Assessment of Diurnal Variability and Region-Specific Connection Across Intensity, Depth & Duration of Rainfall

Abstract

Rainfall remain foremost input entity for regulating any kind of dynamics of water resource systems on the earth. Its correct study and understanding of rainfall are highly crucial in hydrology or any kind of water resource system, to evolve and judge effective management and development of prevailing terrestrial and aquatic ecosystems. This study is focussed towards analysing the diurnal variability of rains with region-specific connectiveness across intensity, depth and duration of Rainfall for central region of Gujarat; having semi-arid climate. It investigates spatio-temporal dynamics of rains at multiple situations, for the situations where a majority of rainfall occurred during a single quarter of the day (i.e., a 6-hour period). An in-depth elaboration on quarter wise distribution of such daily rainy event (covering 20 years time span) is offered, which revealed that the maximum number of storms occurred in second quarter Q_2 (06:00 to 12:00 hours) while the least in first quarter Q_1 (24:00 to 06:00 hours). Three sets of time series of maximum rain intensities (one each for 20, 10 and 5 years, recurrence interval i.e. RI) are also attempted to demonstrate an inclusive scenario in regards to intensity-duration characterizations of rain, cutting across various locations and years of observations. Location specific relationships among depth & durations and intensity & duration are generated with exhaustive comparisons, under 3 specific recurring interval period (5, 10, 20 years) for all the 6 rain stations as adopted herein.

Key Words : Diurnal Variability of Rainfall, IDF, Rainfall Intensity, Rainfall Duration, GPM, Rainfall Modelling

1. INTRODUCTION

The intensity–duration–frequency characterization of rains, is always considered to have an important role in water resources engineering and management. Its true utilities and applications range from assessing rainfall events, classifying climatic regimes, deriving design storms, deriving loss functions to produce runoff patterns, assisting in designing drainage systems, etc. What even be the spatio-temporal scale, being a foremost input hydrologic entity it vastly regulate majority of water resource systems on earth. It remains a proven fact that rainfall based research happens to be one of the weakest link in hydrology, as the due investigations on rainfall variability have experienced pretty less priority and diminutive efforts (Lall, 2014 ; Sivakumar, 2005 ; Bates *et al.,* 2008 ; Allan, 2011). The quantity and quality of runoff from majority of watersheds (micro to macro) is highly influenced and regulated by spatio-temporal variabilities on rains. Performance evaluation and management of any water or watershed-based system gets accomplished by espousing variety of advanced hydrological models or modelling approaches. In all such efforts a compromise is always made via adoption of an inferior input, in-terms of rainfall, for which reason remains non-availability of region-specific rainfall observations at finer spatio-temporal steps. In majority of cases annual, monthly, weekly or at the most daily rainfall values are adopted with wider extent of interpolation/extrapolation; as in most cases the observed rainfall records remain exceedingly scanty, non-uniform & discontinuous. Such inferior input always results into equally mediocre outputs from hydrologic models/modelling approaches; even if they are of marvellous nature. The non-availability of region-specific rainfall observations at finer spatio-temporal steps is always reflected to have significant impacts on hydrological modeling and simulation results (Anandhi *et al.,* 2011; Gao *et al.,* 2018; Moges & Gebremichael, 2014; Tahir *et al.,* 2012; Wang *et al.,* 2019).

Accurate rainfall data is crucial for predicting and managing the impacts of rainfall on various aspects of land and water resources management and catchment health. The predominant duration and intensity of rainfall significantly influence the occurrence of floods in a catchment (Karamouz et al. 2018). The distribution of rainfall over time is also critical in determining the amount of soil erosion, with rain-intensity and durations having a significant impact on the magnitude of soil erosion (Reggiani et al. 2016; Zhang et al. 2019). In sediment dynamics and transport via rivers, rainfall intensity, duration, and distribution play a critical role (Wang et al. 2017; Chen et al. 2019). A clear understanding of rainfall variabilities specific to a region is necessary when attempting any kind of land and water development intervention in natural watersheds (Smith et al. 2018).

Furthermore, the magnitude and distribution of rainfall greatly affect groundwater recharge, which is crucial for sustaining ecosystems and meeting long-term human water needs (Sharma et al. 2017; Luo et al. 2018; Du et al. 2019). Accurate assessment of rainfall variabilities is also vital for agricultural productivity as crop yields have a direct proportional relationship with corresponding rainfall variabilities, which can affect long-term food security targets (Lobell et al. 2019). The dynamics of rainfall patterns and intensity also influence water quality parameters by transporting pollutants into drainage lines or other waterways (Deo et al. 2017).

2.0 Literature Review

The diurnal variation in precipitation can have significant impacts on catchment response, affecting various aspects of water resources management and catchment health. These impacts include changes in the timing of peak flow, soil moisture dynamics, streamflow response, hydrochemical response, and evapotranspiration. Understanding these impacts is important for managing water resources and predicting the response of catchments to changing climate conditions (Delgado et al. 2019; Bales et al. 2011; Zhang et al. 2014; Zhao et al. 2019; Yuan et al. 2016). Present study aimed to analyse a broader spectrum of rainfall variabilities at micro scales cutting across 6 rain stations covering a time span of about 20 years; and offering the on-ground scenario in regards to diurnal variability and region-specific connections across intensity, depth and duration of rainfall as prevailed in the central region of Gujarat.

With an emphasis on tropical areas, Sorooshian et al. (2005) evaluated the effectiveness of the PERSIANN system, a satellite-based approach for calculating rainfall. Their research attempted to assess the system's dependability and accuracy in detecting rainfall patterns. Yang, Smith, and Sheridan (2014) used simulations from a high-resolution land data assimilation system to look at the diurnal precipitation cycle over the United States. The temporal properties and variability of rainfall at various times of the day became well-understood because to their research. In order to improve the precision of precipitation calculation and broaden its regional coverage, Wang et al. (2009) investigated the combination of gauge observations with satellite rainfall estimations in Continental China. The use of an artificial neural network cloud categorization system to estimate rainfall based on remotely sensed imagery was examined by Hong, Hsu, Sorooshian, and Gao in 2004. Their research demonstrated the approach's promising potential for precisely calculating rainfall using satellite data.

