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Meteorological Drought Assessment for Jhelum River Basin, Jammu and Kashmir's Sangam and Ram Munshi Bagh Stations

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Abstract: Drought is a severe natural calamity that harms the global ecology. To examine drought conditions including intensity and duration, a variety of drought indicators (DIs) are commonly employed. This study assesses the occurrences of drought in Kashmir's Jhelum River Basin (JRB) at the Sangam and Ram Munshi Bagh stations. Several DI approaches, such as Deciles, Percent of Normal (PN), and Standardized Precipitation Index (Normal-, Log-, and Gamma-SPI), are used to analyse 20 years of monthly recorded precipitation data from 2002 to 2023. Every technique is used on the annual long-term precipitation data set. The findings indicate that nearly identical outcomes are obtained for the stations by the DI approaches. While the normal-SPI indicates rainy and less droughty conditions, the log-SPI and gamma-SPI forecast moderate dry conditions. The results emphasize that the PN method predicts more moderate drought years in comparison with SPI method, however, Deciles method shows longer period of extreme and severe drought than other methods. As a result, the five methods indicate various drought intensities in 2017, 2018,2001, and 2002 with a peak moderate drought in 2017 in the Sangam station. The Ram Munshi Bagh station area experienced the less drought conditions from 2002 to 2023 with a moderate drought in 2017 and 2018 as well. Therefore, moderate drought conditions happened in 2017 -2018 in both stations confirm to the recorded drought reports for the same region.
Keywords: Jhelum River Basin, Drought Indexes, SPI, PN, Deciles

I. INTRODUCTION

A complex environmental phenomenon, drought is typically described as a period of time during which there is less water available than usual and a negative impact on the local economy, ecology, wildlife, agriculture, and social and cultural life [Zarei et al., 2016; Sirdas, 2003]. In different parts of the world, a variety of drought indices have been established as instruments for drought monitoring and assessment. By combining one or more data variables, such as precipitation and evapotranspiration, into a single numerical value, drought indices are quantitative assessments that establish the degree and intensity of the drought [Yacoub and Tayfur, 2016]. The most widely used drought indices are Palmer Drought Severity Index and Standardized Precipitation Index (SPI), which are both utilized globally. Palmer Drought Severity Index (PDSI),is used in the United States; Deciles Index, commonly used in Australia; China-Z Index (CZ), used in China; and Percent of Normal (PN), used globally, all have uses, but using them alone is not a helpful approach. To calculate the Reconnaissance Drought Index (RDI), precipitation and evapotranspiration data are needed. The majority of DI techniques are typically introduced for a particular region. As a result, no relevant scientific study or article exists that suggests a particular approach or analysis for the drought circumstances in Kashmir.

In fact that Kashmir has experienced very low drought throughout the past 20 years, no published scientific research has assessed the drought indices in Kashmir because of its abundant water resources but a majority of areas are rainfed

The purpose of this study is to assess the historical drought and compare the efficacy of various DI techniques in the Kashmir's Jhelum River Basin. Standardized precipitation index (SPI) with three statistical distribution types (normal, log-normal, and gamma SPI), percent of normal (PN), and deciles are the DI methods used in this work. These techniques need monthly precipitation data that has been taken from the IMD Rambagh Srinagar.

II. METHODOLOGY

The Kashmir valley lies between latitude 33^0 and 35^0 N and longitude 73^0 and 76^0 E. The valley is 100 km (62mi) wide and covers 15,520,3 km2 (5,992.4 sq. mi) in area. It is bounded by sub-ranges of the Western Himalayas. The great Himalayas bound it in the northeast and separate it from the Tibetan Plateau whereas the Pir-Panjal Range in the Lesser Himalayas bounds it on the west and

