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Probability of maximum flows in tropical watersheds: central pacific, Costa Rica

Abstract

The Parrita River basin that is located on the Pacific slope of Costa Rica, which has two defined climatic seasons: dry and rainy, is investigated. The method of the possibility of high flows occurring was applied, some methods address nonstationarity. Two frequency distributions were considered for the classical analysis as (a) the Generalized Extreme Value (GEV), (b) Gumbel to analyze the variation of the location, scale and shape parameters of the Gumbel and Pearson type 3 logarithmic distributions. Another way to estimate the occurrence of extreme flows is by frequency analysis. The probability of not exceeding a certain maximum flow value is considered. The research suggests that the Parrita River basin presents a rapid response to intense precipitation events, possibly associated with steep slopes, inadequate land use, limited surface storage capacity, and a dense hydrological drainage network. As a result of intense river channels. The increase in the frequency of extreme flow values, which would alter the connectivity processes between the main channel and the floodplains. The ENSO event has a direct influence on the flow levels of the Pirris, Candelaría y Parrita rivers. The Cold phase increases maximum flows due to a lot of rainfall and increases the risk of flooding.

Keywords: flow rate, gumbel, person, steep slopes, extreme flow, ENSO

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Introduction

The analysis of frequencies for estimation of extreme flows is essential for the development of any community in urban and rural planning, such as infrastructure and land use works, bridges, hydroelectric dams, sewers, road crossing works, protection dikes, pipes, roads and hydraulic works, among others. These usually have a useful life that takes a few years and are not thought of in the long term. Scientists know that the Earth is getting warmer every year and maximum flows tend to increase, as rainfall is more intense and causes maximum floods, especially in short periods of time (WMO, 2026).[1] This could have strong economic repercussions and on people's quality of life, so its correct estimation and analysis is of great need for the societies of the future that demand much more from their natural resources, especially water resources, forests and greater and stronger infrastructure works are required to meet the needs of the population and protect their habitats.

In the tropics, the hydrological characteristics of rivers depend on rainfall and watershed characteristics, as well as geographical position. For this reason, extreme precipitation events are considered among the most catastrophic weather disasters related to global climate variability and change. These occur with greater frequency and intensity. In recent years, disasters such as high flows, floods and landslides caused by excessive rainfall have occurred in some areas of Planet Earth. These disasters have led to significant losses in agriculture, water resources, forests, rural and urban infrastructure, as well as the mortality of some humans.[2] For this reason, research on extreme flows is urgent and necessary to address climate change and foster regional sustainable development. It is important to continue studying extreme rainfall on a global, national and regional scale to understand the behavior of rivers.

In recent years, it has been seen that the impacts that have occurred in different regions of the world are due to climate change and variability. Similarly, it is no longer possible to carry out studies based on the average values of hydroclimatic variables, but the most significant variations occur in extreme events, which are increasing in frequency and magnitude,[3,4] which makes it even more necessary to consider these variations in frequency analyses.

For the estimation of extreme flows, it is necessary to adjust the series of maximum annual flows to some probability distribution function considering stationarity, in which the frequency and magnitude of extreme flows exceed averages and other central statistical variables, which may or may not vary over time. The likelihood of more frequent and intense flows is becoming more likely. This fact has been exacerbated due to changes in land use, climate variability, climate change, the position of the Intertropical Convergence Zone (ZICT), the possibility of increasingly frequent and intense tropical cyclones, among others.[5–7] Based on this assumption, the most frequent and strongest maximum flows are estimated, as well as the possibility of estimating studies from periods of maximum river flows to longer periods (Bentito et all, 2021). [8]

At the global level, the analysis of frequencies and therefore of the extreme episodes produced by climate variability and change have become more relevant, due to the fact of estimating the correct estimation of maximum flows.[9] This has led different international organizations (OMNs), universities and specialists in the field to give greater importance to analyses that consider nonstationarity in extreme events, and certain uncertainties have been raised, such as the existence of trends in flow series. Hence the question is how trends should be considered in frequency analyses for hydrological designs?.[10,11]

Sometimes important structures such as bridges, dams and hydroelectric dams are designed for a useful life of 10 and up to 25 years, but it is not thought that as they are manifesting more aggressive changes and climatic variations, flow levels could rise even higher. Therefore, by considering the highest levels on average during rainy periods and by increasing the frequency and magnitude, it is more likely that structures will be subjected to peak flood events higher than those designed using stationary methods. This could generate overtime

