Towards a modified urban resilience model for archaeologists

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1. Introduction

Natural hazards have always been part of human life and experience (Mauch and Pfister 2009; Riede 2015; Riede and Sheets, 2020; Schenk 2015). In the past decades, these have been the object of studies that aimed at analysing their impacts to social systems, the changes they caused, as well as the strategies to implement for reducing future risks (Cutter 1996; Drabek 2012; Oliver-Smith 1986; White 1974). Such works have not only considered contemporary examples; in fact, disaster research have been fruitfully applied to past contexts in which natural hazards, such as earthquakes and volcanic eruptions, have altered, accelerated, or caused wide-ranging socio-cultural changes (Chester et al. 2015; Sangster et al. 2015; Sheets 1980; Torrence and Grattan 2002). However, compared to contemporary contexts, this subject has only seldom been studied in specific urban archaeological contexts where whole sites are considered (e.g. Borsekova and Nijkamp 2019; Chelleri 2012; Pelling 2003; Shamsuddin 2020). Hence, there is an urgent need to investigate how towns in the past reacted to natural hazards; inasmuch past experiences hold information about vulnerability and resilient behaviours that are relevant for modern disaster risk reduction policies (Riede 2017; Schenk 2015).

In this paper, I present a preliminary modified urban resilience model, which acts as a theoretical framework and methodological tool useful to those archaeologists focusing on hazard-affected urban contexts in complex societies. Previous works have mainly focused on specific structures of the built environment, such as religious buildings, or on partial sectors of cities; instead, this model seeks to account for the complexity of city systems in the evaluation of post-hazards functioning (e.g. Godschalk 2003; Meerow and

Newell 2019; Schiappacasse 2018). After discussing how the term 'resilience' have become central in much contemporary debate on natural disasters and their effects on societies, I will explore the beneficial consequences to adopt a historical perspective in order to highlight how vulnerable cultural practices of the past might shed light on likewise vulnerable practices of the present. Finally, I will show how the modified urban resilience model can be used to analyse the effects of an earthquake disaster by considering the case study of the earthquake that hit in the Levant in 749 CE.

1.1. Resilience within the framework of social-ecological systems

More than a decade ago, Schenk (2007) pointed out that in the current research on natural hazards and disasters, scholars have reached no conscience about what those terms cover (see also Quarantelli 1985, 1995). On the one hand, hazards are considered as climatological, geophysical, and metrological natural phenomena that occur because of Earth's natural mechanisms. On the other, such events are considered as hazards only when they affect human societies (Oliver-Smith and Hoffman 1999). In order to avoid confusion, in this context, natural hazards are understood as events of great calamity that appear suddenly, without warning, and that can have significant destructive effects on the natural and human environment both in the short- and long-term perspectives.

To investigate societies that have faced harmful environmental hazards, the concept of 'resilience' has proven extremely popular (Cutter 2016; Bankoff 2018; Riede 2015; see Adger 2000 for a coupled social-ecological resilience perspective) and useful when setting out to analyse the complex socio-ecological nexus (see Forlin and Gerrard 2017; Mordechai and Pickett 2018 especially for earthquakes; Mordechai 2019 for a case study on Beirut). The concept of resilience has a long research tradition, and several scholars have sought to identify its disciplinary roots and to chart its quite far-ranging definitions (e.g. Lorenz 2013; Miller et al. 2010; Walker and Cooper 2011). Influenced by its original ecological conceptualisation (Holling 1973), resilience is defined as "the capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions" (Resilience Alliance 2020;

see also Cote and Nightingale 2012; Holling and Gunderson 2002). With this definition, the Resilience Alliance presents a central concept in much modern resilience thinking, that of the social-ecological system (SES). An SES is a heuristic analytical concept that embeds the dialectic relationship between human and natural systems, which has the ability to bounce back or maintain critical system functions (Berkes and Folke 1998; Colding and Barthel 2019). From this perspective, social and ecological systems cannot be studied in isolation, as human systems are components of ecological systems and vice versa.

