Drought assessment based on Meteorological Index in Nainital District of Uttarakhand

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ABSTRACT: Uttarakhand is primarily a mountainous state with only about ten percent of its total geographical area in the plains. Study carried out in Nainital district of Uttarakhand is located in the foothills of Kumaun region of outer Himalayas. Water scarcity is a burning problem for the hill agrarians of Nainital. Therefore, in this region timely information about rainfall amount, variability and distribution pattern is very imperative for planning and management of agriculture or natural resources. Considering the essential role of water in domestic purpose, agriculture, horticulture, animal husbandry, fisheries and forestry, etc., drought pattern were analyzed in Nainital district of Uttarakhand. Rainfall data were used to calculate Standardized Precipitaton Index (SPI) for drought assessment. SPI values on 16 days interval were used to determine the spatial pattern of meteorological drought in Nainital. Impact of drought on rice crop yield of Nainital district was analyzed and year which was facing meteorological and agriculture drought was identified. Rainfall data was observed to be more useful for planning of irrigation schemes, cropping patterns, conservation and management measures so as to manage harvested rainfall in drought conditions.

Key words: Drought, Standardized Precipitation Index (SPI), rice yield.

Drought is a natural disaster which occurs in virtually all climatic regimes. Drought results from a deficiency of precipitation from expected or "normal" such that when it is extended over a season or longer period of time. The amount of precipitation is insufficient to meet the demands of human activities and the environment resulting drought. It is impossible to make a definition of drought that can be universally accepted (Li and Xiao 1992; Wilhite 1993). Drought can be described by three characteristics: intensity, duration and spatial coverage (Wilhite and Glantz, 1985). Intensity refers to the degree of precipitation shortfall and is closely linked to duration in the determination of its impacts. To some extent, drought occurs with uncertainty at a micro-scale, and drought occurrence sites vary from time to time when studying spatial distributions of drought (Wang and Wei, 1998). Meteorologically based drought monitoring refers to point-based analyses which might include simple presentations of specific events relative to their long-term historical averages (often denoted as 'normal'). The point-based drought indices have been used extensively for monitoring drought. The Standardized Precipitation Index (SPI) based only on precipitation gives a better representation of abnormal wetness and dryness (McKee *et al*., 1993, 1995; Guttman, 1999).

SPI has been used extensively for drought assessment as mild, moderate, severe and extreme drought event. SPI also provide greater reliability with minimum input and in lesser time. The methodology in drought assessment, calculation of detrended rice yield and impact of drought on rice yield of Nainital district were studied. SPI values and rice yield from 2001 to 2011 were analyzed showing different agriculture drought pattern in Nainital. Result represented that agricultural drought during the main rainy season has greater impact on food production. Agricultural drought has either direct or indirect impact on agricultural activities. Direct impact includes reduced crop yield, rangeland and forest productivities. Agricultural drought induced physiological stress increases a plant's susceptibility to disease and insects, and reduces crop survival. On the other extreme, agricultural drought has also social impact particularly on farmers that drive the agricultural sectors. This makes drought migrants increase pressure on social infrastructure of the urban areas and leads to increased poverty. Thus, drought assessment in this study is helpful for researchers to generate the information including identify the drought prone area as well crop management and soil moisture conservation practices.

MATERIALS AND METHODS

The study was carried out in Nainital district of Uttarakhand, India. Geographically, Nainital district is located at 29º38'N latitude and 79º45'E longitude. The elevation of this place is 2084 meter above mean sea level. The area lies in the foothills of Kumaun region of outer Himalayas. The study is carried out to assessment of drought in Uttarakhand using Standardized Precipitation Index (SPI). The study region is geo-climato-ecologically; distinct from most other parts of the country and includes diverse climatic conditions from tropical to alpine.

Data used

The research needs data on climate (rainfall) and rice yield of Nainital. Climate data on rainfall of Nainital district of uttarakhand was taken from different sources. Daily rainfall data were collected from India Meteorological Department (IMD) and NICRA's website i.e. http://www.nicra-icar.in/nicrarevised/. Data on yield, production and productivity of rice crop of Nainital district were collected from http://apy.dacnet.nic.in/ .