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from losses in infrastructure, economic losses, environmental effects and even human losses.[12,13]

In the case of Costa Rica, some research has been carried out on climate variability and change, analyzing the impacts or signals in some rivers,[14] which show the existence of both negative and positive trends. In addition, it has been verified that the conditions of stationarity are not met in representative samples of maximum flow series throughout the country.[15,16]

Based on the above analysis, and given that in the Parrita River basin in Costa Rica, no research has been carried out on maximum flows and their relationship with climate variability. Therefore, it is necessary to perform an analysis to determine the probability of occurrence of maximum flows, which could be done from the analysis of the frequency of maximum flows and their relationship with ENSO events.

The purpose of this research is to analyze the frequency of maximum flows and their relationship with ENSO events and a possible hydrological risk in a seasonal context in the Parrita river basin.

Area of study

The study area is constituted by the Parrita River hydrographic basin, which in turn has two sub-basins of great importance for their sizes and flows, which are the sub-basins of the Candelaria and Pirrís rivers, which together with the Parrita River sub-basin form a relatively large basin for the size of Costa Rica. This basin is located on the Pacific slope of Costa Rica, which has two defined climatic seasons, the dry and the rainy.

The basin is located entirely in the Central Pacific of Costa Rica, approximately between parallels 9°40'00" North latitude, and 84°15'00" West longitude with an approximate area of 1288.60 km². Its channels are born in the foothills of the Talamanca mountain range section, and it has an important drainage network that reaches the floodplain of said basin and even flows into the Pacific Ocean, its most precise location is in the center-west of the Republic of Costa Rica (Figure 1).

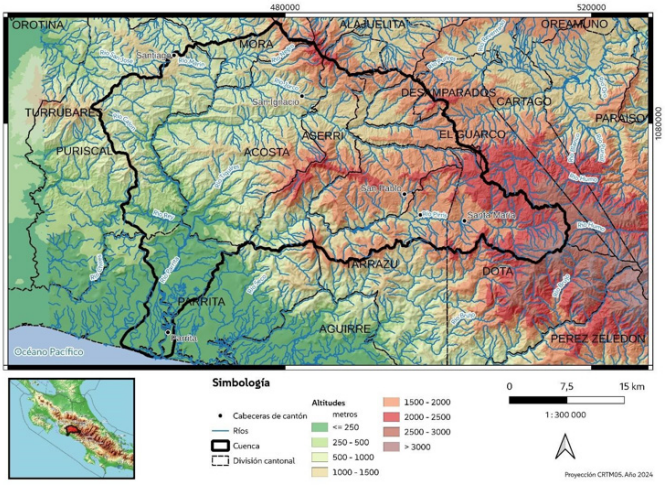

Figure 1 Location of the Parrita River basin, Costa Rica.

Source: Authors' elaboration based on the cartography of the National Geographic Institute (IGN). 2026.

It is a basin that is characterized by presenting a marked topographical irregularity, with altitudes that vary from sea level to approximately 3,150 meters above sea level (masl). This altitudinal variation generates a highly broken relief, which characterizes the basins that originate in the highest parts of Costa Rica.

Methodology

Fluviometric stations

To carry out the study, the three main sub-basins that cover the entire Parrita River basin were chosen. In each of these sub-basins, one fluviometric station is located per sub-basin, which served as the basis for this research (Figure 2).

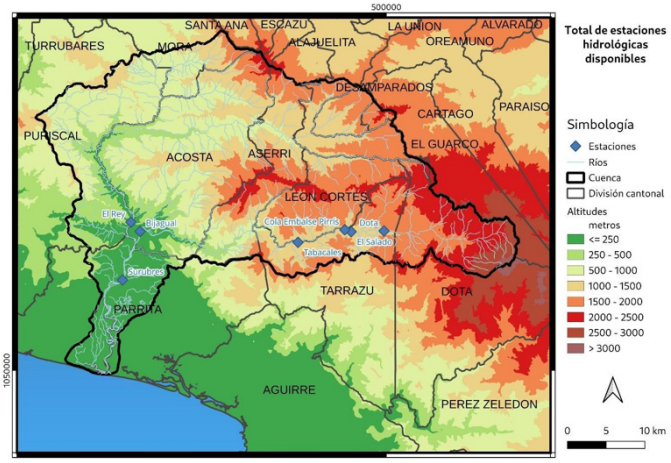

Figure 2 Location of the hydrological stations in the Parrita River basin.