3. MATERIAL AND METHODS

3.1 Study location

This study aims to analyse and quantify the variability of rainfall patterns in the central region of Gujarat, which is characterized by semi-arid climate. The research focuses on three key districts - Anand, Kheda, and Vadodara - which represent Agro-Climatic Zone-III of the state. These districts experience mean maximum temperatures ranging from 28.4°C in January to 41.8°C in May and mean minimum temperatures ranging from 11.7°C in January to 27°C in June. Two locations were selected from each of the study districts. Gudel and Sojitra from Anand ; Kathlal and Dakor from kheda and ; Pilol and Waghodiya from Vadodara district. The exact geographic locations of 6 study sites are well reflected in Fig. 1, showing their wider spatial spreads in study area.

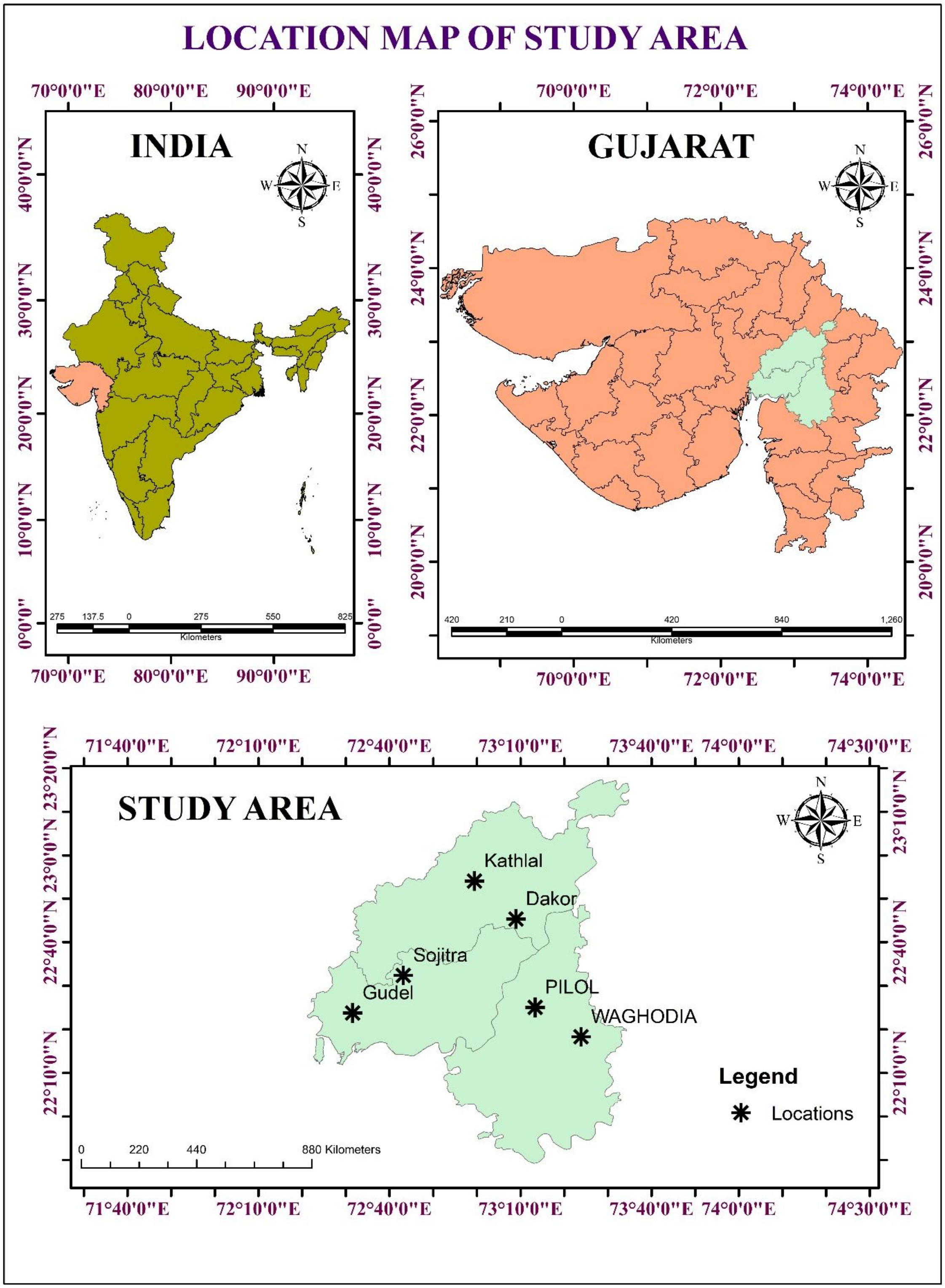


Figure 1. Location Map of the study area

3.2 Data

To gather the necessary data for this study, satellite-based precipitation products were utilized. Global Precipitation Measurement (GPM_3IMERGHH) is an international satellite mission jointly developed and managed by NASA and the Japan Aerospace Exploration Agency (JAXA) (Huffman *et al.*, 2019). The mission aims to provide global measurements of precipitation every half hour using a constellation of satellites that use advanced radar and radiometer instruments to measure precipitation from space. Rainfall records for all the study stations in the three districts were collected for a 21-year period from 2000 to 2020. The rainfall records had a temporal resolution of 30 minutes and a spatial resolution of 11.1 km x 11.1 km.

3.3 Methodological Description

Events were treated differently from daily rainfall data, as they were independent, isolated, and continuous rainstorms of varying durations, ranging from 1 hour to even longer durations well beyond 24 hours. To categorize the smart rainfall data appropriately, a valid check was performed to extract the actual rainfall hours or cells that contained information on rainfall, using R programming applications. The time series data contained significant periods of zero precipitation, which were omitted during the analysis. Upon preliminary analysis of the rainstorms, it was deemed appropriate to exclude those with durations exceeding 24 hours. For other remaining storms (across 1 hr to 24 hr durations) following categorised distribution was adopted in four different categories as provided below. Rainstorms having continuous rains for 1) 1 to 3 hours duration, 2) 3 to 6 hours duration, 3) 6 to 12 hours duration, and 4) 12 to 24 hours duration.

Table 1. Portrayal of isolated continuous rain storms (4 categorized durations) for study locations

Sr. No.	Storm Duration	Number of Storms Extracted					
		Dakor	**Kathlal**	**Gudel**	**Sojitra**	**Pilol**	**Waghodiya**
1	1-3	386 (43)	371 (43)	381 (43)	350 (40)	405 (42)	461 (45)
2	4-6	266 (30)	265 (31)	281 (31)	276 (31)	295 (31)	309 (30)
3	7-12	178 (20)	168 (20)	168 (19)	180 (20)	197 (21)	188 (18)
4	13-24	64 (7)	51 (6)	63 (7)	76 (9)	63 (7)	67 (7)
Total		894	855	893	882	960	1025

(The numbers in parenthesis shows % of total number of storms)

After obtaining the precipitation data from the Global Precipitation Measurement (GPM_3IMERGHH), the following steps were taken.

