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Prajakta B Labade
Ph.D. Scholar,
Department of Soil and Water Conservation Engineering, CAET, DBSKKV, Dapoli, Maharashtra, India

Sagar B Gavit
M.Tech Scholar, Department of Soil and Water Conservation Engineering, CAET, DBSKKV, Dapoli, Maharashtra, India

BL Ayare
Professor and Head, Department of Soil and Water Conservation Engineering, CAET, DBSKKV, Dapoli, Maharashtra, India

HN Bhange
Associate Professor (CAS), Department of Soil and Water Conservation Engineering, CAET, DBSKKV, Dapoli, Maharashtra, India

Corresponding Author:
Prajakta B Labade
Ph.D. Scholar,
Department of Soil and Water Conservation Engineering, CAET, DBSKKV, Dapoli, Maharashtra, India

Analysis of rainfall variability using precipitation concentration index (PCI): A case study of Dapoli station

Prajakta B Labade, Sagar B Gavit, BL Ayare and HN Bhange

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Abstract
Precipitation is an essential climatic variable, because changes in intensity and amount affect the occurrence of hydrological hazards such as floods and drought. So far managing the rainfall variability analysis play a vital role using Precipitation Concentration Index (PCI) which accurately predicts rainfall patterns, floods, and droughts across regions. The purpose of this study is to assess the concentration and variability of rainfall over time using the Precipitation Concentration Index (PCI), which is based on monthly rainfall data of a 34-year period (1990-2023). The PCI was computed at the annual, seasonal, and decadal levels using annual and seasonal equations. According to the statistics, the yearly PCI index for all 34 years exceeded 20. So, strong irregularity of precipitation distribution found 100%. In last 34 years, nearly 20 years (58.73%) had uniform precipitation distribution, followed by 14 years (41.17%) that moderate precipitation distribution. PCI can thus be used as a warning system for flooding and erosion.

Keywords: Annual, precipitation concentration index (PCI), rainfall, seasonal

Introduction
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Introduction
Rainfall is an important variable in monsoons throughout the world and the amount can vary significantly within a week or month or year. Also, the increasing in the mean precipitant in the globe could be a result of the rising atmospheric moisture content associated with warming (Zhang *et al*; 2015) [20]. Therefore, making a plan and the management of precipitation that depend on prediction of precipitation amount can help humankind to face these problems. So, numerous studies on precipitation variability and development of statistical indices to evaluate the changes of precipitation have been undertaken (Alijani *et al*; 2008, Feidas *et al*. 2007, Buttafuoco *et al*. 2011, Coscarelli *et al*. 2012, Shi *et al*. 2013 and Zhang *et al*. 2012) [1, 7, 3, 4, 17, 19]. The optimum time and space scales for rainfall are not well studied in the local domain and therefore it becomes important for one to understand the dynamics of the rainfall seasonally and

annually. However, understanding precipitation variations on various time scales and their correlation is important for assessment of flood risks and for water resource management. Rainfall extremes can, therefore be quantified by the frequency analysis of rainfall series and precipitation heterogeneity indexes (Kumbuyo *et al*. 2014) [11]. Some straight forward indicators have been employed to evaluate precipitation concentration used to provide information on its variability (De-Luis *et al*. 2011, Apaydin *et al*. 2006) [5, 2]. Hence, indices include Precipitation Concentration Index (PCI) (De-Luis *et al*. 2011, Oliver, 1980) [5, 15], Simple Daily Intensity Index, Precipitation Concentration Degree (PCD) and Precipitation Concentration Period (PCP), modified Fourier Index (Hernando *et al*. 2015) [10], Seasonality Index (Kumbuyo *et al*. 2014) [11] etc. In this study, the precipitation concentration index (PCI) is analysed. The PCI allows quantifying the relative distribution of precipitation patterns. It also provides a good presentation to the spatial variability of monthly precipitation (Coscarelli *et al*. 2012 and Raziei *et al*. 2008) [4, 16] and information on long-term total variability in the precipitation amount record (De-Luis *et al*. 2011 Martins *et al*. 2012) [5, 12] Therefore, the precipitation constriction index leads many researchers to make studies about it. The PCI can be used as an indicator of hydrological hazard risks such as floods and droughts.

Materials and Methods

Study Area: The study has been conducted in Dapoli Tehsil which is situated in the Konkan region of Maharashtra state in India. This region is along a coastal belt of the Arabian sea, with length 720 km and width 35-50 km, comprising an area 8.28 km^2. It is characterized with high-intensity, rainfall and runoff. This region is geographically categorized under highly undulating terrain, with lateritic soils.

Climate: The average annual rainfall is 3500 mm, with around 90% received during the south-west monsoon from June to September, with 95-100 rainy days in most years. The climate in the region is temperate, with average minimum and maximum temperatures ranging from 18.8 °C to 34.2 °C. The minimum and highest relative humidity are 53.6% and 91.1%, respectively. The region's average annual evaporation is 1200 mm.