Source. Prepared by the author based on the records of the Costa Rican Institute of Electricity (ICE), 2026.

Maximum flow rate analysis

There are several methods that involve the non-stationarity existing in the series of maximum flows in the estimation of floods associated with different return periods. When forecasting the possibility of the occurrence of maximum floods (high flows), some methods address non-stationarity based on the analysis of the variation of vegetation cover in the basins due to anthropic intervention, waterproofing of surfaces, changes in inadequate land uses, among other factors that generate an increase in the runoff coefficient of the basins. This induces maximum flows to increase in magnitude and frequency.[17,18] Most of the methods developed to consider non-stationarity in the estimation of maximum flows are based on the temporal variation of the statistical moments or parameters of some given probability distribution, considering the existing statistically significant trends.

Classical frequency analysis and mixed distributions

To estimate the frequency of the maximum flow recorded in the Parrita River basin, the classical approach was considered in the first instance, where the maximum levels were estimated from a frequency distribution function. These frequency distributions were considered for the classical analysis as (a) the Generalized Extreme Value (GEV), (b) Gumbel.

On the other hand, the possibility that the maximum values are generated by distributions formed by two or more ENSO populations (El Niño, La Niña, Normal) was also analyzed, considering the application of a mixed probability distribution to model the probability of flow exceedance and its relationship with the ENSO event. The mixed distribution is the result of the sum of the probability distribution function of each sample, affected by a weighting factor that depends on the size of each sub-sample. This model is expressed by equation (1).

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$$F_T\left(X \geq t\right) = \rho_1 F_1\left(X \geq t\right) + \rho_2 F_2\left(X \geq t\right) + \qquad (1)$$
$$\text{where}, \sum \rho i = 1, FT \quad \textit{represents the function of} \quad i = 1$$

mixed distribution, Fi is the probability distribution function of each sub-sample, and *pi* represents the weighting factor of each sub-sample.

It was considered as an influencing factor of the ENSO event, so the series of maximums was divided into two subseries: one affected by the La Niña event and the other not affected by the other two El Niño episodes and the Normal periods.

To this end, the classification of El Niño, La Niña and Normal periods was used, according to the table published by NOAA (National Oceanic and Atmospheric Administration, 2026) which classifies into warm episodes and cold episodes if the ONI (Oceanic Niño Index) reaches a threshold of □0.5°C, in region 3-4 (5°N-5°S, 120°-170°W), calculated from calculated and updated base periods of 42 years. In the series of levels and maximum monthly flows observed, the years where the maximum occurred in each episode will be classified as El Niño, La Niña and Normal years.

Gumbel distribution

The probability density function of the Gumbel distribution is given by the equation:

$$F\left(X \geq x\right) = 1 - \left(\exp\left(-\exp\left(-\alpha\left[x - \beta\right]\right)\right) \qquad (2)$$

By the method of moments, the parameters α and β are estimated as follows:

$$\alpha = 1,281 / \sigma \qquad \beta = \mu - 0,45\sigma \qquad (3)$$

Where μ and σ, are the mean and standard deviation of the data.

He et al. (2006) propose to analyze the variation of the location, scale and shape parameters of the Gumbel and Pearson Type 3 Log distributions. They propose a linear function for the location parameter of the distributions, a logistic regression for the scale parameter of the Gumbel distribution, and also for the shape parameter of the Pearson Type 3 Log distribution. Another way to estimate the occurrence of extreme flows is through frequency analysis. In this, the probability of not exceeding a certain maximum flow value is considered. The following figures show the probability curve of non-exceedance estimated by the models for the maximum flows and the empirical probability of the observations, which are calculated using the formula

which is calculated using the formula

$$\left(x^{(i)}\right) = n \qquad +^{i}1 \qquad i{=}1,2, \ \ldots \ , \mathrm{n} \qquad (4)$$

where corresponds to the -n observation ordered ascendingly.$x^{(i)}i$

To analyze the high levels of flow in the rivers of the basin under study, a GEV distribution was modeled with parameters that are functions of a covariate that denotes the influence of the periods of the ENSO event, with its three populations El Niño, La Niña, and Normal periods.

