THE QUANTIFICATION OF THE THRESHOLD LEVEL METHOD ON LOW FLOWS STUDIES

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ABSTRACT

Streamflow drought properties have been extensively analysed for the design of hydrotechnical projects and water resources planning and management during the last two decades. Information on the magnitude and frequency of low flows is very important for streamflow drought analysis at operational level in public water supply systems. The objective, of this study, is to investigate the sensitivity of the threshold level method in the derivation of low flow severity-duration-frequency (SDF) curves. Low flow severity is defined as the total water deficit volume to the target threshold for a given drought duration. Four (4) threshold level methods (fixed, seasonal, monthly and daily) were employed and compared to assess the subjectivity of the threshold level method (fixed or variable) in the estimation of derived streamflow deficits and durations at Yermasoyia watershed, Cyprus using a thirty year daily discharge dataset. The 50th and 70th percentile values of the flow duration curve are selected as the threshold choices for all study methods which are suitable for semiarid catchments where zero runoff occurs during summer months. Then, the four threshold methods are applied and three pooling procedures are applied to derive independent sequences of low-flow events. Application of the three pooling algorithms showed that the inter-event time and volume criterion is the most unbiased pooling method and this method was selected to estimate the duration and the deficit volume or severity of the identified drought events. Finally, the SDF curves are developed based on the annual maximum severities for fixed durations at 30, 60, 90, 180 and 360 days. Based on individual probabilistic analysis, the best theoretical probability distribution is selected for each threshold method and then the SDF curves for the four thresholds were developed to quantify the relationship among the severities, durations, and frequencies or return periods. These curves also integrate the return period–duration curve to quantify the extent of the threshold method. . Hence, based on typical drought characteristics (deficit volume and duration) and threshold levels, this study developed quantitative relationships among drought parameters using fixed, seasonal, monthly and daily threshold levels.

Keywords: hydrological droughts, low flows, low flow indices, severity–duration–frequency (SDF) curves, streamflow deficits, threshold level method.

1. Introduction

Droughts are extreme hydrological events, which, very often are related to severe socio-economic and environmental issues. The past two decades many scientists tried to describe and quantify their properties. However, due to their complex structure there are still many definitions for droughts and their properties. Over the years, in many researches, various indices were used, because droughts, may differ depending on their nature (e.g. precipitation deficit, soil moisture deficit), on the time unit of data used (e.g. daily, monthly data etc.), on the threshold used to identify the low flow events and on the regionalization method (Dracup *et al.*, 1980; Gustard *et al.*, 1992; Tallaksen, 1995; Smakhtin, 2001). According to American Meteorological Society (1997) droughts are usually grouped into four categories. The lack of precipitation combined with high evapotranspiration rates, usually causes meteorological drought. This may also result in reduction in soil moisture causing the second type of drought which is called agricultural drought. Precipitation deficits usually result in a reduction in surface runoff and water stored in lakes, rivers etc., while the reduction in soil moisture results in a reduction in the amount of water stored in ground water reservoirs. All these, end up in hydrological drought. The last type of drought relates all the above types of droughts to the supply-demand of different water uses such as public water supply, irrigation water uses etc. This study, analyses the hydrological droughts using techniques based on low flow analysis. However, it must be clearly understood that a low flow event may not necessarily be drought. Low flows are usually seasonal-periodical events that many times are integral parts of the hydrograph, while droughts are caused by abnormal lack of precipitation and water resources (Tallaksen and van Lanen, 2004).

2. Study area

The study area is the river basin of Yermasoyia in Cyprus (Figure 1). It is located on the south side of the island and covers an area of 157 km^2. The altitude reaches 1400m above the mean level sea. The mean annual precipitation is 638mm and ranges from 450mm near the sea and reaches 850mm in the mountains. The mean annual runoff is 22,5hm^3, 65% of which occurs during wet season. Concerning the climate of the region it is characterized by seasonal variations in temperature, rain and generally weather. Summers are hot and dry and last from May to September. Winters are wet and last from November to March. The data used in the present study are thirty year daily streamflow data from the hydrological year 1969-70 to the year 1998-99.