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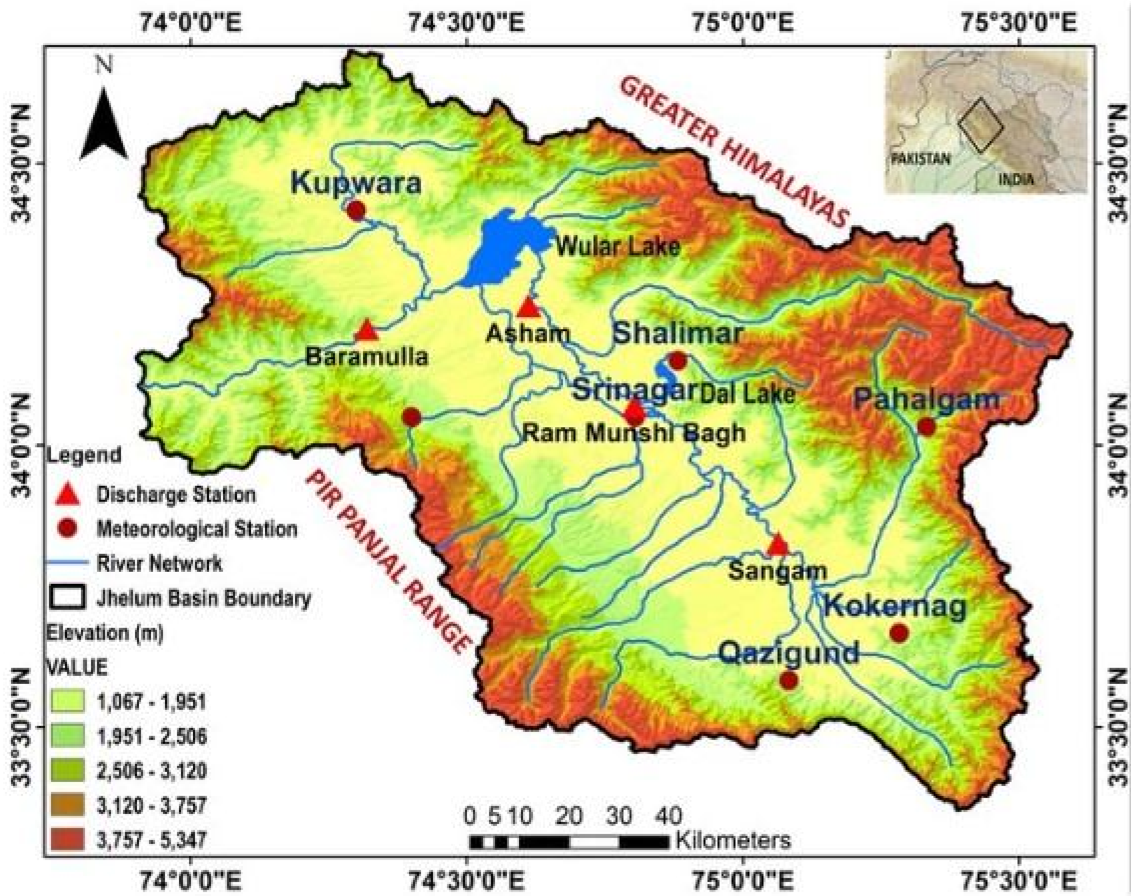
south, and separate it from the Punjab Plains. The Kashmir Valley has a moderate climate, which is largely defined by its geographic location, with the towering Karakoram Range in the north, Pir Panjal Range in the south and west, and Zanaskar Range in the east.



This study uses the Deciles, Percent of Normal (PN), and Standardized Precipitation Index (normal-SPI, log-SPI, gamma-SPI) methodologies to assess the meteorological drought. index for two sites in Kashmir's Jehlum River Basin

The SPI, or Standardized Precipitation Index Standardized Precipitation Index (SPI): This measure is commonly used to assess meteorological drought across the world. McKee et al. created it (1993). The sole input parameter for SPI is precipitation, and its computation is based on the likelihood of precipitation over all time scales, which is subsequently translated into a normal distribution. According to McKee et al. (1993), the mean SPI for a location and desired time is zero. Table 1 displays the drought classification for the z-score (SPI) index. Wet times are indicated by positive SPI values, and dry periods are shown by negative SPI values. This study uses three commonly used SPI distribution types: normal, log-normal, and gamma distribution [Cacciamani et al., 2007].

Table 1: Drought classification for SPI values [Barua et al. 2010]

SPI Value (z-score)	Drought Classification
2.00mor more	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderate wet
0.99 to -0.99	Near normal
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
-2.00 or less	Extreme drought

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A. Gamma -SPI

The most popular observational model for precipitation data is gamma-SPI. It entails fitting a time series of precipitation with a gamma probability density function [Angelidis et al., 2012]. Its probability density function defines it as follows:

$$\frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{\beta} \quad g(x)= \text{for } x > 0 \tag{1}$$

Where α>0 is a shape parameter, β>0 is a scale parameter, and x>0 is the amount of precipitation. Γ(α) is the gamma function, which is defined as:

$$\Gamma(\alpha)= \int_0^{\infty} y^{\alpha-1} e^{-y} dy \tag{2}$$

α and β parameters can be estimated as follows (Thom, 1958):