Data on monthly flows in the locations of Bijagual, Dota and El Rey were taken from 1982 to 2025. These data were loaded and transformed into a long format (tidy) for statistical analysis, using the R programming language. On the other hand, the phases of El Niño and La Niña were also considered, based on NOAA's monthly record.

Distribution of flows by sub-basins

The behavior of the flows at each of the flow gauging stations looks as follows Figure 3:

Figure 3 shows the flow distribution for the Bijagual, Dota and Rey River stations. The presence of differentiated hydrological patterns associated with the physical, climatic and geomorphological characteristics of each sub-basin is evident. From a statistical point of view, the density curves present positive asymmetric distributions with tails extended towards extreme values. This behavior is typical of river systems subject to hydrological events of high variability and nonlinear responses.

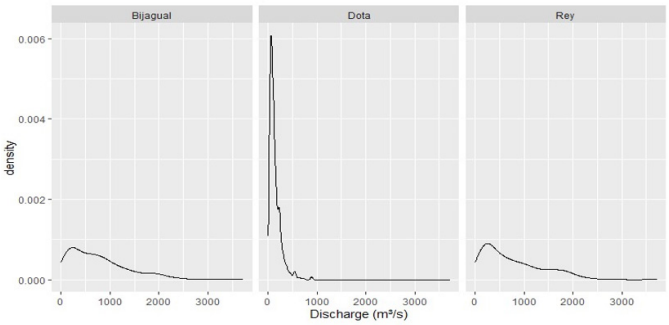

Figure 3 Flow distribution for each of the fluviometric stations.

Source: Authors' elaboration based on the records of the Costa Rican Institute of Electricity (ICE). 2026.

The Dota station has a highly concentrated distribution in low discharge ranges, followed by an abrupt drop in density and a long tail towards extreme flows. This behavior indicates that, although relatively moderate flow conditions predominate, there is a high susceptibility to extreme events of great magnitude under certain hydroclimatic conditions.

In contrast, the Bijagual and El Rey stations show wider and more gradual distributions, reflecting a relatively slower hydrological response at the beginning. However, the persistence of long tails in both distributions also indicates the presence of extreme events capable of significantly exceeding historical mean values. These spatial differences show the hydrological heterogeneity of the basin and highlight the influence of physiographic variables such as vegetation cover, different land uses, steep slopes, infiltration capacity and drainage configuration.

If flows continue to increase progressively over the years, the distributions would tend to shift towards higher discharge values, producing strong alterations in the riverbeds and therefore in the probabilistic structure of the hydrological system, with the tendency to constantly increase flows.

Frequency of flows in the Parrita River basin

This analysis is done to know not only the frequency, but also the magnitude of the flows in each of the sub-basins that make up the Parrita River basin (Figure 4).

Figure 4 shows the frequency of maximum flows corresponding to the Bijagual fluviometric station, where there is a non-linear relationship between the probability of not exceeding and the magnitude of the maximum discharges observed. The upward trend of the adjusted curve shows a hydrological behavior characteristic of river systems exposed to extreme events of high variability, where higher flows show a significant acceleration as the cumulative probability increases.

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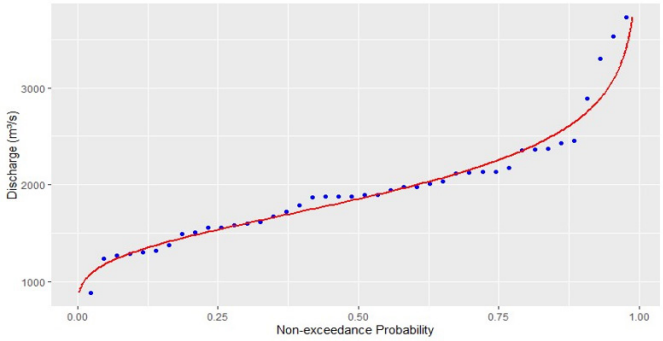

Figure 4 Maximum flow rate (Bijagual).

Source: Prepared by the author based on ICE records, 2026.

From the hydrological point of view, the shape of the curve suggests the presence of a positive asymmetric distribution subjected to intense flows at the upper ends. Although the slope is relatively moderate in the central part, this indicates that the distribution has a statistical stability in moderate events. However, the abrupt curvature in the upper area reveals a disproportionate increase in extreme flows.

The pattern exhibited by the flows of Bijagual is a typical indicator of extreme hydrological systems, which are closely related to convective processes, intense storms, and possible floods that favor the topographic irregularity. Hydrological events of great magnitude could occur, because the curve continues to rise as it approaches 1 (Figure 5).