Examining Distribution of Daily Rainfall: The next step is to examine the distribution of daily rainfall at a finer temporal scale of approximately 1 hour. This enables the identification of the quarter of the day where the bulk of the rainfall occurred.

Identifying Concentrated Storm Events: The analysis includes a large amount of data and focuses on identifying concentrated storm events. Rainfall data is examined at an hourly level to identify days where over 75% of the rainfall occurred during a single quarter of the day.

Investigating Burst Storms: The objective of this analysis was to gain a better understanding of burst storms and their concentration during specific periods of the day.

Identifying Peak Rainfall Intensities: The next step is to identify peak values of rainfall intensities for 24 specific time durations ranging from 1 hour to 24 hours. The occurrence of these peak intensity values is found to be dependent on both the reoccurrence interval and the frequency period.

Segregating Data into Sub-Groups: To account for the dependence on reoccurrence interval and frequency period, the observed data set is segregated into three sub-groups based on predetermined categories or groups, namely pooled data for five years, ten years, or twenty-year spans.

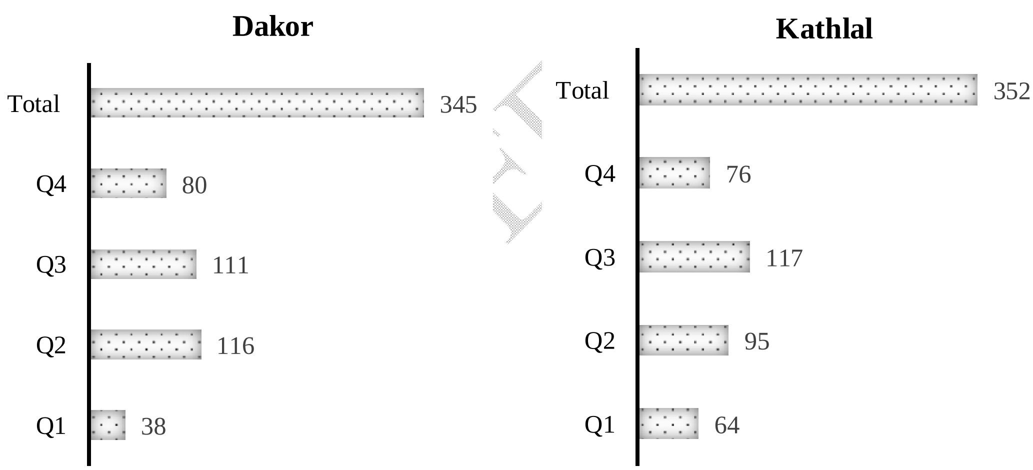
Examining Local Trends: Additionally, the analysis examines the local trends and the relationship between the depth of rainfall and its duration for each station.

Segregating Precipitation Data: Similar to the analysis of intensity duration, the observed precipitation data set for each station is also segregated into three groups, namely pooled data for five years, ten years, or twenty-year spans.

4. RESULTS AND DISCUSSION

4.1 Quarterly Temporal Dispersal across 20 years

This study was carried out to examine scenarios where most of the daily rainfall took place within a specific quarter of the day, which equates to a 6-hour period. The number of storms detected across all the stations remained 345, 352, 262, 316, 390 and 374 for Dakor, Kathlal, Gudel, Sojitra, Pilol and Waghodiya respectively, where its more than 75 % rain fallen in any of the single quartile (6 hr) of the day. A detailed illustration in regards to quarter wise distribution of such event is provided in figure 2. For Dakor such storms were found highest in number being 116 (occurred in Q_2) and 111 (occurred in Q_3). Least occurrence of such events was detected in Q_1. Similar quantified information in regards to occurrence of such events for other five stations are evidently depicted in figure 2. On the same line evidences were also generated to identifying and locate occurrence of rain event where their more than 50 % rain depth fallen in any of the single quarter of the day. The detailed quantified information and dispersals are numerically as well as graphically presented in figure 3, which are self-explanatory in their contents. This information is going to be a vital key of information for planer engineering, irrigation schedulers, water resource managers and other policy planners for the cause of rural development. The diurnal pattern of rainfall was influenced by any of the reason like local topography, surface heating and atmospheric stability, local convective processes and resulted with higher numbers of rainfall events occurring in late afternoon and early evening (Seleshi, et.al., 2018 ; Carbone & Tuttle, 2014 ; Marengo et al., 2012).