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 - \frac{4A}{3}}\right), \quad \beta = \frac{\bar{x}}{\alpha}, \text{ with } \quad A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \tag{3}$$

In Eq. (3), n is the number of observations. After estimating α and β coefficients, the probability density function is integrated with respect to x, which yields the following expression $G(x)$ for the cumulative probability:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx \tag{4}$$

Substituting t for x/β in Eq. (4), then it is reduced to:

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-t} dt \tag{5}$$

As the gamma function is not defined for x=0, for possibility of zero values, the cumulative probability function becomes:

$$H(x) = q + (1 - q)G(x) \tag{6}$$

where q is the probability of zero precipitation, then the cumulative probability distribution is transformed into the standard normal distribution to yield the SPI. The approximate conversion provided by Abramowitz and Stegun (1965) is given as:

$$\text{for } 0 < H(x) < 0.5$$

$$z = SPI = -\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right), t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \tag{7}$$

$$\text{for } 0.5 < H(x) < 1.0$$

$$z = SPI = +\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right), t = \sqrt{\ln\left(\frac{1}{(1.0-H(x))^2}\right)} \tag{8}$$

where c_0 = 2.515517, c_1 = 0.802853, c_2 = 0.010328, d_1 = 1.432788, d_2 = 0.189269, and d_3 = 0.001308

B. Normal SPI

Rather than using the gamma distribution, the normal-SPI makes use of the normal probability distribution [Angelidis et al., 2012]. It is simpler to compute mathematically. The SPI index in this instance just changes to:

$$SPI = z = \frac{x-\mu}{\sigma} \tag{9}$$

where z = SPI value, μ = population mean, and σ = standard deviation.

C. Long SPI

Log SPI distribution is non-negative and positively skewed. It is simple and just a logarithmic transformation of the data. By applying the log-normal distribution with the sample mean of logarithmic transformed data, the SPI becomes:

$$SPI = z = \frac{\ln(x) - \mu}{\sigma}$$

D. Percent of Normal (PN)

The percentage of actual precipitation compared to normal precipitation is known as the (PN) drought index, which is used to assess meteorological data.

When analysing long-term mean precipitation, it is often applied to data spanning at least 30 years [Morid et al., 2006; Yacoub and Tayfur, 2016].

In general, PN values are computed monthly, seasonally, and annually to yield a drought index of 100%; dry times are indicated by PN values that are less than 100%. However, different results may be displayed by the same PN in several locations. As such, using it alone in a given area is not a useful approach [Hayes, 2006]. Table 2 displays the classification of the drought index for the PN values.

Table: 2 Drought index classification for PN [Barua *et al*. 2010]

NP values	Drought Classification
180% or more	Extremely wet
161% to 180%	Very wet
121% to 160%	Moderately wet
81% to 120%	Near normal
41% to 80%	Moderate drought
21% to 40%	Severe drought
20% or less	Extreme drought

E. Deciles

Gibbs and Maher are the ones who invented the deciles technique (1997). Using this method, a cumulative frequency distribution is created by ranking the long-term monthly precipitation from highest to lowest. Based on equal probability, the distribution is divided into ten sections, or deciles [Barua et al. 2010]. Table 3 provides the deciles values and the drought rating classes.

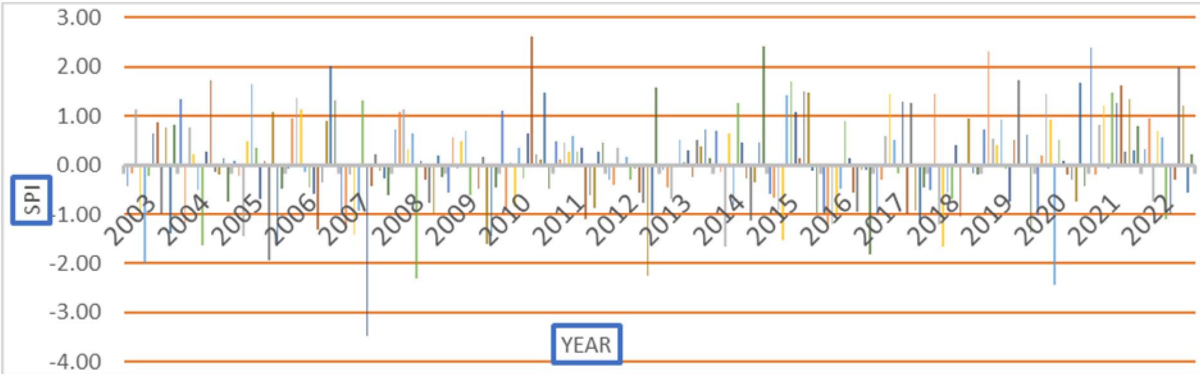
Table 3: Deciles drought ranking classification

