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FLOOD FATALITIES IN ATHENS, GREECE: 1880-2010

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Abstract

Flood-related deaths in urban environments constitute a major issue in flood risk management especially during the last decades, as global urban population grows larger. This work focuses on the analysis of flood-related fatalities in Athens metropolitan area, in Greece between 1880 and 2010. To this aim, a database is compiled, recording spatial and temporal distribution of fatal flood incidents, along with demographic information on the victims. GIS is used to map and spatially analyze the incidents in question and to examine possible migration trends. Results showed a total of 182 fatalities across Athens basin, presenting a decreasing trend, even though flood event numbers are rising. Males, youngsters and elderly people showed an overrepresentation amongst the victims in comparison with the country's general population. Fatal incidents presented a higher spatial density in the central and southwestern parts of the city indicating a higher persistence of flood phenomena in these areas. A gradual migration of fatality locations, from the central parts of the city, towards the outer suburbs during the study period was identified following the city's spatial expansion.
Key words: *Flood deaths, Flood mortality, Hazard, Spatial analysis, Flood migration.*

Περίληψη

Η επίπτωση των αστικών πλημμυρών σε ανθρώπινες ζωές είναι ένα από τα σημαντικότερα ζητήματα στην αντιμετώπιση του πλημμυρικού κινδύνου. Η παρούσα μελέτη εστιάζει στην ανάλυση των θανάτων από πλημμύρες στην περιοχή του Λεκανοπεδίου Αθηνών μεταξύ 1880 και 2010. Για το σκοπό αυτό, αναπτύσσεται μια βάση δεδομένων, σε περιβάλλον GIS, με αναλυτικά στοιχεία για τη χωρική και χρονική τοποθέτηση των συγκεκριμένων συμβάντων και δημογραφικές πληροφορίες για τα θύματα. Τα αποτελέσματα της ανάλυσης δείχνουν μια σταδιακή μείωση των θυμάτων, μολονότι τα πλημμυρικά φαινόμενα γίνονται ολοένα και πιο συχνά. Παράλληλα, προκύπτει υπερεκπροσώπηση των ανδρών, των νέων και των ηλικιωμένων ατόμων ανάμεσα στα θύματα. Η μεγαλύτερη συγκέντρωση θανάτων εμφανίζεται στα κεντρικά και δυτικά τμήματα του λεκανοπεδίου, ενώ παρατηρείται σταδιακή μετατόπιση των θέσεων θανατηφόρων συμβάντων από τα κεντρικά προς τα περιφερειακά τμήματα της πόλης, γεγονός που σχετίζεται με την παράλληλη επέκταση του αστικού ιστού και των ανθρώπινων δραστηριοτήτων στις περιοχές αυτές κατά την περίοδο μελέτης.
Λέξεις κλειδιά: *Θάνατοι, Πλημμύρες, Αθήνα, Επικινδυνότητα, Χωρική ανάλυση.*

1. Introduction

Floods are often cited as one of the most destructive and most lethal natural hazards, recording extensive economic (Barrero 2007; Barrero 2009) and life losses (Kundzewicz and Kundzewicz 2005; Jonkman 2005) worldwide. In Europe, increased population density and enhanced socioeconomic activities lead occasionally to the expansion of urban population into areas of elevated flood hazard. The region shows an abundance of flood phenomena (Llasat et al. 2010b) clustering in several occasions in urban areas (Barrera et al. 2006; Llasat et al. 2010a). Athens metropolitan area, in Greece, is no exception to this regime. The city has experienced too, several catastrophic events during the last century inducing a significant number of damages and fatalities (Nikolaidou and Hatzichristou 1995; Diakakis et al. 2012).

Athens, which is the largest urban area in Greece, is situated in the region of Attica, and is built in a morphologic basin that occupies an area of approximately 534 km^2 between Penteli, Parnitha, Ymitos and Aigaleo mountains and Saronikos Gulf in the south (Figure 1). During the last century, it has been a rapidly evolving urban centre, both in terms of population and spatial extension, leading to a gradual urbanization of a significant part of the basin (Evelpidou et al. 2009; Skilodimou et al. 2003; Papazoi et al. 2010; Baltas and Mimikou 2002). Nowadays, approximately 68% of the basin is occupied by urban expanses that are host to about 4 million people (ELSTAT 2001). The basin, in terms of morphology, is shaped primarily by Kifissos and Ilissos river networks. The area is mostly dry (Mimikou et al. 2002) with a mean annual rainfall of approximately 390mm (Koutsoyiannis and Baloutsos 2000) and a poorly developed river network dominated by streams, with small amounts of water for most of the year. The increased density of population, has led to the development of human activities and infrastructure in the vicinity of these ephemeral watercourses, in many cases in areas of elevated flood hazard, not suitable for building.

