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Role of rainfall intensity and urban sprawl in the 2014 flash flood in Genoa City, Bisagno catchment (Liguria, Italy)

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ABSTRACT

Flash floods are typical for the Mediterranean region, however they have been recurring at increasing frequency over the past few decades especially over the Italian Peninsula. The region of Genoa has recently moved into the international spotlight due to frequent and disastrous flash floods of the Bisagno River and its tributaries as a result of intense autumn rainfall and dense floodplain urbanization. The last flood events even caused loss in human lives, with 6 casualties in 2011 and 1 in 2014. However, it has not yet been investigated whether the increase in these flash flood events is due to a change in rainfall regime or due to urban expansion in areas prone to flash floods. This study investigates the meteorological conditions and the ground effects of the Bisagno River flash flood of October 9th, 2014 in the city of Genoa. Application of a Standard Anomaly Index and a Cluster Analysis reveals a positive trend in intense and short-duration rainfall recorded in the Bisagno Valley for the period of 1945–2016. Urban sprawl in the catchment, assessed through a multi-temporal cartographic and photographic comparison, highlights the progressive and total consumption of land in the floodplain. In the river basin surrounding Genoa the risk of flash floods has increased, both due to a change in rainfall regime and associated increase in discharge but also due to increased vulnerability caused by progressive urban expansion and land use change, including in particular transformations of the Bisagno riverbed. The results obtained demonstrate the need for urgent action to mitigate flood risk by introducing, amongst other measures, a citizen observatory for early warning of flash floods.

1. Introduction

Recent flash flood events affecting Europe (Kvočka, Falconer, & Bray, 2016) and the Mediterranean area are mainly studied with relation to climate variations (Barrera-Escoda & Llasat, 2015) or land use change (Saurí, Roset, Ribas, & Pujol, 2001; Mcewen, Hall, Hunt, Dempsey, & Harrison, 2002; Morelli, Segoni, Manzo, Ermini, & Catani, 2012; Morelli, Battistini, & Catani, 2014). Issues related to historical land use change have been linked to historical climate cycles (Böhm, Jacobeit, Glaser, & Wetzel, 2014) and recurrence of extreme floods in Europe (Elleder, 2015). Studies monitoring the influence of urbanization processes and urban sprawl on floods have been predominantly carried out in China using geoprocessing tools integrated in remote sensing (Lv et al., 2011).

Flash floods are increasingly studied in Europe due to their recent intensification (Llasat, Ghabeli, & Turco, 2014; Petrović, Dragićević, Radić, & Pesic, 2015; Vinet, 2008) but also in other parts of the world (Tripathi, Sengupta, Patra, Chang, & Jung, 2014; Mahmood, Khan, & Mayo, 2016; Rahman, Aldosary, Nahiduzzaman, & Reza, 2016) in response to climate change (Krellenberg, Müller, Schwarz, Höfer, & Welz, 2013; Velasco Droguet, Versini, Cabello Gómez, & Barrera-Escoda, 2013; de Jong, 2015). Marafuz, Rodrigues, and Gomes (2015) found an increase in urban flood events linked to rapid urban sprawl in their analyses of flash floods in a small catchment in Portugal. They focussed on flood concentration times, water balance and surface runoff towards critical areas or exposed features.

Flash floods are the most widespread geo-hydrological hazard in the Mediterranean (Canuti, Casagli, Pellegrini, & Tosatti, 2001) and coastal floodplains are particularly vulnerable to recurring floods. They result from interactions between intense precipitation, topography, geology, stream network and land use (Pazzi et al., 2016a; Norén, Hedelin, Nyberg & Bishop, 2016; Pazzi et al., 2016b). Most such flash floods are

