

Meteorological Drought Intensity Assessment using Standardized Precipitation Index

Ashish Srivastava¹, Dr. Geeta Singh²

¹M. Tech Scholar, Delhi Technological University, Delhi

²Assistant Professor, Delhi Technological University, Delhi

Abstract - Drought is a condition which due to deficiency of moisture in a region due to uneven rainfall, drying up of rivers and loss of ground water. It is estimated that droughts effects around 200 million people are affected from drought every year in India. In 2019, 42% of the country's area is under drought with almost 500 million people severely affected in some ways. The study focuses on the Uttar Pradesh region of Bundelkhand Plateau, which faces continuous droughts every year. The study is carried out for six districts of Uttar Pradesh viz. Auraiya, Banda, Jalaun, Jhansi, Hamirpur and Lalitpur. To identify drought conditions and classify it Standard Precipitation Index (SPI) was computed. The monthly rainfall data from 1988 to 2018 was collected from various sources. The 3-Month SPI (April-June), 3-Month SPI (July-September) and 6-Month SPI (Oct-Mar) were computed using DrinC software and MS excel. The SPI values were used to categorise drought under four groups based on its severity namely mild, moderate, severe and extreme from 1988 to 2018. The IMD classification of rainfall involves categorizing drought by computing the percentage deviation of the current rainfall from normal rainfall. The SPI values of thirty years are compared with actual rainfall and deviation from normal rainfall. The aim is to assess if SPI can provide better drought analysis in comparison to rainfall deviation method which is conventionally used.

Key Words: Drought, Standardized Precipitation Index, DrinC, IMD, Rainfall

1. INTRODUCTION

Droughts are natural disasters related to water deficiency which has an impact on various activities related to environment such as vegetation, agriculture, wildlife, humanity and economy. Drought is one of the most significant natural disaster associated to weather which is often intensified by human activities, since its impacts affect greater areas for time ranging from months to years, thus it has a stern effect on life expectancy, food and grain production for entire population. In recent times large-scale severe droughts have been noticed across the globe leading to starvation due to restricted food supply and shortage among millions, destruction of ecological resources and heavy losses in economy.

The disaster management actions are organized into following:

- Preparedness stage in which prediction of disaster and the zone of risk are identified well in advance before the occurrence of event;
- Prevention stage during which early forecasting and warning, monitoring and preparation of emergency plans are easily executed before or during the occurrence of event;
- Mitigation and Action stage where actions are taken just after the occurrence which comprise damage valuation and mitigation.

The statistics of the disaster events show the alarming trend (Manikiam, 2003). One of the worst natural catastrophes that distress India is the occurrence of drought on large-scale during the (June to September) south-west monsoon season. Semi-arid region faces the greatest drought hazard and is characterized by low and uncertain crop yields, mostly rainfed. For most of dry crops, the yields are invariably dependent on residual soil moisture storage (Dhopte, 2002).

1.1 Drought definitions

Drought is an event when the rainfall for a week is less than fifty percent of the normal, when the weekly normal rainfall is more than or equal to 5 mm. Drought is a period when dry conditions than normal are seen which results in water-scarcity.

According to the Indian Meteorological Department (IMD) drought occurs in an area when the deviation from normal or precipitation deficiency is more than or equal to 26 percent of long-term normal rainfall of that area. Further it is classified in to moderate and severe drought based on the rainfall. A drought incident is well-defined as a year or a period of time during which the total rainfall is less than 75% of the normal rainfall. If the deficit of rainfall lies between 26 percent to 50 percent it is classified as a moderate drought and when it is more than 50 percent it is classified under severe category.

1.2 Drought Classification

- Meteorological drought:** It is a condition during which a substantial (more than 25%) deficiency from normal precipitation occurs over a region.

- b. **Hydrological drought:** Longer duration meteorological drought results in hydrological drought. It also results in drying up of rivers, streams, lakes, reservoir and decreasing levels of underground water. Hydrological drought impacts agriculture and industries as it causes scarcity of water.
- c. **Agricultural drought:** If there is not sufficient rainfall to retain enough moisture levels in soil which result in reduced plant growth or no growth at all and also wilting of crops then a situation of agricultural drought is marked.
- d. **Socio-Economic drought:** When there is such scarcity in precipitation that it affects the growth of the country economically it marks socio-economic drought.