Calculation of Standardized Precipitation Index (SPI)

SPI was developed in Colorado by McKee *et al*. (1993) to quantify the precipitation scarcity for multiple time scales which reflect the impact of drought on the availability of the different water resources. The SPI calculation is based on the long-term precipitation record for a time period. The study showed the drought pattern in Nainital district using the Standardized Precipitation Index (SPI):

$$SPI = \frac{X - \overline{X}}{\sigma}$$

Where, σ = standardized deviation for the i^{th} station; X = precipitation for the i^{th} station and k^{th} observation
X = mean precipitation for the i^{th} station

Standardized Precipitation Index (SPI) on 16 days interval was calculated at Nainital district using daily rainfall data from year 2001 to 2011 to estimate drought. The index has the advantages of being easily calculated, having modest data requirements, and being independent of the magnitude of mean rainfall and hence comparable over a range of climatic zones. The interpretation of positive SPI values indicates greater values than the median precipitation, while negative values indicate less value than the median precipitation. One of the advantages of SPI is its ability to monitor dry and wet climate as it's a normalized index. According to McKee *et al*. (1993), SPI values can be classified as shown in Table (1) to describe drought intensities.

The negative values indicate the occurrence of drought event. The drought event will finish when SPI values become positive. Therefore, each drought event has a duration limited by its beginning and end, and an intensity for each month in which the event continues.

Calculation of Trended and Detrended Yield

Trend yield: Trend yield is basically that yield which is being produced by the help of different agro-inputs like fertilizer, high yielding varieties, irrigation facilities etc. due to the effect of these inputs there is an increase of yield this is called trend yield.

The trend yield has been calculated on the basis of Rice yield Data of *kharif* season. The trend yield has been calculated by following formula:
Trend yield = Slope* S.N. + Constant

Detrended yield:
On contrary of the trend yield detrended yield is increase or decrease in yield only due to weather conditions. The detrended yield has been calculated on the basis of trend yield and actual yield. It is the ratio of difference between actual yield and trend yield to trend yield i.e.

Table 1: Classification of SPI values

SPI range	Drought intensity class
>2	Extremely wet
1.5 to 1.99	Very wet
1 to 1.49	Moderately wet
0.5 to 0.99	Mild wet
0.5 to -0.5	Near normal
-0.5 to -0.99	Mild drought
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

De-trended yield = (Actual yield - Trend yield)/Trend yield

Effect of Drought on Rice Crop

Relationship between SPI on 16 days interval and detrended rice yield was developed in *kharif* season for Nainital district in Uttarakhand.

RESULTS AND DISCUSSION

Drought assessment based on SPI

On the basis of SPI Nainital district of Uttarakhand were categorized in to mild, moderate, severe and extreme drought conditions. Graph shown in figure 1 represents drought pattern in Kharif season on 16 days time scale in Nainital. From graph (1) it is clear that there was mild drought conditions were observed in 2002, 2003, 2004, 2006 and 2007. Year 2001, 2005 and 2009 showed near normal conditions while year 2010 represented extreme wet conditons on first fornight of July. Second fortnight of July in the month 2001, 2004, 2006 and 2007 represented mild drought , while moderate drought condition were found in 2009. Remaining years represented drought free condition on second fortnight of July in Nainital. SPI trend in Nainital on first fortnight of August showed moderate drought on 2001and mild drought on 2003, 2006 and 2009. Year 2007 was observed under extreme wet condition. On second fortnight or 29th of August moderate drought event was seen in 2001, 2002 and mild drought occur in 2009. So, second fortnight of August only three years i.e. 2001, 2002 and 2007 from 2001 to 2011 comes under drought and remaining years were drought free.

SPI pattern in the month of September were explained on first and second fortnight.first fortnight of September represented mild drought in 2001, 2004, 2006, 2007, 2008 and moderate in 2009, while on second fortnight or 30th of September only moderate drought were taken place in 2001, 2002 and 2009. In the month of October in nainital SPI trend was same as in Almora. Nainital on first fortnight i.e. on 16 October was free from drought and on 1 November mild drought event was observed in 2001, 2002, 2003, 2004, 2008 and 2009 while remaining years were free from drought event.