However, contradictions arise when resilience and SES are framed within disaster mitigation policies, in which post-disaster rebuilding efforts seek to return to pre-disaster equilibrium states (Alexander 2000; Mercer et al. 2012). While such equilibrium states may exist in some ecological domains, in fact, the conservative conceptualisation of resilience seems to fit poorly to social systems because, as Barrios (2016) explains, social systems are never stable but always changing due to both external and internal dynamics and engagements. In other words, in the period following a disaster, societies are rarely identical to their pre-disaster characteristics. Therefore, identifying complex and historically grounded causal processes and their consequences on an SES is essential to fully understand the adaptive mechanisms of a community (Garcia-Acosta 2002; Hewitt 1997; Oliver-Smith 2002). For instance, Bankoff (2003) interpreted this 'culture of disaster' to describe the specific ways societies experienced and dealt with frequent environmental hazards, concluding that perceptions of natural hazards were historically and culturally built (Bankoff 2003: 152-183). In his work on the Philippines, he was able to show how communities affected by multiple hazards found ways of understanding these stressors by adapting preventive and mitigating measures into their daily practices (Bankoff 2009). Oliver-Smith (2002: 25) deems this view as the 'multi-dimensionality of disaster', which we must comprehend when investigating the role of environmental disasters as possible triggers of change in an SES (see also Riede 2014 and Schenk 2017).

2. Lines of enquiry of past earthquakes

To understand how past earthquakes affected people and places, scholars have made use of four main lines of evidence, each providing different pieces to the puzzle of disaster studies (Mordechai 2018; Rucker and Niemi 2010): historical texts, epigraphy, archaeology, and geology. Within this framework, for instance, written historical sources have been utilised to create a range of essential earthquake catalogues covering several regions of the world (Ambraseys 1971, 2009; Ambraseys and Melville 1982; Guidoboni 1994; Guidoboni and Comastri 2005), whereas geology have classified stratigraphic markers of earthquakes in archaeological contexts (Hough 2017).

Alternatively, past historiographers and chroniclers give us vivid descriptions of earthquake effects, often providing the date of the events described. However, these accounts must be treated carefully. For instance, they may tend to overemphasise certain events' destructiveness or even amalgamate different earthquake events into a major one (Ambraseys 2005). In addition, authors may even have written their accounts at long distances, either physically or temporally, so that their reference might be distorted from reality (see Guidoboni and Ebel 2009 for a detailed discussion; and Rucker and Niemi 2010 for the challenge of circular reasoning). Still, if accessed with proper caution, historical accounts do offer us great insights (see Zohar et al. 2016 for a recent reassessment of earthquake catalogues covering Israel and adjacent areas).

In addition, archaeoseismology investigates earthquake damage as it is shown in archaeological sites (Sintubin 2015). Because it adds data that support hypotheses about natural causes for destructions at archaeological sites (Stiros 1996), it is considered a contributory field within environmental archaeology and history (Galadini et al. 2006). As it happens with modern geological studies, many ambiguities exist within archaeoseismology, such as distinguishing between individual earthquake events or differentiating between anthropogenic, structural, or earthquake-inflicted hazards to the built environment (see Sintubin and Stewart 2008 for further discussions of ambiguities; Rodríguez-Pascua et al. 2011 for classification of typical earthquake damages to the built environment of the past). However, by combining different investigations techniques, such as remote sensing, archaeoseismology, surface geology, and structural data, multidisciplinary efforts have proven very successful and have widened our understanding of individual buildings and site-wide earthquake destruction horizons (e.g. Jusseret et al. 2013; Similox-Tohon et al. 2005; Sintubin et al. 2010; Yerli et al. 2011). Overall, it is challenging to combine various disciplinary stances as to ancient earthquake events into a coherent synthesis. Mordechai and Pickett (2018) observed how the drawbacks mentioned above have pushed researchers into pursuing qualitative assessments of earthquake hazards. They embrace Sintubin's (2010) call for a role of archaeoseismology leaning more on the ability to examine distinct earthquake sequences, which likely allows inferences about how they affected people and places rather than to contribute significantly to understanding active tectonics (see Stiros 1988 for early suggestions for the usefulness of archaeology in this respect).