Precipitation Data Collection: Daily rainfall dataset of 34 years (1990-2023) has been collected from AICRP on Agrometeorology, Department of Agronomy, College of Agriculture, Dr. BSKKV, Dapoli. The rainfall data is consistent and does not required interpolation due to no gaps.

Precipitation Concentration Index (PCI)

The PCI is powerful tool for temporal precipitation distribution. It was develop to analyze and compare the concentration of rainfall because of its emphasis on the relative distribution of rainfall irrespective of the total rainfall received. The PCI was computed on an annual and seasonal scale, with a modified version used to predict the monthly variability of rainfall (Oliver, 1980) [15]. For annual PCI calculation, firstly the conversion of daily rainfall to monthly was done for each respective month of particular year and by using monthly rainfall of 12 months for selected year Annual PCI were calculated using equation 1. For each year same procedure were applied and PCI index for total 34 years were estimated.

$$\text{PCI annual} = 100 \times \frac{(\sum_1^{12} P_i{}^2)}{(\sum_1^{12} P_i)^2} \quad (1)$$

Where, Pi is the monthly precipitation in a month i.

After that, for seasonal PCI estimation only four months monthly rainfall considered, i.e. June, July, August and September. The seasonal PCI calculated with its respective formula is given as equation 2.

$$\text{PCI seasonal} = 33 \times \frac{(\sum_1^{4} P_i{}^2)}{(\sum_1^{4} P_i)^2} \quad (2)$$

Where, Pi is the monthly precipitation in a month i.

For the decadal estimation, Three decades (1990-1999, 1999-2009 and 2009-2019) was considered. The mean of PCI values of 10 year considered as decadal PCI value. By using mean annual and seasonal value PCI, obtained the PCI values for each decade. Which helps to understand the decadal precipitation distribution.

PCI was used to acquire long-term variability in rainfall amount on a seasonal and annual basis. The PCI looks at the monthly average precipitation over a specified time and assesses how uniform the precipitation is. The number 100 in the formula for the annual PCI represents 12 months of the year signifying 100% and the number 33 for the seasonal PCI represents the four monsoon months in each season as a percentage of 12 months of the year (Nandargi and Aman, 2018) [13]. It ranges from 8.3 to 10. The graph of annual and seasonal PCI was plot between the year against to their PCI values. According to Oliver (1980) [15], a PCI value less than 10 represents mostly uniform precipitation distribution. The detail spatial distribution according to their ranges is given in Table1.

Table 1: PCI Range and Classification (Oliver, 1980) [15]

PCI	Spatial distribution
<10	Uniform precipitation distribution
10to 15	Moderate precipitation distribution
16 to 20	Irregular precipitation distribution
>20	Strong irregularity precipitation distribution

Results and Discussion

The annual distribution of the mean PCI value is given in Figure 1. The range varies from the lowest value 23.40 in year 2012 to the highest of 37.78 recorded in 1991. Further results of PCI values shows Strong irregularity of precipitation distribution according to PCI values. Table. 2 shows that annual PCI index for all 34 years obtained PCI value was greater than 20. So, strong irregularity of precipitation distribution found 100%. The graphical representation of annual precipitation concentration index shown in Figure 1.The Table 2 shows the obtained PCI range for annual precipitation.

Table 2: Percentage of total years of PCI ranges for annual precipitation concentration index

Sr. No.	Remark	PCI values	No of Years	Percentage (%) of total year
1	Uniform precipitation distribution	<10	0	0
2	Moderate precipitation distribution	10to 15	0	0
3	Irregular precipitation distribution	16 to 20	0	0
4	Strong irregularity of precipitation distribution	>20	34	100
Total			34	100