1.3 Drought Impacts

Drought can be referred to as a prominent moderate catastrophe as compared to other normal disasters. It negatively impacts life, economy, horticulture, animals, water bodies, small insects etc.

a. Economic Impacts of Drought

Areas like agriculture and fish culture or aqua culture, may affect economy of the country. These jobs require water in considerable amount whether it is ground water or surface water.

b. Environmental Impacts

Drought impacts on the environment can be interpreted by evaluating the loss in green cover, loss of bio-diversity, drying up of wetlands further resulting in restriction on coming migratory birds, loss of various species and extreme drying up of land which leads to cracking and disintegration of soil.

c. Impact on society

Drought has huge impacts on society during the time period through which it lasts and also after it. Lack of harvests, increasing loans which result in debts, bring about suicides of farmers which is a major cause of concern in India.

1.4 Meteorological drought indices and drought detection

Drought indices are frequently applied to measure the possible danger of incidence and drought severity. They also are used to assess spatial-temporal behaviour. A number of the indices have been used for sensing magnitude and variability of the drought temporally across different areas. Few extensively used drought indices include Crop Moisture Index (CMI), Palmer Drought Severity Index (PDSI),

Standardized Precipitation Index (SPI), and Surface Water Supply Index (SWSI).

a. Standardized Precipitation Index (SPI)

Even though there are many indices present to compute drought related parameters, assess its severity and classify it, the SPI is the most extensively used index according to Jain(2010). The SPI was computed by Tom McKee, Nolan Doesken, and John Kleist of the Colorado Climatic Centre in 1993. Its computation can be done at different periods and time scales and therefore it can measure water deficiency of different duration. The design of SPI is such that it makes possible to concurrently monitor dry conditions on a specific time scale and wet conditions on a different time-scale. The rainfall difference from the mean of an equal normally distributed function with a mean 0 and a standard deviation of 1 then gives the SPI. The soul premise of the current effort is that using a drought index, such as SPI, leads to more suitable understanding of drought duration, magnitude, and spatial reach in semiarid regions (Karavitis et al. 2011). The SPI is a tool for measuring drought that differs from the PDI. Like the PDI, this index is positive for wet conditions and negative for drought. But the SPI only considers precipitation and is a probability index, while Palmer’s indices uses precipitation, evapotranspiration, and loss due to runoff and are water balance indices.

Table 1: SPI based Classification

SPI VALUES	CLASSIFICATION
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately 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

2. STUDY REGION AND METHODOLOGY

The study area includes the districts of Lalitpur, Banda, Auraiya, Jhansi, Jalan and Hamirpur in Uttar Pradesh State of India.

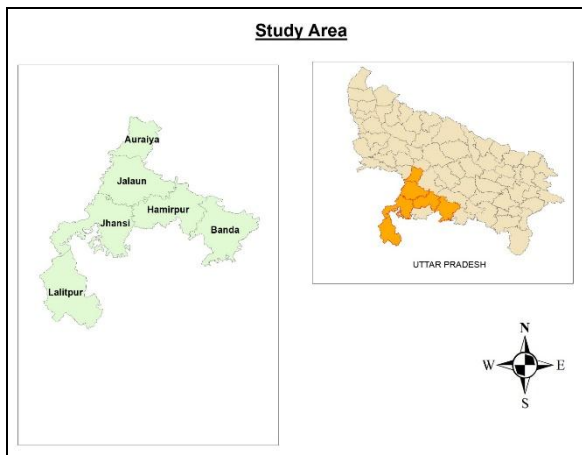


Fig-1: Study Area

3. RESULTS AND DISCUSSIONS

3.1 Drought Classification Using SPI

The results and discussions in this study, are based on the 3-month SPI (April-May-June) and 3-month SPI (July-Aug-Sept) used to signify short-term and is also used seasonally drought during the summer season and the 6-month SPI (Oct-Mar) is used for intermediate-term drought during the winters in the region.

