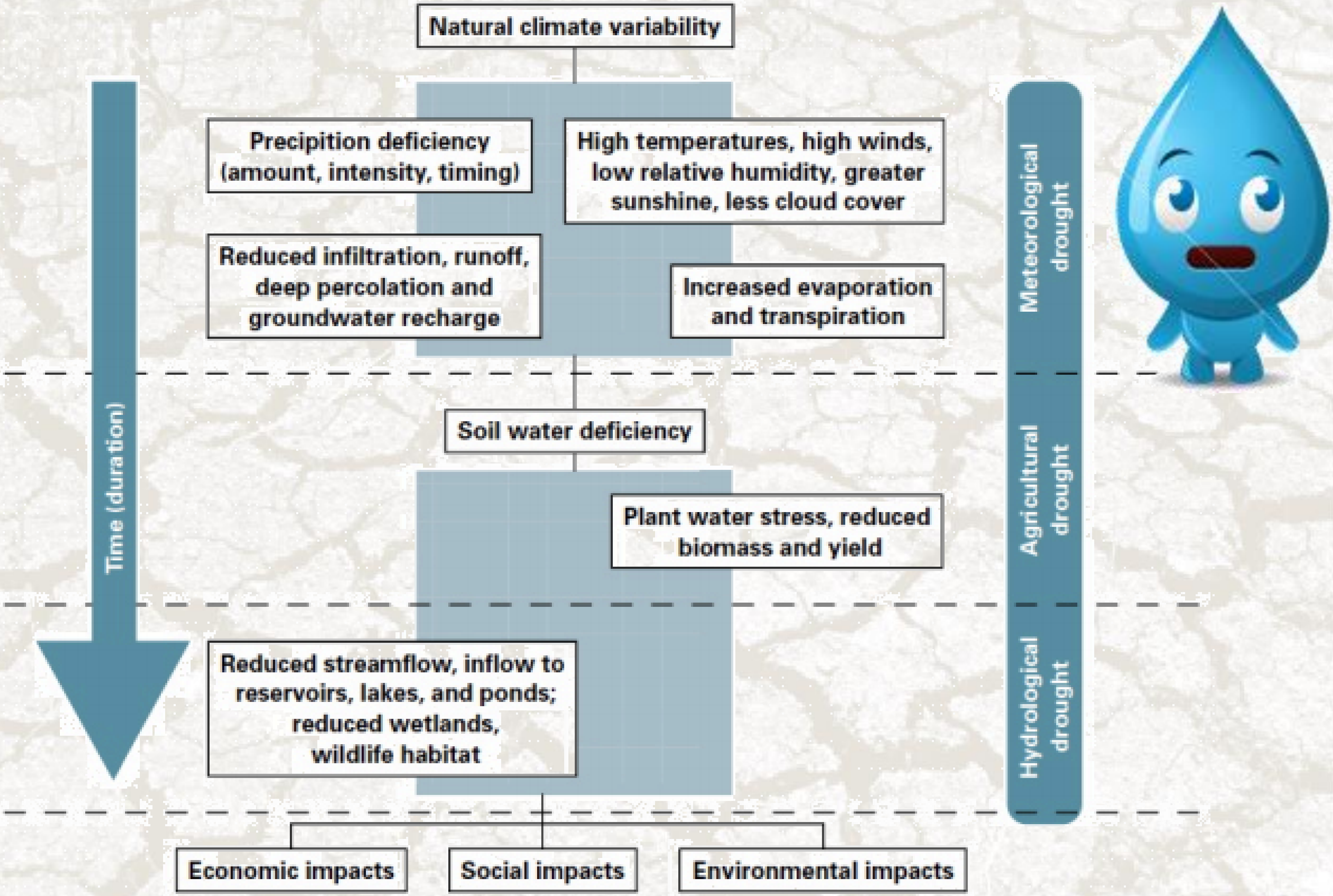


(Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.)

