Training Programme
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Satellite and GIS technologies for drought management

Drought Indices

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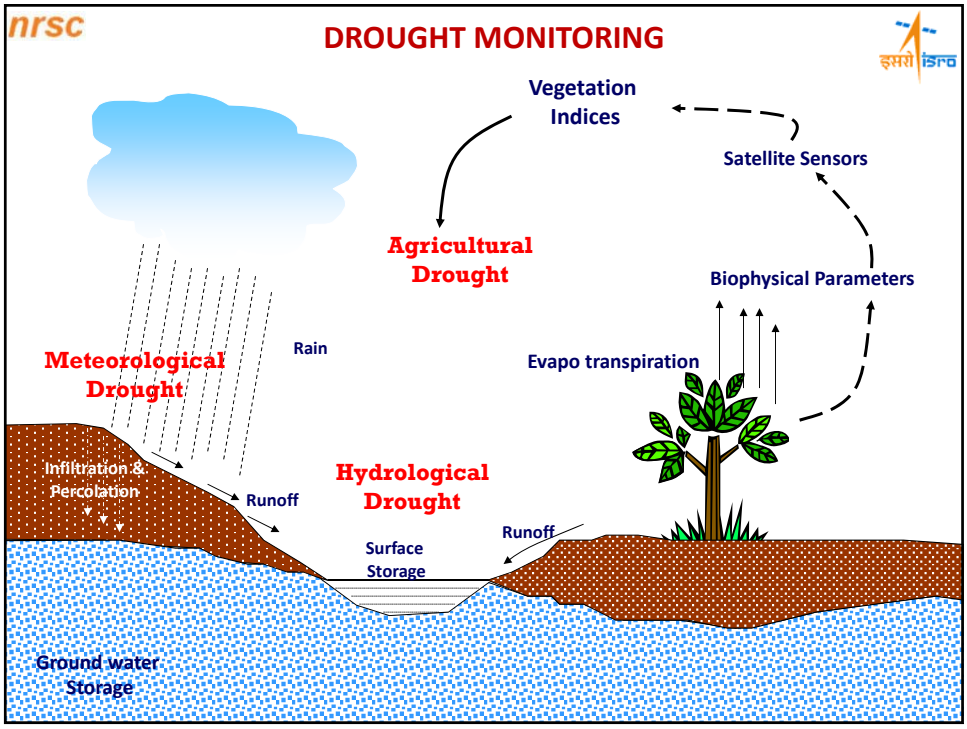

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Drought Indices

Causative factors

- weather related

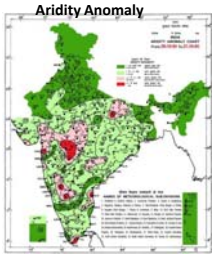
Effect

- hydrology
- soil
- crops

Indian Meteorological Department

Met. Drought season – if rainfall is less than 75 % of normal

Aridity Anomaly



- Sparse observations
- Sharp variability in weather
- Physical nature of parameters partly related to biological nature of crops.

State Depts. of Agriculture/Revenue/Relief

Weekly reporting of information

- Rainfall
- Crop sown areas (delay in sowings/reduction in sown area)
- Reservoir levels
- Manually observed agricultural situation at district/sub district level

- Non spatial and subjective manual observations.
- Inconsistency w.r.t to data collection and availability among the states.
- No uniform criteria for drought assessment/drought declaration

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Meteorological drought indicators

Rainfall – in season
+/- 20 % dev. Normal
-20 to -60 % Deficit
<-60 % dev. Scanty

Rainfall – Met. drought
50-75 % of normal – moderate
< 50 % of normal - severe
in 20% of area

SPI Values	
2.0+	extremely wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Rainfall – most common indicator

Standardized Precipitation index (SPI)

Indicators based on water balance

- Palmer drought severity index
- Moisture Adequacy Index (MAI)
- Aridity Index and its anomaly

MAI Values	
76-100	No drought
50-75	mild
25-49	moderate
< 25	severe

Aridity anomaly	
0	Non arid
1-25	mild
25-50	moderate
>50	severe

Palmer Classifications	
4.0 or more	extremely wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 or less	extreme drought