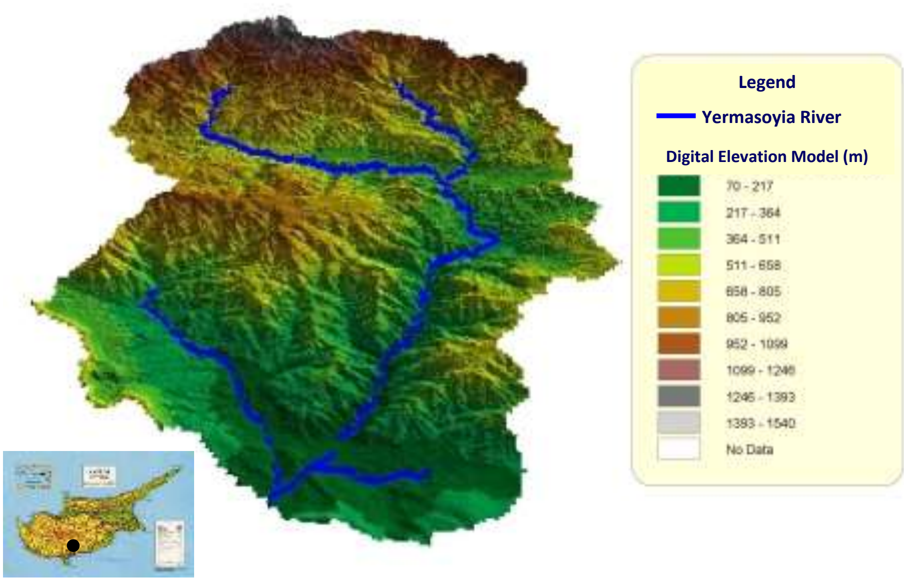

Figure 1: Yermasoyia watershed, Cyprus.

3. Methodology

Streamflow deficits were calculated using the threshold level method, according to which a deficit is defined as a period when the flow is below a predefined discharge. As deficit duration is defined the period of time (d_i), when the flow is below the threshold. As volume of deficit (v_i), is defined the sum of discharges for the corresponding deficit duration, as intensity of deficit is defined the ratio between the volume and the duration of deficit, and finally, the last characteristic is the minimum flow of a deficit.

In this study, discharge values resulting from Q_{50} and Q_{70} quantiles form the flow duration curve were used as thresholds. Furthermore, four different techniques for threshold derivation is used: constant, seasonal, monthly and daily variable thresholds. In constant threshold there is one fixed value derived from the entire time series, while in the other three cases, there are variable thresholds, derived from the values of flows for each corresponding time step. For example, in monthly varying threshold, there are twelve different thresholds, one for each month. The threshold for January results from the values of flow of January for the entire period of record. Figure 2 shows the four estimated thresholds for fixed annual, seasonal, monthly and daily variable threshold methods. Furthermore, three pooling procedures (moving average (MA), inter event time criterion (IT), inter event time and volume criterion (IC)), were applied and investigated, to derive independent sequences of deficits. Details and more information concerning the three pooling methods could be found in WMO, 2008. The three procedures are also investigated in order to understand which one of them doesn't display subjectivity in the choice of the period of days (or ratios) of pooling.

