Indian Agricultural Research Institute, ICAR

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Spatio-temporal Trends of Standardized Precipitation Index for Meteorological Drought Analysis across Agroclimatic Zones of India

Somnath Jha 1 , Vinay K Sehgal 2, R.C. Raghava 1

1 Centre for Atmospheric Sciences, IIT, Delhi

2 Division of Agricultural Physics
Indian Agricultural Research Institute
New Delhi- 110012 INDIA

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Background

- Drought is a normal part of climate of India
- Every year it affects one or the other State.
- Droughts have spatial and temporal characteristics that vary significantly from one region to another.
- The understanding of the spatio-temporal trends of drought helps in undertaking informed decisions on their preparedness and mitigation measures.

Climatic Trends in India: Past Studies

- **Drought**
  - Incidence variable in time & space
  - More frequent during years following ENSO event
  - Frequent droughts: 1891 – 1920 & 1961 - 1980
  - Few droughts: 1930 – 1960 & 1980-2000

- **Rainfall**
  - No discernable trend ASMR of India
  - Increase in extreme RF event over North-West India (Singh & Sonatake, 2001)
  - Over East Coast, decrease in no. of rainy days during monsoon
  - Significant increasing trend of climatic extremes (flood and drought) and significant decreasing trend in moderate rainfall events are found in India (Goswami et al., 2006)
  - Rainfall deficit (frequency & magnitude) has significant increasing trend for India whereas rainfall excess (frequency & magnitude) has a significant decreasing trend (Pal & Al-Tabbaa, 2009)

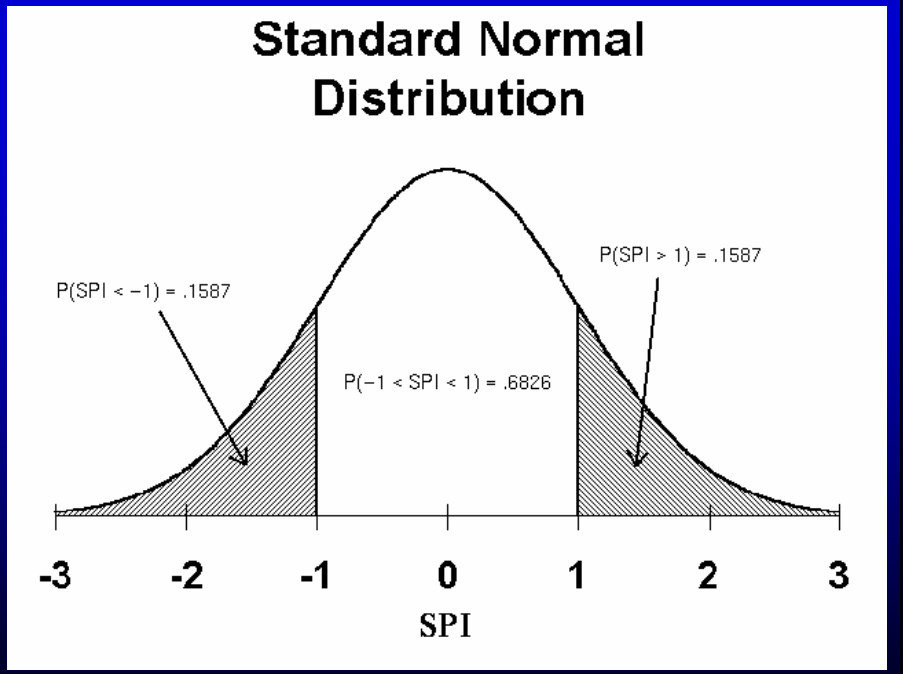
Methodology

- Gridded (0.5X0.5°) CRU TS 3.0 monthly average precipitation data for the period 1951 to 2006
- Computed gird wise SPI for different months & JJAS period
- SPIs aggregated to Agro-climatic zones of India
- Used Mann-Kendall and Regional-Kendall test to determine significant trend
  - 1% level of significance
  - 5% level of significance

Standardized Precipitation Index

- Based on cumulative probability of a given rainfall event occurring at a station.
- Historic rainfall data of a particular station is fitted in Gamma distribution and transformed into a standard normal variable Z with mean of zero and standard deviation of one.
- The SPI is a representation of the number of standard deviations from the mean at which an event occurs, often called a "z-score"

