Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 87 (2015) 35613-35616

ISSN: 2229-712X

Rainfall characteristic under meteorological drought condition using CDS analysis in Vindhyan zone (Mirzapur District), U.P

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ARTICLE INFO

Article history:

Received: 14 August 2015;

Received in revised form:

27 September 2015;

Accepted: 05 October 2015;

Keywords

Drought,

Critical Dry Spell,

Supplemental Irrigation etc.

ABSTRACT

The occurrence of drought leads to reduction in reservoir and tank levels and depletion of soil moisture and groundwater. There is a need to develop suitable criteria for planning supplemental irrigation to crops for increasing and stabilizing crop yields during non-drought conditions, and minimizing crop damages during drought. The present study is aimed to study metrological drought and agriculture aspects of drought in Mirzapur districts the recurrence of drought in these parts of the country in recent years have caused unprecedented economic losses and great suffering to the affected areas. The study is based on the analysis of rainfall and critical dry spell (CDS). In this study, crop water requirement and irrigation requirement for the crop during the drought situation is also analyzed and introducing the supplemental irrigation under drought condition. In Mirzapur district the deficiency of annual rainfall is observed up to 16%. In the district approximately one out of every four to five year is drought year. The year 2007 and 2009 was most severely affected as most of the area of the district was under drought and major area of the district is found as drought prone. In the district on an average three critical dry spells (CDS) have been observed during the monsoon season.

Introduction

Drought is generally defined as water shortage caused by the imbalance between water supply and demand. Drought is generally viewed as a sustained and regionally extensive occurrence of appreciably below average natural water availability, either in the form of precipitation, surface water runoff or ground water (Gbeckor-Kove, 1995). The recurrence of drought over many parts of the country in recent years caused unprecedented economic losses and great suffering to the affected areas. They not only reduced the agricultural production but also threatened country with famine. Drought causes innumerable problems immediately or with the time lag as the economy gradually experiences the adverse shock of the phenomenon. According to Indian Meteorological Department (IMD), a meteorological subdivision (part of India) is considered to be affected by drought if it receives total seasonal rainfall less than 75% of the normal value.

According to the National Commission on Agriculture (1976), agricultural drought refers to the inadequate soil moisture during crop growing period and the hydrological drought refers to marked depletion of surface water storage in lakes, reservoirs, rivers and streams etc. in fact the meteorological drought precedes the agricultural and hydrological drought. The agricultural and hydrological drought needs not to occur simultaneously but occur subsequent to a meteorological drought (Sastry, 1986).

In literature, no criterion is available for planning a supplemental irrigation to crop based on critical dry spells and critical crop growth stages. However, excess runoff collection and storage of water on dug out ponds or tanks is more expensive than the national resource (Verma and Sarma, 1989). Thus, there is a need to develop suitable criteria for planning. Supplemental irrigation to crops for increasing and stabilizing crop yields during non- drought conditions, and minimizing crop damages during drought.

The present study is aimed to study hydrological and agricultural aspects of drought in Mirzapur district as the recurrence of drought in this part of the country in recent years caused unprecedented economic losses and great suffering to the affected areas. The analysis of dry spells within monsoon season is very important especially for minted agriculture in the country. The occurrence of dry spells may result in drought occurrence even if the total amount of rainfall during monsoon season is about 75% of the normal rainfall in the period. Occurrence of dry spells may cause partial to total crop failure. If a long dry spell occurs during active growing period of crops, especially during fruiting and flowering stages it will be disastrous for crops.

Materials and Methods

Mirzapur is a district of Uttar Pradesh lies between the parallels of 25°18 and 25° 32' north latitude, and 82°7' and 88°18' east longitude and 128.93m altitude. The physical aspect of the district presents a variety of landscape which is as pleasing, as it is surprising, to an eye accustomed only to the level monotony of the districts situated entirely in the Gangetic plain. The climate of Mirzapur differs actual discomfort is often greater owing to the fitful and uncertain character of the hot winds. For geological description its area may be divided into five tracts namely the vindhyan tableland, the Kaimur hills, the son valley, the hilly tract south of the son and the Singrauli basin. Each of these divisions has the longitudinal strips, with their length from east to west.

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There are three major soil black soil, sandy loam soils and red lateritic soils. The soils of the Ganges plain on either side of the river do not present any peculiar features. The same varieties, namely dumat, matiyar and balua occur here as another alluvial district, the first named preponderating. Index map of Mirzapur district shown in fig.1.