Wet Mild Drought Moderate Drought Severe Drought Extreme Drought

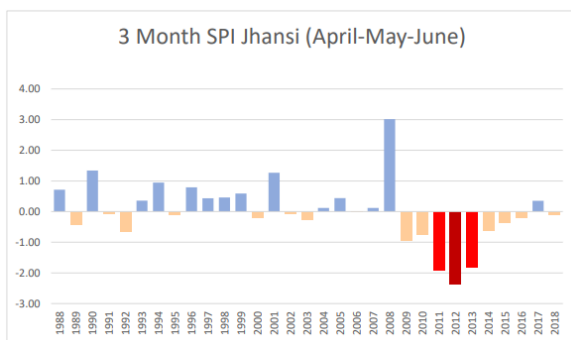


Chart-1: 3-Month SPI Jhansi (April-May-June)

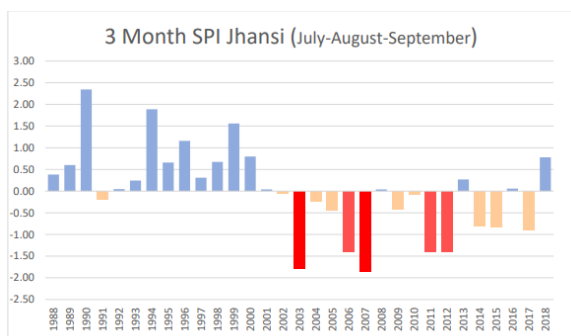


Chart-2: 3-Month SPI Jhansi (July-Aug-Sep)

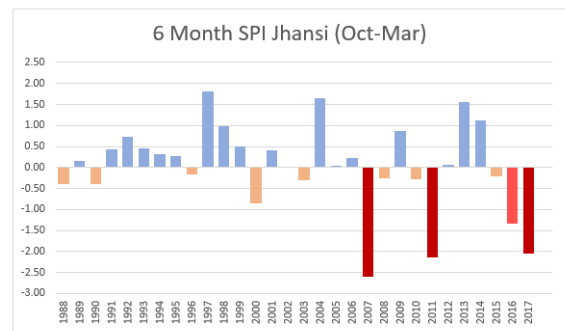


Chart-3: 6-Month SPI Jhansi (Oct-Mar)

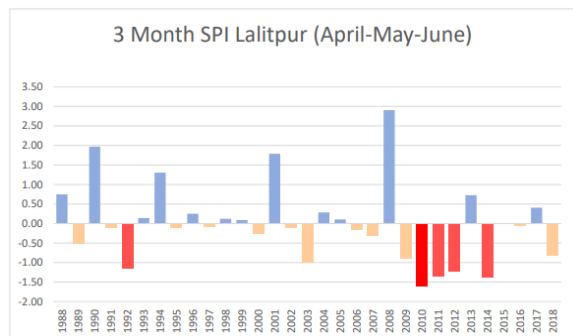


Chart-4: 3-Month SPI Lalitpur (April-May-June)

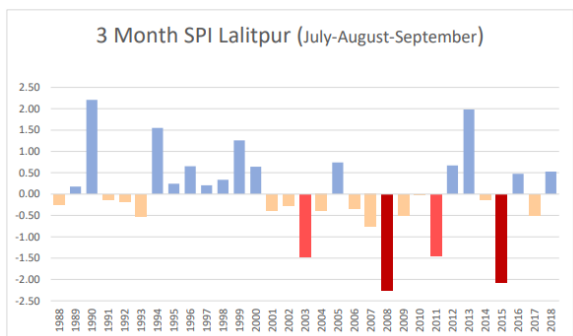


Chart-5: 3-Month SPI Lalitpur (July-Aug-Sep)

