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Brief communication: Comparing top-down and bottom-up paradigms for global flood hazard mapping

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Abstract. Global floodplain mapping has rapidly progressed over the past few years. Different methods have been proposed to identify areas prone to flooding, resulting into a plethora of freely available products. Here we assess the potential and limitations of two main paradigms, and provide guidance on the use of these global products in assessing flood risk in data-poor regions.

1 Introduction

As economic losses and fatalities caused by floods have dramatically increased over the past decades (Winsemius et al., 2016), there has been much progress in the development of analytical tools for the identification of the areas that can be potentially flooded (Ward et al., 2015; Dottori et al., 2018; Nardi et al., 2019). This progress has also been accelerated by the adoption of the Sendai Framework for Disaster Risk Reduction and the Warsaw International Mechanism for Loss and Damage Associated with Climate Change Impacts (Ward et al., 2015). As such, more and more scientists, experts and practitioners use global floodplain maps in data-poor regions for the identification of flood risk hotspots or the mapping of flood-prone areas (Ward et al., 2015; Winsemius et al., 2016; Dottori et al., 2018; Nardi et al., 2019).

2 The top-down paradigm

There are two main paradigms to map flooding. The traditional paradigm is (implicitly or explicitly) based on a definition of the floodplain as the area falling within the extent of a given flood event. In this paradigm, which can be seen as *top-down*, a synthetic event with a given probability of occurrence or return period (Pappenberger et al., 2013; Ward et al., 2015; Dottori et al., 2018), such as the 1-in-200 year flood event, is typically estimated via hydrological modelling or statistical analysis of flood data. This synthetic event is then propagated along the river with hydrodynamic models to estimate the corresponding

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inundated areas. The top-down paradigm has been widely used across multiple places and scales (Ward et al., 2015), including large-scale flood hazard modelling in data-poor regions in Africa (Figure 1). While hydrodynamic modelling of floods has been successful in simulating historical events (Horritt and Bates, 2002), large uncertainties come into play when used to simulate synthetic events (Di Baldassarre, 2012). The estimation of a flood hydrograph with a given return period, for example, is extremely uncertain as time series of flood data are hardly ever available, especially in data-poor areas (Blöschl et al., 2013).