The analysis of dry spell within monsoon season is very important especially for raided agriculture in the country. Generally, a dry spell is defined as the interval of dry days between two consecutive wet spells. Dry days are considered as days having rainfall less than 2.5 mm. If a single rainy day having at least 5ET rainfall after a dry spell can wet the soil profile up to the desired depth and is taken as a wet day for breaking the dry spell. then two consecutive rainy days whose total rainfall is SET or more can be considered as two-day wet spell for the same purpose (Varma, and Sarma, 1989) Further, three or more rainy days occurring in a week, not necessarily consecutively, having at least a total rainfall of 5ET is also considered a wet spell. In view of the above discussion the definition of a wet spell can be summarized as:

- A rainy day with rainfall equal to or more than 5ET or
- A spell of two consecutive rainy days with rainfall totalling at least 5ET or
- A 7- day period having at least 3 or 4 rainy days with a total rainfall not less than 5ET.

For calculating the duration of CDS, an appropriate approach is to divide the crop growth period into some important growth phases according to water demand as evapotranspiration of crop varies according to growth stages. In order to predict probable period of CDS the median dates of beginning of 1st, 2nd and 3rd CDS for growing season have computed. On the basis of crop-soil combination the minimum length of a dry spell is considered as 10 days that become critical to the crop.

The potential crop evapotranspiration (ETp) has been estimated using modified penman method (1963). The ETp (mm/day), for 52 standard weeks, has been calculated based on mean air temperature (maximum and minimum), dry bulb and wet bulb temperature),wind velocity, relative humidity (maximum and minimum), sun shine hours and using the standard table values given by Doorknobs' and Pruitt (1977). The ETp estimates are made using meteorological data recorded at Banaras Hindu University, IMD Station, Varanasi. In order to account for the effect of crop characteristics on ETp,the crop evapotranspiration (ETcrop) are made as follows.

$$ETcrop = Kc \times ETp \quad \ldots\ldots (i)$$

Where, ETcrop = crop-evapotranspiration, mm/day
ETp =reference evapotranspiration, mm/day
Kc = crop coefficient

Particularly following sowing and during the early growth stage, the frequency of rain or irrigation is important. The crop growing season has been divided in to four stages (i) initial stage (ii) crop development stage (iii) mid season stage and (iv) late season or ripening stage. Crop coefficient (Kc) values for different growing phases of crops are obtained from a Guide for Estimating Irrigation Water Requirements, Govt. of India (1984). In seasonal crops failure happen due to water stress during critical dry spells. The crop water requirement (ETcrop) for first three critical dry spells has been estimated.

$$\text{Irrigation Requirement (IR)} = ETcrop - ER \quad \ldots\ldots.(ii)$$

For appropriate planning of supplemental irrigation for crops, it is important to have careful consideration of crop variety and its critical growth stages, analysis of critical dry spells and availability of stored water etc.

Results and Discussion

Assessment of Drought

The mean annual rainfall in mirzapur district varies from 955 mm at Sadar to 1142 mm at Barkachha, which indicate that there is normal variation in the rainfall distribution pattern over the district. The coefficient of variation of annual rainfall is highest at Jargo side areas with 50.24%.the rainfall of the district generally increase from the southwest to northeast.

The annual rainfall departure analysis shows that the deficiency of annual rainfall varies from 0-65% in the different sites of Mirzapur district. It is observed that drought frequency varies from 4 to 7 out of 16 year period of rainfall data of all sites. This clearly shows that approximately one out of every three to four year is drought year, which is rather an alarming situation. The percentage annual rainfall departures in all sites of Mirzapur district are given in Fig.2,Fig .3,Fig.4 and Fig .5. From the annual rainfall departure analysis, the drought years have been identified and its average frequency of drought represented in Table.1.

The annual and seasonal rainfall departure analysis show that in the year 2009 all the sites faced drought condition and about 90% area of the district was under severe drought condition. Similarly in 2007, all four sites of the district leading to 75% of the area was affected by drought, where in 2006 and 2010 of three sites of district were subjected to drought condition. The probability distribution analysis of annual rainfall shows that the probability of occurrence of rainfall equivalent to 75% of normal annual rainfall in different sites of the district varies from 55 to77%. The average value probability of occurrence of rainfall equivalent to 75% of normal of district as whole is estimated about 64%. All the sites in the district can be considered to be drought prone as the probability of occurrence of rainfall equivalent to 75% of normal annual rainfall is less than 80%. All the sites of district come under drought prone area.