Drought effects

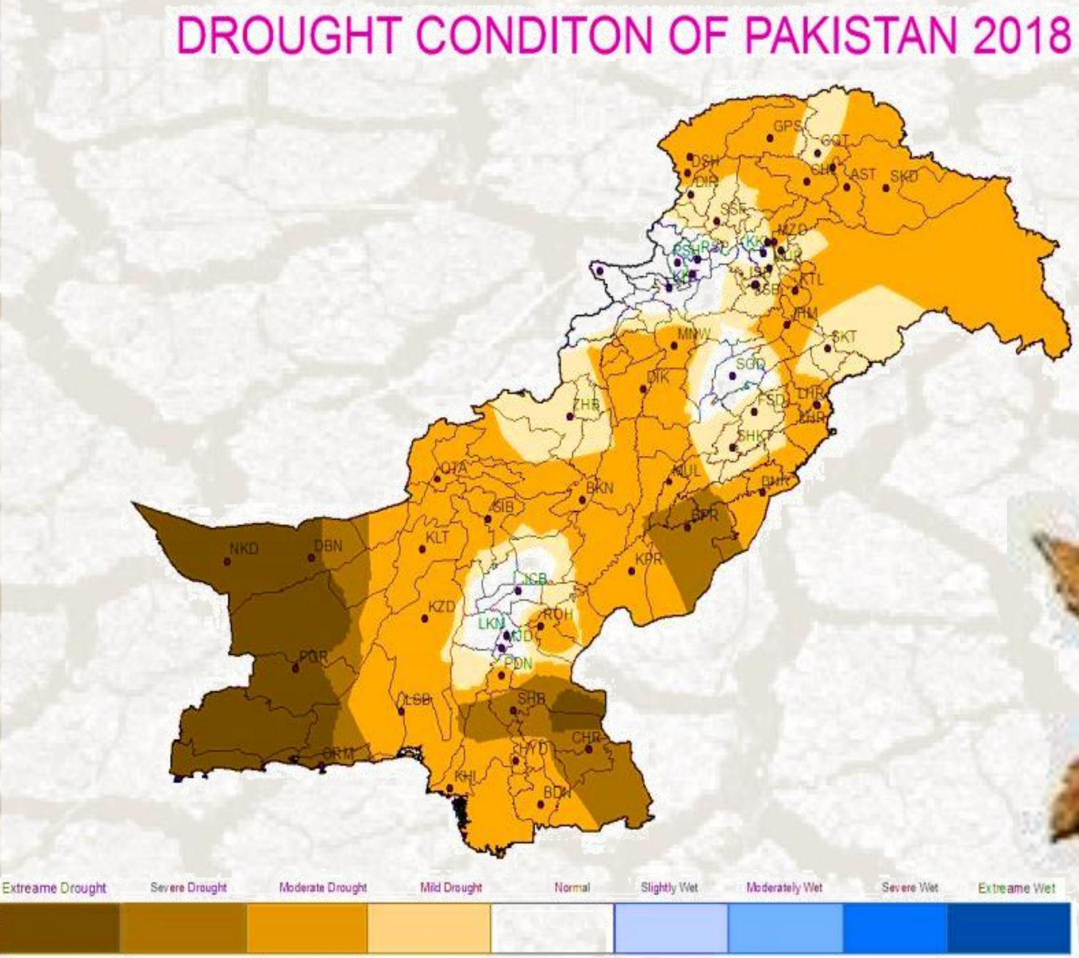
Droughts are expected to increase in frequency and severity → economic, social and environmental sectors of effected populations of virtually all nations (IPCC 2012).