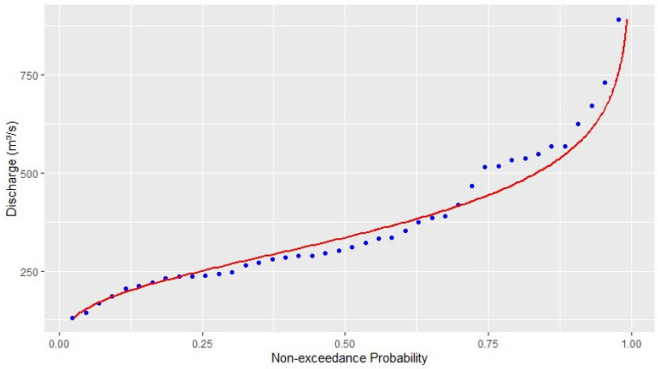

Figure 5 Maximum flow rate (Dota).

Source: Prepared by the author based on ICE records, 2026.

Figure 5 shows a strong curvature at the top of the distribution, indicating a chance of a river versus small variations in cumulative probability. This means that relatively moderate increases in hydroclimatic conditions could translate into disproportionate increases in flow, a phenomenon characteristic of basins subject to intense convective rainfall and high climatic variability. However, the sub-basin where this river is located does not have high flows throughout its course, except at the end of the curve. In contrast, with the previous rivers (Figure 6).

Figure 6 shows the frequency of maximum flows corresponding to the El Rey station, which shows a non-linear hydrological distribution, characterized by a progressive increase in maximum discharges as the probability of not exceeding increases The shape of the adjusted curve reflects a typical dynamic of river systems highly influenced by extreme events, where higher flow values present accelerated growth and a marked statistical probability of extreme flows occurring.

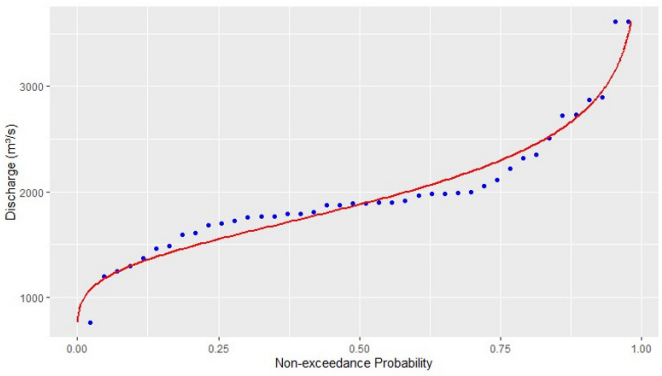

Figure 6 Maximum flow frequency (El Rey).

Source: Prepared by the author based on ICE records, 2026.

From a hydrological perspective, the configuration of the curve indicates a positive asymmetric distribution with a tail that always tends to rise, which is a sign of high hydrological variability and susceptibility to extreme precipitation events. The middle region of the curve shows relatively stable behavior associated with recurrent events. However, in the upper section, a strong intensity of maximum flows is observed, which suggests a hydrological response that intensifies under conditions of extreme storms or hydroclimatic events of great magnitude.

Influence of ENSO on the frequency of extreme flows

The flows in each sub-basin show a somewhat different relationship when compared to the ENSO phases (Cold (La Nina), Warm (El Niño) and Neutral) (Figure 7).

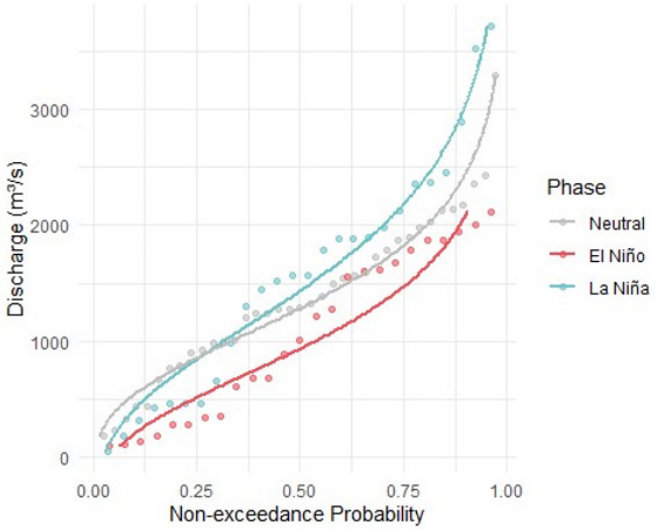

Figure 7 Maximum flow rate per phase (Bijagual).