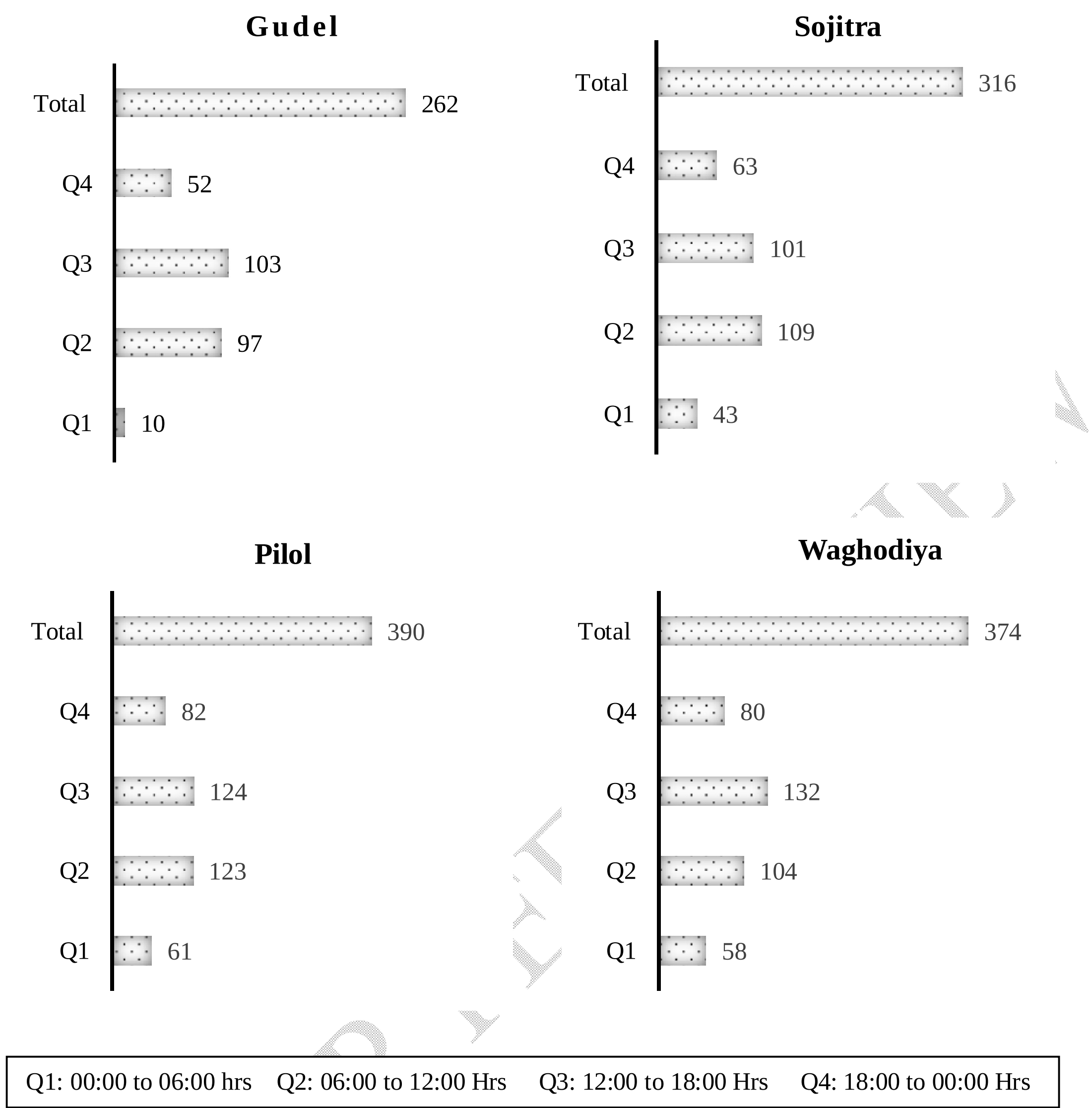


Figure 2. Observed number of rainy days having 75% rains in a single Quarter of the day at different stations