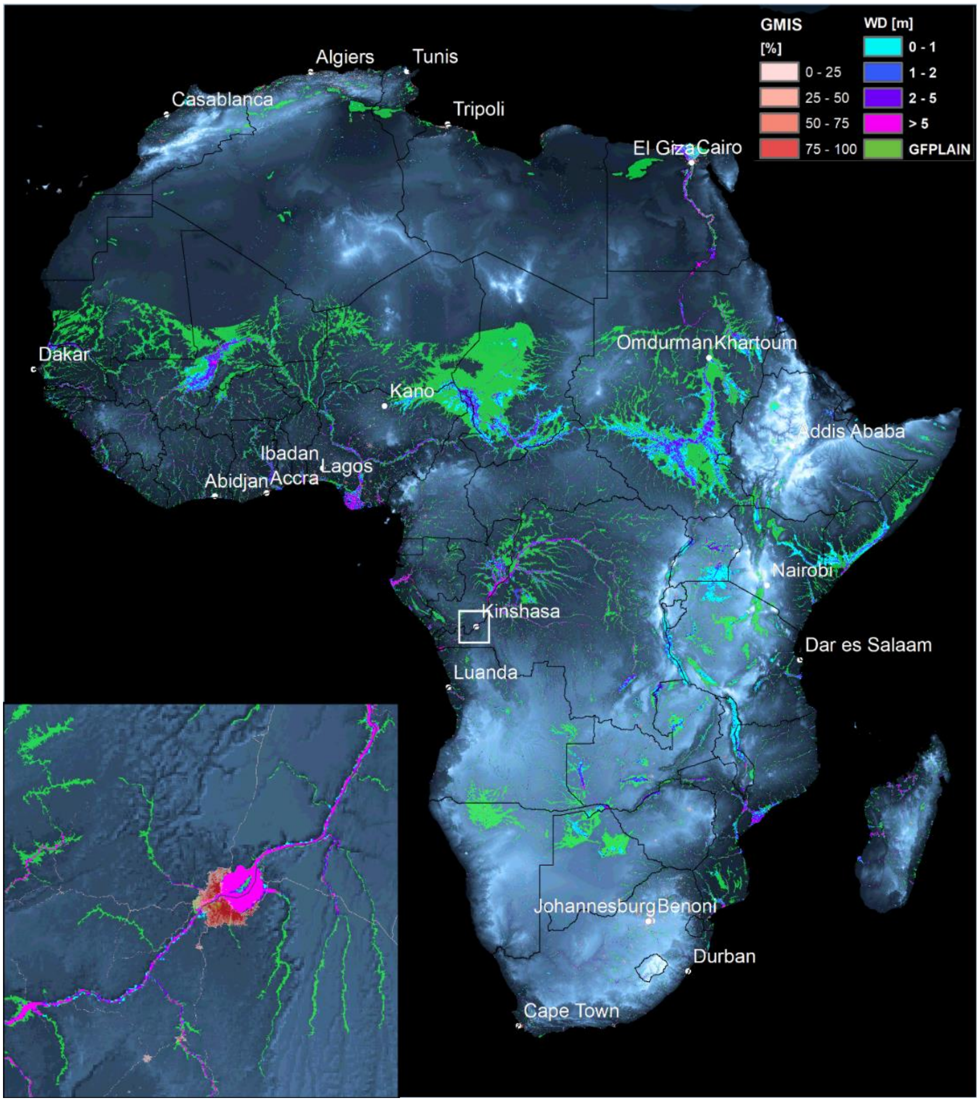

Figure 1. Top-down and bottom-up paradigms to map flooding in Africa. Continental floodplain mapping using hydrodynamic models (top-down) is color-coded cyan-to-violet representing water depths (WD, Dottori et al., 2016) with a return period of 200 years. The floodplain areas derived with the hydrogeomorphic approach (bottom-up) are shown in green color and based on the GFPLAIN250m dataset4. The inset shows estimated flood-prone areas in Kinshasa (Democratic Republic of the Congo) as well as the Global Man-made Impervious Surface (GMIS) layer (Brown de Colstoun et al., 2017) depicting urban areas as percent of impervious cover in an orange-to-red scale.

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3 The bottom-up paradigm

An alternative paradigm to map flooding is based on a definition of floodplains as distinguished landscape features that have been historically shaped by the accumulated effects of floods of varying magnitudes, and their associated hydrogeomorphic processes (Nardi et al., 2006; Dodov and Foufoula-Georgiou, 2006). In this paradigm, which can be seen as *bottom-up*, floodplains are identified directly from the topography (Nobre et al., 2011; Samela et al., 2017; Nardi et al., 2019), which is assumed to have been shaped by past flooding events, and building on the concept of fractal river basins (Bras and Rodriguez-Iturbe, 1985; Rodríguez-Iturbe and Rinaldo, 2001) or hydrogeomorphic theories (Bhowmik, 1984; Tarboton et al., 1988). The bottom-up paradigm does not require the estimation of a synthetic flood hydrograph, and consistently identify flood-prone areas across diverse climatic regimes with varying parametrizations (Manfreda et al., 2014; Nardi et al., 2018; Annis et al., 2019) which can be seen as an advantage in data-poor regions. Also, with the recent development of global DTMs (Ward et al., 2015; Nardi et al., 2019) and EO-based cloud computing platforms (Pekel, et al., 2016), worldwide mapping of floodplain areas is a reality and these global maps can be derived in a standard PC with a single click and limited computation time. Hence, it allows to easily detect floodplains, and it is a useful tool for a variety of environmental and socio-economic analyses at large or global scale.

4 Comparing top-down and bottom-up paradigms

Figure 1 shows, as an example, floodplains of the African continent derived with both paradigms (Dottori et al., 2016; Nardi et al., 2019), while its insert compares them in the area around the city of Kinshasa, Democratic Republic of the Congo. International development banks, water sector organizations, national and international bodies mandated with disaster risk reduction, sustainable development and humanitarian response use these global maps in data-poor regions for mapping risk hotspots and flood-prone areas (Ward et al., 2015). To provide guidance in using these global products, we list limitations and advantages of the products derived using the two main paradigms in Table 1.

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Table 1. Advantages and limitations of the two paradigms in mapping floodplain areas.

	Cons	Pros	Links to an example of global datasets (references)
Top-down paradigm **(based on hydrodynamic models)**	More sensitive to data scarcity (time series of flood data are only seldom available and often too short for a robust estimation of a design flood). Computationally expensive. Variable over time, e.g. any interventions would require and updating of the hydrodynamic model.	Less sensitive to scales. Floodplains are defined based on a specific probability of occurrence: this allows cost-benefit analyses for e.g. the design of risk reduction measures is not possible. It can explicitly account for the role of hydraulic structures, e.g. flood gates. It provides additional variables, such as maximum flow depth, velocity and volume useful for some applications.	Flood Hazard Maps at European and Global Scale by the Joint Research Center (JRC) https://data.jrc.ec.europa.eu/collection/id-0054 (Dottori et al., 2016)
Bottom-up Paradigm **(based on hydrogeomorphic theories)**	More sensitive to scales. Do not provide a specific probability of occurrence: cost-benefit analyses for the design of e.g. risk reduction measures are not possible. It cannot account for the role of hydraulic structures, e.g. flood gates. Scaling laws have limitations in dry climates.	Less sensitive to data scarcity (it does not require any time series). Computationally efficient. More consistent over time, e.g. floodplain is identified as if protection structures were not in place. This can be seen as an advantage as erring on the side of least consequences (and total protection is impossible anyway).	Global High-resolution Dataset of Earth's Floodplains (GFPLAIN250m) https://figshare.com/articles/GFPLAIN250m/6665165/1 (Nardi et al., 2019)

5 Conclusions

Both paradigms are based on consolidated theories, and they have opposite advantages and uncertainties (Table 1). Thus, we argue that these maps are complementary and they should be exploited following the precautionary principle (Foster et al., 2000), which is an important component of much of the environmental legislation in the western world. The principle calls for erring on the side of least consequences. In this context, this means the identification of flood risk hotspots in data-poor areas should consider *both* flood inundation areas derived by the two paradigms as depicted in the insert of Figure 1.

Data availability

Maps and data are available online, and can be accessed using the links provided in Table 1 (last access: 12 December 2019).

Author contributions

GDB, FN, and SG conceptualized the study. AA prepared the figure with the support of GDB, FN and SG. GDB wrote the original draft of the brief communication. FN, AA, VO, MR, and SG provided comments and reviewed the original draft.

Competing interests

The authors declare that they have no conflict of interest.

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