Finally, despite inherent shortcomings, such as accurately dating occupational layers, archaeology is well suited to study potential links between affected social-ecological systems and post-disaster change because of the long-time frames available for investigation (Riede 2014; Torrence and Grattan 2002). Furthermore, archaeological research allows examination of causal routes from previous conditions to post-event characteristics (Riede and Sheets 2020). While some practices and cultural traits persist in periods following a disaster, others may change or vanish. However, even simple monocausal relationships between single or multiple environmental stressors and cultural change of highly complex societies are difficult to identify, and because various factors may be at play, caution is warranted (Riede 2018; Rigby 2015). Yet, by combining multiple source materials, such as paleoenvironmental proxies and written accounts to the material record, constructive interpretations can be possible.

3. Developing a modified urban resilience model

The four lines of enquiry for past earthquakes are supported by recent developments within the discipline of human geography. In this discipline, resilience has only recently been conceptualised within a specific urban context. In their work, Meerow and colleagues (2016) have reviewed the existing definitions of urban resilience, defining it as "the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity" (Meerow et al. 2016: 39). This definition is as overarching as the Resilience Alliance's one, and it emphasises the transformative capacities of cities in the aftermath of a disaster. However, it leaves us with the challenge of defining what constitutes a city.

Earlier, the Resilience Alliance (2007) published a schematic model that conceptualised four overall domains constituting a typical modern urban fabric: metabolic flows, governance networks, social dynamics, and the built environment. The domain of metabolic flows is understood as the overall consumption of the urban system, which includes flows of energy, material goods, and non-material services. The fundamental premise here is that all urban inhabitants are dependent on their immediate and far-away productivity of ecosystems to sustain life and wellbeing (Decker et al. 2000; Folke et al. 1997). The Resilience Alliance's primary concern with this domain was to understand how crucial the dependency between production, supply, and consumption chains is. Central pursuits are to chart how some form of interference from natural hazards affects their abilities to function effectively (Resilience Alliance 2007). In contrast, the governmental domain embodies institutions and organizations or 'seats of power' (Resilience Alliance 2007), which to some degree have an influence on urban services such as water supply, law enforcement, health care, education, and general wellbeing. Questions about which governmental components influence the resilience of urban systems are important. In addition, the cultural/social domain engages with the social build-up of cities. Here, primary interests are demography and human capital. In this domain, the variety of individuals and communities within cities are described, and subsequent analysis charts the behaviours of these (Resilience Alliance 2007). Finally, the domain of infrastructure or built environment consists of the spatial organisation of an urban context. The locations of roads, electricity, heat production facilities, railways, ports, and so on influence goods and people's movements and provide possibilities for attracting specific industries and thereby employment to cities (Resilience Alliance 2007). Understanding the patterns of cities, the role of infrastructures, and how these are in danger of being disrupted by natural hazards are often highlighted.

With these four domains and by highlighting their interdependencies, the Resilience Alliance moved towards a holistic conceptualisation of an urban context. Understanding this urban complexity is crucial to recognise resilience, or the lack of it, in urban contexts (Chelleri et al. 2015). In addition, these domains provide the basis for a reflexive discussion of what is understood as belonging to the 'urban' in urban resilience debates. While it is rarely possible to fully account for all those four domains in past urban contexts, the challenge is to convert the model to fit the cultural environment under scrutiny and to identify archaeologically definable proxies. Figure 1 shows a modified version of the Resilience Alliance model, which addresses archaeological proxies for urban resilience. In this case, the governance domain is converted into two categories, religious and governance structures. Metabolic flows, urban infrastructure, and form are converted into infrastructure, while some aspects of the socio-economic domain are converted into civic institutions/public spaces. Lastly, the socio-economic and cultural dynamics sections are converted into housing.

