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Evaluation of Hydrological Drought Characteristics for Bearma Basin in Bundelkhand Region of Central India

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Abstract

Drought is a natural hazard that can have severe impacts on a variety of sectors and at a variety of scales. The Bundelkhand region in Central India has been under the grip of continuous and recurrent drought in the recent years. This has caused large scale economic losses and severe hardships for the local population leading to large scale out-migration and massive poverty in the entire region. Even though the drought starts with the deficit in rainfall, but it ultimately translates into hydrological drought which indicates the reduced water availability in the rivers and groundwater aquifers. The scientific analysis of the hydrological drought is one of the many primary necessity for the development of an effective drought management plan for a region. The hydrological drought characteristics have been evaluated for Bearma basin located in the Bundelkhand region using the variable threshold level approach. The dependable flow in the river at 75% dependability (Q75) for each month has been computed to arrive at the variable threshold level. It has been observed that hydrological droughts of varying severities occurred during 27 years out of the total period of analysis spanning 35 years from 1974-75 to 2008-09. The most severe hydrological droughts were observed during 1978-79 and 2002-03 with a combined severity of -238.26 MCM and -210.39 MCM respectively.

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1. Introduction

Drought is one of the most extreme water-related natural hazards and along with desertification is expected to affect as many as one-third of the world's population. Drought is considered one of the most damaging natural disasters in terms of economic costs (e.g. navigation and hydropower production [1],[2],[3]), societal problems (e.g. increased mortality and conflict, [4],[5]) and ecological impacts (e.g. forest dieback and impacts on aquatic ecosystems, [6],[7],[8]). It is the most critical environmental phenomenon having special hydrological and meteorological characteristics [9].Based on the nature of the water deficit, there are four different classifications of drought viz., meteorological, hydrological, agricultural and socio-economic drought [10],[11],[12]. The meteorological drought is related to precipitation deficits which cause decreases in water supplies for domestic and other purposes affecting the flora and fauna of a region. The hydrological drought is resulted from low stream flows that directly affect established water uses under a given water resources management system. The agricultural drought is linked to crop failure as a consequence of decreases in soil moisture and has no reference to stream flow [13],[14].

Hydrological drought is determined by the propagation of meteorological drought through the terrestrial hydrological cycle and is therefore influenced by the properties of the hydrological cycle [15],[16],[17]. For example, drought propagation is different in a semi-arid climate and in a climate with snow accumulation in winter, and it differs between mountainous catchments, catchments with many lakes and wetlands, and catchments withmild slopes and large, porous aquifers [18]. The investigation of the hydrological drought is important due to dependence of most of the activities (including industrial, water and power plants) to surface water resources [19]. For many aquatic ecosystems for example the duration of a drought in streamflow is crucial [20], whereas for hydropower production the missing volume of water compared to normal conditions (deficit volume) is more relevant [21],[22],[23]. The results of hydrological drought analysis can be useful for proper water resources management including better planning for water supply and demand.

2. Study Area

The river Bearma is one of the important tributaries of Ken river passing through the heartland of Bundelkhand in the State of Madhya Pradesh and is located between latitudes of 23° 07′ N and 24° 18′ N and longitudes of 78° 54′ E and 80° 00′ E. The index map of the study area is given in Fig.1. The basin is located in Damoh and Sagar districts in the Bundelkhand region falling in Madhya Pradesh, India. Bundelkhand region is in the limelight due to the frequent and regular occurrences of drought in the last decade. The drought frequency which used to be once in 16 years has now increases substantially to 1 in 3 to 4 years in the region [24].

3. Methodology

The surface water drought results as a consequence of deficits in the rainfall pattern and can be identified through low flow analysis and deficit storage analysis of reservoirs. Among the most commonly used parameters are a) flow equalled or exceeded a specified percentage of time (flow-duration curve) and b) flow of specified duration that can be expected to occur only once during a specified number of years (low-flow frequency analysis).A flow duration curve (FDC) is very useful method of displaying the complete range of river discharges from low flows to flood events. It is a relationship between any given discharge value and the percentage of time that this discharge is equalled or exceeded, or a relationship between magnitude and frequency of stream flow discharges. Low flow data are normally specified in terms of the magnitude of low flow for a given time interval within a year or a season.

The stream flow time series is bifurcated into monthly time series from June to May. The time series of each month contains the complete length of record for all the years pertaining to that month. All further steps in the analysis has to be repeated for each month; sorting the stream flow data in descending order; In the stream flow data, the problem of zero flows have to be tackled to arrive at the accurate estimate of the probability of exceedance. The number of 'zero' and 'non-zero' flow values needs to be separated from the available flow records for each