Due to the lack of instrumental data on river discharges, a large portion of information on local flooding history was until recently recorded in an anecdotal form (Diakakis 2010, Diakakis et al. 2011). Evidence of past flood events presented an increased level of fragmentation, which hampered the evaluation of the flooding problem as a whole. However, recent scientific work illustrated the severity of the problem by recording certain catastrophic events. Mimikou et al. (2002) and Evelpidou et al. (2009) stress the significance of high-intensity storm in flash flood triggering in the area. Mimikou et al. (2002), Baltas and Mimikou (2002), Alexoudi-Livaditi et al. (2007) and Papazoi et al. (2010) suggest that anthropogenic factors play a crucial role in flood generation in the area and that the rapid development of the city took place without implementing an appropriate plan of drainage works that would help the river network accommodate flood flows. In fact, several parts of the drainage network were shrunk or converted into streets and critical river cross sections were diminished (Baltas and Mimikou 2002). Skilodimou et al. (2003) study a flood in November 1993 in the south suburbs of the city and suggest too, that urbanization of the area is one of the most important factors in flood generation. Mazi and Koussis (2006) analyse the flood of July 2002 in the lower part of Kifissos River and conclude that human intervention to hydrologic processes was very critical in flood genesis.

Although several authors analyze flood hazard in Athens (Lekkas et al. 1997; Parharidis et al. 2000; Diakakis et al. 2011; Kandilioti and Makropoulos 2012), there is limited research regarding flood-related fatalities in the area. Nikolaidou and Hatzichristou (1995) developed a catalogue of flood events in Athens area between 1887 and 1994 identifying 29 fatal flood events that induced several fatalities across Athens basin. This catalogue was later adopted by Mimikou and Koutsoyiannis (1995) and Baltas and Mimikou (2002). Diakakis et al. (2011) studied the flooding history of western Athens recording 76 fatalities in 4 flood incidents and 10 more non-fatal events in this part of the city. Despite the existence of catalogues enlisting associated deaths, there are no works studying all the recorded fatalities in terms of their spatial distribution and the circumstances under which they occurred.