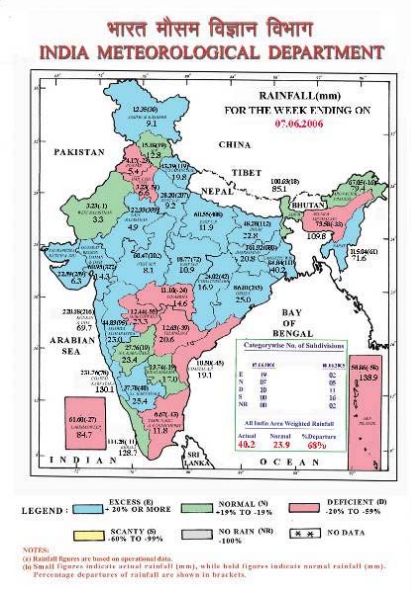
Rainfall deviation from normal

Normal rainfall: long term mean

Deviation = (Current rainfall – Normal rainfall)/Normal rainfall

Extent of negative deviation is directly related to drought

Limitation of rainfall deviation as drought indicator



Standardized Precipitation index (SPI)

SPI is being widely used in recent years because of its computational simplicity and reliable interpretation.

SPI is a simple and more effective method for studying drought climatology.

SPI produces the rainfall deviations normalised for mean and standard deviaitions and hence comparable across space and time.

SPI = (x – mean of x)/ Std of X for a given time series of rainfall.

- **Based on precipitation alone**
- **Detection of dryness or wetness**
- **Versatile indicator**
- **Data transformation**
- **Gamma probability density function**
- **Needs long term data base**

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STANDARDIZED PRECIPITATION INDEX (SPI)

SPI vs. rainfall deviation (Rd)

Rd is mean dependent and not applicable across different rainfall zones.

SPI is mean normalized indicator

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

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\beta = \frac{\bar{x}}{\alpha}$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx$$

$$G(x) = \frac{1}{\Gamma(a)} \int_0^t t^{a-1} e^{-t} dt$$

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right)$$

$$\text{for} \quad 0 < H(x) \le 0.5$$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right)$$

$$\text{for} \quad 0.5 < H(x) \le 1.0$$

SPI-based Drought categorization

SPI Values	
2.0+	extremely wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
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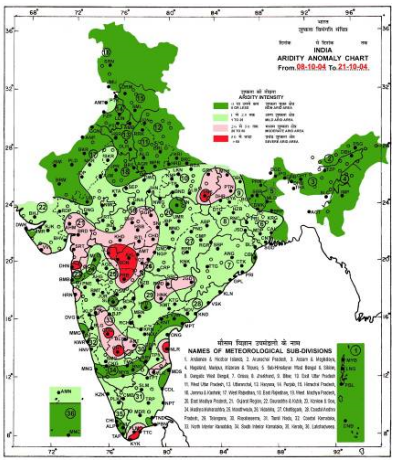
Aridity Anomaly

Aridity = AET/PET

Climatic water balance

Soil water balance



Hydrology

Surface Water Storage Indices

- Reservoir water storage
- Stream flow indices (run off)

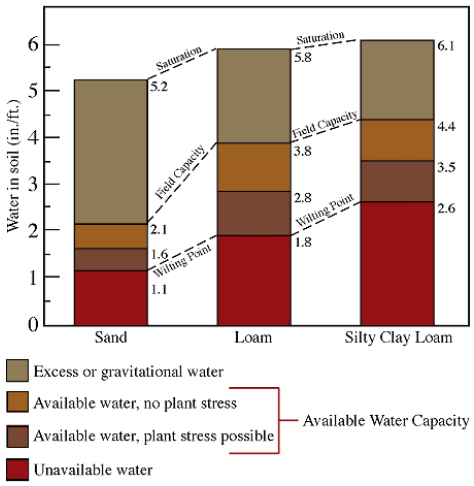
Ground water storage

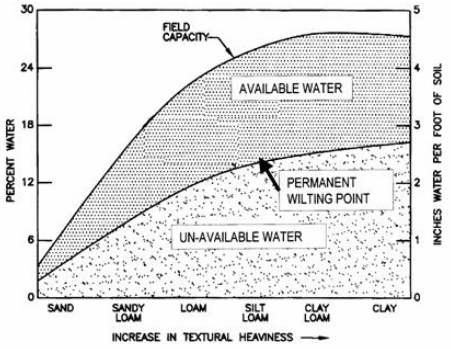
Soil factor

Soil is a strong determinant of agricultural drought

Profile soil moisture – a critical indicator

Drought early warning, Crop planning, Agro advisories, drought declaration





Available Water Capacity by Soil Texture	
Textural Class	**AWC (Inches/Foot of Depth)**
Coarse sand	0.25–0.75
Fine sand	0.75–1.00
Loamy sand	1.10–1.20
Sandy loam	1.25–1.40
Fine sandy loam	1.50–2.00
Silt loam	2.00–2.50
Silty clay loam	1.80–2.00
Silty clay	1.50–1.70
Clay	1.20–1.50

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Soil moisture

Soil moisture important data for hydrology, agriculture, environment, climate system etc.