4. Methodology

Based on the modified urban resilience model, I propose the following methodology when working with earthquake hazard assessment of towns and hinterlands in archaeological context (fig. 2). The methodology is developed to rely on already published materials and does not require additional fieldwork. It enables archaeologists to move beyond deterministic reasoning when analysing the effects of natural hazards, and earthquakes specifically, on urban sites and their related communities. The fundamental idea here is not to present a qualitative assessment of the development of towns and their domains, but to show how these domains fluctuate and to hint at which urban resilience domains were prioritised over time. Creating this overview provides an opportunity to hypothesise how and why urban contexts became vulnerable or resilient to earthquake hazards.

However, applying this methodology has certain drawbacks. First, the bias of data resolution may hamper the ability to compare specific domains. For instance, some towns have been excavated over long periods and with specific goals in mind, such as exposing the monumental centres while neglecting domestic quarters and exploring hinterland synergies. Therefore, reaching a holistic point where all urban resilience domains are relatively well-represented is difficult. Alternatively, the chronology of specific proxies may be too coarse to document with any precision under 100 years. Yet, despite those uncertainties, there is still potential to gain knowledge of how urban entities adapted and changed to natural disasters.

4.1. Stage 1: hazard horizon

The first stage of the research strategy aims to provide us with a map showing urban sites with the highest probability of being affected by an earthquake. To establish such a hazard horizon, three main steps are necessary: 1) gathering written sources describing the event and locations affected by it; 2) collecting archaeoseismic studies from sites mentioned in the written sources; and 3) correlating data obtained by the first two steps. Therefore, when working within historical periods, primary written sources describing the event must be consulted. Second, archaeoseismic studies of the sites under investigation should be collected. Such studies provide data on direct earthquake-related damages to the built environment and potentially show rebuilding and reconstruction efforts. Lastly, findings from step 1 and 2 should be correlated such that if both archaeoseismic and written accounts observe earthquake damages to a specific site, the site's probability of being affected increases. With this initial exercise, a hazard map with a higher or lesser likelihood of earthquake-affected sites can be produced.

4.2. Stage 2: regional / site hazard history

This stage considers the study region in a longer temporal perspective, and it implements a regional hazard history perspective where multiple disaster occurrences are recorded. Multiple disasters occur when two or more hazards of geophysical, anthropogenic, climatologic, hydrological, biological, or meteorological origin affect a given context within the same time span or simultaneously. This perspective enables us to evaluate whether the potential changes following a particular event should be scrutinised from a long- or short-term perspective or perhaps be linked to other events. Clusters of wide-ranging disasters may provoke more profound changes in societies, and a comprehensive account of a region's hazard history leads us to understand how they might have interacted.

Data of various kinds of hazards are obtained in much the same fashion as in stage 1. Written sources can mention other earthquakes, fires, warfare, epidemics, famines, droughts, or volcanic eruptions, whose traces can be later exposed in the archaeological record. However, for example, high-resolution evidence of past periods of droughts or heavy precipitation can be scarce (Bar-Matthews et al. 1999; cf. Enzel et al. 2003; Izdebski et al. 2016). At this stage, potential problems are to establish relevant criteria determining the time span for analysis and what to include and exclude in the recording. Such criteria vary from region to region and must be grounded according to such regional circumstances.

4.3. Stage 3: applying the modified urban resilience model

At this phase, data from the urban centre and its hinterland is collected. A synergy between the centre and hinterlands is sought here because it is a fundamental assumption that the urban centres of the past did not exist in isolation (Smith 2014). In fact, the centre was likely dependent on the economic subsistence activities of the agricultural hinterland and the infrastructure, such as water supply and road networks. Or, as stated by Patrich (2019: 39), in the case of Caesarea Maritima, "the city and its countryside were a single administrative and economic entity with respect to the provision of food supply, taxation, and administration".