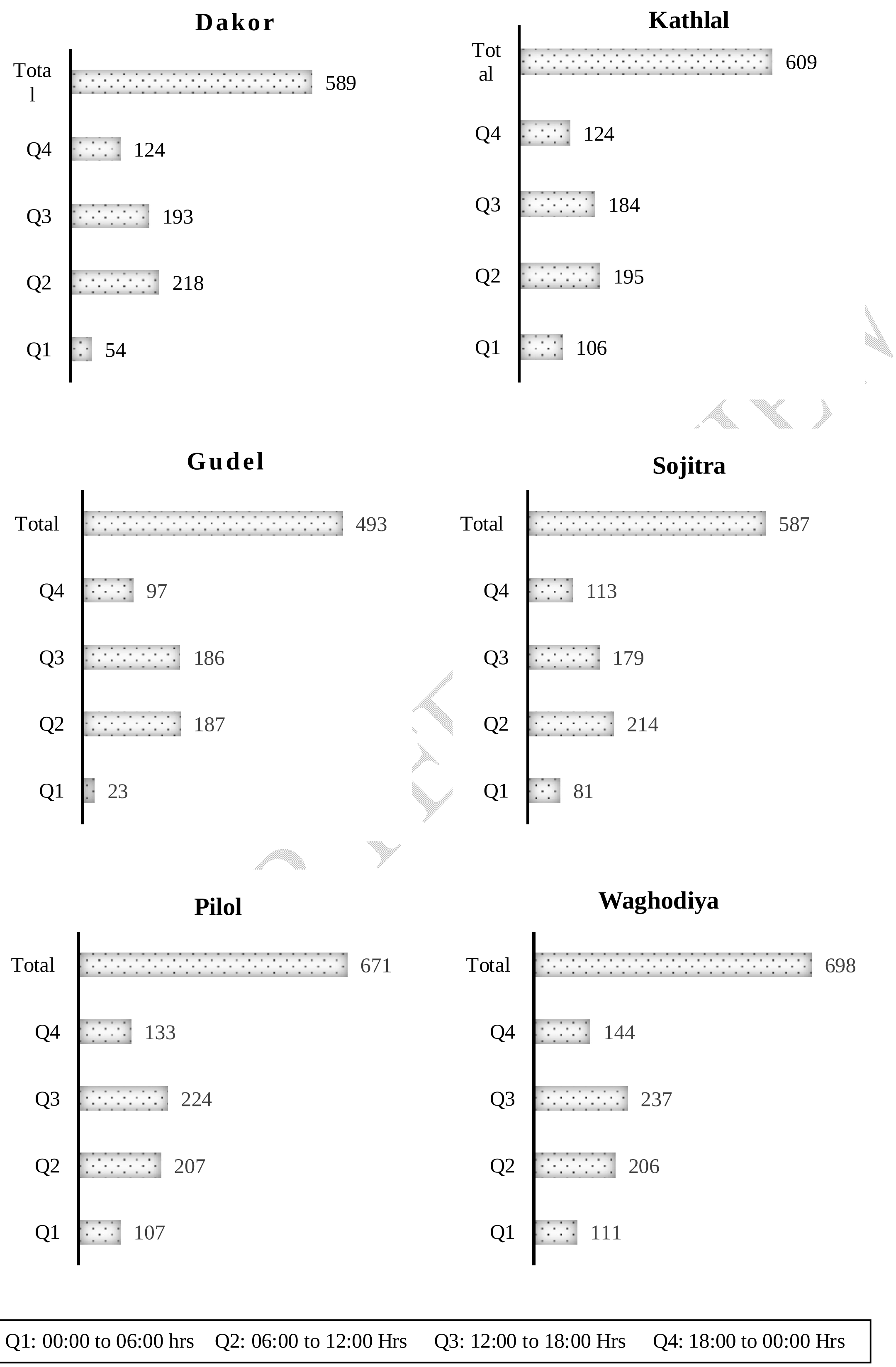


Figure 3 Observed number of rainy days having 50% rains in a single Quarter of

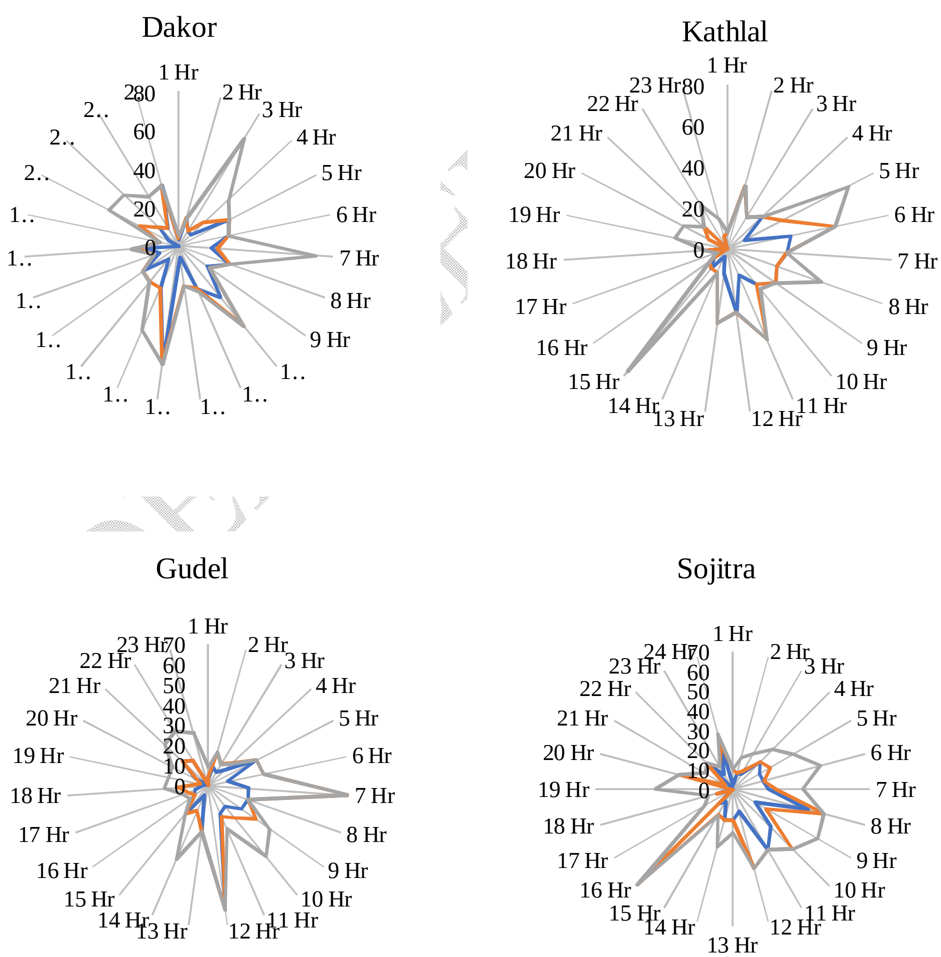
the day at different stations

4.2 Intensity Duration Relationships

The analysis of rainfall data is crucial in understanding the intensity, duration, and frequency of rainfall events in a particular region. We aimed to identify the highest recorded values of rainfall intensity across 24 distinct time intervals ranging from one hour to 24 hours. The data was collected from six stations in the study location, and the highest values of peak rainfall intensities were identified for each station. The results of the analysis were presented graphically in Figure 4, which shows the peak rainfall intensities observed under real space time spans. The figure also includes three sets of time series of maximum rain intensities for recurrence intervals (RI) of 20, 10, and 5 years to provide a comprehensive view of intensity-duration configurations across the study location. The data presented in Figure 4 can be used to understand the rainfall patterns in the study location and design appropriate measures to manage the risks associated with extreme rainfall events.

The comparison of the temporal existence of the three most peaked values of maximum rainfall intensities across all durations (1-24 hrs) for all six stations provides clues on intensity-duration relations for each station and specific RIs. For example, at Dakor, the existence of the three highest peak rain intensities for an RI of 20 years were found to be located for 3, 7, and 13 hours durations. Similarly, at Kathlal, Gudel, Sojitra, Pilol, and Waghodiya, the three highest peak rain intensities for an RI of 20 years were found to be located in different durations.

However, the comparison of the above features for other sets of RIs (10 years and 5 years) for all the stations shows that the three highest peak intensities do not follow the same trend as found for an RI of 20 years. The occurrences of these values are located in different durations, as shown in Figure 4.. These further highlights the fact that different recurrence intervals can lead to varying magnitudes and durations of extreme rainfall events (Kundzewicz et al., 2014; IPCC, 2014; Sharma et al., 2017), which can have significant impacts on the hydrological cycle, flooding, and water resources management in any given region. The analysis of rainfall data provides insights into the intensity-duration relations for each station and specific RIs, which can be useful in understanding the rainfall patterns and designing appropriate measures to manage the risks associated with extreme rainfall events. The data presented in Figure 4 can also be used to develop rainfall models that can aid in predicting the frequency and intensity of rainfall events in the study location.



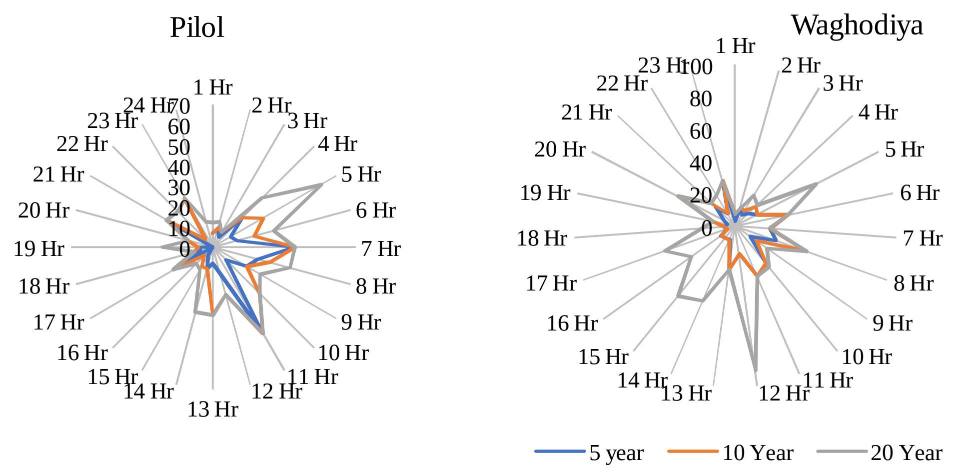
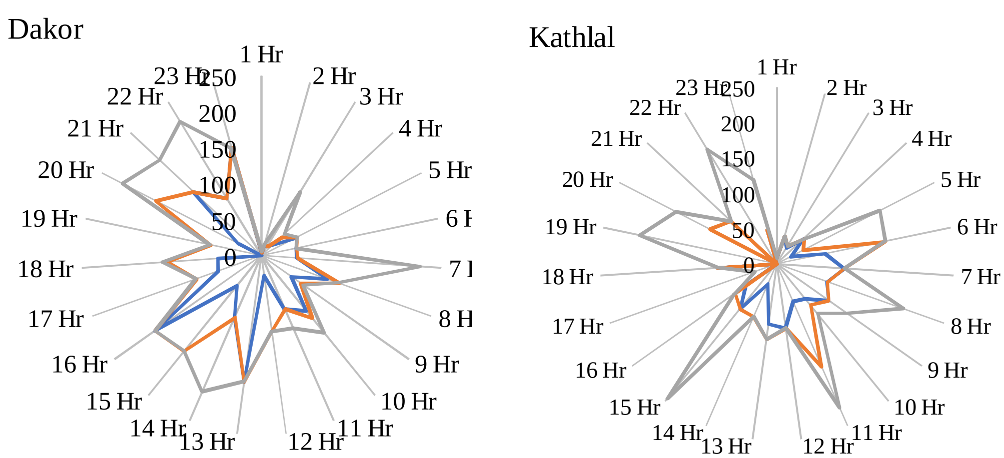


