REGIONAL FLOW DURATION CURVES FOR UNGAUGED SITES IN SICILY

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F. Viola[1], L. V. Noto[1], M. Cannarozzo[1], G. La Loggia[1]

[1] Dipartimento di Ingegneria Idraulica e Applicazioni Ambientali, Università di Palermo, viola@idra.unipa.it

Abstract

Flow duration curves (FDC) are simple and powerful tools to deal with many hydrological and environmental problems related to water quality assessment, water-use assessment and water allocation. Unfortunately the scarcity of streamflow data enables the use of these instruments only for gauged basins. A regional model is developed here for estimating flow duration curves at ungauged and unregulated basins in Sicily. Due to the complex ephemeral behaviour of the examined basins, this study distinguishes dry periods, when flows are zero, from wet periods when flows are non-zero. A three parameters power law has been used to describe the frequency distribution of flows. This relation allows to individuating the frequency of wet (or dry) periods. A large dataset of streamflow has been analyzed and FDC parameters have been fitted on 53 basins. Regional regression equations have been developed to derive FDC from morphological basin characteristics.

STUDY AREA AND DATASET

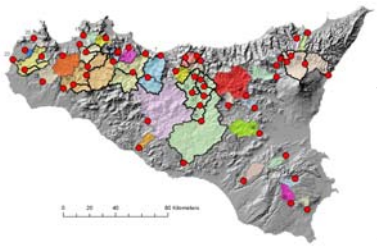


Figure 1: Catchments location.

This study has been carried out for the catchments of the largest island in the Mediterranean Sea: Sicily which extends over an area of 25,700 km^2. The mean annual rainfall over the island is about 715 mm (period 1921-2004); precipitations are concentrated in the winter period while the July-August months are usually rainless.

Daily flows have been provided for the study by OA-ARRA (Osservatorio delle Acque - Agenzia Regionale per i Rifiuti e le Acque). Only data from unregulated basins with at least ten years in record length have been used. 53 streamflow historical series have been analyzed. The mean daily flow vary from 0.04 to 7.6 m^3/s.

The location (Figure 1) and variability of the characteristics of selected catchments make the used sample representative of the heterogeneity of Sicilian basins.

METHODOLOGY

Considering that several Sicilian catchments are ephemeral, the model distinguishes between wet periods, in which flows are different from zero, and dry periods, when flow is absent. For each gauged catchment used in the study, the relative duration of wet periods, D_w, can be identified and easily calculated starting from streamflow data.

The empirical FDCs for wet periods have been obtained by Eq.(1) where D^* is the relative duration [0:1] during wet periods. The empirical FDC derived from the non-zero flow data for the study catchments in Sicily are presented in Figure 2, plotted on log-axes

In order to represent FDC during wet periods a two parameters (a, b) power relationship has been chosen, as reported in Eq. (2).

Eq. (1) $$D^*(Q_{obs,i}) = 1 - \frac{i}{N+1}$$

Eq. (2) $$Q(D^*) = a\left(\frac{1-D^*}{D^*}\right)^b$$

FDC for the whole year can be viewed as an integration of information coming from the knowledge of dry and wet periods.

The first are characterized by zero flow with relative duration (1- D_w), while the streamflows during the wet periods, which last D_w, are fully described by Eq. (2). FDC can be rewritten for the whole year using the key Eq. (3)

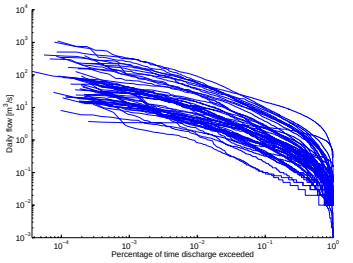


Figure 2: Empirical flow duration curves from non zero flows.

$$Q(D) = \begin{cases} a\left(\frac{D_w}{D} - 1\right)^b & 0 \le D \le D_w \\ 0 & D_w < D \le 1 \end{cases}$$

Eq. (3)

ESTIMATED FDC

Two estimated FDCs are shown to describe the model potentialities. From Eq.(3) it is clear that the model is able to deal both with ephemeral or perennial flows. Here two FDCs, one ephemeral and one perennial, computed using the proposed procedure are presented. The results shown in Figure 3 are relative to the "Senore a Finocchiara" basin, with ephemeral flows, and to the "Oreto a Parco" basin, which instead has continuous flows. Figure 3 shows a good fit between empirical and estimated FDC in both ephemeral and perennial conditions for the [0.05:1] range of durations, with some critical divergences for extreme flows.

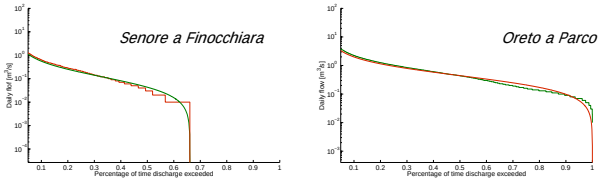
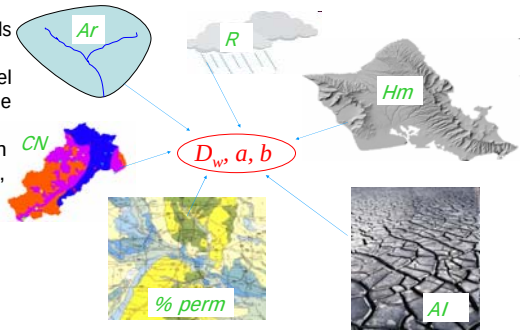


Figure 3: Empirical (red) and estimated with Eq.(3) (green) flow duration curves for the "Senore a Finocchiara" basin and for the "Oreto a Parco" basin.

THE REGIONAL MODEL

The most of the catchment characteristics used in this analysis comes directly from a GIS based tool called SIRI (Noto et al., 2001). The following ones have been computed: the basin area (*Ar*) [km^2], the mean areal annual precipitation (*R*), [mm], the average basin elevation (*Hm*), [m], the mean areal value of Curve Number (*CN*), [-], the percentage of permeable area (*%perm*) [-]. Following Thornthwaite (1948) also the Aridity Index (*AI*) has been calculated.

Regressive methods have been used to link the three model parameters to some catchment characteristics such as climatic indexes, geolithologic and geopedologic parameters, land coverage and geomorphic parameters.

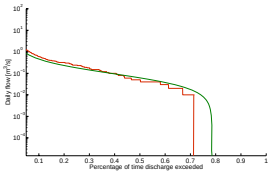


The use of stepwise regressive analysis has led to the determination of three equations which relate model parameters to some catchment characteristics, below reported:

$$D_w = 0.06346\ln(Ar) + 0.4108\ln(R) + 0.0839\ln(Hm) + 0.0014(\%perm) - 2.7308$$ R²=0.63; RMSE=0.105

$$a = 0.000119\frac{Ar^{0.7634} \cdot R^{1.9686}}{CN^{2.0843}}$$ **Eqs. (4)** R²=0.83; RMSE=0.425

$$b = 0.0079 Ar^{0.067} R^{0.4167} AI^{0.8754} \exp(0.00051 Hm)\exp(-0.0053\%perm)$$ R²=0.63; RMSE=0.120



The regional model has been validated, with good results, on five basins. The comparison between the empirical FDC and the one obtained using the regional model are shown in Figure 4 for the "Alberì a Irosa" basin. Notwithstanding a slight overestimation of the wet period (about 5%), the fitting is quite good. Similar results have been obtained for the remaining validation catchments.

Figure 4: Model validation: empirical (red) and estimated with Eq.(5) (green) flow duration curves for the "Alberì a Irosa" basin.

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