Urban centres with their civic buildings and religious institutions have often been excavated for decades, and the amount of archaeological data from excavations is often vast compared to stage 1 and 2 (Smith 2014). However, moving beyond the monumental centre is often accompanied by a lack of data on non-elite material culture in the overall townscapes (but see Roskams 2006 for a methodological discussion of this issue). The data representativeness may thus be more robust for some of the urban resilience model domains compared to others. Moreover, structures in the urban hinterland are often not securely dated, and data may be scarce for some areas. Hence, it is often problematic to define the spatio-temporal extent of the urban hinterland (but see Patrich 2019 for a recent study on the town of Caesarea Maritima). In order to overcome or somehow limit the impact of such issues, two main steps are identified for this stage and related to the 1) definition of the extent of the urban hinterland and 2) categorisation of archaeological proxies. The former can be achieved through different research and data processing methods, such as written historical accounts, archaeobotanical evidence, archaeological findings, and remote sensing. These four lines of evidence help to identify some physical structures in the landscape that may indicate boundaries of towns' territories if such boundaries are not natural, such as mountain ranges, rivers, deserts, seas. For instance, written sources can describe jurisdictions and administrative reach of towns and capitals (Walmsley 1987; Wheatley 2001). Then, the findings within the urban hinterland are recorded and listed under the appropriate urban resilience domain (step 2). For example, an aqueduct, an olive press, or a terrace system may reasonably be associated with the water supply of a town or agricultural production of its hinterland. In that case, these are categorised under the domain of metabolic flows, while a church, monastery, or burial ground are listed under religious and governance structures. The structures thus become a proxy in their specific domains.

5. Case study: the 749 CE earthquake in The Jordan Rift Valley

In this section, I briefly discuss the earthquake that hit in the Jordan Rift Valley in 749 CE (Agnon 2014; Ambraseys 2009: 230-238; Fandi 2018; Tsafrir and Foerster 1992). Among the affected locations were several large urban sites, ranging from Damascus in the north to Jericho in the south, from Umm el-Jimal in the east to Caesarea Maritima on the coast of the Mediterranean in the west (Marco et al. 2003) (fig. 3). At Pella, shortly after the ground started shaking, people were trapped under the collapsed walls while trying to get out of their house in time (Walmsley 2007). At Umm el-Jimal, several houses were torn apart, and the site was almost abandoned in the aftermath of the event (de Vries 2000), while at Beit Shean, the town was severely damaged (Tsafrir and Foerster 1997). Across Greater Syria, churches and mosques were ravaged, water supply and irrigation systems disrupted, and production centres for various commodities collapsed within a matter of minutes (Keilholz 2017). In other words, cities and societies were affected, to a greater or lesser extent, by this event.

As to the historical framework, when the earthquake hit, the political regime of the second Islamic caliphate of the Umayyad had entered its final year. In fact, in 750 CE, the Abbasid revolution overthrew the Umayyads (Gil 1992). The former power base of Damascus was soon abandoned as the seat of government, and Baghdad became the new socio-political focal point, leaving behind a depopulated and neglected Greater Syria. The coincidence of the earthquake and the caliphate's abolishment is striking, and the chain of following events intriguing. One may wonder whether the region was already on the trajectory towards depopulation, and the earthquake represented just the final blow to this process, or whether its role was insignificant.

