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The urbanisation on the slopes of SARAJEVO and the rise of geomorphological hazards during the post-war period

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ABSTRACT

Within the interdisciplinary field of urban geomorphology, scholars have recently paid attention to the increasing vulnerability of landscapes, due principally to the construction of housing and infrastructure. With regard to the case of Sarajevo and more specifically the capital of Bosnia and Herzegovina, historically, its particular geographic setting has maintained a central role in the spatial distribution of its population, with residential areas exposed to potential geomorphological hazards. Urbanisation on the slopes of Sarajevo was resumed after the Bosnian War (1992–1995) in areas with steep slope gradients. This was a consequence of the impossibility or unwillingness of those internally displaced, sheltered in Sarajevo during the conflict, to return to pre-war homes. Thus, this paper explores the political, social and economic factors that have influenced both the historical process of urbanisation on the slopes, surrounding the central areas of the city, and its subsequent reproduction during the post-war period. The aim of this paper is to evaluate the exposition of these urbanised slopes to potential geomorphological hazards. Moreover, the extent of urbanisation on the slopes will be quantified in five study areas for periods between 1987–2003 and 2003–2015. It precedes the evaluation of the geomorphological vulnerabilities of constructions developed in these sites. Finally, corrective measures are proposed in the current process of elaboration of the new Urban and Strategic Plans.

1. Introduction

Cities are complex systems that are developed in specific environmental settings and condition urban planning and development policies. In many European countries, the increasing vulnerability of landscapes, mostly because of the construction of housing and infrastructures, (e.g. Berhane & Walraevens, 2013; Pueyo Anchuela, Casas Sainz, Pocoví Juan, & Gill Garbí, 2015) has gradually been incorporated into urban planning tools in order to reduce any hazards affecting topographical conditions, e.g. landslides in areas of rough terrain (Alcántara-Ayala & Goudie, 2010; Alexander, 1991; Bathrellos, Kalivas, & Skilodimou, 2009; Cascini, Bonnard, Corominas, Jibson, & Montero-Olarte, 2005; Degg, 1998; Luino & Castaldini, 2011). In fact, the geomorphological vulnerability of urban environments has been widely studied over the last decade from a broad range of perspectives (Gupta & Ahmad, 1999; Huang & Mu, 2000; Adeli & Khorshiddoust, 2011; De Waele, Gutierrez, Parise, & Plan, 2011). In the karst environments of the Mediterranean, flash flooding has been identified as one of the major potential hazards that can cause significant damage in urban areas (Maréchal, Ladouche, & Dörfliger, 2008). Interestingly, some recent works focus on the impact that geomorphological processes, namely floods, slope processes, ground deformation and collapses, may have on newly emerging urban and suburban areas of eastern and southeastern European cities (Stecchi, Mancini, Ceppi, & Gabbianelli, 2012; Papadopoulou-Vryniotia, Bathrellos, Skilodimoua, Kavirisb, & Makropoulos, 2013).

In the case of Sarajevo (Bosnia and Herzegovina, BiH hereinafter), historically, its particular geographical setting has maintained a central role in the spatial distribution of its population, with the existence of residential areas exposed to potential geomorphological hazards. More recently, and despite efforts to align Sarajevo with European regulations for urban sustainability, the built environment of the city has moved in an increasingly unsustainable direction as a result of the post-war and post-socialist urban processes, with a rise in urban areas potentially affected by some critical geomorphological hazards, i.e. landslides and flooding. Both post-war and post-socialist urban

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processes have respectively encouraged the construction of housing on steep slopes and the development of major new urban projects in the most floodable areas of the city (Martín-Díaz, Nofre, Oliva, & Palma, 2015). These potential urban problems become especially relevant during the current process of updating local urban planning tools, initially up until the year 2015, such as the Sarajevo Urban Plan and the Sarajevo Canton Development Strategy. No less important, the increasing environmental unsustainability of some of these urban areas was highlighted following the massive and fatal floods that occurred between 14 and 16 May 2014, when approximately 3000 landslides were recorded in the whole country, 27 people perished and 100,000 buildings were destroyed or damaged (Agencies, 2014; Jukić, 2014).

This paper historically analyses the urbanisation process that occurred on the slopes in the central areas of Sarajevo and pays special attention to the constructions developed during the last 15 years. One of the main objectives of this work is to examine the factors leading up to urbanisation during the post-war period, particularly in areas where geomorphological hazards were higher, as suggested by recent geomorphic events. Furthermore, we quantify the urbanisation process that occurred between the periods 1987–2003 and 2003–2015 by examining the evolution of five selected study areas.[1] These areas (Pofalići-Dolac, Pofalići-Velešići, Soukbunar, Širokača and Alifakovac-Bistrik-Hrid) are representative of the urbanisation process that has taken place in the city during the aforementioned study period and include landslide zones. Through GIS-based spatial analysis, we measure the extent of the recent urbanisation on the slopes and examine to what extent these areas may be affected by various potential geomorphological hazards. Finally, this paper concludes by discussing the necessity of an efficient environmental approach in the new urban planning of the city.