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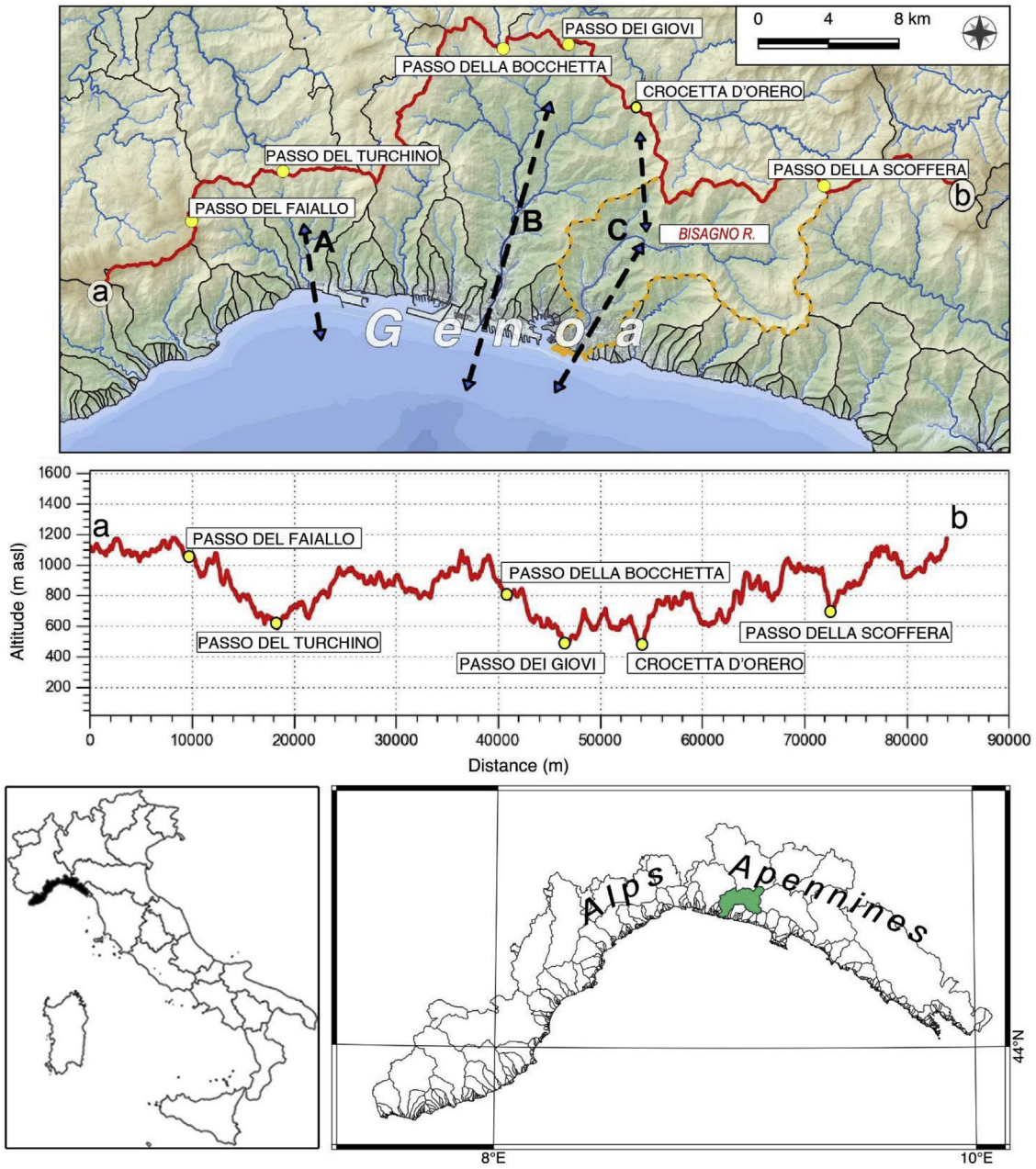

Fig. 1. Geographical sketch maps of the study area. Top: The Bisagno River (colored area), Genoan (top) and Ligurian (bottom) hydrographic network and basins. Direction of air mass movement: A = Axis of the Passo del Turchino-Leira River Valley-Sea, B = Axis of the Passo dei Giovi-Polcevera River Valley-Sea and C = Axis of the Crocetta d'Orero-Geirato River-Bisagno River Valley-Sea. Red line highlights the main watershed in plan and section (below). B alignment represents the Alps-Apennine arrangement. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

triggered by cloudbursts which are characterized by "sudden, very heavy rainfall, usually local in nature and of brief duration" (https://www.britannica.com/science/cloudburst) or in other words "a torrential downpour of rain which by its spottiness and relatively high intensity suggests the bursting and discharge of a whole cloud at once" (Wooley, 1946).

The frequency of flash floods and their severe effects on the urban Genoa Metropolitan Area have made it an internationally emblematic case study for flooding, climate change and urban sprawl (Brandolini, Cevasco, Firpo, Robbiano, & Sacchini, 2012; Ferrari, Belicchi, Carlini et al., 2014; Dunaieva et al., 2014; Silvestro, Rebora, Giannoni, Cavallo, & Ferraris, 2015). As a consequence, the Bisagno River drains one of the most well-known catchments in the Mediterranean with repeated flooding effecting the densely populated Genoa city center, often causing serious damage and fatalities (Faccini, Paliaga, Piana, Sacchini, & Watkins, 2016).

The socioeconomic vulnerability to flash floods studied in Genoa showed that, not surprisingly flood prone areas with the highest exposure also have the highest vulnerability (Sorg et al., 2018). Under these circumstances, the main perception of the Genoa citizens with relation to adaptation to flash floods is the need for an improved Early Warning System. Other authors (Scolobig, 2017) point out that a deadlock in disaster risk reduction has been created in Genoa. Few projects have been implemented to reduce flood risk due to political, institutional, financial and legal barriers. Furthermore, "*Residents in the most affected areas lamented that the required structural risk mitigation measures have not been taken, thus exposing them to an even higher risk.*" (Scolobig, 2017).