Figure 4. Inter relationship across observed sets of peak rain intensity (mm/hr) v/s duration (hr) of rains for 5, 10 and 20 years RI at 6 study locations

4.3 Depth Duration Relationships

The rainfall data was analysed to identify the maximum depth of rainfall that occurred during distinct time intervals ranging from one hour to 24 hours. The results of this analysis were illustrated graphically in Figure 5, which showed the maximum depth of rainfall in any particular hour across all 24 hours. Some preliminary conclusions can be drawn from these figures. For example, at Dakor, it was found that the three highest depths of storm rains for a recurrence interval (RI) of 20 years were located during rain storms of 7, 14, and 20 hours durations. Similarly, for Kathlal, Gudel, Sojitra, Pilol, and Waghodiya, the three highest depths of rainfall (20 year RI) were located during rain storms of 15, 11, and 19 hours; 23, 22, and 12 hours; 16, 19, and 24 hours; 23, 13, and 19 hours; and 12, 17, and 20 hours durations, respectively.

However, when comparing the above features for other sets of recurrence intervals (10 years and 5 years) for all the above stations, the three highest depths of rainstorms did not follow the same trend as found for the 20 years RI and described above. The occurrences of these values were fallen under different durations, as shown in Figure 5. These findings suggest that the duration of rainfall events can play an important role in determining the maximum depth of rainfall, and that this relationship can vary depending on the recurrence interval being considered (Smith et al., 2014 ; Schmitt et al., 2016 ; Woldemeskel et al., 2020). Therefore, it is important to analyze rainfall data for different recurrence intervals and durations to gain a better understanding of the characteristics of extreme rainfall events in a given region. This information can be used to develop appropriate strategies for managing the risks associated with extreme rainfall events.



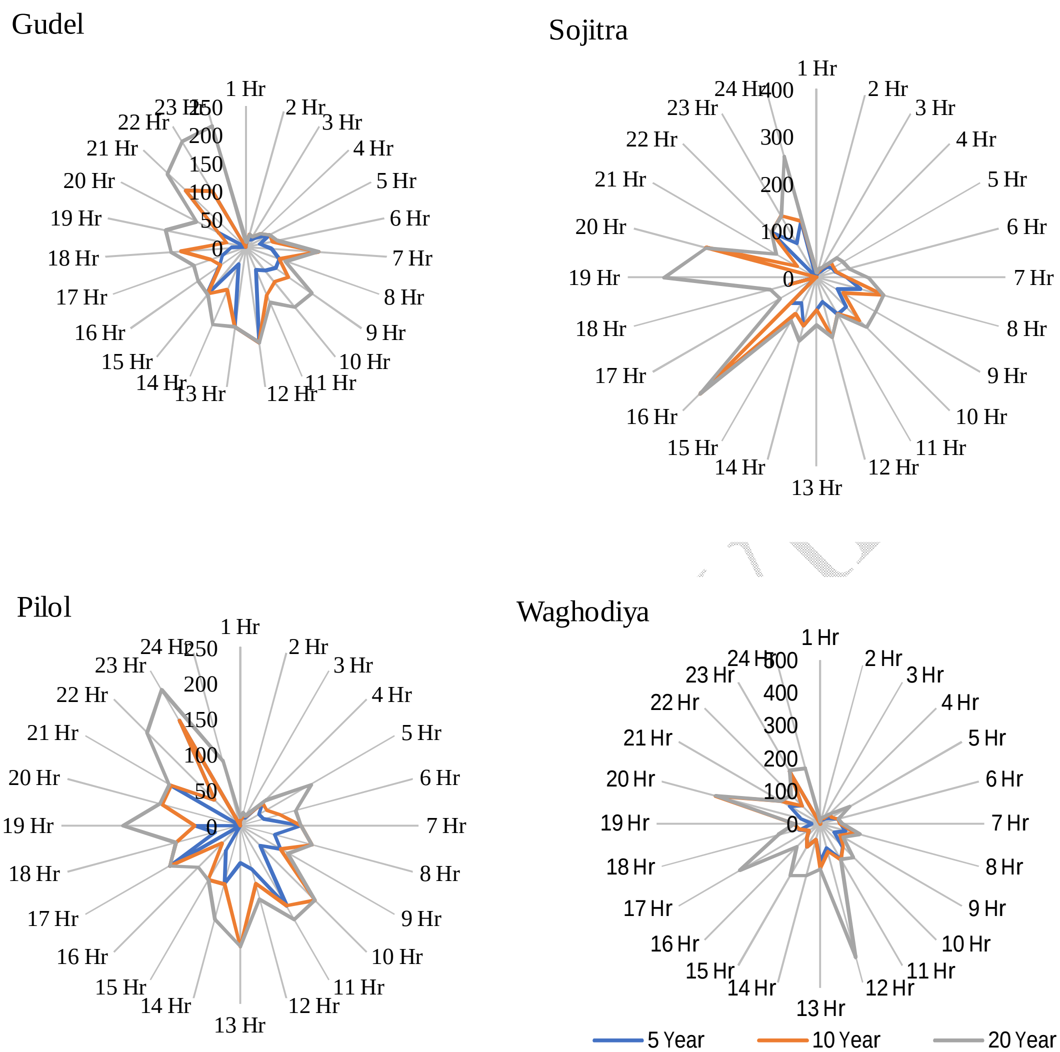


Figure 5. Inter relationship across observed sets of depth (mm) v/s duration (hr) of rains for 5, 10 & 20 years RI at 6 study locations

5. CONCLUSION

Rainfall data from GPM was collected using standard protocols and analysed for 6 locations in 3 districts of middle Gujarat. The data included discrete and continuous rainfall values, patterns, and uncertainties for various storm durations. This study was focussed towards analysing the diurnal variability of rains with region-specific connective ness across intensity, depth and duration of Rainfall for central region of Gujarat; having semi-arid climate. The relationships between depths, durations, and intensities of rainfall for different recurrence intervals were determined using mass curves. Maximum rainfall intensities were derived for each rainstorm, and the relationships among depth and duration, intensity and duration, and other combinations for 3 specific recurring interval periods were analysed for all 6 stations.