Following on the proposed methodological workflow of the model (fig. 2), I recorded the physical appearance each town and its hinterland had in the periods under study, cataloguing the presence of the structures under each of the four domains. In order to monitor historical developments in a more detailed way, an arbitrary time range of 200 years before and after the 749 CE earthquake event was set, which resulted in the definition of three time bins. In this case, these include parts of the Late Byzantine period (LB, 550-650 CE) and the Early Islamic period, Umayyad (Um, 650-750) and Abbasid (Ab, 750-950) (see Whitcomb 2011 for the chronology of the region). Consequently, the presence of each proxy was counted for each time bin. Figure 4 summarises archaeologically definable proxies for the urban resilience domains. Indeed, this list is not exhaustive, but it records some of the most common features that researchers may encounter in an urban context from the study period. Worth to mention, each proxy is assigned to one domain only, a process that is subjected to a degree of subjectivity. The resulting presence-absence matrices can be used to grasp an overall knowledge of post-hazards consequences on urban structures and thus to assess long-term changes in urban societies.

5.1. Preliminary data analysis and interpretation

After creating a dataset through the methodology above, quantitative data analyses can be used to detect causal processes (e.g. Carlson 2017; Drennan 2009; Madsen 1988). In this particular case, which focuses on monitoring the urban resilience domains as they develop before and after the 749 CE earthquake, the multivariate statistical method of correspondence analysis (CA) is a useful tool for exploring if any hidden patterns in the dataset exist (e.g. Alberty 2017; Clouse 1999; Glynn 2014). Data is arranged in a contingency table with the towns in the rows and the attributes (resilience proxies) in the columns. As exemplified by Alberty (2018: 1), CA "reduces the number of dimensions needed to display a table by decomposing data variability (termed total inertia in CA terminology) and defining the smallest number of dimensions capable to capture it. The graphical output of CA is a scatter plot where row and column profiles (i.e., sets of relative frequencies into which tows and columns are preliminary turned) are represented as points on a sequence of low-dimensional spaces". In the CA plot, the degree of correlation and variation is visualised by relative proximity, i.e. the closer the points are to each other, the more similar their profiles are.

Correspondence analysis facilitates data interpretation as it helps understand the relationship between specific towns and their urban resilience attributes. Also, when applied to several periods, it can spot if towns prioritised specific resilience domains similarly. The distribution in the towns' structural build-up as witnessed by the resilience proxies can potentially delineate patterns of functional and socio-cultural aspects of the towns. Figure 5 shows some preliminary results of a correspondence analysis of proxies obtained from the towns of Caesarea Maritima, Umm el-Jimal, and Tiberias. Each resilience domain is coloured for the ease of following their locations on the biplot, whereas towns are marked in black with the suffix representing their chronology, i.e. Late Byzantine (LB), Umayyad (Um), and Abbasid (Ab). In the plot, each town emerges in individual quadrants, and their inter-distance can be used to assess their (dis)similarity as to urban designs and forms.

Overall, Caesarea Maritima experiences the most substantial changes in the long term. In the LB period, the town had many civic institutions, extensive elite residencies, and monumental entertainment structures. In the Um period—preceding the earthquake, the distribution of the proxies in the biplot shows that the town now focused more on production facilities and commerce. Conversely, in the post-earthquake Ab period, it moved closer to the urban structure of Umm el-Jimal, where extended family housing and low-scale production and farming activities dominated. In turn, Umm el-Jimal is noticeable for its absence of civic institutions, and the diversity of building types is generally low in all periods. On the other hand, Tiberias shows similarities with both Umm el-Jimal and Caesarea Maritima in the LB period. In the later periods, changes are observed, with Tiberias shifting noticeably towards the structure of Umm el-Jimal. Finally, the development in Caesarea Maritima may reflect a slow move towards a more decentralised production practice in the aftermath of the earthquake. Whether the development was accelerated by the earthquake or in any way linked to the event remains to be investigated. A more detailed qualitative assessment of direct earthquake affected buildings in Caesarea and their subsequent usage can potentially shed light on this case in point and expand on the pattern observed here.