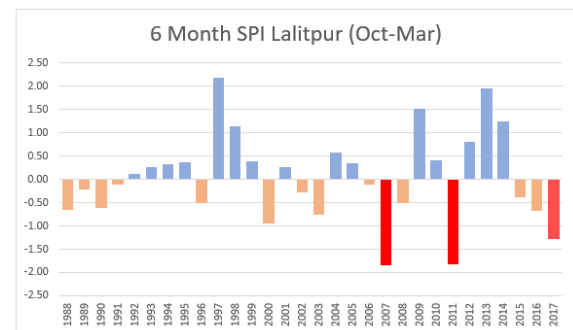


Chart-6: 6-Month SPI Lalitpur (Oct-Mar)

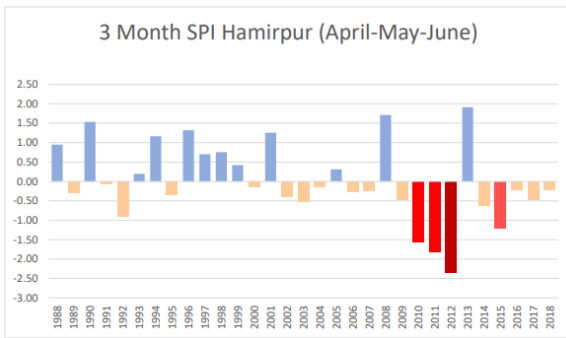


Chart-7: 3-Month SPI Hamirpur (April-May-June)

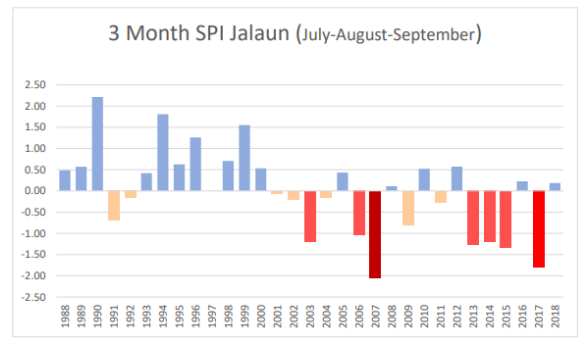


Chart-11: 3-Month SPI Jalaun (July-Aug-Sep)

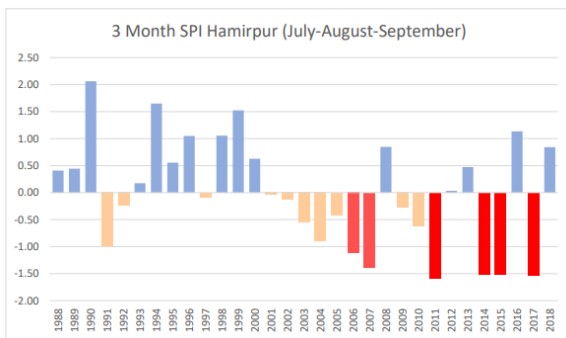


Chart-8: 3-Month SPI Hamirpur (July-Aug-Sep)

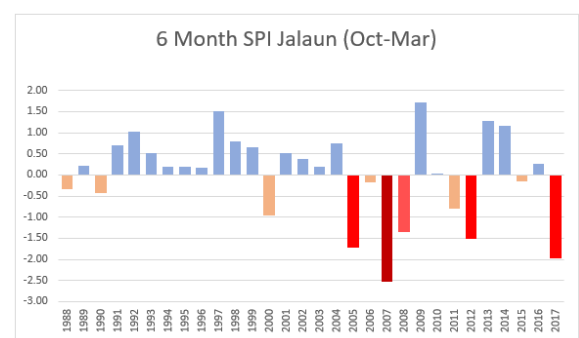


Chart-12: 6-Month SPI Jalaun (Oct-Mar)

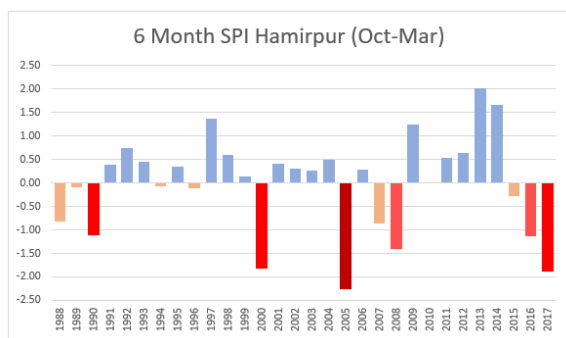


Chart-9: 6-Month SPI Hamirpur (Oct-Mar)