Source: Prepared by the author based on ICE records, 2026.

Figure 7 shows the frequency of maximum flows by climatic phase at the Bijagual station, showing a significant hydrological differentiation between the ENSO phases, particularly under Cold Phase conditions, where the highest magnitudes of extreme discharge are recorded. The observed distribution reflects a hydrological response that is highly sensitive to interannual climate variability, showing a progressively accelerated increase in flows as the probability of non-exceedance.

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From a hydrological perspective, the curve associated with the Cold Phase presents a markedly higher slope with respect to the Neutral and Warm Phase conditions, especially at the end of the line corresponding to the events extremos.

This persistence indicates a substantial intensification of the surface runoff generation processes, associated with higher volumes of effective precipitation, an increase in moisture-laden air masses and a relative decrease in the infiltration capacity in the basin. Therefore, the river system exhibits a faster response, possibly due to topographic irregularity in the face of extreme weather events.

The Neutral phase shows an intermediate consistency, with discharge values higher than the Warm phase, but lower than the Cold phase. On the other hand, the curve corresponding to El Niño presents the lowest flows in the distribution, which is consistent with scenarios of relative reduction of precipitation and lower regional water availability. However, even under this climatic phase, an upward trend is observed in the upper extremes, indicating that the occurrence of severe flows continues (Figure 8).

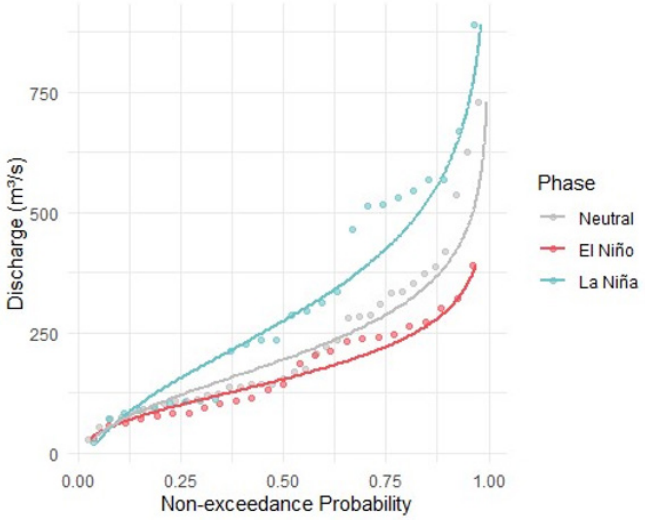

Figure 8 Frequency of maximum flow rates per phase in Dota.

Source: Prepared by the author based on ICE records, 2026.

Figure 8 shows the frequency of maximum flows by climatic phase at the Dota station shows a marked hydrological differentiation between the different phases of the ENSO event, particularly between La Niña, Neutral and El Niño. The observed distribution shows a non-linear behavior, where the maximum flows increase in an accelerated manner as the probability of not exceeding increases, reflecting a probability of the river system in the cold phase.

From a hydrological perspective, the curve associated with the La Niña phase has the highest discharge magnitudes throughout much of the distribution, especially at the upper ends. This behavior suggests a significant intensification of the processes of surface runoff generation, because of higher volumes of precipitation, although this sub-basin does not present high flows throughout its trajectory compared to the other two rivers. The Neutral phase shows an intermediate behavior, maintaining discharges higher than El Niño in various probability ranges, while the curve corresponding to El Niño registers the lowest flow values (Figure 9).