Calculation of Detrended Rice Yield of Nainital

Rice yield data of Nainital district from year 2001 to 2011 were taken and trend were analyzed (Fig. 2). Fig. 2 represented increasing linear trend of rice yield from 2001 to 2011 in Nainital. Linear equation Y=0.00976x-17.11 (fig. 2) was used to calculate the detrended rice yield (Table 2).

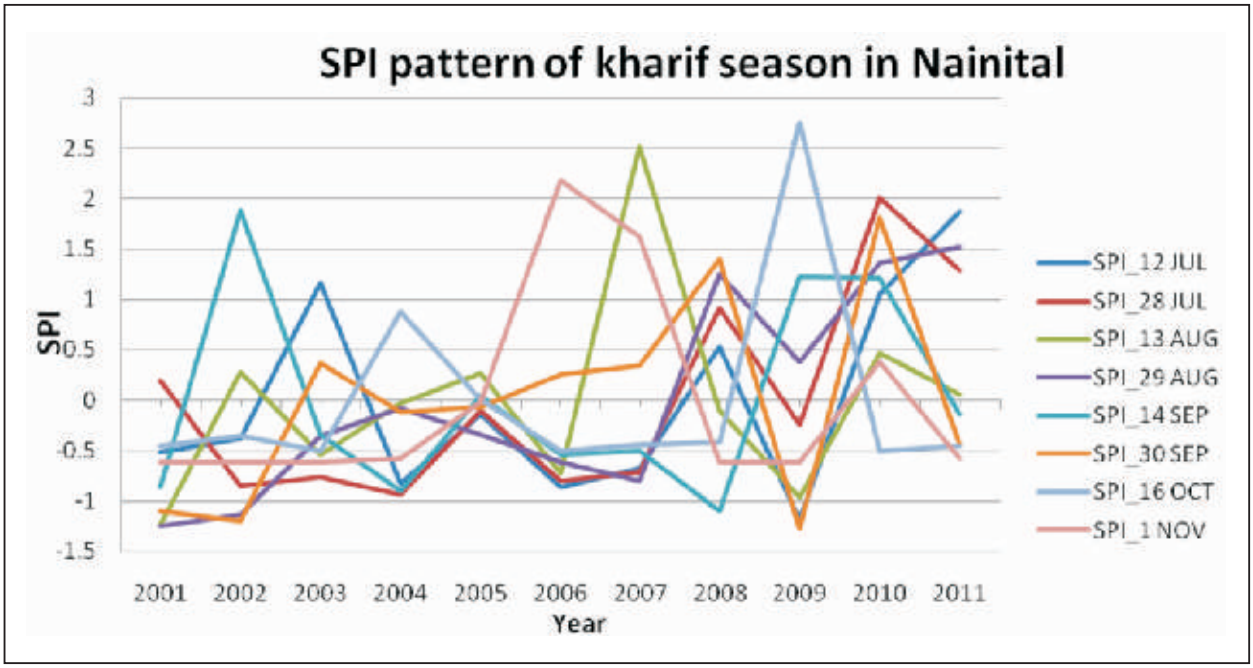

Fig. 1: SPI pattern of Kharif season in Uttarakhand

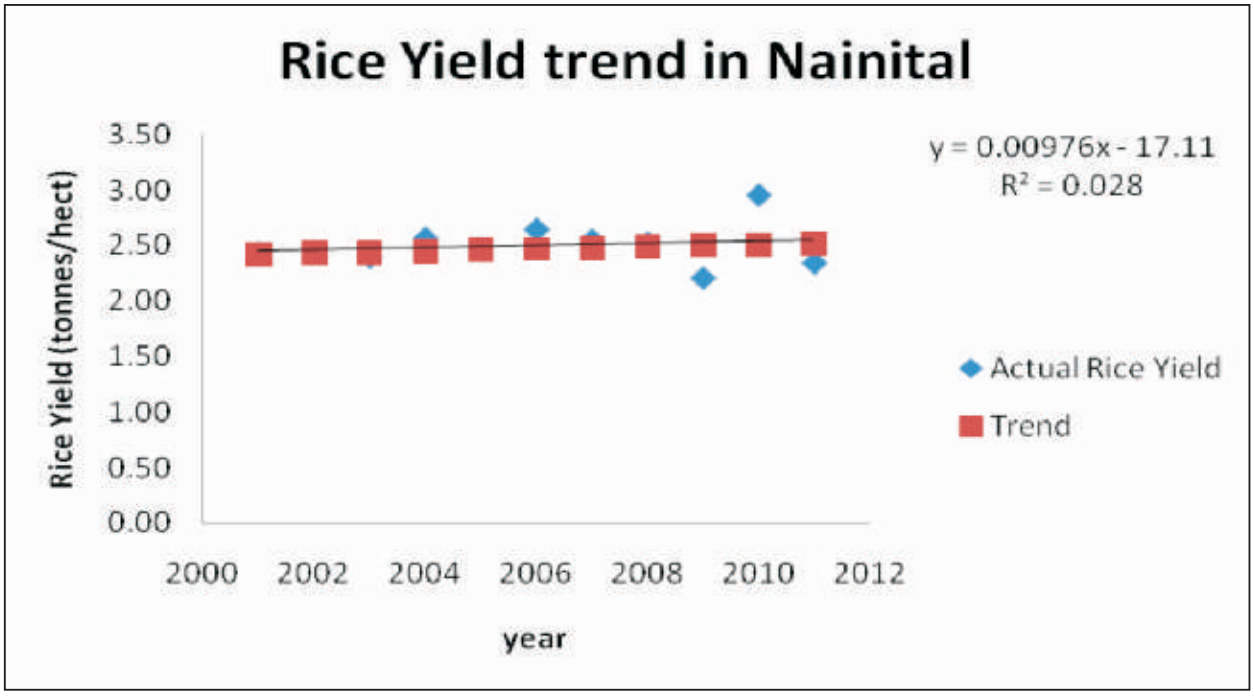

Fig. 2: Rice yield trend in Nainital

Table 2: Detrended Rice yield data in Nainital district

Year	NAINITAL Actual Rice Yield	y=0.00976x-17.11	Detrend Rice Yield
2001	2.43	2.42	0.36
2002	2.42	2.43	-0.31
2003	2.39	2.44	-1.98
2004	2.56	2.45	4.53
2005	2.47	2.46	0.47
2006	2.64	2.47	6.94
2007	2.54	2.48	2.68
2008	2.52	2.49	1.32
2009	2.20	2.50	-11.92
2010	2.95	2.51	17.66
2011	2.34	2.52	-7.21

Impact Assessment of Drought on Rice crop in Nainital

The relationship has been developed between SPI and detrended yield of Rice crop to analyze the impact of drought on rice productivity. Relationship has been depicted in Figure (3) where a, b, c, d, e, f g, and h are for the months of first and second fortnights of July, August, September and October, respectively

From figure (3) negative relationship were observed between detrended yield and SPI on first fortnight of September and October month, while positive relationship was seen on first and second fortnight of July and August, second fortnight of September and October. However, all the months represented very poor values of coefficients of determination ranging from 0.001 to 0.50, which was statistically insignificant. The insignificant relationship shows that low SPI is not translating into poor yield. Same time it is also observed that with increasing SPI values, the rice yield was not increasing. This suggests that variation in rainfall activities in Nainital district does not have any significance for rice productivity. Probably, other factors like air temperature,