6. Conclusions

This paper aimed to develop a new methodological framework for those archaeologists working with urban sites affected by natural hazards and, in the specific, earthquakes. It has been argued that, because methodologies seeking to encompass complete urban sites are rare in archaeology, the discipline might benefit from borrowing ideas from other fields such as human geography, where models have been developed to investigate modern urban cases. In this sense, a modified urban resilience model, which identifies four urban domains (infrastructures, governmental structures, civic institutions, and public spaces) and their archaeological proxies, has been proposed.

By highlighting how the term resilience is helpful to understand the effects of natural hazards to past societies, the paper presented a preliminary case study that included the towns of Caesarea Maritima, Tiberias, and Umm el-Jimal, which were all affected by a devastating earthquake in 749 CE. Results show that, thanks to statistical analyses, urban resilient traits can be detected and that preliminary considerations on broader socio-cultural patterns and developments can be made. Indeed, further research, supported by qualitative assessments of specific and well-documented structures—and preferably from each urban resilience domain—is required for a more refined and detailed interpretation.

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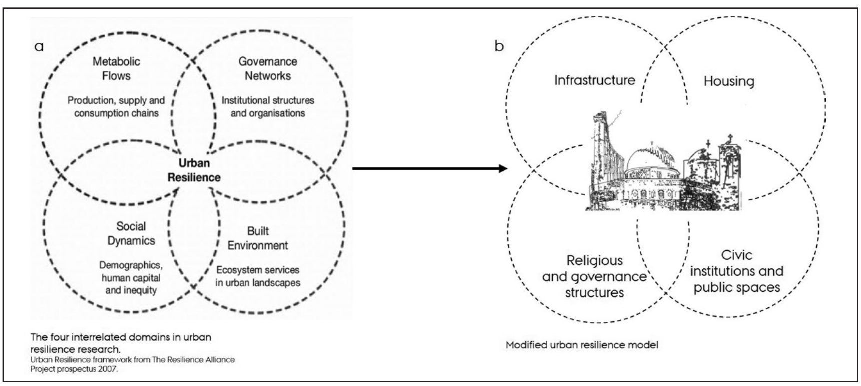

Fig. 1. Urban resilience model.

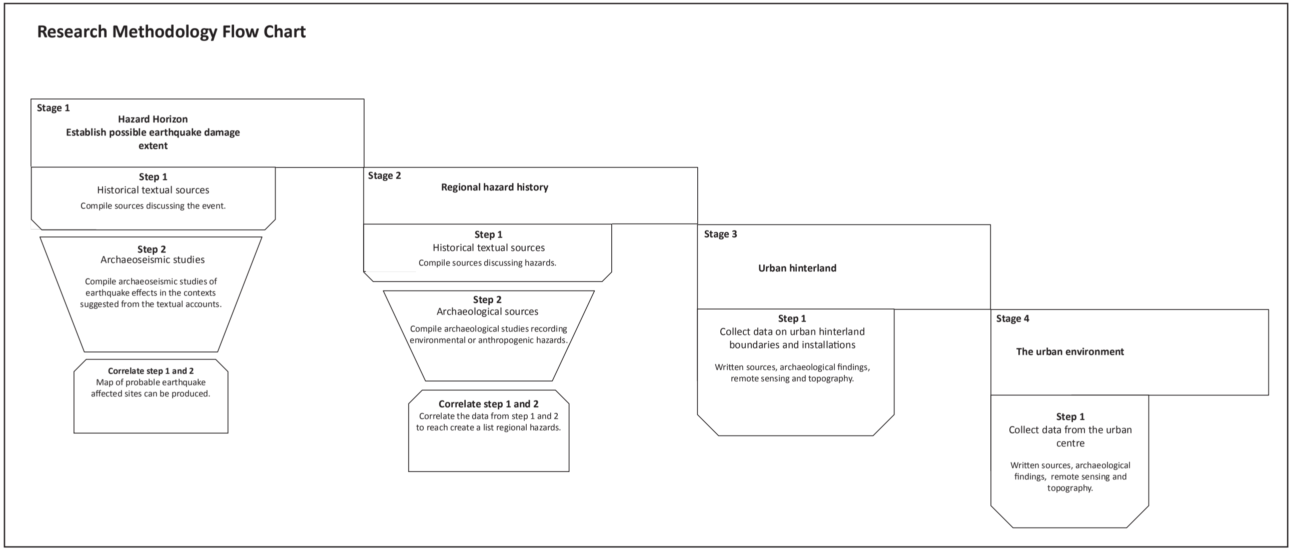

Fig. 2. Method flow chart v2.