Deciles values	Drought classification
Deciles 1-2 (lowest 20%)	Much below normal
Deciles 3—4 (next lowest 20%)	Below normal
Deciles 5-6 (middle 20%)	Near Normal
Deciles 7-8 (next highest 20%)	Above normal
Deciles 9-10 (highest 20%)	Much above normal

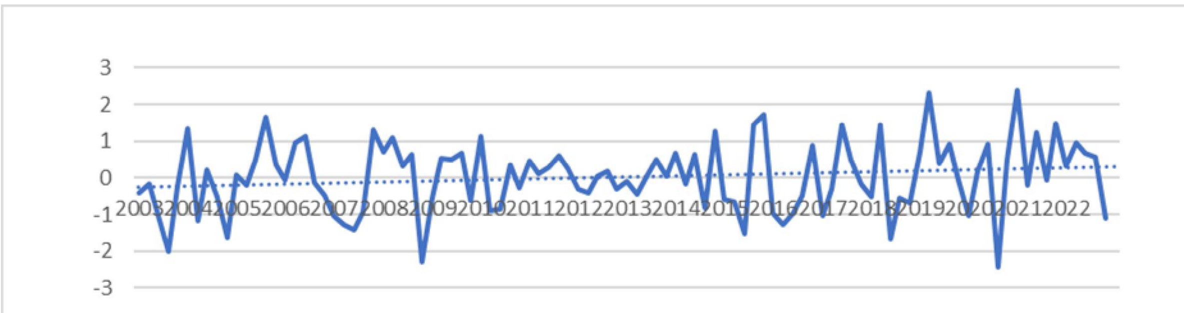
III. RESULTS AND CONCLUSIONS

SPI (Normal-SPI, Long-SPI and Gamma -SPI), Percent of Normal (PN), and Deciles values were computed for 12 months for Sangam and Ram Munshi Bagh Stations of River Jhelum of Kashmir. The normal -SPI determines wet and less drought conditions on Sangam station.

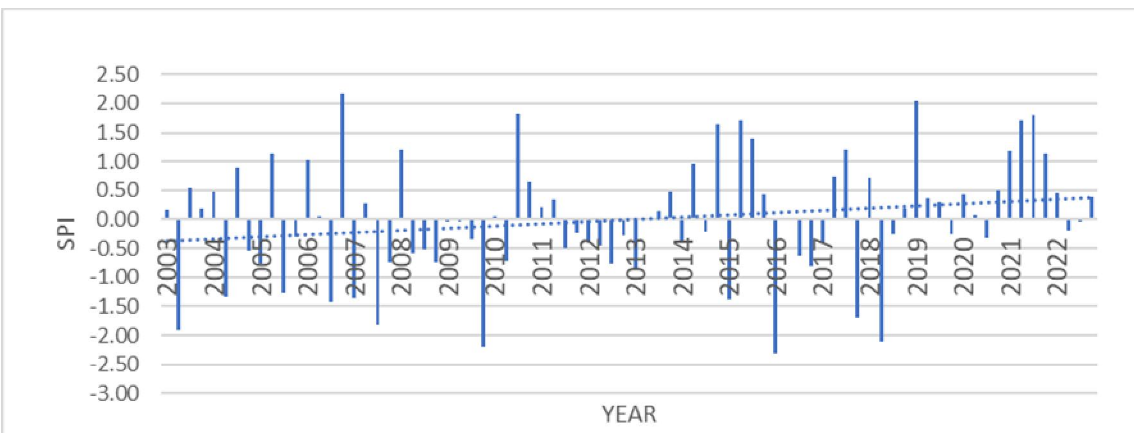
On the other hand the long , the long -SPI predicts moderate drought conditions. The gamma -SPI shows the results mostly between normal -SPI and long -SPI. According to the SPI results in Sanagam station



The deciles results and threshold ranges for Sangam station are given below. According to results, the drought conditions occurred when precipitation was less than 84’63mm/year. When precipitation is less then 80.43mm/year and 59.19mm/year moderate and less drought occurred respectively



The annual result graph of SPI, deciles and Percent of Normal methods respectively for Ram Munshi Bagh station for drought index method show almost same results for this station too.



