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Floodplain management in Africa: Large scale analysis of flood data

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ABSTRACT

To mitigate a continuously increasing flood risk in Africa, sustainable actions are urgently needed. In this context, we describe a comprehensive statistical analysis of flood data in the African continent. The study refers to quality-controlled, large and consistent databases of flood data, i.e. maximum discharge value and times series of annual maximum flows. Probabilistic envelope curves are derived for the African continent by means of a large scale regional analysis. Moreover, some initial insights on the statistical characteristics of African floods are provided. The results of this study are relevant and can be used to get some indications to support flood management in Africa.

1. Introduction

Floodplain management and, in particular, floodplain mapping often requires the estimation of the so-called design-flood, i.e. the discharge value corresponding to a given recurrence interval or return period. Often, design-flood estimation is complicated by the lacks of sufficient hydrological information. In fact, the prediction of floods in ungauged (or poorly gauged) basins is one of the key tasks of the PUB (Predictions in Ungauged Basins) initiative launched in 2003 by the International Association of Hydrological Sciences (IAHS; Sivapalan et al., 2003).

This problem has been addressed by adopting several approaches, characterised by the same philosophy: transferring hydrologic information or knowledge from gauged catchments to ungauged or poorly gauged ones. Statistical regionalization is a viable and intensely used means to operate this information transfer (Blöschl and Sivapalan, 1997; Merz and Blöschl, 2008; Pallard et al., 2009).

The use of empirical regional envelope curves (REC's) of flood flows is a traditional approach to predict extreme floods in ungauged basins (e.g. Castellarin, 2007). An envelope curve represents the bound on current experience of extreme floods in a region gained up to the present through systematic observation of flood discharges. A traditional fashion to represent envelope curves of a given region is the normalised record flood (defined as the logarithm of the ratio of the maximum observed flood to its basin area) versus the logarithm of the basin area (Fig. 1). The envelope curve is the line drawn on such a diagram which provides an upper bound on all the normalised record floods at present. REC's therefore provide an effective summary of regional flood experience (Fig. 1).

Flood-related fatalities in Africa, as well as associated economic losses, have increased dramatically over the past half-century (Di Baldassarre et al., 2010a). In Africa, flood-prone areas are being developed for both industrial and urban settlements. This may have serious consequences in the wake of extreme flood events with continuous pressure from increasing population and economic development. Furthermore, gauging stations (sites) on the African rivers are few and poorly managed. As a result, at-site flood frequency analysis for floodplain management and flood control purposes at poorly gauged sites poses a great deal of challenge. This paper describes a comprehensive analysis of African flood data, which was performed using reliable, and consistent information reported in two large databases (UNESCO, 1984; IAHS, 2003). More specifically, the paper applies the concept of probabilistic envelope curves of flood flows (Castellarin et al., 2005; Castellarin, 2007) to the African continent by means of a large scale regional flood frequency analysis. The main aim of the study is to develop a straightforward graphical tool that enables one to (1) determine plausible extreme-flood values at ungauged sites as a function of catchment size, and (2) estimate the recurrence interval associated with such flood values. We believe that this tool may be of use for local Institutions and Authorities in charge of flood risk mitigation and management and civil protection services. We also deem the analysis to provide some initial insights on the statistical characteristics of African floods, which are presented in the discussion and recommendations paragraph.

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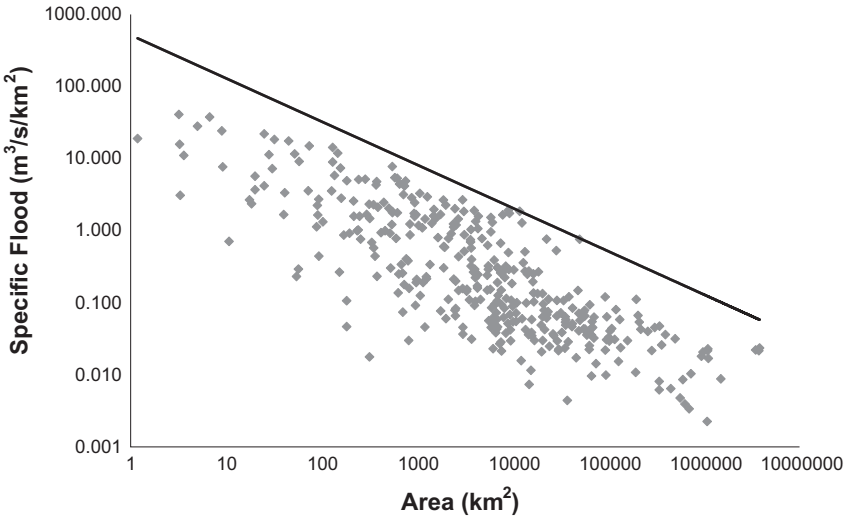