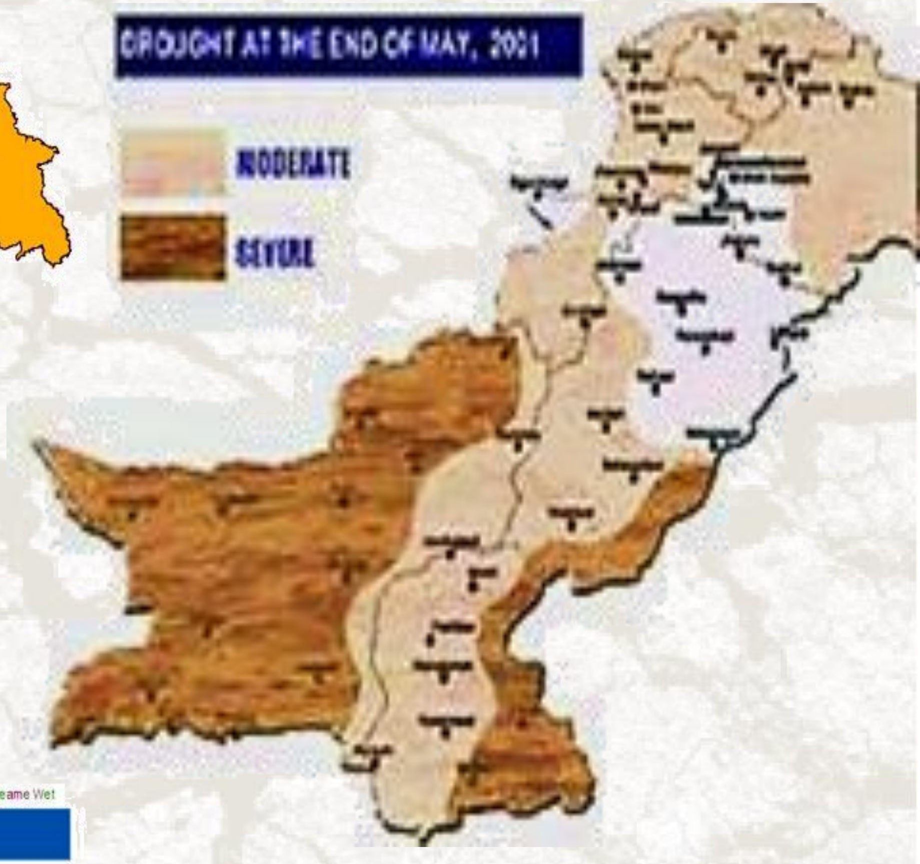
FAO: $29 billion in losses to developing world agriculture between 2005 and 2015.

23 Mha of Asian rice producing areas experience frequent yield loss due to drought.

In Europe → €5.3 billion, In 2003, drought in Europe → €8.7 billion (European Communities, 2007).

Drought Events In Pakistan





The situation of drought in Pakistan during 2018. Source: PMD the Pakistan Meteorological Department (PMD)

Drought Events In Pakistan

- Pakistan in the grip of drought





FAO Report 2018 for Pakistan

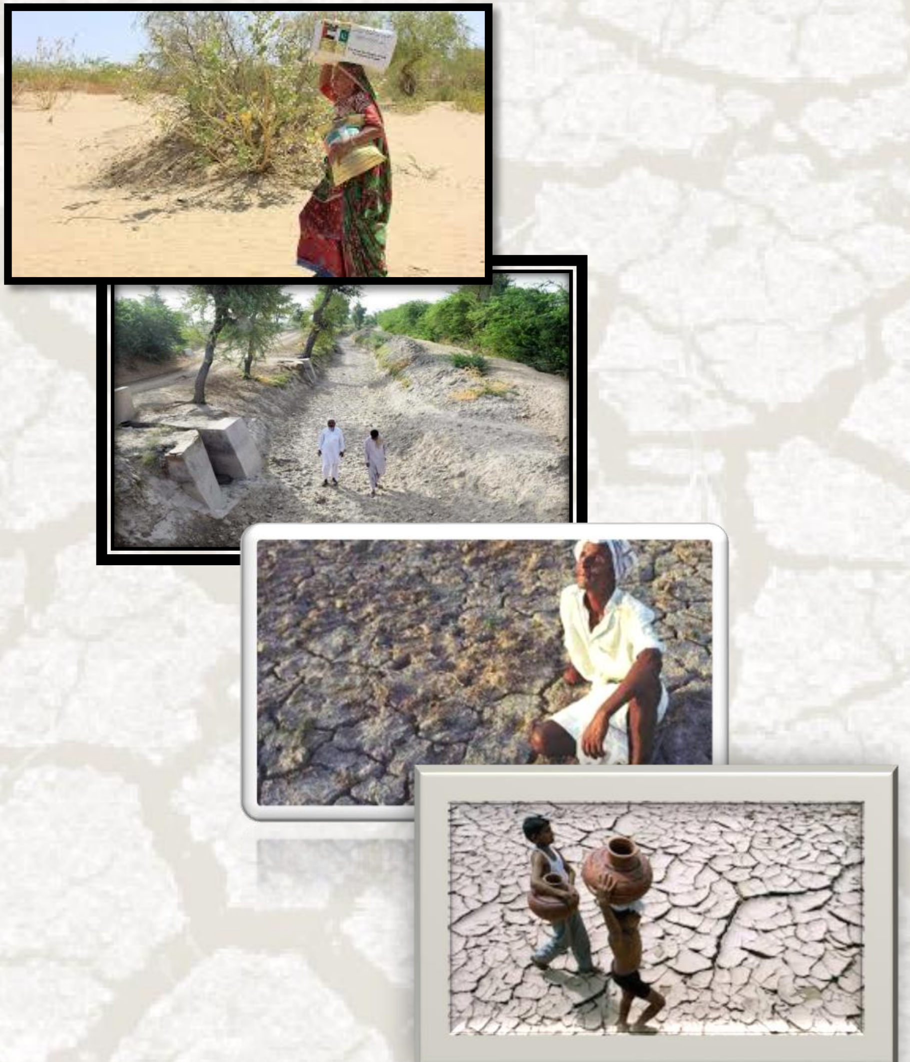
- Pakistan has the fourth highest rate of **water** use in the world. Its agricultural sector is the largest consumer of fresh water resources in the country.