Standard Precipitation Index	Cumulative Density Function	Moisture category
−3.0	0.001	Extreme dry (ED)
−2.5	0.006	
−2.0	0.023	
−1.5	0.067	Severe dry (SD)
−1.0	0.159	Moderate dry (MD)
−0.5	0.309	Incipient dry (ID)
0.0	0.500	Incipient wet (IW)
0.5	0.691	
1.0	0.841	
1.5	0.933	Moderate wet (MW)
2.0	0.977	Severe wet (SW)
2.5	0.994	Extreme wet (EW)
3.0	0.999	

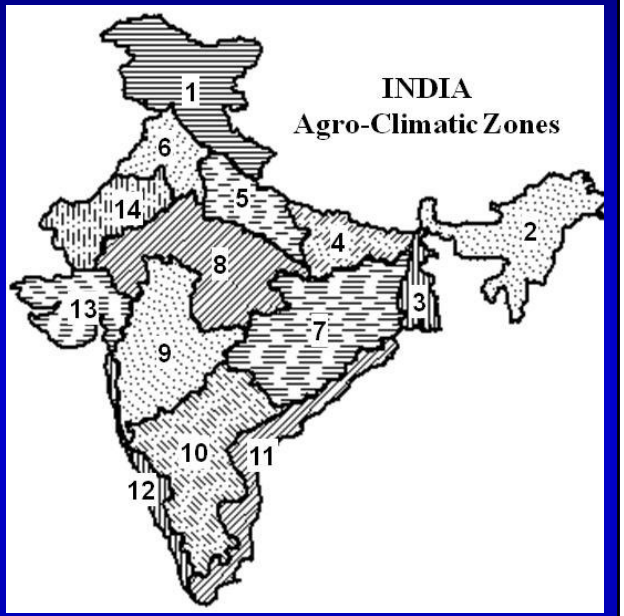


(McKee et al., 1993)

Agro-Climatic Zones

- Delineating homogeneous region based only on single variable eg. rainfall is catastrophically a wrong assumption and results of such homogeneous zone have produced a contradicting result (Ghosh et al., 2009)

- Mean annual rainfall
- Mean seasonal rainfall
- Mean temperature
- Soil Types
- Topography
- Cropping pattern



Index	Status of agro-climatic zones		
	Low	Medium	High
Infrastructure Status Index (ISI)	1, 4, 7, 14	2, 3, 5, 8, 9, 13	6, 10, 11, 12
Agricultural Status Index (ASI)	1, 2, 7, 14	3, 4, 8, 9, 10, 12	5, 6, 11, 13
Nutrition Status Index (NSI)	3, 4, 7, 13	2, 5, 10, 11, 12, 14	1, 6, 8, 9
Economic Status Index (ESI)	3, 4, 5, 7, 9	1, 2, 8, 11, 14	6, 10, 12, 13
Health and Sanitation Status Index (HSSI)	2, 3, 4, 7	5, 8, 9, 10, 11, 14	1, 6, 12, 13
Food Availability Status Index (FASI)	1, 2, 4, 12	5, 7, 8, 9, 10, 14	3, 6, 11, 13
Livelihood Status Index (LSI)	1, 2, 4, 7	3, 5, 8, 9, 11, 14	6, 10, 12, 13

Mann Kendall Test

- S =Statistic, Each pair of observed values yi, yj (i>j) of the random variable is inspected to find out whether yi>yj (number of this type is P) or yj>yi(number of this type is M). S is defined as
- S=P-M
- For sample of random variable n>10 instead of S statistic standard normal distribution of S is taken into account which is Z;

$$Z = \begin{cases} (S-1)/\sigma_s & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ (S+1)/\sigma_s & \text{if } S < 0 \end{cases}$$