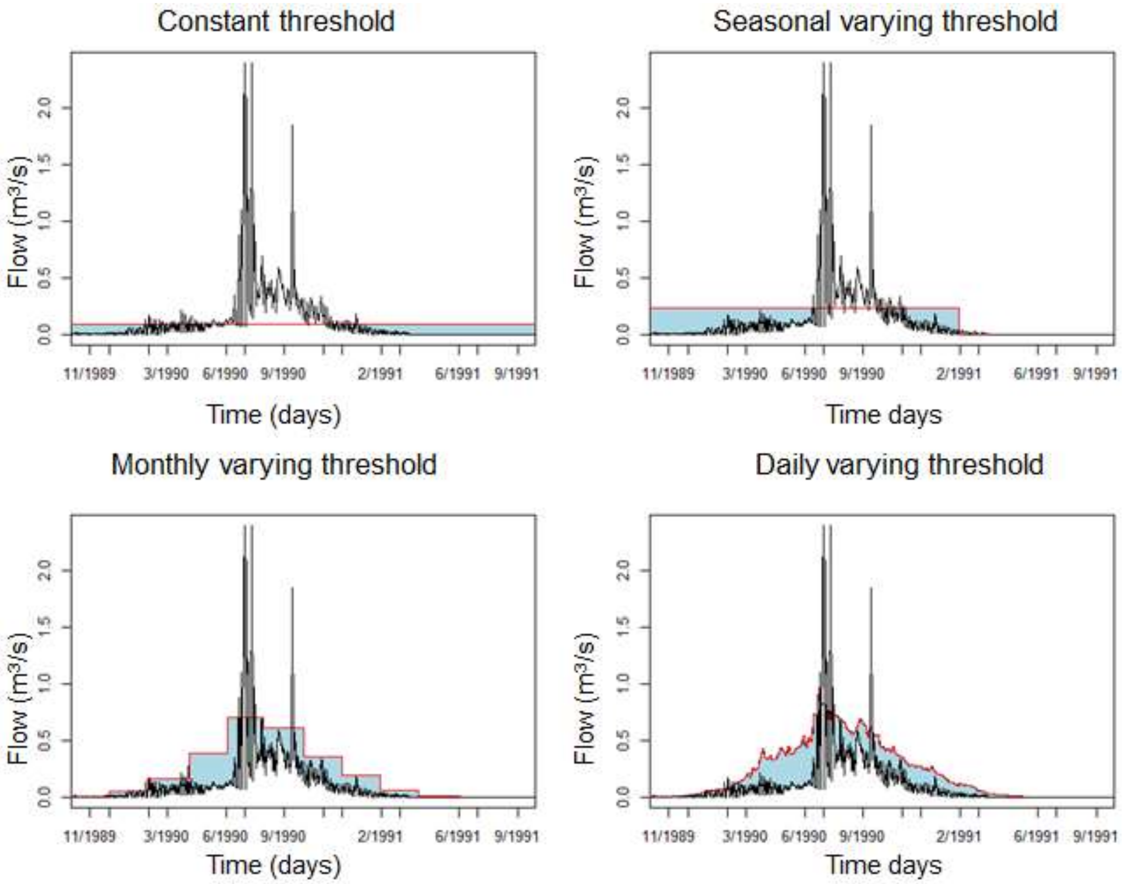

Figure 2: An example of the four different threshold methods used in this study**.**

The knowledge of future volume of deficits is very important for the design of hydro-technical projects. In this study, a statistical analysis of maximum volumes of deficits was done for return periods 10, 20, 30, 50, 100, 250 and 500 years. In order to incorporate the influence of drought duration, maximum volumes were extracted for selected drought durations (30, 60, 90, 180, 360 days) for each hydrological year, for the four thresholds. Statistical tests using Kolmogorov-Smirnov test, were evaluated for the four thresholds to evaluate which theoretical probability distribution fits better to estimated deficits. Several theoretical probability distributions were tested using L-moments for the estimation of distribution parameters (Greenwood *et al*., 1979; Hosking, 1990).

4. Results

Among the three pooling procedures, inter event time and volume criterion seems to be the best because there is no subjectivity in the choice neither of days of pooling nor of the ratio of volumes. This is reflected in Figure 3, where there is a good convergence of the different periods of days of pooling, and a good convergence of the three different ratios of pooling.

a)

b)