- Rainfall has steadily declined over the past decades and international experts warn the country will approach "**absolute scarcity**" of water by 2025.

- In the village of Azeezabad in the country's eastern Punjab province, the farming communities are being hit hard. The impacts of **climate change** are further intensifying the problem.

National Drought Mitigation Center

What Causes Drought?

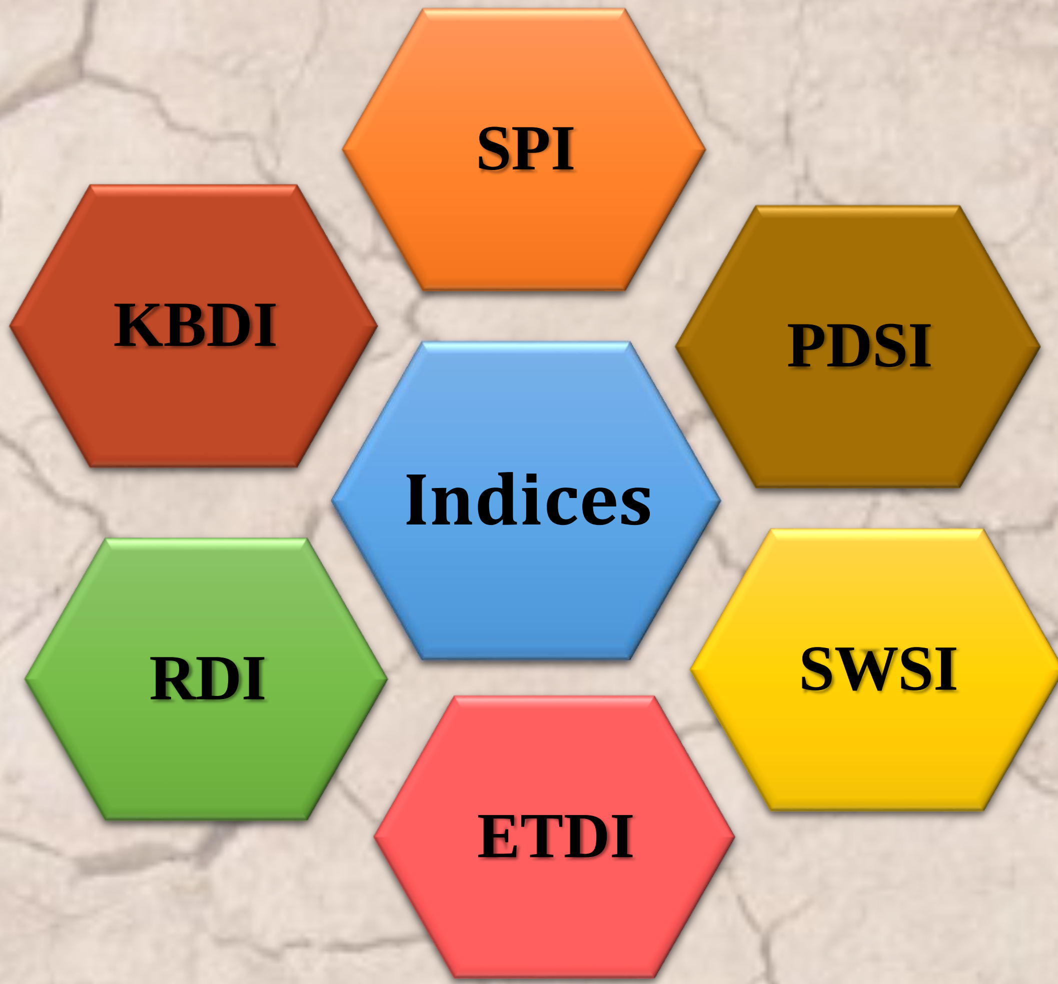


- Lack of rainfall (or precipitation)
- Global warming
- Surface water flow
- Human factors