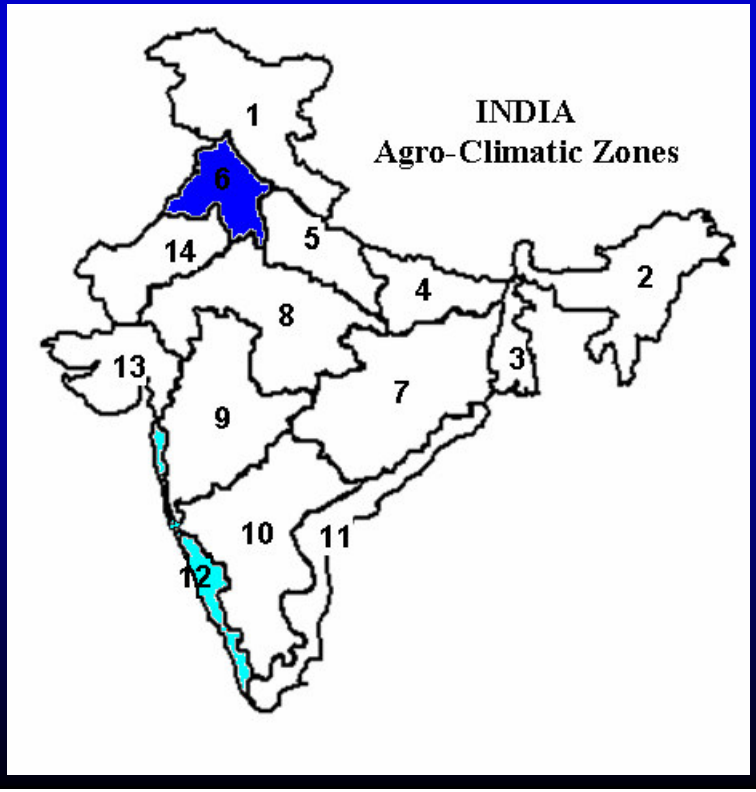
$$\sigma_s = \sqrt{\frac{n(n-1)(2n+5)}{18}}$$

- The null hypothesis is that there is no trend is rejected when computed Z value is greater than Za/2 in absolute values

(Onoz & Bayazit, 2003)

JUNE SPI TREND

Zones	Tau corr. Coeff.	S value	Z value	P value	Intercept	Slope
ACZ6	0.275	423	2.983	0.003	-38.436	0.0194
ACZ12	0.204	314	2.212	0.027	-22.179	0.0113



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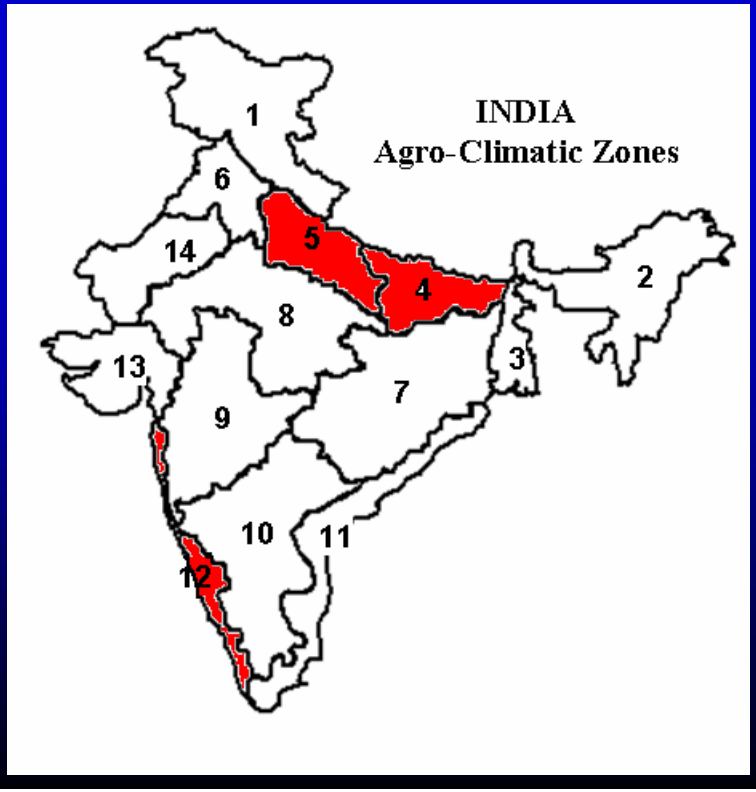
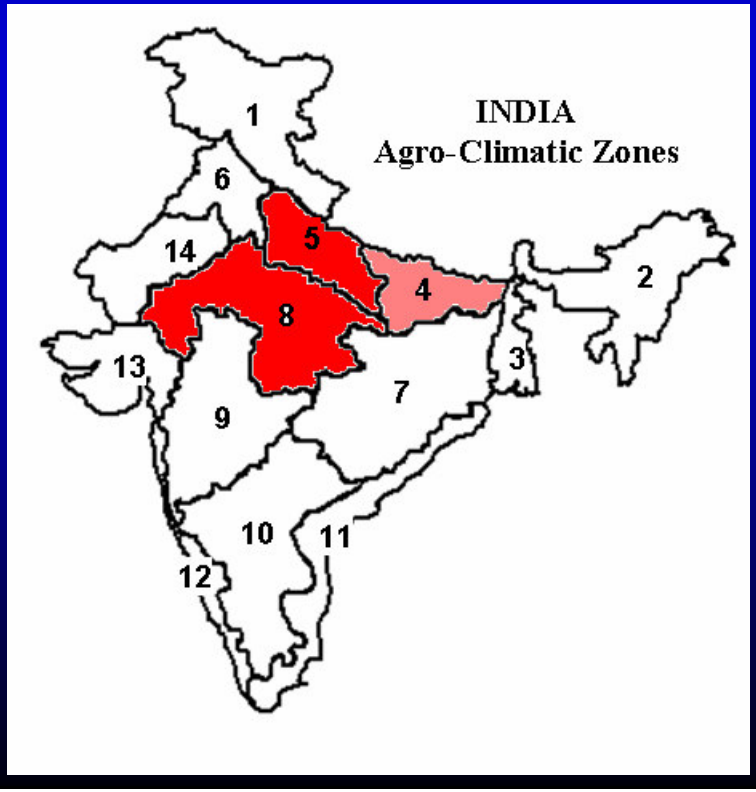
JULY SPI TREND