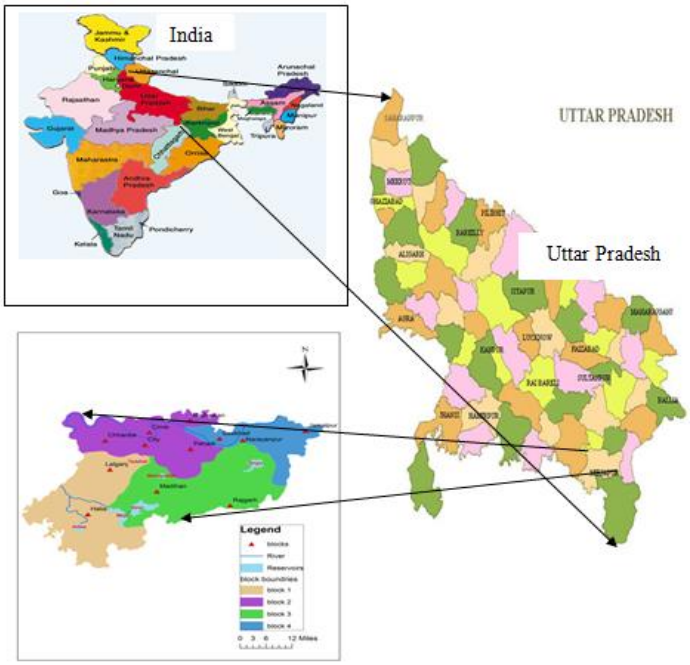

Fig 1. Index Map of Mirzapur District, Uttar Pradesh

Effective Monsoon and Critical Dry Spell

It is concluded that the mean date of onset of effective monsoon (EMO) in Mirzapur district varies from 30 June at Sadar to 9 July at Barkachha with an average standard deviation of 14 days. This shows that there is moderate variation in the dates of onset of effective monsoon in different years. The date

of withdrawal of EMO in mirzapur district varies from 18th August to 8th September. The knowledge of mean date of onset of effective monsoon is important to the formers to be prepared for primary tillage operations and timely seedbed preparation. The analysis of critical dry spell (CDS), there are three CDS per year was observed on an average during the monsoon season. The first CDS is observed generally in last week of July and first week of august, second CDS observed in august second and third week where as third CDS has been observed in third week of September. The average duration of first CDS varies between 14 to 27 days, second CDS varies 14 to 24 days whereas the duration of third of CDS varies from 14 to 23 days. As a period of 10 days of dry spell may prove to be critical for the crop, it is essential to make provisions for supplemental irrigation during these critical dry spell periods by creating additional storage wherever necessary.

Jargo Station

Crop Water Requirement

It is seen that during first CDS maximum crop water requirement was 38.86 mm for rice at Sadar, the maximum crop water during second CDS was 34.95mm at Barkachha and maximum water requirement in third CDS was 58.38mm in jargo areas. In generally, the water requirement in other crops has been observed to be more during second CDS as compared to first CDS. This is due to the fact that during second CDS maximum crop were under developmental stage and mid-season stage and also the average duration of second CDS was more than that of the first CDS.

Table 1. Frequency of drought year in Mirzapur district for Annual rainfall

S.No.	Name of Station	Mean Annual Rainfall (mm)	Drought Frequency (In 16 Yrs)	Moderate Drought Year	Severe Drought Year
1	Barkachha	1142	4	1998, 2002, 2007, 2009	Nil
2	Sadar	955	3	2007, 2009, 2010	Nil
3	Chunar	1072	5	2004, 2006, 2007, 2010	2009
4	Jargo	1082	7	2006, 2007, 2008, 2010, 2012	2005, 2009

