A PROBABILITY DISTRIBUTION OF ANNUAL MAXIMUM DAILY RAINFALL OF TEN METEOROLOGICAL STATIONS OF EVROS RIVER TRANSBOUNDARY BASIN, GREECE

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ABSTRACT

Establishing an appropriate distribution to stand for the precipitation depth at various rainfall durations yields potential rainfall data which are not only crucial inputs in hydrologic design, with reference to the study of storm sewer pipe networks, bridges, culverts, artificial canals conveying water for agricultural purposes, river and riparian areas corridors maintenance, and a wide range of many other structural works but they also constitute input data of the utmost importance when building rainfall-runoff models. The present study tests the outliers of the annual maximum daily recorded rainfall data series of ten meteorological stations located within the Greek sector of Evros River transboundary basin, performs frequency analysis concerning Four-Parameter S_B, Kumaraswami, Normal, 2P, 3P Lognormal, Generalised Extreme Value (G.E.V.), Gumbel Max., 2P Gamma (Log-Gamma), Gamma, Pearson Type III (Gamma 3P), Log-Pearson Type III and 3P Weibull rainfall distribution functions, examines which most perfectly fits the available recorded rainfall data series, ranks them by the perspective of Chi-square, Kolmogorov-Smirnov and Anderson-Darling goodness of fit tests and calculates the annual maximum daily rainfall for different recurrence intervals for each probability distribution function as well as for each meteorological station separately, employing EasyFit computer software.

Keywords: outlier, recorded rainfall data series, probability distribution function, Evros River, transboundary river basin, recurrence interval, goodness of fit test, EasyFit computer software.

1. Introduction

The devastating effects of extreme hydrological events upon human properties structures and in many cases lives is unquestionable. Precipitation is the most important environmental factor limiting agricultural activities (Khudri and Sadia, 2013). The amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands of agriculture, industry, and other human activities. Therefore, the study of the distribution of rainfall in time and space is very important for the welfare of the national economy. Many applications of rainfall data are enhanced by knowledge of the actual distribution of rainfall rather than relying on simple summary statistics (Abdullah and Al-Mazroui, 1998; Omran *et al.*, 2014). Rainfall events exceeding the normal intensity rates and durations overwhelm the soil infiltration capacity resulting to water excess which becomes impossible to get routed by the existed, natural watershed drainage network provoking flood events well-correlated in terms of magnitude with the associated rainfall one. Rainfall intensities of various frequencies and durations are the basic inputs in hydrologic design. They are used, for example, in the design of storm sewers, culverts and many other structures as well as inputs to rainfall-runoff models. Precipitation frequency analysis is used to estimate rainfall depth at a point for a specified exceedance probability and duration (Rao and Kao, 2006). The probability that a specific extreme rainfall event to take place, such a, 24-h total maximum rainfall (24-hour duration) cannot be ignored because it’s that most commonly used for purposes of design and can not be considered as negligible especially when studying small urban watersheds which have in many cases times of concentration of 1-hour or even less and designing their stormwater infrastructure (Rosenberg *et al*., 2010). Hydrological and crop models usually require daily precipitation time series as input (Barkotulla, 2010). Moreover, a 24-hr maximum rainfall is important (Subramanya, 2009).

Rainfall is the principal phenomenon driving many hydrological extremes such as floods, droughts, landslides, debris and mud-flows; its analysis and modeling are typical problems in applied hydrometeorology (Barkotulla, 2010). Rainfall exhibits a strong variability in time and space. Hence its stochastic modeling is not an easy task (De Michele and Bernardara, 2005). Due to man’s ignorance and lack of complete knowledge about the evolution of natural processes, the recorded time series are considered to be random, and future values cannot be known exactly. Therefore any variable related to the time series, such as drought duration and intensity, reservoir capacity, design discharge etc., is also regarded as a random variable. The treatment of such a variable can only be achieved through using probabilistic, statistical and mathematical tools (Sen, 1980). Since most of the extreme rainfall phenomena are stochastic processes, extensive use of probability theory and frequency analysis are needed to fully understand and describe the phenomena (Win and Win, 2014; Yevjevich, 1972).

The selection of the best-fit distribution of the rainfall process is always the main interest in the study of hydrology (Kang and Yusof, 2013). Choosing a probability distribution that provides a good fit to daily rainfall has long been a topic of interest in hydrology, meteorology and others (Win and Win, 2014). Analysis of rainfall data strongly depends on its distribution pattern. It has long been a topic of interest in the fields of meteorology in establishing a probability distribution that provides a good fit to daily rainfall. Several studies have been conducted in India and abroad on rainfall analysis and best fir probability distribution function such as normal, log-normal, gumbel, weibull and Pearson type distribution were identified (Sharma and Singh, 2010). The investigations into the daily rainfall distribution are primarily spread over the main research areas, namely, (1) stochastic precipitation models, (2) frequency analysis of precipitation, and (3) precipitation trends related to global climate change (Hanson and Vogel, 2008). The present study focuses on the frequency analysis of precipitation occurring within the Greek sector of the Evros River Basin, incorporating the selection of a suitable distribution for exhibiting precipitation depth with the view to investigate, at last, the most great events.