Based on all available methodologies, the common less drought year for both sites is 2017–2018. Since this method only identifies extreme and severe droughts, the extreme, severe, and moderate drought intensities are not provided for deciles. As a result, throughout the same time period, both stations saw nearly identical instances of drought and rainy weather.

The findings show that, in contrast to the SPI technique, the PN method tends to overpredict the number of years with mild drought. The Sangam and Ram Munshi Bagh stations yield nearly identical findings when using the DI approaches. It is shown that whilst long-SPI, gamma-SPI, and deciles represented past extreme droughts, normal -SPI and PN suggested less and moderate drought circumstances.

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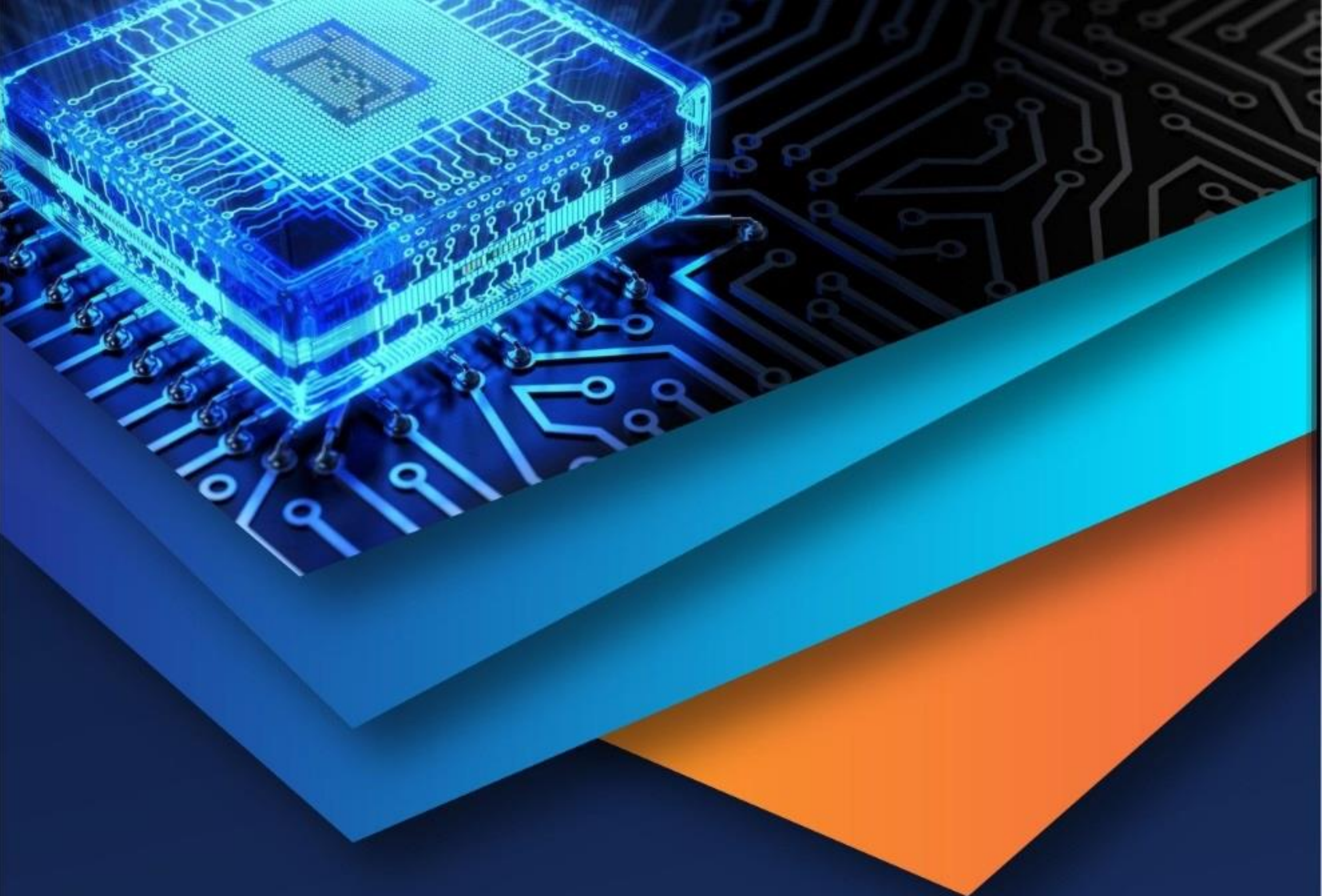

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