Sources of soil moisture data

Non-spatial data

I. Insitu measurements

non-spatial data

Manual

- accurate
- inadequate coverage

Automatic systems

- calibration related issues
- large area coverage is expensive

Spatial data

Hydrological models

- Mass balance approach
- Profile level moisture
- Parameterisation of models – challenge

Satellite based

- Large area, daily coverage
- 25-50 km resolution
- Increasing popularity

Several microwave sensors

- SMRR – 1978-1987
- TRMM – TMI since 1997
- Scatterometer – ERS 1 & 2
- ASCAT – MetopA
- AMSRE – 2002-2011
- SMOS – 2009
- SMAP - 2015

Retrieval algorithms from passive systems

- NASA
- LPRM
- PRI

Soil moisture products from NRSC

- VIC hydrological models – daily soil moisture images
- AMSR 2 LPRM soil moisture 25 km, 2 day frequency

Crop related indices

Reduction in crop sown area - manual enumerations

Delay in planting time - manual enumerations

Crop condition – satellite based indices

Crop yield – manual enumerations

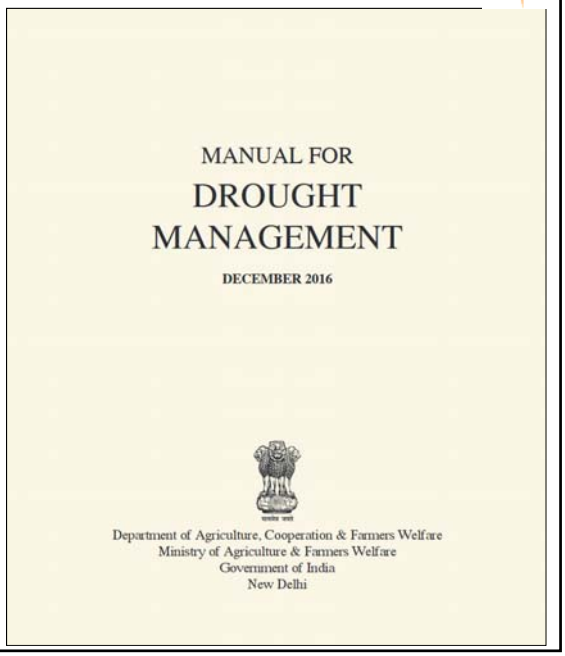
Guidelines for drought management in India

Department of Agriculture, Cooperation and Farmers Welfare (DACFW), Govt. of India is the Nodal agency for drought management

Guidelines to states

- National Drought Manual 2009
- **National Drought Manual 2016** (www.agricoop.nic.in)

Manual provides
- indices for drought monitoring
- Drought declaration protocols
- Relief management
- Long term measures
- Training to states



Satellite based indices

Present day Operational Assessment of Drought

- ✓ Spectral response in V, NIR region
- ✓ Spectral response in the SWIR region
- ✓ Thermal response
- ✓ Mainly using data from polar orbiting satellites
- ✓ Assessing and Monitoring the *in situ* conditions
- ✓ Weak forewarning and preparedness capability

REFELECTANCE BASED INDICES

- **Difference Vegetation Index**
- **Ratio Vegetation Index**
- **Infrared Percent Vegetation Index**
- **Perpendicular Vegetation Index**
- **Soil Adjusted Vegetation Index**
- **Weighted Difference Vegetation Index**
- **Greenness Vegetation Index**
- **Atmospherically Resistant Vegetation Index**
- **Normalized Difference Vegetation Index**
- **Normalized Difference Wetness Index**
- **Enhanced Vegetation Index**

NDVI = NIR-R/NIR+R

DROUGHT SEVERITY = $NDVI_i - NDVI_{Mean, m}$

EVI = G* ((NIR – RED) / (NIR + $C_{1*\,Red} - C_{2\,*\,Blue}$ + L))

Where

NIR = NIR reflectance
Red = Red reflectance
$NDVI_i$ is current $_{month}$ NDVI
$NDVI_{Mean, m}$ Long term NDVI mean for calendar month m
Blue = Blue reflectance
C_1 = Atmospheric resistance red correction coefficient (6)
C_2 = Atmospheric resistance Blue correction coefficient (7.5)
L = Canopy background brightness correction factor (1)
G = Gain factor (2.5)