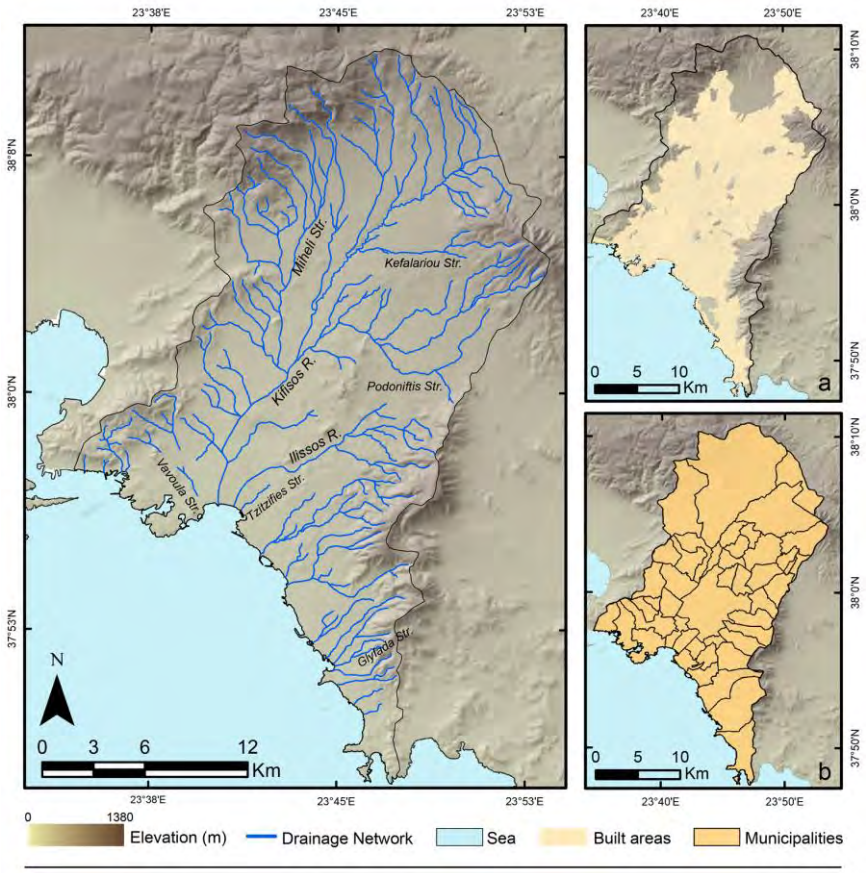

Figure 1 - Map of Athens basin showing the river network, the built areas (a) and the municipality administrative limits.

In this field, the literature discusses a number of different short and long-term consequences of floods to human health (Alderman et al. 2012). Several studies in different parts of the world analyse mortality attributed to flood disasters, focusing on the factors that affect vulnerability of individuals (Jonkman and Kelman 2005). Such factors include the victims' age (Coates 1999; Ashley and Ashley 2008; FitzGerald et al. 2010), their gender (Coates 1999; French et al. 1983, Rappaport 2000; Jonkman and Kelman 2005), their activity at the time of the flood (Staes et al. 1994; Rappaport 2000; Ashley and Ashley 2008) and several other parameters (Jonkman and Kelman 2005).

2. Materials and Methods

2.1. Data

Primary data on flood events were based on the flood database developed by Diakakis et al. (2012) for the Greek territory and for the period between 1880 and 2010. This catalogue contained data on the date and the number of fatalities that occurred during each flood along with a vague determination of their location. This inventory was used as the basic record upon which additional information was aggregated. Detailed scientific reports (Nikolaidou and Hatzichristou 1995; Mimikou and Koutsoyiannis 1995; Mimikou et al. 2002; Baltas and Mimikou 2002; Skilodimou et al. 2003; Evelpidou et al. 2009; Diakakis et al. 2011) and press articles were used to identify the exact location of each fatality and the age and gender of each victim. In total, 135 press reports were ana-

lysed, published in several issues of 13 national newspapers recovered from the Digital Newspaper Collection (2010) of the Greek National Library and the Greek National Newspapers Archive (2010) of the Library of the Hellenic Parliament.

2.2. Submission Steps

A systematic database was developed to link primary information deriving from the Flood Database of Diakakis et al. (2012) with information on location and demographic details of each victim. Each entry of the database, corresponding to one fatality, consisted of several variables that provided detailed information on each incident, recovered from the sources described above. An identical database was developed in a GIS environment, with the aid of which location of each fatality was plotted on the map. Following this step, an 800m X 800m grid was developed across the study area. Based on this grid, the number of fatalities in each cell was calculated, as a mean to illustrate the spatial distribution of fatalities across the study area and identify the locations with the higher concentration. The number of fatalities in the different administrative divisions (municipalities) of Athens Metropolitan area was calculated too. Calculation in both cases was carried out with the aid of ArcMap software (ESRI 2011).

Afterwards, the study period was divided in 13 decadal segments in order to examine the temporal evolution of fatalities. In addition, fatality locations were investigated in terms of changes in their spatial distribution in different parts of the study period. Finally, demographic details of the victims were analyzed and compared to the demographic distribution of the country's general population using simple mathematical operations.

2.3. Data Treatment and Uncertainties

In general, location information presented an overall good quality in all selected sources, mainly due to the stationarity of most city features, road network and landmarks during the study period. Regarding their spatial accuracy, it should be noted that in general the nature of data, allowed identification of location (through exact address or identified landmark) with a margin of error not more than 20m. However, one source of uncertainty was associated with the non-scientific nature of part of the data. Although press databases have been used before as data sources in the study of natural hazards (Llasat et al. 2009), to deal with the possibility of subjectivity, the variables selected to describe fatalities were specifically chosen in a way that they would not be subject to the reporter's opinion. In addition, to assure an accurate determination of the locations of fatalities, spatial data were cross-checked in two independent sources. With regard to the completeness of the catalogue, it should be noted that the record is considered complete given the continuous presence of human population in the area and the examination of multiple sources.

Finally, it should be noted that due to unavailability of data regarding the demographics of the country throughout the study period, comparison of the victims' age and gender details with these of the general population, was carried out using the 2001 census (ELSTAT 2001), and should be therefore considered with caution.