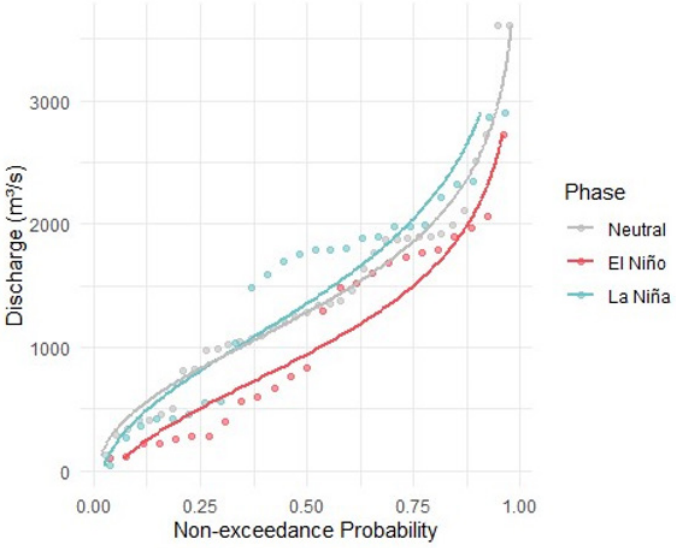

Figure 9 Maximum flow rate by phase (El Rey).

Source: Prepared by the author based on ICE records, 2026.

Figure 9 shows the relationship between the ENSO event and the discharge levels of the river at the El Rey hydrological station. The Cold phase, represented by the light blue line, shows the maximum flows recorded at this hydrological station. This indicates that during this stage rainfall increases considerably, which causes an increase in the volume of water discharged by the river. The records reach values above 3000 m³/s, evidencing a greater probability of floods and significant floods.

The episode of the Cold phase remains above the other phases in almost its entire route, which confirms that this phase favors rainier conditions.

In Figure 9 the red line remains below the other curves for a large part of its route. This shows that the Warm phase has a reducing effect on maximum flows, which can generate water scarcity problems and affect activities such as agriculture, water supply and hydroelectric generation.[19–24]

Discussion and conclusion

The figures analyzed in the research suggest that the Parrita River basin presents a rapid response to intense precipitation events, possibly associated with steep slopes, inadequate land use, limited surface storage capacity and a dense hydrological drainage network. The figures themselves show a higher relative frequency of extreme events and an expansion of distribution queues towards higher flows. These episodes are congruent with the processes of hydrological non-stationarity induced by climate change and hydroclimatic variability, which seems to be more intense during some rainy periods.

In hydrological and hydraulic terms, the increase in extreme flows could produce significant increases in the specific energy of the flow. This could lead to a higher hydraulic speed (greater flow accompanied by debris and other materials such as trunks, branches, etc.) and shear stress on the bed and banks of the riverbeds.

As a result of these processes, processes of fluvial erosion, infrastructure scour and geomorphological modification of river channels could intensify. The increase in solid transport capacity

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would also favor differential sedimentation processes, hydraulic obstruction and alterations in the morphodynamics of the basin.

Likewise, the expansion of extreme events would have direct implications on the hydrological and ecological connectivity of riparian systems. The floodplains would experience a greater frequency of flooding, modifying ecological processes associated with the transport of silt, clay, gravel and sand, that is, a greater load of sediments and on the lower parts of the basin. In short, altering the dynamics of permanent transformations in the functional structure of river ecosystems.

From the perspective of hydraulic engineering and territorial planning, the displacement of distributions towards higher discharge values would represent a significant challenge for the design of resilient infrastructure. Hydraulic works built under historical criteria could be insufficient in the face of new flow magnitudes, increasing the risk of structural failures, economic losses and affecting vulnerable populations located in areas of fluvial influence.

The Bijagual, El Rey and Dota rivers have shown an intensification of maximum flows, which could lead to significant hydrological implications. The increase in the frequency of extreme flow values, which would alter the connectivity processes between the main channel and the floodplains, modifying nutrient transport and sedimentation patterns in riparian ecosystems. These changes could affect the environmental stability of the basin in the long term.

In conclusion, the ENSO event has a direct influence on the discharge levels of the Bijagual, Dota and El Rey rivers. The La Niña phase increases maximum flows due to increased rainfall and increases the risk of flooding. In contrast, the El Niño phase reduces flows due to drier conditions and less precipitation. Finally, the Neutral phase presents an intermediate and more balanced behavior.

Probabilistic models allow us to understand how climatic phenomena affect riverbeds, margins and some sectors of the basin when landslides and floods occur in various sectors of the basin, especially in the lower part of the basin.

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Conflicts of interest

The author declares there is no conflict of interest.