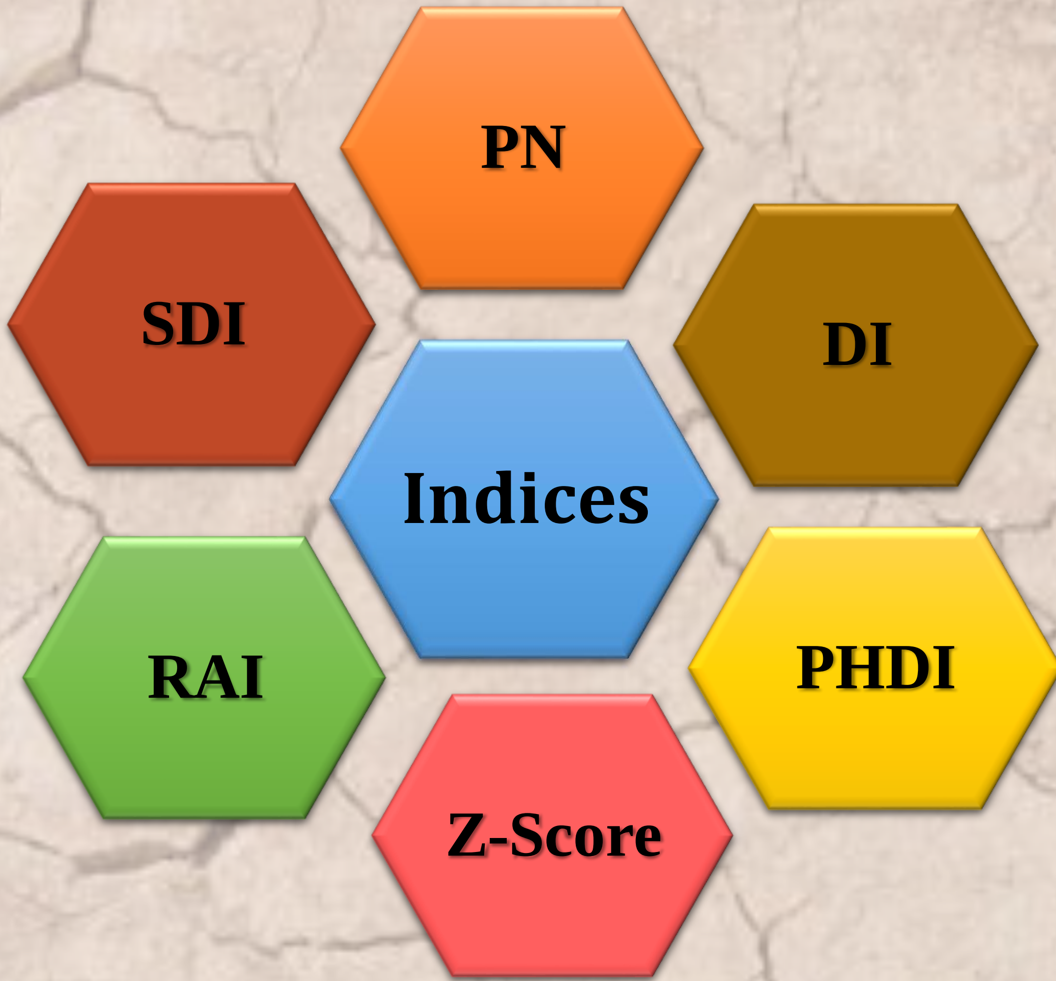
Monitoring Drought

- ☼ Monitoring meteorological drought is a vital and important part of drought risk mitigation (Li et al., 2017) on a global scale (WMO, 2013; Li et al., 2014).
- ☼ For drought monitoring, various drought indices have been developed to describe the intensity of a drought.