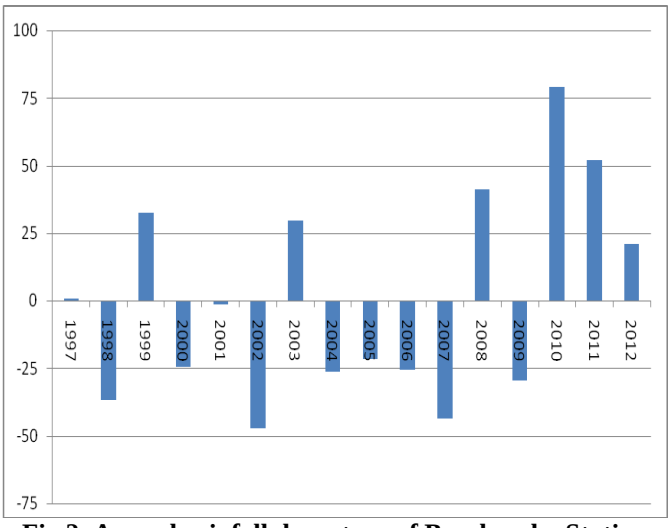

Fig 2. Annual rainfall departure of Barckaccha Station

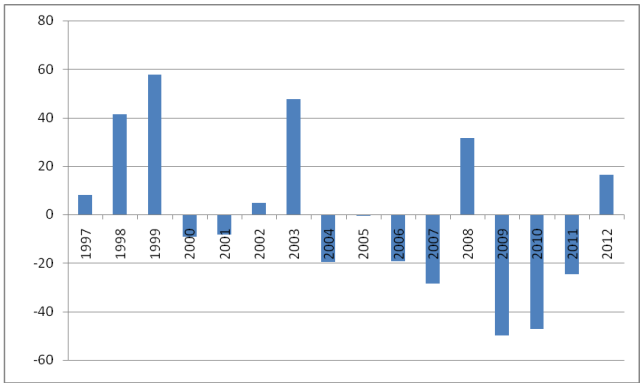

Fig 3. Annual rainfall departure of Barckaccha Station

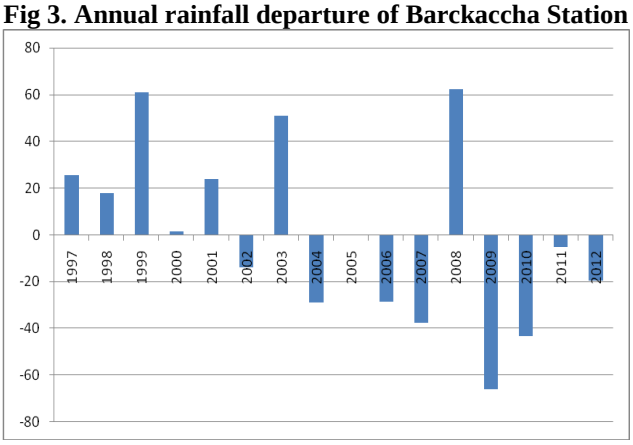

Fig 4. Annual rainfall departure of Chunar Station

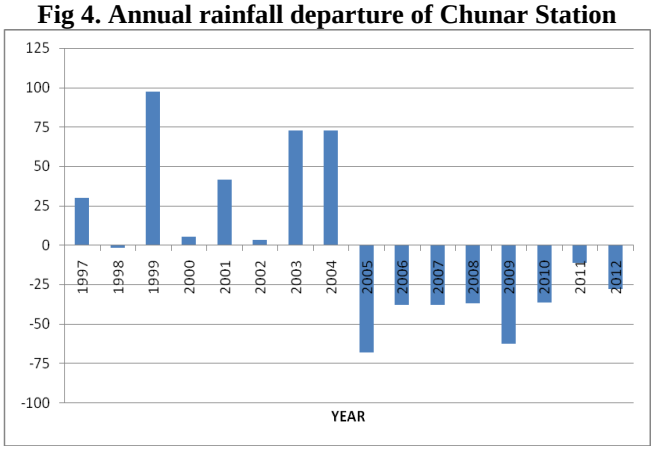

Fig 5.Annual rainfall departure of Irrigation Requirement

It is observed that the total irrigation requirement during the three critical dry spells varied from 40.42 mm at Barkachha to 106.79 mm at Jargo. It can also be seen that the maximum irrigation requirement of 106.79mm during three CDS at Jargo and minimum of 7.01 mm at Chunar.

Conclusion

The mean annual rainfall of Mirzapur district is 1063 mm estimated using four rainfall stations data and the deficiency of annual rainfall is varies up to 16% in various station of Mirzapur district. The drought frequency analysis indicated that approximately one out of every four to five year is drought year, which needs to be taken care of while planning for irrigation and other water resource project development in the district. The year 2007 and 2009 was most severely affected as most of the area of the district was under drought as revealed from the annual and seasonal rainfall departure analysis. As the probability of occurrence of rainfall equivalent to 75% of normal rainfall is less than 80% in most of the station, so Mirzapur district as a whole can be considered as drought prone.

The mean date of onset of effective monsoon (EMO) in Mirzapur district varies from 30 June to 9 July and there is moderate variation in the dates of onset of effective monsoon in

the different years .The date of withdrawal of monsoon from 18th August to 8th September. In the district on an average three critical dry spells (CDS) have been observed during the monsoon season. The first CDS is observed generally in last week of July and first week of august, second CDS observed in august second and third week where as third CDS has been observed in third week of September. The average duration of first CDS varies between 14 to 27 days, second CDS varies 14 to 24 days whereas the duration of third of CDS varies from 14 to 23 days. It is essentially make provision for supplemental irrigation during these critical dry spell periods by creating additional ground water storage wherever necessary and store the rainfall water when the heavy rainfall takes place and minimize the wastage of water.

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