This study investigated instances where most of the daily rainfall occurred within a 6-hour period (a quarter of the day). The number of such storms detected across the six stations varied. The information on quarter-wise distribution of these events can be useful for planners, engineers, irrigation schedulers, water resource managers, and policy planners. From the diurnal study of rainfall storms, it was revealed that highest number of storms occurred in Q_2 (06:00 to 12:00 hours) and least occurrence of such events was detected in Q_1 (24:00 to 06:00 hours) in semi-arid regions like study area. The diurnal pattern of rainfall was found to be influenced by factors such as local topography, surface heating and atmospheric stability, and local convective processes, resulting in higher numbers of rainfall events occurring in the late afternoon and early evening.

It is important to note that extreme rainfall events can have varying magnitudes and durations depending on the recurrence interval, which can greatly impact the hydrological cycle, flooding, and water resource management in a given region. Analysing rainfall data can provide valuable information on intensity-duration relationships for each station and specific recurrence intervals, which can aid in understanding rainfall patterns and developing appropriate strategies to mitigate the risks associated with extreme rainfall events. The results revealed that the three highest depths of rainfall for a 20-year recurrence interval were located during rainstorms of certain durations for each station. The duration of rainfall events is a significant factor in determining the maximum depth of rainfall and this relationship varies with different recurrence intervals. It is important to analyze rainfall data for different recurrence intervals and durations to better understand the characteristics of extreme rainfall events and develop appropriate strategies for managing the associated risks.

References

Allan, R. P. (2011). Climate change and global water resources. The Royal Society, 369(1938), 20110421.

Anandhi, A., Srinivasan, R., & Nanjundiah, R. S. (2011). Rainfall variability and its impact on water availability in Indian river basins. Current Science, 101(3), 318-328.

Bales, R. C., Goulden, M. L., Hunsaker, C. T., Conklin, M. H., & Rice, R. (2011). Diurnal and seasonal variations in soil and plant water isotopes reveal ecohydrologic dynamics in a seasonally dry tropical montane cloud forest. Ecohydrology, 4(1), 64-76. https://doi.org/10.1002/eco.181

Bates, B. C., Kundzewicz, Z. W., Wu, S., & Palutikof, J. P. (Eds.). (2008). Climate change and water. Technical paper of the Intergovernmental Panel on Climate Change, 6, 210.

Carbone, R. E., & Tuttle, J. D. (2014). The diurnal cycle and its depiction in the Community Climate System Model. Journal of Climate, 27(15), 5696-5711.

Chen, Y., Wang, G., Chen, L., & Wang, Y. (2019). Effects of rainfall intensity and duration on sediment transport in a typical karst watershed of southwest China. Catena, 178, 46-54. doi:10.1016/j.catena.2019.02.015

Delgado, J. M., Gallegos, H. A., & Ayala, R. (2019). Effect of diurnal rainfall variation on peak flows in an urban catchment. Water, 11(6), 1166. https://doi.org/10.3390/w11061166

Deo, R. C., Şahin, M., & Muttil, N. (2017). A review of multivariate statistical applications in hydrology: a 25-year update. Journal of Hydrology, 540, 387-396. doi:10.1016/j.jhydrol.2016.06.041

Du, Y., Wang, L., He, Y., & He, C. (2019). Spatiotemporal variability of groundwater recharge in the Wei River Basin and its response to climate change and human activities. Science of the Total Environment, 647, 1607-1620. doi:10.1016/j.scitotenv.2018.08.166

Gao, Y., Sun, H., Zheng, H., Wang, D., & Lu, H. (2018). Impact of spatiotemporal rainfall resolution on hydrological simulations in a mountainous watershed. Journal of Hydrology, 556, 768-780.

Hafeez, M., Ahmed, N., & Liu, J. (2020). Climate change impacts on water resources: issues and challenges for adaptation and mitigation in Pakistan. Science of the Total Environment, 716, 136845. doi:10.1016/j.scitotenv.2020.136845

Hong, Y., Hsu, K., Sorooshian, S., & Gao, X. (2004). Precipitation estimation from remotely sensed imagery using an artificial neural network cloud classification system. Journal of Applied Meteorology, 43(12), 1834-1853. write a one paragraph gist of above researches with its intext citattion

Huffman, G.J., E.F. Stocker, D.T. Bolvin, E.J. Nelkin & Jackson Tan (2019), GPM IMERG Final Precipitation L3 Half Hourly 0.1 degree x 0.1 degree V06, Greenbelt, MD, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: [30/09/2021], 10.5067/GPM/IMERG/3B-HH/06

Jiang, J., Liu, Y., Hu, C., & Jiang, J. (2018). Assessment of surface water quality impacted by heavy rainfall events: a case study in Beijing, China. Environmental science and pollution research international, 25(21), 20720-20731.

Karamouz, M., Nazif, S., Moridi, A., & Mahdavi, M. (2018). A review of flood frequency analysis and its applications in Iran. Journal of Hydrology, 564, 45-62. doi:10.1016/j.jhydrol.2018.06.006

Kundzewicz, Z.W., Kanae, S., Seneviratne, S.I. et al. "Flood risk and climate change: global and regional perspectives." Hydrological Sciences Journal 59(1), 1-28 (2014). https://doi.org/10.1080/02626667.2013.857411

Lall, U. (2014). Rainfall variability research in the past decade: Achievements and challenges. Hydrology and Earth System Sciences, 18(1), 47-70.