3. Results and Discussion

3.1. Inventory of Flood Events and Associated Fatalities

Analysis showed that Athens metropolitan area has suffered 52 major flooding events, 19 of which induced 182 fatalities between 1880 and 2010 (Table 1). The most lethal event occurred in 1896, inducing 62 deaths, followed by the November 1977 event (36 fatalities) and the November 1961 event (33 deaths). Sixteen other flood incidents were identified inducing 1 to 13 fatalities Thirty-three other flood events have taken place in the study area in 1886, 1901, 1906, 1928, 1930, 1934, 1936, 1939, 1949, 1950, 1952, 1955, 1965, 1972, 1978, 1980, 1981, 1986, 1987, 1988, 1993, 1997, 1998, 2002, 2004 and 2005 inducing no fatalities.

Regarding the activity of the victims at the time of each incident, for the 112 instances where this detail was known, it was found that outdoor activities (such as walking, evacuating and driving) accounted for 35.7% (40 cases). Amongst these, 18 cases, all of which occurred after 1960, were vehicle-related. In the rest 72 cases (50 before 1960 and 22 after this year) the victims passed away indoors.

Table 1 - Catalogue of fatal flood events in Athens between 1880 and 2010, their locations across the study area and the number of fatalities that they induced.

Date	Locations in summary	Deaths	Date	Locations in summary	Deaths
05-11-1896	City centre	1	14-10-1955	Tzitzifies, Chalandri	2
14-11-1896	Piraeus, Moschato	62	06-11-1961	Peristeri, Ilion	33
05-11-1899	Piraeus, City centre	7	02-11-1977	Ilion, Peristeri	36
23-11-1925	Nea Ionia, Fahlero	13	10-12-1977	Chalandri, Nea Ionia	3
22-02-1930	City centre	1	30-5-1979	Argiroupoli, Glyfada	1
27-10-1930	City centre, Fahlero	2	15-1-1991	Ilioupoli, Alimos	1
02-12-1933	City centre, Fahlero	2	31-1-1994	A. Liosia, Acharnes	2
22-11-1934	Nea Ionia, Fahlero	7	21-10-1994	Nea Ionia, Glyfada	5
05-11-1936	Kallithea, Moschato	2	08-7-2002	Moschato	1
30-09-1951	Petroupoli, Nikaia	1			

3.2. Temporal Evolution

Although significant variations were observed, results showed that fatalities present an overall decreasing trend during the study period. In the last 30 years only 9 deaths were identified (significantly less than the previous period), even though flood events are recording a noteworthy increase in the same time segment. Given the fact that the majority of deaths occurred indoors, and that the indoor deaths are showing a decline after 1960, the overall reduction of fatalities is attributed partly to the gradual improvement of buildings in terms of structural endurance. The decline may be connected also with improved education and awareness of the general public regarding natural disaster hazards.

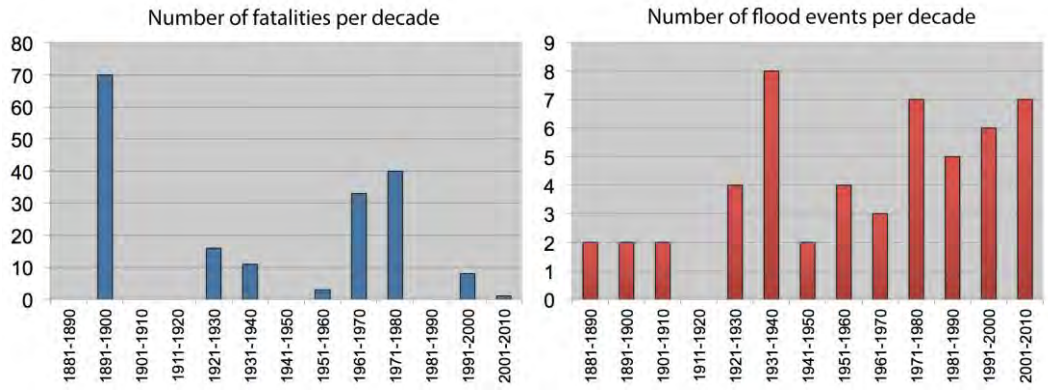

Figure 2 - Number of fatalities per decade showing a slight decreasing trend (left), despite the noteworthy increase of flood events in the same period (right).