2. Methodology

Fieldwork in Sarajevo was conducted between 2008 and 2015 to analyse both post-war and post-socialist urban transformations in the capital of BiH. The multi-method approach developed in this paper includes 19 semi-guided interviews between local and international actors to obtain primary information relating to the spatial changes that occurred during the post-war period. The purpose of these interviews was to attempt to understand the political, social and economic factors that have influenced the historical process of suburbanisation on the slopes and, more particularly, the internationally led policy of housing repossession, which was implemented during the post-war period. The technicians and representatives consulted were those who worked on urban planning and development in the relevant local and international organisations, mainly from the Development Planning Institute of the Sarajevo Canton, the City Council and the Office of the High Representative (OHR), and were responsible for overseeing and implementing the civilian issues of the peace agreement.

Second, any areas susceptible to being affected by landslide activity were identified and mapped,[2] thereby creating a georeferenced photographic archive to support the research. Third, the temporal analysis of the urbanisation process during the post-war period was processed through a system known as Geographic Information Systems (ArcGIS 10) in order to identify, quantify and examine the construction of housing on Sarajevo's slopes. Yet, there were a number of issues with this system. A multispectral satellite imagery of high resolution was not available, making it impossible to perform an accurate classification based on spectral pattern recognition. In this regard, an alternative approach implementing photo-interpretation techniques was applied over satellite images.[3] This enabled the identification of urban land use and permitted an examination and assessment of the evolution of the urbanisation process during the post-war period, i.e. between 2003 and 2015. Data regarding the year 1987 were gathered in a collection from Urbanism and Spatial Planning Chair.[4] As a result of the political and economic crisis in the late 1980s and the subsequent siege, we assume that most of the new constructions between 1987 and 2003 can be attributed to the post-war period, despite acknowledging the existence of an unknown number of post-1987 constructions.

Such an approach allowed the definition of the five study areas that encompass a land total of 7.3 km^2 out of the 141 km^2 occupied by the city of Sarajevo. All of these areas are located in three central municipalities of Sarajevo, i.e. Stari Grad, Centar and Novo Sarajevo. According to the Spatial Plan (Kanton Sarajevo, 2003), these areas include active and passive landslide zones with significant levels of urbanisation, either historically or in more recent times. Although the highest number of recorded landslides between 2000 and January 2016 is registered in the Vogošća municipality, with a total of 213 out of 855, this number is not analysed in the current paper as the suburban character of this municipality implied that its slopes did not receive, to the same extent, the level of post-war urbanisation analysed in this paper.

The elevation data we used to extract the slopes was the model of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).[5] Both *ArcGIS Spatial Analyst Tools* and *3D Analyst Tools* were used along with the DEM provided by ASTER to create a slope surface. This surface was later reclassified according to the slope values, arising from land management regulations, effectively used to prevent constructions.[6] On the basis of the criteria that construction is restricted in areas with slopes above 30%, three slope intervals were used: 0%–15%, 15%–30% and > 30%. Essentially, the outcome of this research helps us to assess those urban areas on the slopes that were constructed in unsuitable zones.

3. Historical background of the urbanisation and housing construction up to the early 1990s

The geographical and environmental setting of Sarajevo has had a central role in the current distribution of the population in the city. Today, the Canton of Sarajevo encompasses a total population of 413,593 inhabitants (FZS, 2013) in a total land surface of 1276 km^2. This means that the population density in the capital of BiH is 324.13 inhabitants per square kilometre, with the highest rates distributed along the Miljacka River plain and on the lower slopes surrounding the central areas of the city. Indeed, housing developments on these slopes have historically been

[1] Although the focus of this paper is the analysis of housing construction during the post-war period, there are no data available in the aftermath of the war; therefore, the first period includes the years before the war, which occurred between 1992 and 1995.

[2] Geomorphic field evidence observed on the slopes in the central part of Sarajevo between February 2015 and July 2015.

[3] This process was performed using images from 2003 (Google Earth, historical imagery – 2003) and 2015 (ESRI world imagery: CNES/Airbus Ds – Pléiades Satellite, resolution of 0.5 m).

[4] This collection was generously provided by the Faculty of Architecture of the University of Sarajevo. Although the focus of this paper is on the analysis of housing construction during the post-war period, there is no data available in the aftermath of war.

[5] Previously used in various scientific works, particularly in the field of geomorphology (Bolch, Kamp, & Olsenholler, 2005; Kääb et al., 2003; Kamp, Bolch, & Olsenholler, 2005).

[6] Slope categories for construction suitability are not standardised in the entirety of BiH. Bognar's proposal (Bognar, 1990, 1992) is often used in the country. It includes six categories of inclination with respect to suitability for construction: from very convenient for the construction to unsuitable (> 64%). In mountain areas, however, the limit for construction land is often set at 45%. In these cases, the interval 30%–45% is for construction land, but it is only used in specific situations, depending on seismic, geomechanic and infrastructure limitations and spatial capacities for urbanisation. Having consulted the situation in other countries and regions, in Catalonia (Spain), it is prohibited to construct in areas with slopes above 20% or in Pennsylvania state (USA) where steeper areas than 25% are only used for open space and certain recreational uses (Lehigh Valley Planning Commission, 2008), while in other districts of the same state, the value is 30%. This level also represents a restriction on urban development in some districts of Canada. The most frequent values range between 20% and 30%, yet we decided to adopt the less restrictive one in this paper.