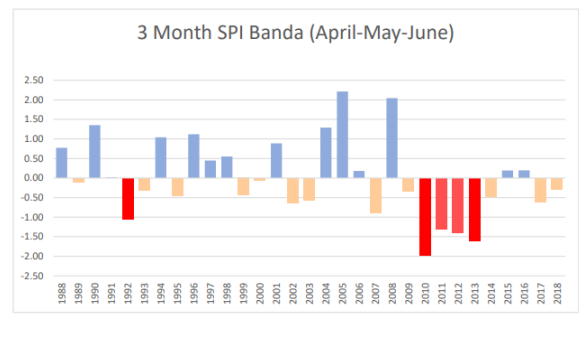


Chart-13: 3-Month SPI Banda (April-May-June)

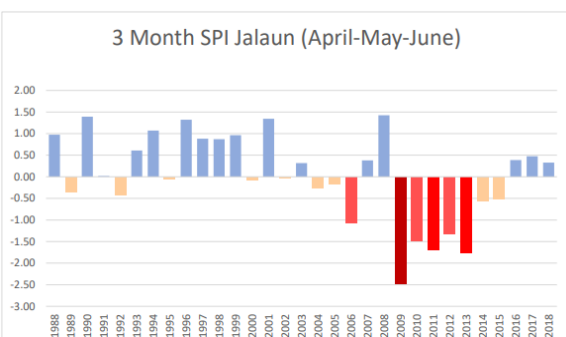


Chart-10: 3-Month SPI Jalaun (April-May-June)

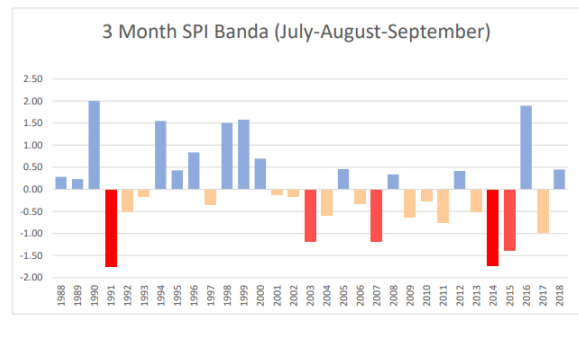


Chart-14: 3-Month SPI Banda (Jul-Aug-Sep)

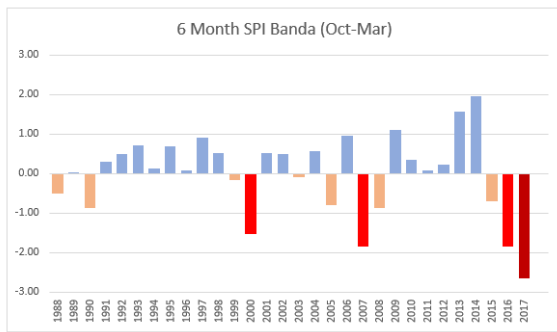


Chart-15: 6-Month SPI Banda (Oct-Mar)

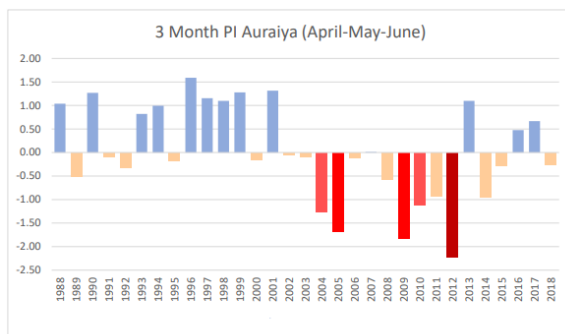


Chart-16: 3-Month SPI Auraiya (April-May-June)