3.3. Seasonal Distribution

Regarding their seasonal distribution, it was shown that autumn presents the vast majority of fatalities (94%) followed by winter (4.9%), summer (0.5%) and spring (0.5%). November was found to be the month presenting most deaths, as all three most-lethal floods occurred during this period. Although these results are not in disagreement with previous works findings (Diakakis et al. 2012), it appears that flood-related fatalities present stronger seasonality than flood events, which show a smaller autumn percentage. This fact is attributed probably to a difference in intensity of flooding between the seasons. However, a future revision of this distribution with a greater sample would improve the reliability of this analysis.

3.4. Demographic Analysis

Regarding the age of the victims, analysis shows an overrepresentation of youngsters (younger than 15 years old) and elderly people (older than 75 years old) in comparison with the general population (Figure 3). This result is in accordance with the conclusions of Chowdhurry et al. (1993), Rappaport (2000), Pradhan et al. (2007) and Ashley and Ashley (2008) who suggest that there is an increased vulnerability amongst the young and the elders, attributed to their physical inability to flee and occasionally to the propensity for risk-taking amongst the youngsters (Coates 1999; Ashley and Ashley 2008; FitzGerald et al. 2010). In 22.4% of the cases the age of the victims was not reported.

Regarding the gender of the victims, it was found that the majority of victims were males (51.1% of cases) whereas females showed an underrepresentation (40.7%) in accordance with the literature findings (French et al., 1983, Coates 1999). In 8.2% of cases the gender of the victim was not reported.

3.5. Spatial Analysis

Projection of fatality locations on the map of the study area shows a clustering of deaths in the central and western parts of the city near Piraeus and along the course of Kifissos River (Figure 4). Northern, eastern and southern suburbs present a very limited amount of casualties. This fact is attributed partly to the shorter history of these parts of the city and partly to the reduced density of buildings and urban fabric and the higher percentage of open spaces, leaving more space for drainage in these suburbs.

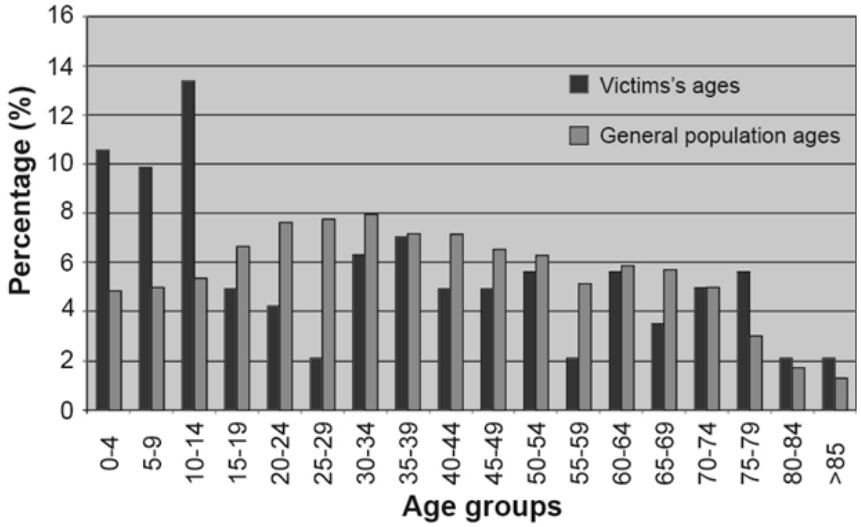

Figure 3 – Age distribution of flood fatalities (1880-2010) in comparison with the country's population in 2001 (ELSTAT 2001).

However, projection of incident locations in specific periods shows that, their distribution changes over time, presenting a gradually increasing dispersion (Figure 5). Comparison with the city's development shows that fatalities migrate towards the newly developed areas. In certain time segments when the city's development or population presents significant shifts or changes, fatality locations follow the same spatial pattern. In particular, between 1880 and 1920 when the city is very limited in space, fatality locations present a significant clustering. After 1920, when the city experiences a sudden population increase, fatalities too show a higher dispersion following the city's spatial expansion. In addition, flood deaths show a significant shift and an increased clustering in the western suburbs between 1945 and 1980, when this part of the city experienced a development boost. Finally, after 1980 when the city is developed across the whole basin, fatalities although much fewer seem to disperse across the whole area.