2. Data used in this study

The Basin of the Evros River (GR10) is one of the five river basins set by the National Water Commission. The transboundary Evros River Basin has total area of 53,000 km^2, is located in the eastern part of the Balkan Peninsula and extents to the territories of Bulgaria,Turkey and Greece. The total length of the river is 528 km, of which 310 km are in Bulgaria, whilst the remaining 208 km define the borders of Greece and Turkey. The river basin is extended to the above three states according to the following percentages: (i) the 35,085 km^2 (66,20%) belong to Bulgaria (where it springs), (ii) 14,575 km^2 (27,50%) belong to Turkey, and (iii) 3,340 km^2 (6,30%) belong to Greece (where the river ends). The total catchment area of Evros-Maritsa River is devided into the following four main sub-catchments: (i) Ergene, 11,000 km^2, (21%), 218 km (ii) Tundzha, 8,500 km^2, (16%), 310 km, (iii) Ardas, 5,600 km^2, (11%), 250 km, and (iv) Erythropotamos, 1,500 km^2, (3%). The Evros River has a length of 528 km, and it is the longest river that runs solely in the interior of the Balkans. Its origins come from the Rila Mountains in Western Bulgaria. A small section of the Northern Branch is not a border line and runs entirely in Turkey. The rest of the river flows to the sea along the border, near “Kastanies”, from where it turns south to enter the Aegean Sea, where it forms a delta. The Tundzha River is its chief tributary and the Arda River is the other major one as well as Erythropotamos and Ergene. Evros River is possible to handle quantities of water up to 1,500 m^3 per second. In past floods have been registered over 5,000 m^3 per second (Kampas, 2014).

Rainfall data at ten stations (Didimoticho, Dikaia, Kyprinos, Lefkimi, Megalo Dereio, Metaxades, Mikro Dereio, Orestiada, Protoklisi, Sitohori) for Evros river basin (Greek sector) are collected and used in this study. The locations of rainfall stations under study is shown in Figure 1.

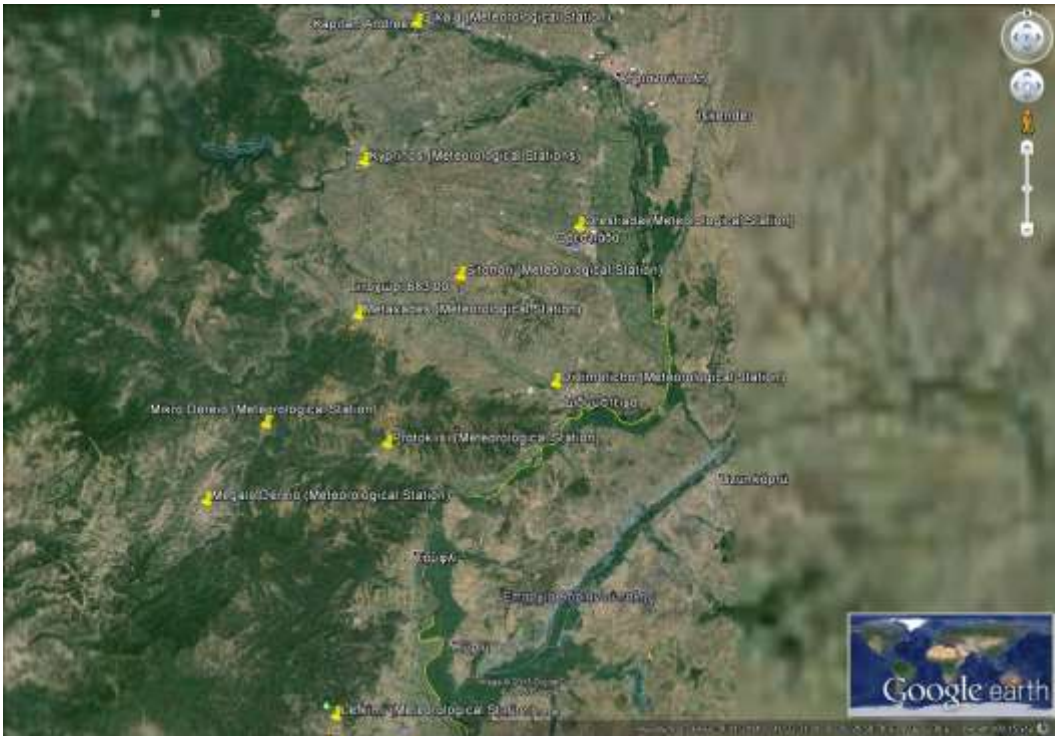

Figure 1: Location of rainfall stations (yellow pins) at Evros river basin, Evros Prefecture, Greece

The statistical characteristics (descriptive statistics) of annual maximum daily rainfall series respecting each rain gage station are illustrated in Table 1.