Different Drought Indices



Different Drought Indices



Sources of Data

1. In-Situ
- ✓ Synoptic station
- ✓ Climatology Station
- ✓ Hydrometric Station
- ✓ Agricultural Station

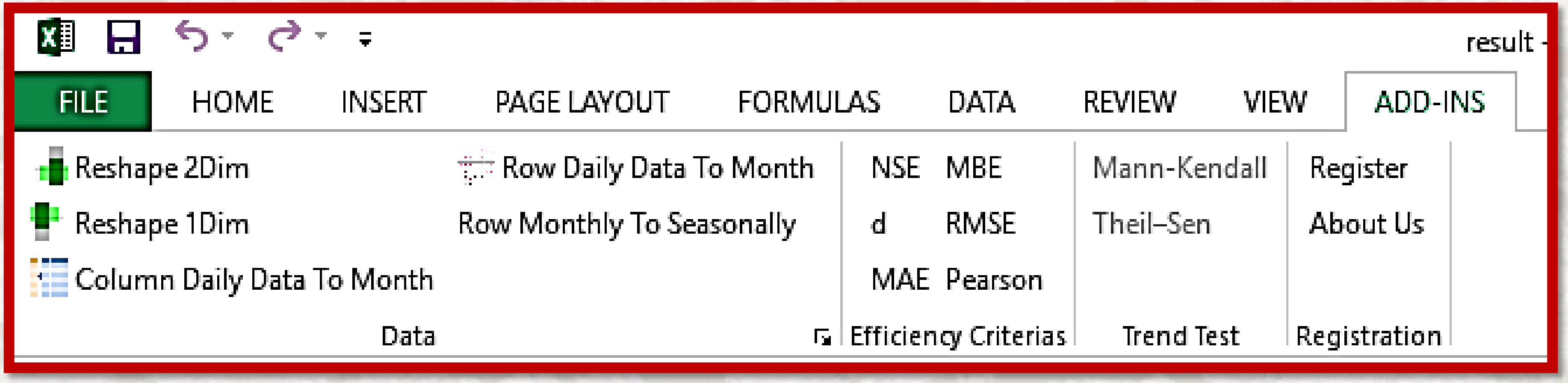
2. Gridded Data
- ✓ AgMERRA
- ✓ CRU
- ✓ TRMM
- ✓ ERA

3. Satellite Data & Products
- ✓ MODIS
- ✓ MERRA
- ✓ AVHRR
- ✓ ….

4. GCM Data
- ✓ CMIP3
- ✓ CMIP5
- ✓ CMIP6

WD (Weather Data Tool (Excel add-ins))

☼Reshape your data in a desirable format



WD (Weather Data Tool (Excel add-ins))

☼Efficiency Criteria

- When you want to make comparisons between simulated and measured data, you need EC indices.
- Efficiency criteria are defined as mathematical measures of how well a model simulation fits the available observations.

WD (Weather Data Tool (Excel add-ins))

Pearson's correlation coefficient (r)

$$r = \frac{\left(\sum_{i=1}^{N} Ag \times St\right) - \left(\frac{\sum_{i=1}^{N} Ag \times \sum_{i=1}^{N} St}{N}\right)}{\sqrt{\left(\sum_{i=1}^{N} Ag^2 - \frac{\left(\sum_{i=1}^{N} Ag\right)^2}{N}\right)} \times \sqrt{\left(\sum_{i=1}^{N} St^2 - \frac{\left(\sum_{i=1}^{N} St\right)^2}{N}\right)}},$$

- It is used to measure the degree of agreement between the two sources of data

WD (Weather Data Tool (Excel add-ins))

- The correlation coefficient, which ranges from -1 to 1, is an index of the degree of linear relationship between observed and simulated data.
  - If $r = 0$, no linear relationship exists.
  - If $r = 1$ or -1, a perfect positive or negative linear relationship exists.

WD (Weather Data Tool (Excel add-ins))

Nash-Sutcliffe Efficiency (NSE)

$$E = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} (O_i - \bar{O})^2}$$

- ✓ NSE ranges between 1.0 (perfect fit) and $-\infty$.
- ✓ An efficiency of lower than zero indicates that the mean value of the observed time series would have been a better predictor than the model.