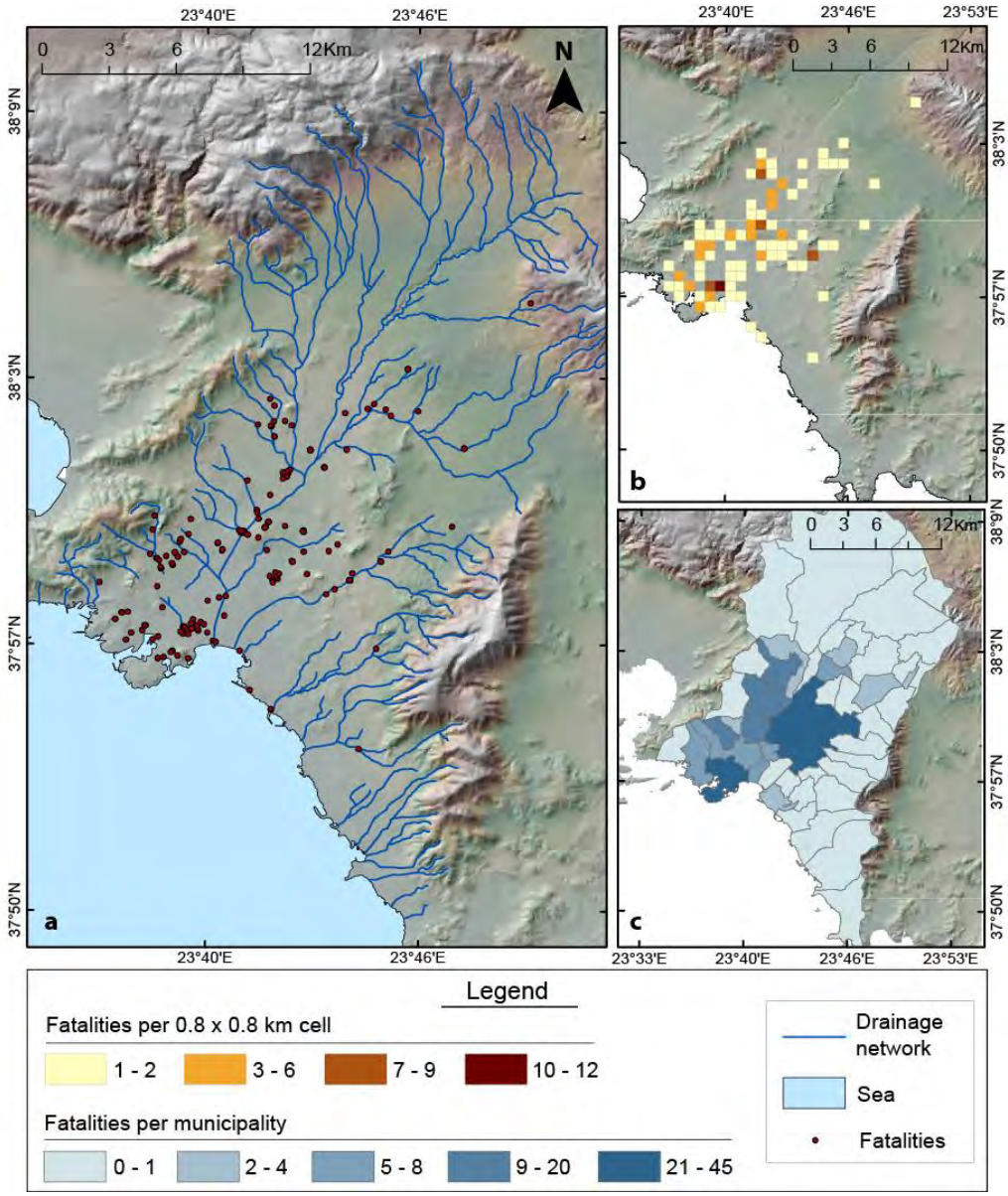

Figure 4 – (a) Locations of flood fatalities across Athens basin between 1880-2010, (b) number of fatalities on a 0.8 Km X 0.8 Km grid and (c) the number of fatalities per municipality.