References

1. He Y, Bárdossy A, Brommundt J. Non-stationary flood frequency analysis in southern Germany. 2006
2. Soria L, Vásquez N. Impact of climate change through the variability of precipitation and temperature in the Lago Agrio Canton. *Ciencia Latina Revista Científico Multidisciplinar*. 2025;9(1).
3. Fowler A, Hennessy K. *Potencial Impacts of Global Warming in the Frequency and Magnitud of Heavey Precipitation*. 1995;283–303.
4. Claude L, Cardoso A. Determinación y análisis de los caudales de evento extremo mediante tormentas estocásticas en la cuenca de Misicuni-Cochabamba, Bolivia. *Investigación & Desarrollo (I&D)*. 2024;24(2)):29–24.
5. Álvarez DM, Poveda G. *El colapso de la hipótesis de estacionariedad por cambio y variabilidad climática: implicaciones para el diseño hidrológico en ingeniería*. 2012. p. 65–76.
6. Milly P, Betancourt M, Falkenmark R, et al. Stationarity Is Dead: Whither Water Management. 2008.
7. Quesada A, Hugo Hidago, Eric Alfaro. *Evaluación del impacto de los ciclones tropicales en los sectores económicos de Costa Rica*. Centro de Investigaciones Geofísicas de la Universidad de Costa Rica. Mini congreso anual. 2024.
8. Khaliq M Ouarda, Ondo TBMJ, Gachon JC, et al. Frequency analysis of a sequence of dependent and/or non-stationary hydro-meteorological observations: A review. *Journal of Hydrology*. 2006;329(3-4), 534–552.
9. CSU. *Workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management*. 2010. p. 1–309.
10. Moglen GE. *Frequency Analysis under Nonstationary Land Use Conditions*. Modeling Hydrologic Change - Statistical Methods by R.H McCuen (p. Chapter 3). Boca Raton, Florida: Lewis Publisher. 2003. p. 20.
11. Montes J, Álvarez M, Pertierra L, et al. Análisis regional de frecuencia de avenidas en la vertiente cantábrica y noratlántica de España**.** *Ingeniería del Agua*. 2018;22(2):93–107.
12. Mailhot A, Duchesne S. Design Criteria of Urban Drainage Infrastructures under Climate Change. *Journal of Water Resources Planning and Management*. 2009;136(2), 201–208.
13. Rosner A, Vogel RM, Kirshen PH. A Risk-Based Approach to Flood Management Decision in a Nonstationary World. *Water Resources Research*. 2014;50(3):1928–1942.
14. Waylen P, Laporte S. `Flooding along the Pacific Slope of Costa Rica. Hydrological Processes. 1999;13:2623–2638.
15. Álvarez DM, Poveda G. Nuevos Enfoques Para la Estimación de Caudales Extremos en Colombia. *Universidad Nacional de Colombia, Sede Medellín*. 2007.
16. García G, Ormaza A. Análisis de estacionalidad del caudal y la dinámica del régimen fluvial *al río Guayllabamba.* Aplicación. *Pol Con (Edición núm)*. 2021;59(6):24–39.
17. Cunha LK, Krajewski WF, Mantilla R, et al. A framework for flood risk assessment under nonstationary conditions or in the absence of historical data. *Journal of Flood Risk Management*. 2011;4(1):3–22.
18. Villarini G, Smith JA, Serinaldi F, et al. Flood Frequency Analysis for Nonstationary Annual Peak Records in an Urban Drainage Basin. *Advances in Water Resources*. 2009b.
19. Benitito GC, Beneyto, Aranda J, et al. Inundaciones y cambio climático: certezas e incertidumbres en el camino de la adaptación. *Cuadernos de Geografía*. 2021;107:191–216.
20. Cashalo Felício, Beskow Samuel, Martins Vargas Marcelle, et al. Hydrological regionalization of maximum stream flows using an approach based on L-moments. Revista Brasileira de Recursos Hídricos. *Porto Alegre, Brasil*. 2017.
21. Guillen HL Cid, E Alfaro. Comparación de parámetros de valor extremo de la distribución generalizada asociada a eventos de precipitación extrema en América Central. *Uniciencia*. 2021;34(1).
22. Justo Domé, Asociados SRL. *Modelo Hidrológico, Cuenca del Arroyo Feliciano, puente en Ruta Provincial N°5*. Paraná, Entre Ríos, Argentina. 2019.
23. National Oceanic and Atmospheric Administration. Atlantic Hurricane season forecast to be milder than normal thanks to El Niño. May 21. 9:31 PM ET. 2026.
24. Organización Meteorológica Mundial (OMM). El clima del planeta está cada vez más descompensado. 2026.