REFLECTANCE AND EMITTANCE BASED INDICES

$VCI = (NDVI-NDVI_{MIN}) / (NDVI_{MAX}-NDVI_{MIN})*100$

$TCI = (BT_{MAX}-BT) / (BT_{MAX}-BT_{MIN})*100$

$VTI = a*VCI + b*TCI$

Where NDVI $NDVI_{Max}$ and $NDVI_{min}$ are smoothed weekly NDVI absolute maximum and its minimum

BT, BT_{Max} and BT_{min} are smoothed weekly brightness temperature absolute maximum and its minimum

VCI is Vegetation Condition Index,
TCI is Thermal Condition Index
VTI is Vegetation Health Index

Kogan 1995

PROCESS BASED INDICATORS

$Rn = G + H + \lambda E$

Rn = Net Radiation
H = Sensible heat flux
λE = Latent heat flux

$\lambda E = (Rn-G) - c_p * \rho_{air} * 1 / r_a * (T_s-T_x)$

$c_{p=}$ Sp. Heat of air
$\rho_{air=}$ Density
$r_{a=}$ Surface roughness
$T_{s=}$ Surface temoerature
$T_{x=}$ Maximum temperature

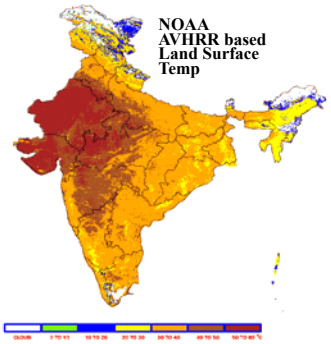
$EF = \lambda E / (R_n - G)$

EF is Evaporative fraction

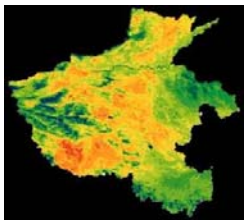
Land Surface Temperature / Evapotranspiration / Soil moisture

Land Surface Temperature

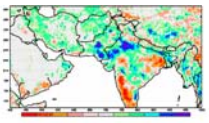
- NOAA AVHRR
- TERRA/AQUA MODIS
- LANDSAT TM



LST= T4+1.8(T4-T5) + 48(1-ε)-75Δε
Where,
Δε = ε4- ε5 = 0.01019 + 0.01344 x ln (NDVI)
ε4=0.9897 +0.029 x ln (NDVI)
ε= ε4+ ε5/2

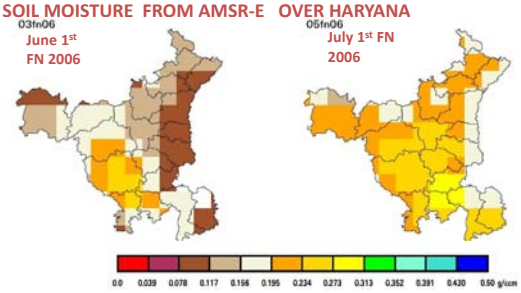


➢ Soil moisture is directly proportional to thermal inertia.



➢Soil Wetness Index (SWI) is the difference between the 85 GHz and 19 GHz channels data from the special Sensor Microwave/Imager (SSM/I) on the (DMSP) of the USA

SOIL MOISTURE FROM AMSR-E OVER HARYANA



Automatic Weather Stations

- Affordable alternatives to get detailed weather information.
- AWS measures – meteorological parameters like rainfall, humidity, temperature

- Special sensors for measuring soil moisture
- Data transmission through communication satellites – Kalpana - 1, INSAT 3A
- consistency in data recording, enhanced frequency of coverage,
- Coverage of inaccessible areas, all weather and all time operations

Standardization of data collection and Transmission system

1. **Weather data -- IMD stations**
   Revenue stations
   Increasing the density - Automatic Weather Stations

2. **Agriculture – Soil information (Soil maps)**
   Deep Soils
   Shallow soils
   Geo morphology – uplands, low lands
   Cropping pattern,
   Irrigation support
   Crop sown area progression
   Irrigation support

3. **Geospatial data bases**
   Land Use / Land cover
   Crop condition
   Bio physical parametrs etc

4. **Consistency in the data collection procedures, timeliness etc**

Data transmission to centralised servers

Surface mail, e mail
Satellite transmission