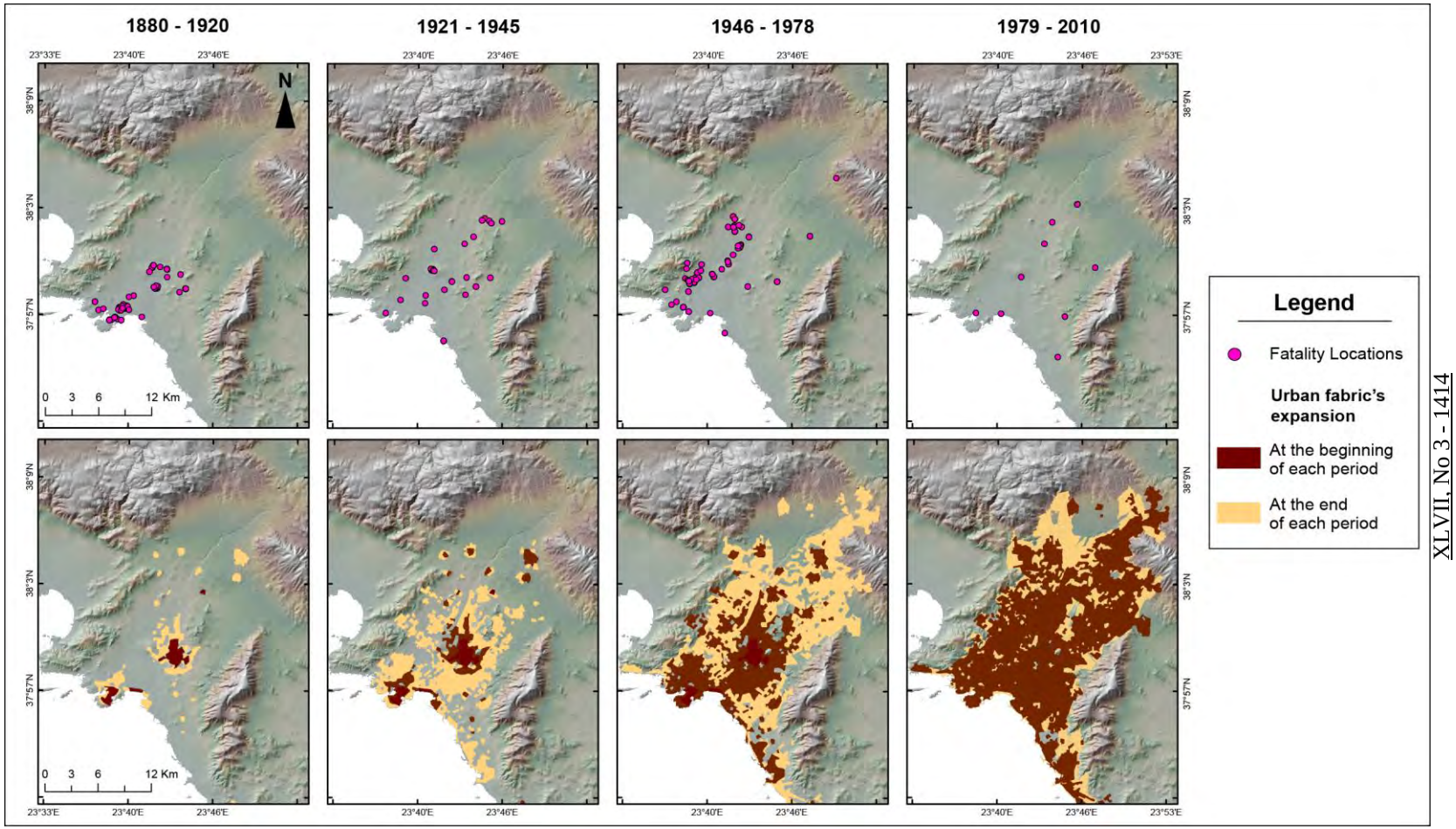

Figure 5 - Gradual migration of flood fatalities in 4 periods associated with the expansion of the city (EKKE 2000, Leontidou 2001, Avdelidi 2010) during the same time segments.

4. Conclusions

The study develops and analyzes a database of flood-related fatalities in Athens, Greece, between 1880 and 2010, identifying a total of 182 fatalities associated with flooding in the area. The record proves to be a useful tool for studying vulnerability of individuals and can be used as the basis for future research in flood risk mitigation. Flood mortality in the study area was found to present strong seasonality and a declining trend, more obvious during the last 30 years, even though flood events in the area are becoming gradually more frequent. Males, youngsters and elderly people show an overrepresentation amongst the victims. Spatial distribution of fatalities shows an increased clustering of deaths in the central and western parts of the metropolitan area, although their locations present a gradual migration, following the city's newly developed expansions throughout the study period.

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