Fig. 1. Empirical envelope curve: flood experience in Africa.

2. Flood database

The flood information used in this study was obtained from two reliable world catalogues of maximum floods (UNESCO, 1984; IAHS, 2003). The database includes a total of 369 observation sites from 33 countries (Fig. 2) with an overall station-years of data of 9000 years; among them, 77 sites have data on annual maximum discharge (Fig. 2). The observation period of the time series, though variable, is subsumed within the time span from 1900 to 2000. The uncertainty of the river discharge data used in this study was found to be between 10% and 15% (Herschy, 2002), which is relatively low compared to the standard uncertainty of flood data (Di Baldassarre and Montanari, 2009). The study area is characterised by different climatic regimes (the mean annual precipitation

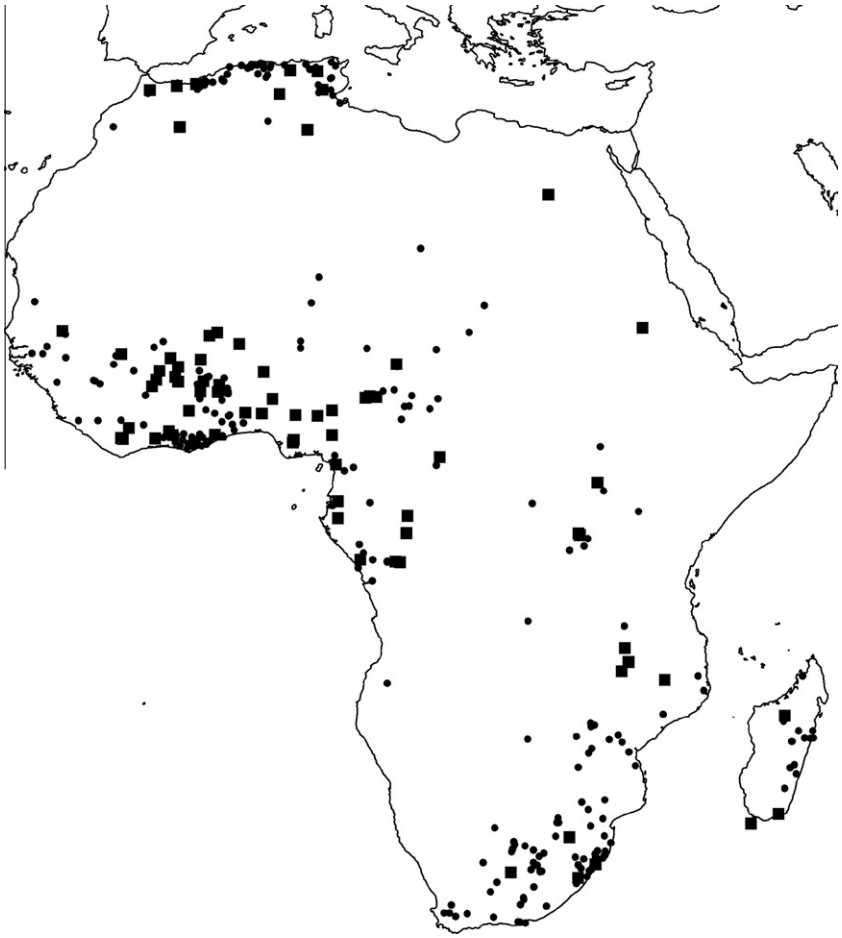

Fig. 2. Study area and locations of the 369 river stations with information about maximum observed floods (dots). The larger square dots indicate the locations of the river stations for which maximum annual flow series (AMS) were available.