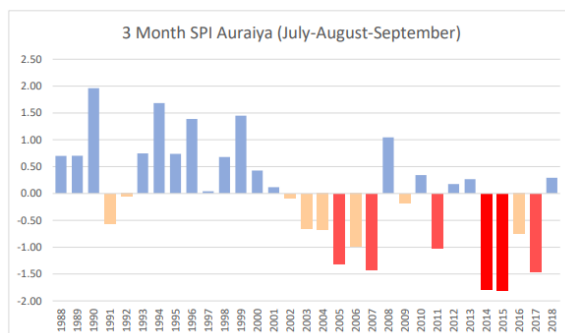


Chart-17: 3-Month SPI Auraiya (July-Aug-Sep)

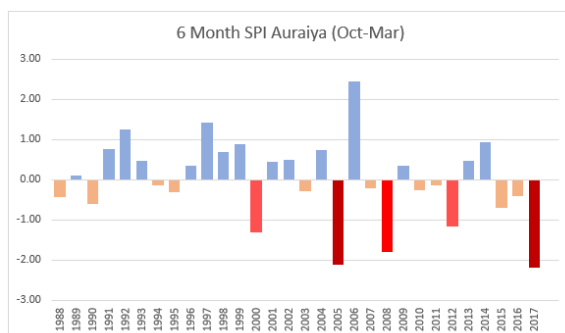


Chart-18: 6-Month SPI Auraiya (Oct-Mar)

3.2 Scatter Plots between SPI and Rain fall Deviation

Scatter charts of 3-Month SPI vs. Rainfall Deviation from average for 2009-2018 using excel for both positive and negative rainfall deviations as shown in the Figure 2 and Figure 3.

It is clear from Figure 2 for Auraiya district that even at negative rainfall deviations of -30% to -40% as shown the SPI values incline to be very negative around -2.0 which represent severe to extreme drought condition. Where as in the same area from Figure 3 in which SPI is plotted during a wetter period, the SPI values are found to be more in accordance but still negative rainfall deviations of around -60% to -80% which represent extreme drought conditions correspond to a lower SPI of around -1.5 to -1.8 rather it should be near -2.0 and above.

Negative rainfall deviations in Hamirpur district (-75% to -95%) represent extreme dryness, but the SPI values corresponding to -70% and -80% represent only a severe case of drought and at -92% SPI drops to -2.35 correctly depicting an extreme drought as shown from Figure 2. The 3-month SPI (July-Aug) from Figure 3 for Hamirpur represent the values of SPI in better agreement with Negative Rainfall Deviations.

Similar observations can be made from for Jalaun where negative rainfall deviations of above -80% which otherwise represent very dry conditions and extreme drought are only once indicated under the same. Similar analysis can be made through Figures 2 and 3 for Jhansi, Lalitpur and Banda where also very high negative deviation from rainfall greater than -70% are not exactly referred under extreme condition but under severe condition with values less than -1.5.

In the case of positive deviations from rainfall which indicates that actual rainfall is more than the normal rainfall with the positive values of SPI representing wet condition, the degree of positive SPI did not correspond with the range of the positive deviation. The rainfall deviations of 100 to 400% which represent fairly wet conditions are only shown by SPI values of 1.5-3 a particular case being the year 2008 when during April-June good rainfall can be seen which otherwise correspond to the drier months.

On the other hand, during periods of high rainfall in the area from July-August the SPI values are better distributed and stretched between +2.5 to -2.5 correctly representing the drought conditions reported by both positive and negative rainfall deviation .The SPI values for all the districts during this period for most of the year can be seen in accordance.

Hence, even the very less amount of precipitation which is surely not enough for keeping moisture of optimum level in soil have led to the SPI values around -1.5 which otherwise must have represented very high level of dryness with SPI of less than and near -2.0. In the same way, excess

rainfall events are represented by SPI near 1.5. This tendency of extreme high rainfall not representing a greater SPI and less rainfall not representing less SPI and can be seen in all the districts during all the time scale of SPI calculation.

Hence, from this analysis we can infer that values of SPI are under-valued during high rainfall and over-valued during less rainfall particularly during dry spells of April-June. Whereas, during the period of ample rainfall the SPI values give a fair representation in agreement to the deviations from normal.

