The Intensity – Duration (I-D) curves towards to a spatially distributed flood early warning tool (F-EWT)

Feloni E.*, Baltas E.

Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, 5 Iroon Polytechniou, 157 80, Athens, Greece; +302107722413

*corresponding author: e-mail: feloni@chi.civil.ntua.gr

Abstract

Attica region suffers from rainfall events of high intensity, inducing flash-floods and significant damages in the urbanized areas. This analysis concerns the determination of the maximum intensity-duration thresholds regarding flooding (F) or non-flooding (NF) regime, using the available precipitation records and the dataset of Fire Service operations in flooded properties for the period 2005-2016. Each event is classified as 'F' or 'NF' in case of flooded properties or not, respectively. As expected, 'F' events prevail for the higher rainfall intensities. Based on this characteristic, it was found that when excluding outlies in these two groups of events, then two clear limits of I-D are determined using a power-law equation. The first one ('lower limit') defines the area below which floods are absent and above which flood occur or not, while the second ('upper limit') defines the minimum limit of maximum intensities above which only events linked to flooding are observed. Based on these limits, a Flood Early Warning Tool (F-EWT) that provides the corresponding limits of cumulative precipitation as a function of the event's duration is defined and evaluated indicatively for the severe flood event of October 24, 2014.

Keywords: floods, Attica region, early warning, flood mitigation, rainfall intensity

1. Introduction

The fact that rainfall and particularly some characteristics, such as, the intensity and duration (I-D) of a storm are highly important for the flood occurrence has been highlighted by many researchers (e.g., Amadio et al., 2003; Norbiato et al., 2008). The I-D threshold is a typical meteorological-threshold approach that initially adopted for rainfall events induced landslides and debris flow (Guzzetti et al., 2007). In the field of flood-related research, the adoption of such methodologies is not widespread, however, in recent years monitoring of rainfall characteristics is assumed as an important tool for flood risk prevention (e.g., Cannon et al., 2008; Golian et al., 2010). Therefore, the relationship between the rainfall characteristics and the flood occurrence is a way to determine critical I-D thresholds that indicate conditions of no flood potential (NF), mixed conditions (M), and conditions that are probably linked to the flood occurrence (F). In this framework, this paper presents the results of an analysis applied for 30 subareas of the entire Attica region. For each subarea a unique power-law equation is fitted to describe the limits among the aforementioned three cases (NF, M, F). The transformation of maximum rainfall intensities per duration to cumulative precipitation in time led to the definition of a Flood Early Warning Tool (F-EWT) that provides the corresponding limits for the assessment of the potential flood occurrence using real-time rainfall measurements. Also, this F-EWT has been evaluated for selected events and its performance is presented indicatively for the severe flood event of October 24, 2014.

2. Materials and Methods

The I-D curves that are determined in order to finally define a spatially distributed F-EWT are estimated for 30 subareas of the entire Attica region. Each subarea is defined utilizing the GIS capabilities and a number of geospatial data. Rainfall measurements of 10min interval from 32 stations were collected, processed and analyzed to finally calculate the maximum intensity of various durations per event and subarea. Finally, the identification of flood events is conducted by using the entire database of citizens' calls to the Integrated Emergency Coordination Centre of the Hellenic Fire Service within the period 2005-2016. Each record in this dataset contains information regarding the cause of alarm, the accurate time of call and the corresponding postal address. Data were subjected to a quality control and then to a geocoding process, in order to obtain the geographic coordinates of the flooded properties to use it for the characterization of rainfall events induced flooding in a subarea level. Finally, the series of intensities per duration were subjected to a statistical analysis and, thus, outliers were omitted from the sample used for the I-D curves determination. The final step of the calculation of each equation's parameters was accomplished by applying optimization techniques.

3. Results

As shown in Figure 1(a), there are two categories of rainfall events (the F with red dots and NF with black).

Thus, two main thresholds can be determined (dashed grey lines); the lower, below of which events not inducing floods are observed, and the upper, above which only events inducing floods are observed. These two thresholds highly deviate each other for short durations and are very close for durations higher than 6h. Furthermore, the analysis per subarea revealed that the values of these thresholds differ significant among the 30 subareas for short durations. After the thresholds determination, the fitting of power-law distributions follows to define the corresponding limits (Fig. 1(b) orange and red lines). Then the critical intensity for a specific duration is transformed to a cumulative amount of precipitation in a specific period of time, to estimate the so-called F-EWT, a premise in a flood early warning system design. As I-D curves resulted from the two limits of I-D pairs, the corresponding thresholds of cumulative precipitation in a F-EWT are higher than a usual period of time in which intensities equal to the maximum and minimum coexist. Early warning systems should enhance the preparedness of decision – maker and this attribute is unique and useful as it secures immediately the alert. The general concept is that, based on the lower and upper I - D curves, three levels of alert are determined, as shown in Figure 1(c).

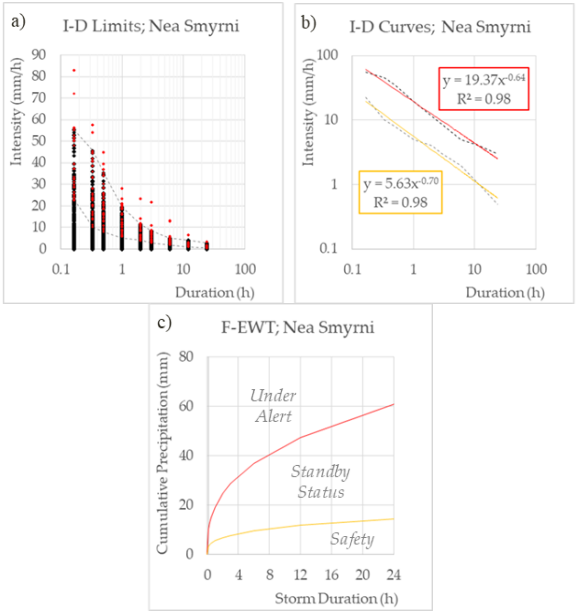

Figure 1. (a) I-D limits, (b) I-D curves and (c) F-EWT for the subarea of Nea Smyrni

This tool may function either operationally, near nowcasting (with real-time precipitation records of the station that is designed for), or as part of a flood-forecasting system (with precipitation forecast products). As it is static, the plot of the event's cumulative precipitation allows the assessment of the level of alert in a region. Indicatively, to illustrate its performance, the intense flood event of October 24, 2014 is used as a case study for demonstration purposes. This was a relatively spatially localized flood event, as impacts on flooding properties mainly recorded at the western suburbs of Attica Basin. For this case study, the 10min records of Patissia, for a subarea where flood occurred, and of Vari, where flood did not occurred, are used in order to calculate and plot on the corresponding F-EWTs the cumulative precipitation. As Figure 2 depicts, the observed accumulated rainfall depth exceeded upper limits in Patissia, but not this in Vari, where no flooded property is recorded.

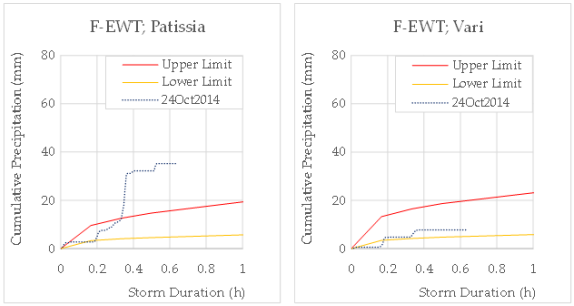

Figure 2. Indicative performance of F-EWT for the flood of October 24, 2014

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