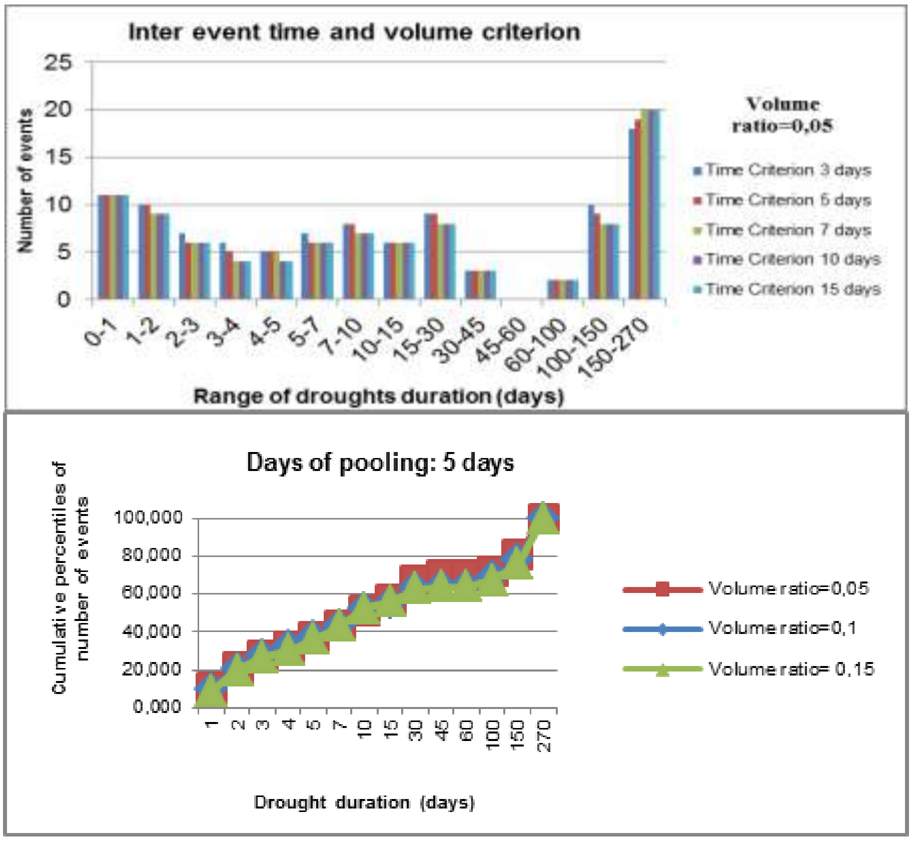

Figure 3: The inter event time and volume criterion method a) the effect of inter event time on low flow events and b) the effect of volume criterion of the estimated low flow events.

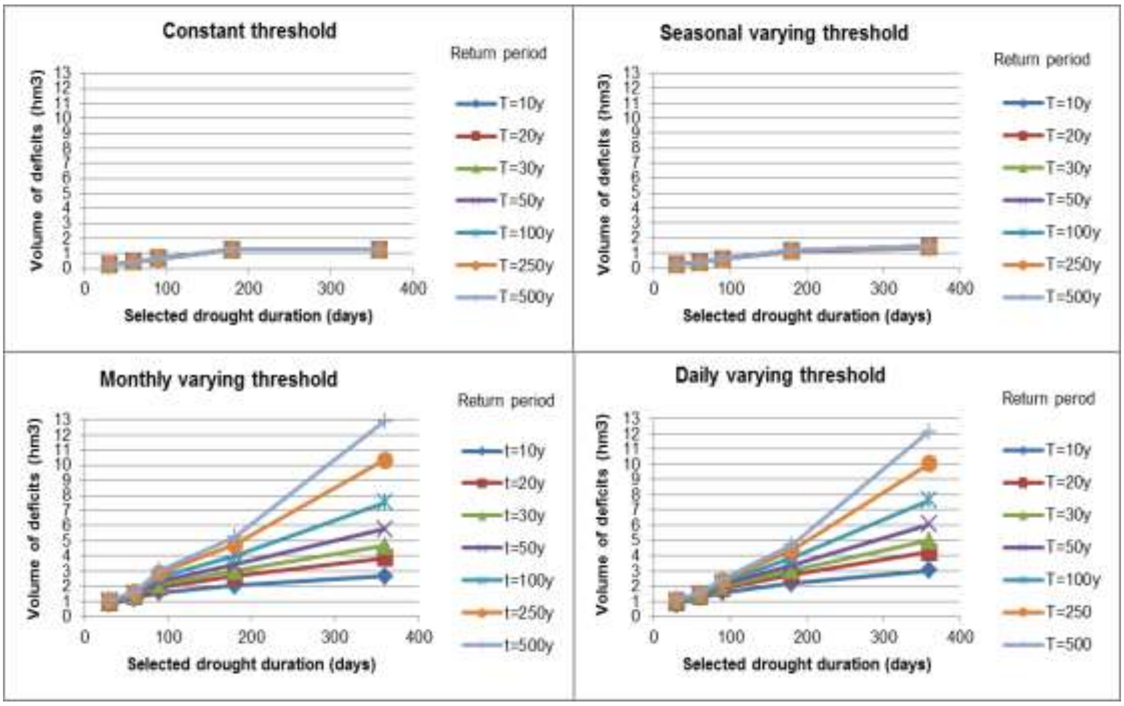

Figure 4: Severity-Duration-Frequency curves for the four threshold methods.

5. Conclusions

This study provides a detailed description of deficits characteristics using the threshold level method. A comparison among four thresholds (constant, seasonal, monthly, daily varying) was done. SDF curves for the four thresholds were developed and compared. Inter event time and volume criterion is the most unbiased pooling procedure, among the three, in the choice both of the days of pooling and the volume ratio. Using monthly and daily varying thresholds are derived more deficits which, however, last less and create less severe deficits than the other two thresholds. It must be notice that when using Q70 as threshold, were derived less deficits than Q50, which followed the same pattern. Namely, the most unbiased pooling procedure was proved inter event time and volume criterion for this case too. Monthly and daily varying thresholds derive more deficits than constant and seasonal varying threshold, also, when using Q70. Monthly and daily varying thresholds forecast more severe volumes of deficits, while, the longer the return period the larger the volume predicted.

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