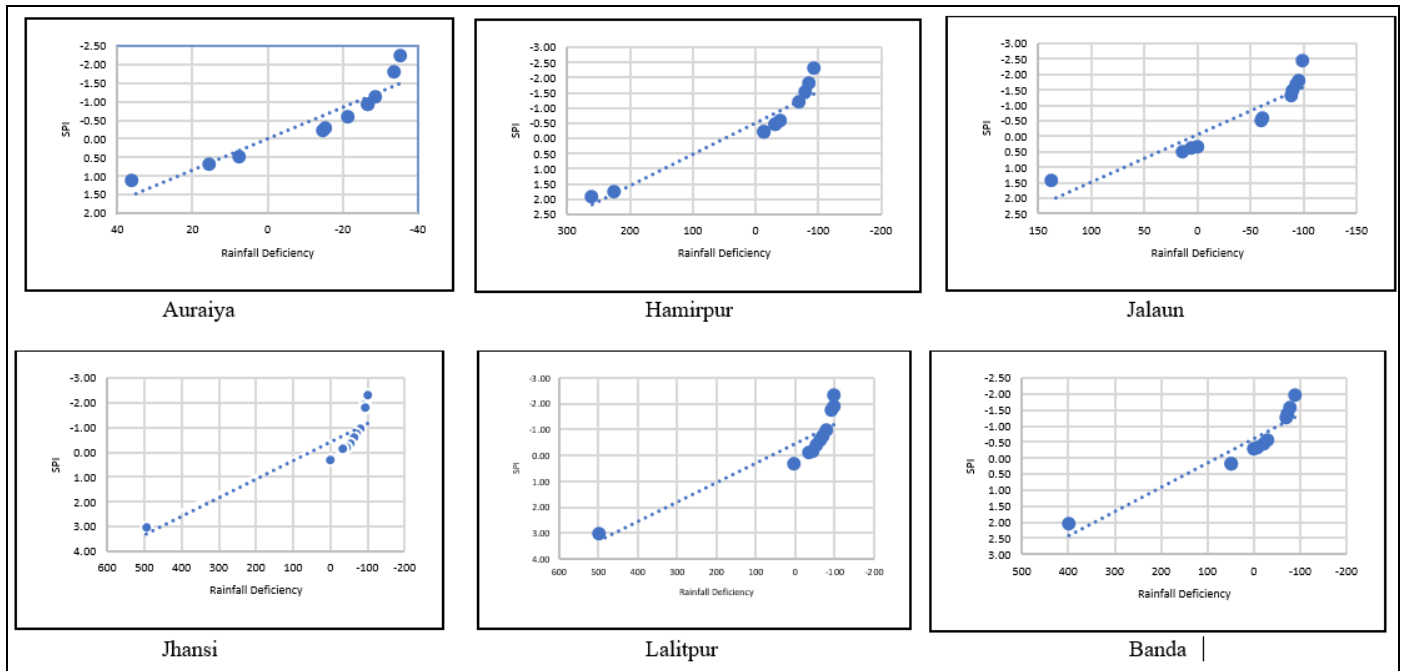


Figure-2: 3-Month SPI(April-May-June) vs. Rainfal deviation Scatter Plots

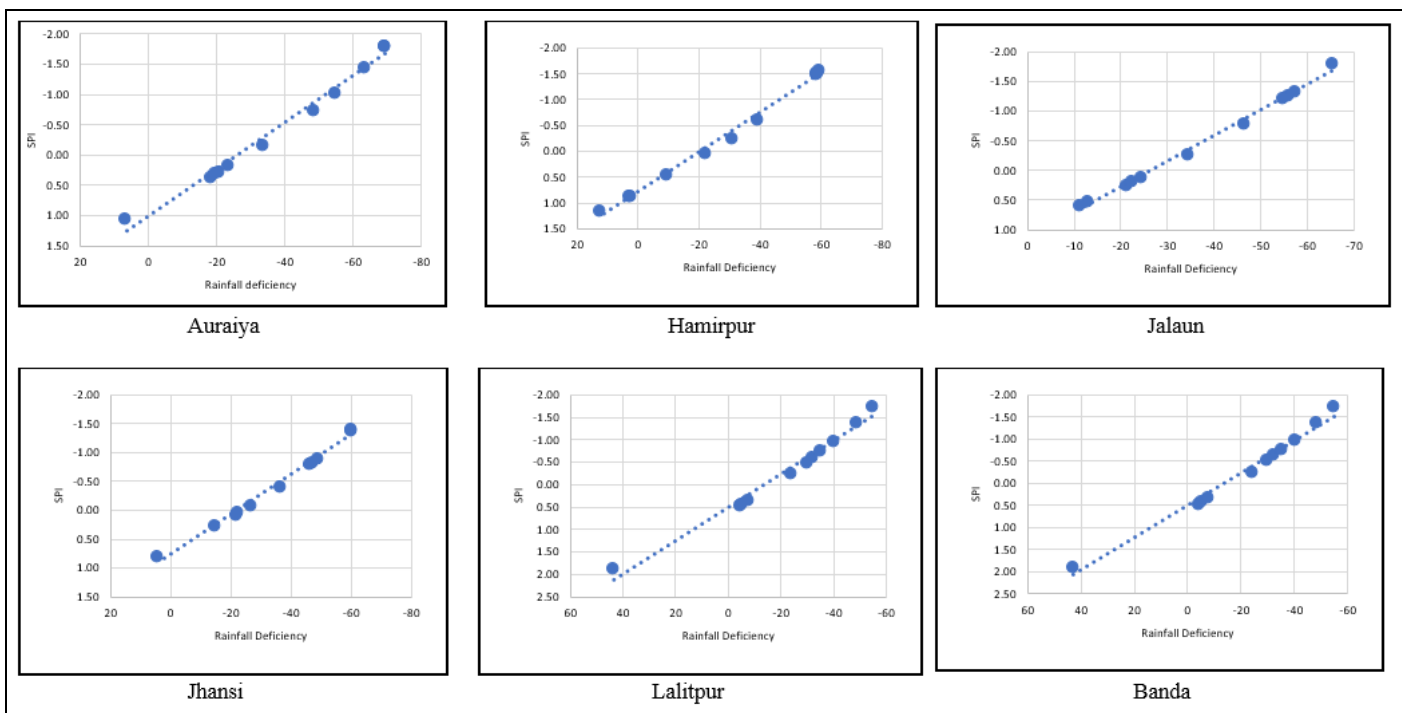


Figure-3: 3-Month SPI(July-Aug-Sep) vs. Rainfal deviation Scatter Plots

4. CONCLUSIONS

1. It is found that during years 2009,2010,2011,2012,2013 almost all the districts are severely and extremely affected by drought with 2012 being the worst year with SPI values below -2 and less based on 3-Month SPI (April-June).
2. In the years 2007,2011,2014,2015 and 2017 severe and extreme drought has affected all the districts as classified by 3-Month SPI (July-Sep) with 2014 and 2015 being the worst affected years having SPI values in Range of -1.5 to -3.
3. The drought in the 6-month period is due to less rainfall during receding south-west monsoon and the region depends on winter agriculture but as can be seen from the results that most of the past ten years have been drought affected. 2008, 2012 and 2018 have seen extreme drought events based on 6-Month SPI (Oct-Mar).
4. To ascertain the validity of SPI in the region, the SPI values for the last ten years for April-June and July-September are compared with the rainfall deviation from mean. Scatter plots are plotted to see the variation in SPI and Rainfall deficiency.
5. It is found that when there is very low rainfall the SPI values under-estimate the drought situation like in 2010,2011 and 2013 for Hamirpur, Jalaun, Jhansi, Lalitpur and Banda rainfall deviations of -60% to -90% are only represented by SPI values of severe drought stations with values lying between -1 to -2.

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BIOGRAPHIES



Ashish Srivastava,
M. Tech Scholar, Delhi
Technological University, Delhi



Dr. Geeta Singh,
Assistant Professor, Delhi
Technological University, Delhi