WD (Weather Data Tool (Excel add-ins))

The index of agreement “d”

$$d = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} \left(|P_i - \overline{O}| + |O_i - \overline{O}|\right)^2}, \quad 0 \leqslant d \leqslant 1$$

- The range of d lies between 0 (no correlation) and 1 (perfect fit).

WD (Weather Data Tool (Excel add-ins))

Mean Absolute Error (MAE)

$$MAE = \frac{\sum_{i=1}^{N} |P_i - O_i|}{N}$$

It is computed to determine overall magnitude of error.

WD (Weather Data Tool (Excel add-ins))

Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\sum_{i=1}^{n} (O_i - P_i)^2 / n}$$

- RMSE measures the average magnitude of error, calculated as the square root of the average of squared differences between prediction and observation data.

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Applicable and Useful Software Tool

Let’s go to run the WD tool

MDM (Meteorological Drought Monitoring)

J Arid Land (2017) 9(6): 797–809
https://doi.org/10.1007/s40333-017-0070-y

Science Press   Springer-Verlag

Estimation of meteorological drought indices based on AgMERRA precipitation data and station-observed precipitation data

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Citation: Nasrin Salehnia, Amin Alizadeh, Hossein Sanaeinejad, Mohammad Bannayan, Azar Zarrin, Gerrit Hoogenboom. 2017. Estimation of meteorological drought indices based on AgMERRA precipitation data and station-observed precipitation data. Journal of Arid Land, 9(6): 797–809. https://doi.org/10.1007/s40333-017-0070-y

Abstract: Meteorological drought is a natural hazard that can occur under all climatic regimes. Monitoring the drought is a vital and important part of predicting and analyzing drought impacts. Because no single index can represent all facets of meteorological drought, we took a multi-index approach for drought monitoring in this study. We assessed the ability of eight precipitation-based drought indices (SPI (Standardized Precipitation Index), PNI (Percent of Normal Index), DI (Deciles index), EDI (Effective drought index), CZI (China-Z index), MCZI (Modified CZI), RAI (Rainfall Anomaly Index), and ZSI (Z-score Index)) calculated from the station-observed precipitation data and the AgMERRA gridded precipitation data to assess historical drought events during the period

Who am I?

- BSc. is civil engineering ().
- M.S. in water engineering ().
- I love coding and research.
- Now I am a developer.

MDM (Meteorological Drought Monitoring)

The MDM software is used for calculating precipitation-based indices:

- SPI (Standardized Precipitation Index),
- DI (deciles index),
- PN (Percent of Normal Index),
- RAI (Rainfall Anomaly Index),
- EDI (effective drought index),
- CZI (China-Z index),
- MCZI (modified CZI),
- ZSI (Z-Score Index)

In the form of yearly, seasonally, monthly and moving average for 3, 6, 9,12,18, 24, and 48 months.

Calculate SPI in the MDM

- The SPI is the most popular drought index and is a widely recognized index for characterizing meteorological droughts.

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{\frac{-x}{\beta}}$$

Calculate DI in the MDM

Monthly historical precipitation data are sorted from lowest to highest and divided into ten equal categories or deciles. So, precipitation in a given month can be placed into the historical context by decile.

Calculate PN in the MDM

The PNI is a percentage of normal precipitation. It can be Calculated for different time scales (monthly, seasonally, and yearly).

$$PNI = {P_i}/{P} \times 100$$

Calculate RAI in the MDM

The RAI considers two anomalies, i.e., positive anomaly and negative anomaly.

$$RAI = 3 \times \left[\frac{(p - \bar{p})}{(\bar{m} - \bar{p})} \right]$$

Calculate EDI in the MDM

The EDI is calculated in daily time step

$$EP_i = \sum_{n=1}^{i} \left(\frac{\left(\sum_{m=1}^{n} P_m \right)}{n} \right),$$

Calculate ZSI in the MDM

The ZSI is occasionally confused with SPI.

$$ZSI = \frac{P_i - \overline{P}}{SD}$$

Calculate CZI and MCZI in the MDM

The National Climate Center of China developed the CZI in 1995 as an alternative to the SPI when mean precipitation follows the Pearson type III distribution.

$$CZI_{ij} = \frac{6}{C_{si}} \times \left(\frac{C_{si}}{2} \times \varphi_{ij} + 1 \right)^{1/3} - \frac{6}{C_{si}} + \frac{C_{si}}{6}$$

substituting the median precipitation for mean precipitation.