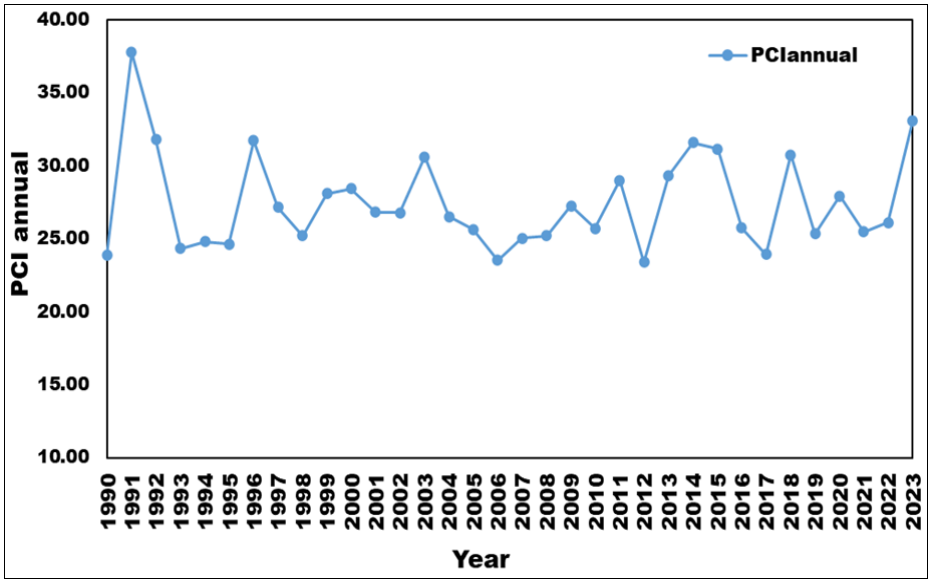

Fig 1: Annual Precipitation Concentration Index

For, Seasonal analysis the result revealed that, PCI calculated for study area showed the PCI value range from the lowest value 8.39 in year 2007 to the highest of 12.52 recorded in 1991. From total 34 years 20 years (58.73%) were uniform precipitation distribution followed by 14 years (41.17%) were moderate precipitation distribution which shown in Table 3. It can be concluded that in monsoonal month of study region shows Uniform precipitation distribution and Moderate precipitation distribution. The graphical representation of Seasonal precipitation concentration index shown in Figure 2.

Table 3: Percentage of total years of PCI ranges for seasonal precipitation concentration index.

Sr. No.	Remark	PCI values	No of Years	Percentage (%) of total year
1	Uniform precipitation distribution	<10	20	58.83
2	Moderate precipitation distribution	10to 15	14	41.17
3	Irregular precipitation distribution	16 to 20	0	0
4	Strong irregularity of precipitation distribution	>20	0	0
Total			34	100

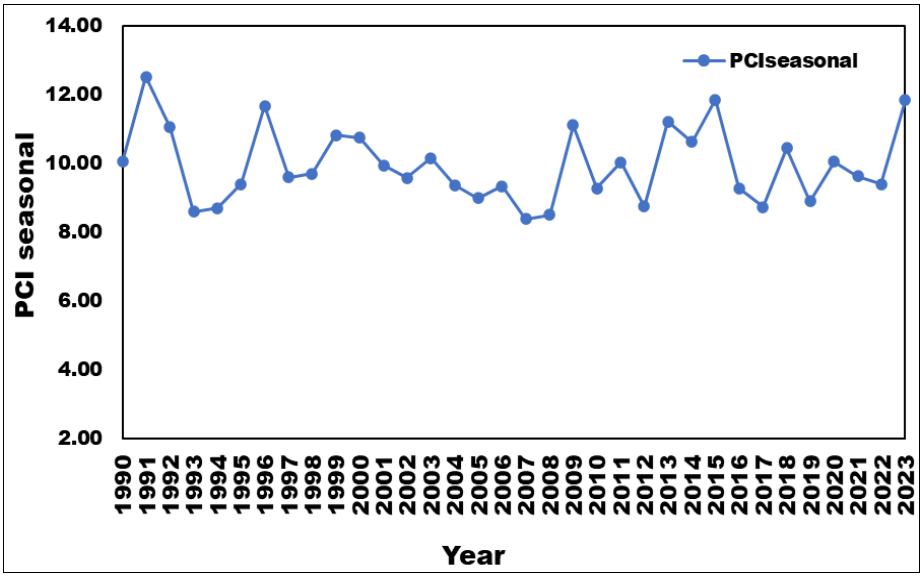

Fig 2: Seasonal Precipitation Concentration Index

To further investigate the characteristics of PCI for selected study area, decadal values were calculated. On the decadal scale, the annual PCI for 1990-1999 and 1999-2009 fall within the moderate precipitation concentration category giving average value of 27.95 and 26.73 respectively while the period 2009-2019, with a PCI value of 27.57, is characterized by strong irregularity of precipitation distribution. For the seasonal basis, while rainfall concentration was observed to be moderately distributed for the periods 1976 -1985 and 2009-2019, it is of uniform precipitation distribution for the 1999–2009 period.

Table 4: Mean decadal values of Seasonal and Annual PCI

Decade	PCI annual	PCI seasonal
1990-1999	27.95	10.21
1999-2009	26.73	9.72
2009-2019	27.57	10.02

Conclusion

This paper has attempted to determine PCI as an index to analyse rainfall variability and concentration. As a result, the findings of this study demonstrate that PCI is a critical input for water resource planning and management, disaster preparedness, and providing information on water variability to relevant government agencies, and should be considered. The implications of such observed changes have a significant impact on natural processes such as soil erosion, flooding, fluvial regimes, and groundwater recharge. PCI can, therefore, serve as a warning tool for flooding and erosion

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