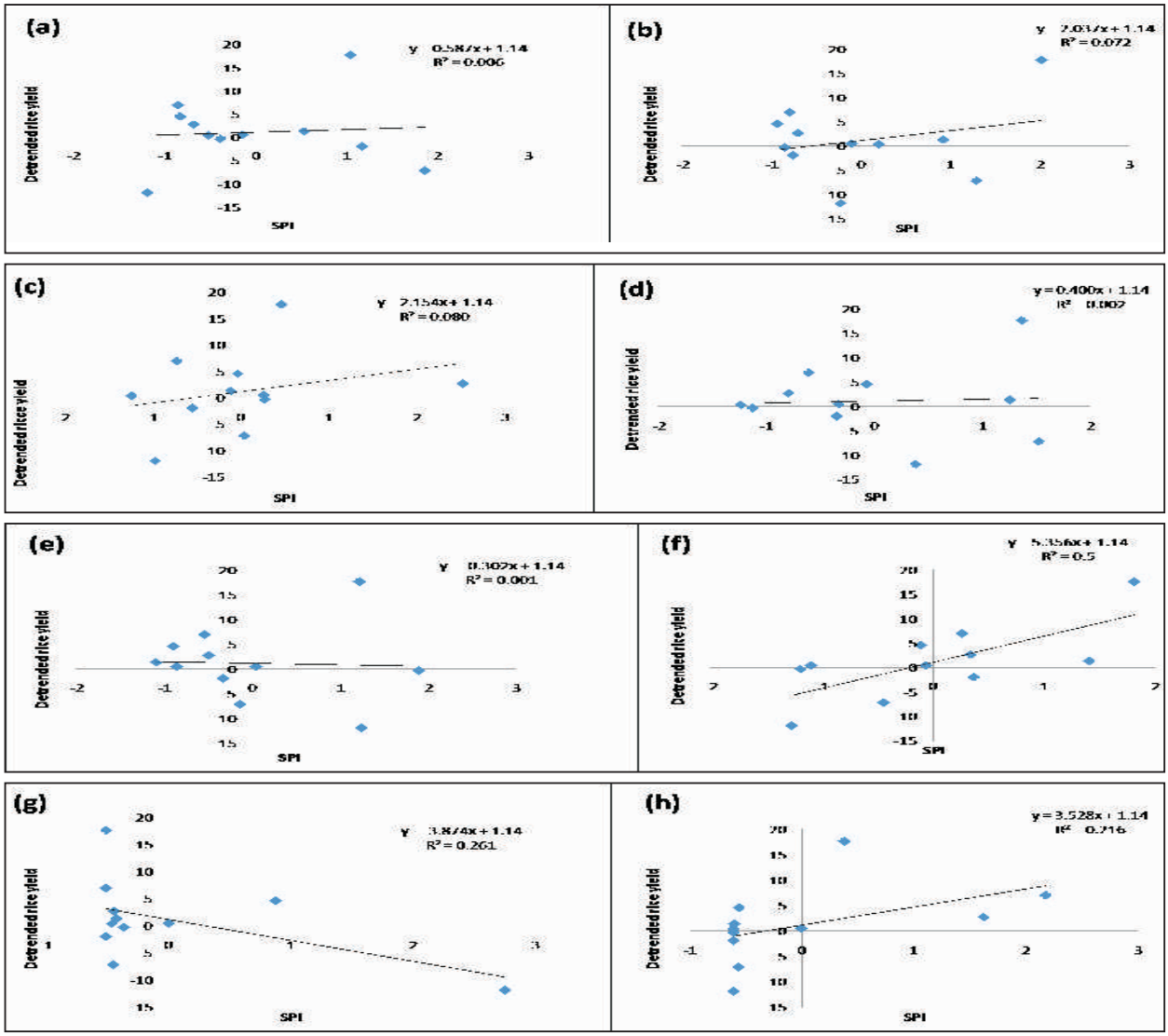

Fig. 3: Relationship between SPI and detrended yield for 12 July (a), 28 July (b), 13 August(c), 29 August (d), 14 September (e), 30 September (f), 16 October (g) and 1 November (h) in Nainital.

availability of fertilizers, chemical, seeds, slope etc. are more important than rainfall.

CONCLUSION

This study has assessed the drought condition based on SPI and identified that precipitation is an important parameter for this type of study. The spatial pattern of SPI over Nainital shows that the district has different pattern of drought like conditions. Year 2001, 2002 and 2009 was highly affected by moderate drought event, while year 2002, 2004 and 2006 were prone to mild drought condition in Nainital. Impact assessment of Drought on Rice crop in Nainital was analyzed from 2001 to 2011 on the basis of SPI and represented insignificant result. Aher *et al.* (2012) were used weekly rainfall data of Gagar watershed in Nainital district of Uttarakhand for drought analysis and this indicate the likelihood of failure of Rabi crops under rainfed conditions. This suggests that variation in rainfall activities in Nainital district does not have any significance for rice productivity. Probably, other factors like air temperature, availability of fertilizers, chemical, seeds etc. are more important than rainfall. This study has represented vast scope for future study on drought by taking more parameters under consideration.

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