Zones	Tau corr. Coeff.	S value	Z value	P value	Intercept	Slope
ACZ4	-0.266	-410	-2.891	0.004	35.456	-0.0180
ACZ5	-0.248	-382	-2.693	0.007	38.774	-0.0195
ACZ12	-0.269	-415	-2.926	0.003	32.910	-0.0166



AUGUST SPI TREND

Zones	Tau corr. Coeff.	S value	Z value	P value	Intercept	Slope
ACZ4	-0.206	-318	-2.240	0.025	27.696	-0.0140
ACZ5	-0.296	-456	-3.216	0.001	46.432	-0.0235
ACZ8	-0.244	-376	-2.650	0.008	30.653	-0.0155



SEPTEMBER SPI TREND

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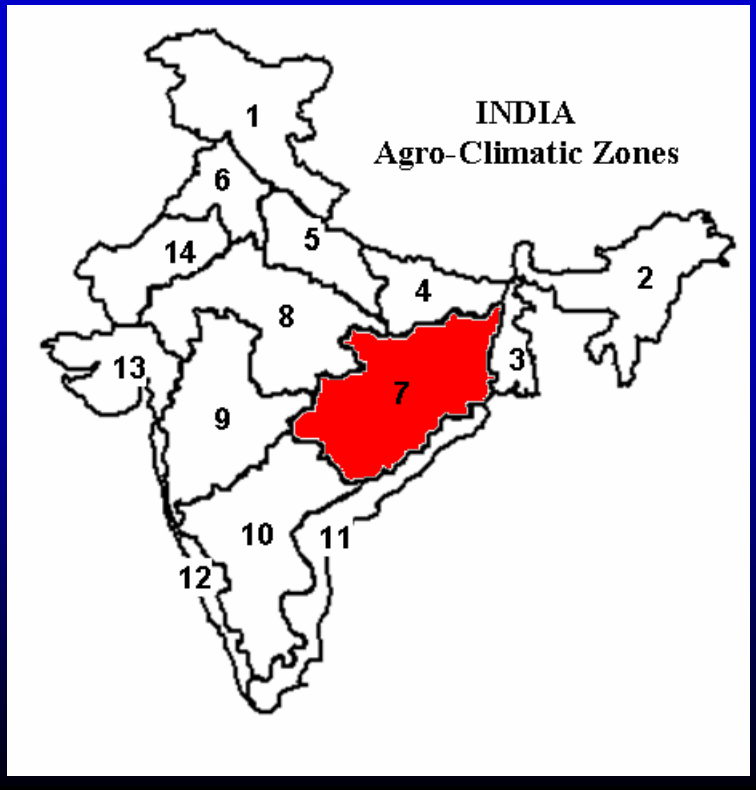
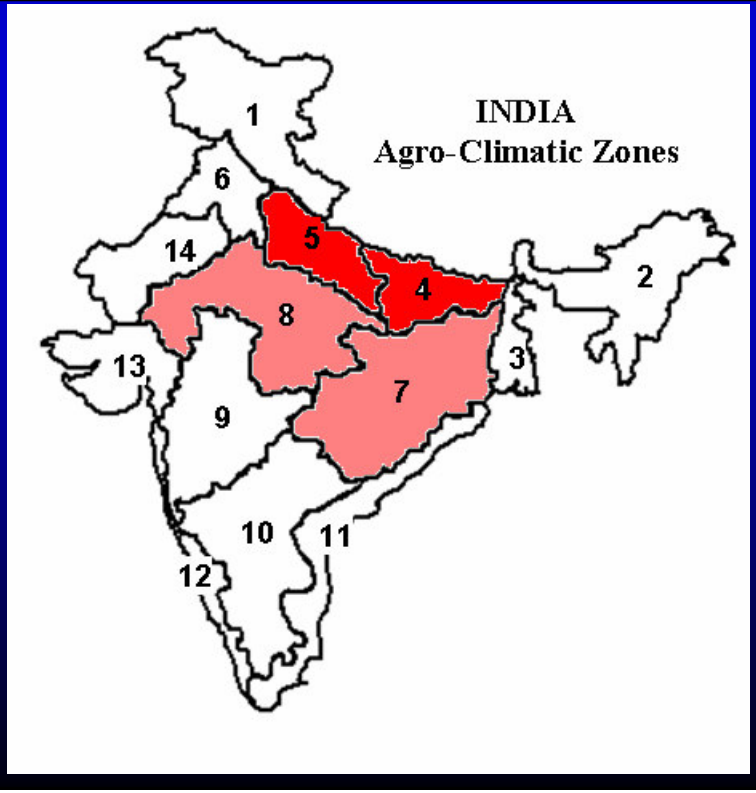
Zones	Tau corr. Coeff.	S value	Z value	P value	Intercept	Slope
ACZ7	-0.269	-414	-2.919	0.004	32.952	-0.0167



SPI TREND FOR JJAS

ACZ	Tau corr. Coeff.	S value	Z value	P value	Intercept	Slope
ACZ4	-0.367	-565	-3.986	0.000	42.708	-0.0216
ACZ5	-0.264	-406	-2.862	0.004	39.075	-0.0197
ACZ7	-0.188	-290	-2.043	0.041	25.387	-0.0129
ACZ8	-0.226	-348	-2.452	0.014	27.300	-0.0138



Regional Kendall test for all ACZs

Month	Tau corr. Coeff.	S value	Z value	P value	Estimated Median Trend Equation
June	0.099	1696	3.789	0.1E-5	Change in Y= 0.0075 per year
July	-0.100	-1715	-3.832	0.1E-5	Change in Y = -0.0075 per year
August	-0.072	-1228	-2.743	0.006	Change in Y = -0.0054 per year
Sept	-0.038	-656	-1.464	0.143	Change in Y = -0.0031 per year
JJAS	-0.082	-1409	-3.148	0.002	Change in Y = -0.0065 per year

Conclusions

- Increasing trend in drought in states of Bihar, Uttar Pradesh, Madhya Pradesh, Orissa and Eastern Rajasthan.
- Significant decreasing trend in rainfall of these regions for different months (July, Aug) as well as for JJAS monsoon period.
- Overall for India as a whole, there is an increase trend in meteorological drought due to decreasing trend in rainfall for JJAS period.
- Overall for India, the months of July and August are become drier and while June month is become wetter.

Conserve Water When in Plenty

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THANKS

vksehgal@gmail.com

sehgal@iari.res.in

somnath.jha@gmail.com

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