Table 1: Statistical characteristics of the data series

Station	Mean (mm)	Std. dev. (mm)	Skewness	Kurtosis
Didimoticho	37.54700	15.95500	1.18530	0.54127
Dikaia	58.49600	22.13300	0.43702	-0.90718
Kyprinos	52.19300	19.49100	0.61098	-0.22104
Lefkimi	64.96400	25.18500	0.58518	0.80044
Megalo Dereio	58.80700	16.50300	0.11829	-0.71126
Metaxades	44.93200	18.15800	0.02438	-1.26720
Mikro Dereio	56.02100	19.83200	1.43030	2.65480
Orestiada	62.32200	36.32700	3.42610	13.72000
Protoklisi	59.81100	19.03900	0.61063	-0.20099
Sitohori	52.57500	19.12500	0.29905	-0.93514

It is demonstrated in Table1 that the data series recorded and collected at all rain gage stations are skewed right (positive skewness) and Didimoticho, Lefkimi, Mikro Dereio and Orestiada stations have the peak distributions, whilst, on the other hand Dikaia, Kyprinos, Megalo Dereio, Metaxades, Protoklisi and Sitohori ones do not. The series of annual maximum daily rainfall with reference to Dikaia rain gage station is illustrated in Figure 2 as a cross section.

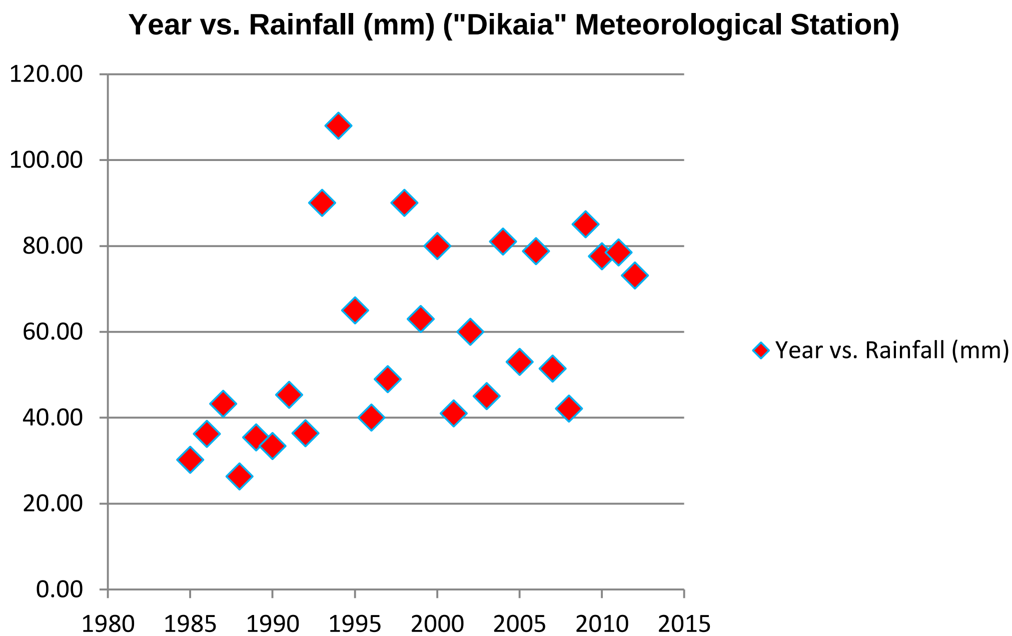

Figure 2: Series of annual maximum daily rainfall of Dikaia station

It can be easily observed from Figure 2 that the rainfall in the year 1994 in Dikaia rain gage station is relatively high therefore testing for high and low outliers has been performed.

3. Methodology

Three well-known tests of goodness of fit namely Chi-Square (CS), Kolmogorov-Smirnov (KS) and Anderson-Darling (AD) tests are employed and applied to the data series for investigating the fit of probability distributions examined in this study. Each set statistics are calculated and examined at level of significance (α=0.01). If the calculated statistic is lower than that critical value, it points out that the distribution fits the data appropriately and the distribution can be adopted with the view to calculate various annual maximum daily rainfall recurrence intervals.

4. Results

The parameters of the twelve distributions under examination are computed for ten data series employing EasyFit and StatAssist software. Furhermore, annual maximum daily rainfall for five return periods are computed applying these parameters.

5. Conclusions

A total of twelve probability distributions are employed and applied to the data series of annual maximum daily rainfall of ten rain gage stations for the Greek sector of Evros transboundary river basin. The conclusions derived from this study are the following:

Taking into consideration the analysis of Chi-square statistical test, Generalised Extreme Value (G.E.V.) probability distribution evidently is the most appropriate distribution for annual maximum daily rainfall at Didimoticho station, and Johnson S_B at Dikaia station, Log-Gamma at Kyprinos station, Gumbel-Max. at Lefkimi station, Lognormal (3P) at Megalo Dereio station, Weibull (3P) at Metaxades station, Lognormal (3P) at Mikro Dereio station, Lognormal (3P) at Orestiada station, Lognormal (2P) at Protoklisi station, and Johnson S_B at Sitohori station.

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