MDM (Meteorological Drought Monitoring)

Advantages:

1. Just Precipitation
2. 8 indices
3. Use different sources

MDM (Meteorological Drought Monitoring)

Drawback:

1. • It calculates just rain-based indices
2. • Can’t compute severity
3. • Can’t draw specific graphs

MDM (Meteorological Drought Monitoring)

Do the steps to run it:

1. Setup and installation
2. Select the format of input data
3. Select your desirable index

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Sohrab Kolsoumi

Applicable and Useful Software Tool

Let’s go to run the MDM tool

KBDIS(Keetch-Byram Drought Index Software)

Theor Appl Climatol
https://doi.org/10.1007/s00704-017-2315-2

CrossMark

ORIGINAL PAPER

Predictive value of Keetch-Byram Drought Index for cereal yields in a semi-arid environment

Nasrin Salehnia[1] · Hossein Zare[1] · Sohrab Kolsoumi[1] · Mohammad Bannayan[1]

Received: 24 June 2016 / Accepted: 30 October 2017

Abstract Meteorological drought indices associated with soil moisture status have potential for varying applications including predictive power for crop yields estimation. The Keetch-Byram Drought Index (KBDI) was initially developed to estimate forest flammability, based on quantification of the moisture deficiency in upper soil layer as a function of daily precipitation and maximum air temperature. In this study, we characterized the utility of KBDI to accurately trace and monitor vegetation change and crop yield fluctuation in a semi-arid environment. It is tried to find any temporal association for both the 16-day MODIS-derived NDVI and KBDI from 2002 to 2012 and the correlation between KBDI and wheat and barley yield from 1984 to 2010. Correlation between KBDI and NDVI showed a general seasonal

first century (Houghton et al. 2001; Beranová and Kyselý 2015). The agricultural sector is especially vulnerable to climate variability in arid lands (Farhangfar et al. 2015). Because of its dependence on precipitation and soil moisture reserves in areas with limited irrigation infrastructure, agriculture is often impacted early by the onset of drought (Narasimhan and Srinivasan 2005; Katiraie-Boroujerdy et al. 2016).

The country of Iran with area of 1,648,000 km^2 covers both arid and semiarid regions with annual precipitation of about 250 mm. The coefficient of variation of annual rainfall in Iran is as high as 70%, presenting challenges to the agricultural sector and consumers. Under such conditions, crop production varies widely and drought has severe impacts (Bannayan and

KBDIS(Keetch-Byram Drought Index Software)

- It is based on daily precipitation, daily maximum temperature, and mean annual precipitation.
- The output value of 0 to 800 is categorized into four classes where 0 represents soil saturation and 800 indicates severe drought.

$$DF = \frac{[800 - KBDI_{t-1}][0.968\exp(0.0875T_{max} + 1.5552) - 8.30]}{1 + 10.88\exp(-0.001736R)} \times 10^{-3} \quad (1)$$

$$\begin{aligned}
KBDI_t &= KBDI_{t-1} \quad \text{if } P_t = 0\,\text{cm and } TMAX_t \leq 6.78^{\circ}\text{C} \\
KBDI_t &= KBDI_{t-1} + DF_t \quad \text{if } P_t = 0\,\text{cm and } TMAX_t > 6.78^{\circ}\text{C} \\
KBDI_t &= KBDI_{t-1} + DF_t \quad \text{if } P_t > 0\,\text{cm and} \sum P_t \leq 0.51\,\text{cm} \\
KBDI_t &= KBDI_t' + DF_t \quad \text{if } P_t > 0\,\text{cm and} \sum P_t > 0.51\,\text{cm} \\
KBDI_t' &= KBDI_{t-1} - 39.37\sum P_t
\end{aligned} \quad (2)$$

KBDIS(Keetch-Byram Drought Index Software)

The drought increment on a given day, called the drought factor, is determined by:

1. The mean annual rainfall for the study location,
2. The drought index of yesterday
3. The maximum temperature for today

Reduction in drought occurs only whenever the 24-h rainfall exceeds 0.20 in.

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Applicable and Useful Software Tool

Let’s go to run the KBDIS

Sincere Thanks For Your Attention

Who you are tomorrow begins with what you do today.

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