Lobell, D. B., Hammer, G. L., McLean, G., Messina, C., Roberts, M. J., & Schlenker, W. (2019). The critical role of extreme heat for maize production in the United States. Nature Climate Change, 9(3), 218-223. doi:10.1038/s41558-019-0411-0

Luo, L., Wu, J., & Zhang, Y. (2018). Modeling groundwater recharge based on the Budyko framework: a case study in the Yellow River Basin. Journal of Hydrology, 563, 200-211. doi:10.1016/j.jhydrol.2018.05.010

Marengo, J. A., Nobre, C. A., Tomasella, J., Oyama, M. D., de Oliveira, G. S., & de Oliveira, R. (2012). The drought of Amazonia in 2005. Journal of Geophysical Research: Atmospheres, 117(D12).

Moges, M. A., & Gebremichael, M. (2014). On the effect of rainfall temporal resolution on hydrologic modeling. Journal of Hydrology, 519, 2302-2312.

Reggiani, P., Cerdà, A., & Prosdocimi, M. (2016). Rainfall intensity and soil erosion: A review. Journal of Hydrology, 1-17. doi:10.1016/j.jhydrol.2016.04.011

Schmitt, R., Weiler, M., & Hergarten, S. (2016). Rainfall duration controls on the variability of soil water repellency effects on infiltration. Hydrology and Earth System Sciences, 20(4), 1437-1449. doi: 10.5194/hess-20-1437-2016

Seleshi, Y., Camberlin, P., & Williams, E. R. (2018). Diurnal and seasonal variability of rainfall in Ethiopia: climatology and dynamics. Journal of Hydrology, 563, 153-170.

Sharma, A., Babel, M. S., & Tripathi, N. K. (2017). Assessment of groundwater recharge in a watershed with scarce data: a case study from Nepal. Journal of Hydrology: Regional Studies, 14, 38-51. doi:10.1016/j.ejrh.2017.09.003

Sharma, A., Chen, S., Sharma, R., & Singh, V. P. (2017). "Impact of different recurrence intervals on rainfall-runoff processes and hydraulic design of culverts in a watershed." Journal of Hydrologic Engineering, 22(4), 04017003. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001507

Sivakumar, M. V. K. (2005). Interannual variability of rainfall: its association with ENSO and diverse atmospheric-oceanic conditions. Meteorological Applications, 12(3), 243-254.

Smith, J. A., & Krajewski, W. F. (1991). Rainfall interception. In Handbook of Hydrology (pp. 4.1-4.53).

Smith, J. A., Baeck, M. L., Villarini, G., Wright, D. B., & Krajewski, W. F. (2014). Rainfall duration–frequency relationships for the design of urban stormwater systems. Journal of Hydrology, 514, 198-210. doi: 10.1016/j.jhydrol.2014.04.025

Smith, L., Zhang, L., Leyton, L., & Gichaba, M. (2018). A regional view of rainfall variability in Africa: a call for a better understanding of the sources of variability. Climate, 6(3), 61. doi:10.3390/cli6030061

Sorooshian, S., Hsu, K., Gao, X., Gupta, H. V., Imam, B., & Braithwaite, D. (2005). Evaluation of PERSIANN system satellite-based estimates of tropical rainfall. Bulletin of the American Meteorological Society, 86(5), 673-688.

Tahir, A. A., Chevallier, P., & Arsenault, R. (2012). Sensitivity of hydrological simulations to spatiotemporal resolution of rainfall data. Hydrological Processes, 26(18), 2766-2778.

Wang, D., Sun, H., Lu, H., Gao, Y., & Liu, W. (2019). Effects of rainfall spatiotemporal resolution on runoff simulation in a mesoscale basin using a distributed hydrological model. Journal of Hydrology, 573, 181-193.

Wang, H., Zhang, Y., Wang, Y., & Yan, J. (2018). Uncertainty analysis of river flow and sediment transport processes under different flow scenarios. Water, 10(11), 1642.

Wang, J., Adler, R. F., Huffman, G. J., & Curtis, S. (2009). Integration of gauge observations and satellite rainfall estimates over Continental China. Journal of Applied Meteorology and Climatology, 48(4), 734-744.

Wang, X., Wang, D., Chen, X., Sun, L., Zhang, M., & Li, X. (2017). Impacts of rainfall intensity and vegetation cover on sediment dynamics in the mountainous areas of the Loess Plateau, China. Science of the Total Environment, 574, 563-572. doi:10.1016/j.scitotenv.2016.09.148

Woldemeskel, F. M., Keesstra, S., Stroosnijder, L., & Baartman, J. E. (2020). Rainfall characteristics and erosivity in the upper Blue Nile basin: Implications for soil erosion management. Catena, 184, 104261. doi: 10.1016/j.catena.2019.104261

Yang, J., Zhang, J., Liu, Y., Liu, Y., & Zhang, Y. (2021). Impacts of rainfall variability on soil moisture and ecosystem health in the drylands of northwestern China. Science of the Total Environment, 767, 144377.

Yang, S., Smith, J. A., & Sheridan, S. C. (2014). Examining the diurnal cycle of precipitation over the United States using high-resolution land data assimilation system simulations. Journal of Climate, 27(5), 1863-1879.

Yatagai, A., Kamiguchi, K., Arakawa, O., Hamada, A., Yasutomi, N., & Kitoh, A. (2012). APHRODITE: Constructing a long-term daily gridded precipitation dataset for Asia based on a dense network of rain gauges. *Bulletin of the American Meteorological Society*, *93*(9), 1401-1415.

Yuan, Y., Si, B., Zhu, X., Wang, J., & Gong, Y. (2016). Effects of diurnal precipitation variation on soil water dynamics in a rubber plantation in Southwest China. PloS One, 11(3), e0152124. https://doi.org/10.1371/journal.pone.0152124

Zhang, H., Li, L., Wang, D., Liu, Q., & Lei, T. (2014). Diurnal variation in streamflow response to precipitation in a forested headwater catchment. Journal of Hydrology, 519, 3927-3935. https://doi.org/10.1016/j.jhydrol.2014.10.052

Zhang, J., Wu, P., Lu, Y., & Fu, B. (2019). Effects of rainfall intensity and duration on soil erosion on steep slopes. Geoderma, 354, 113843. doi:10.1016/j.geoderma.2019.113843

Zhao, Y., Yin, H., Huang, J., Zhou, J., & Wang, Z. (2019). The influence of diurnal variation in precipitation on hydrochemical responses in the Changle coastal recharge area. Water, 11(4), 710. https://doi.org/10.3390/w11040710