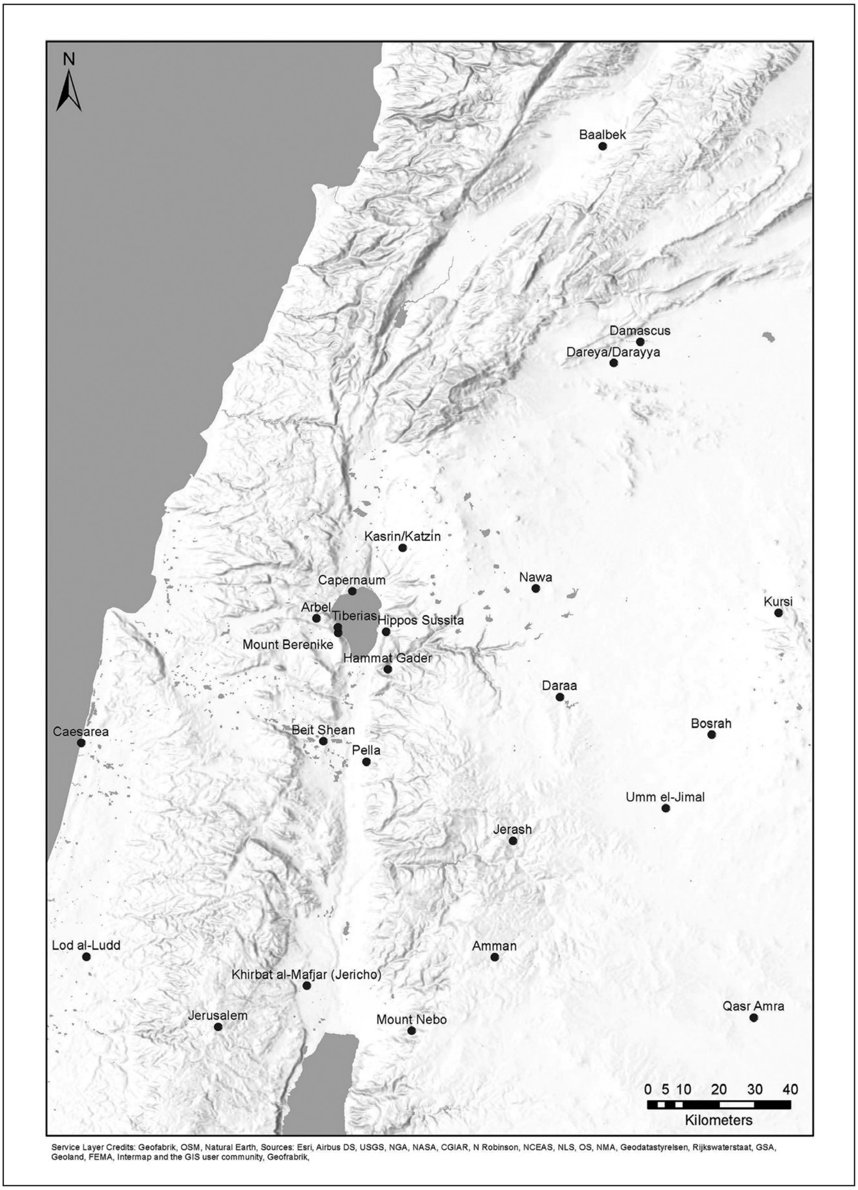

Fig. 3. Map of towns affected by the 749 CE earthquake according to written accounts.

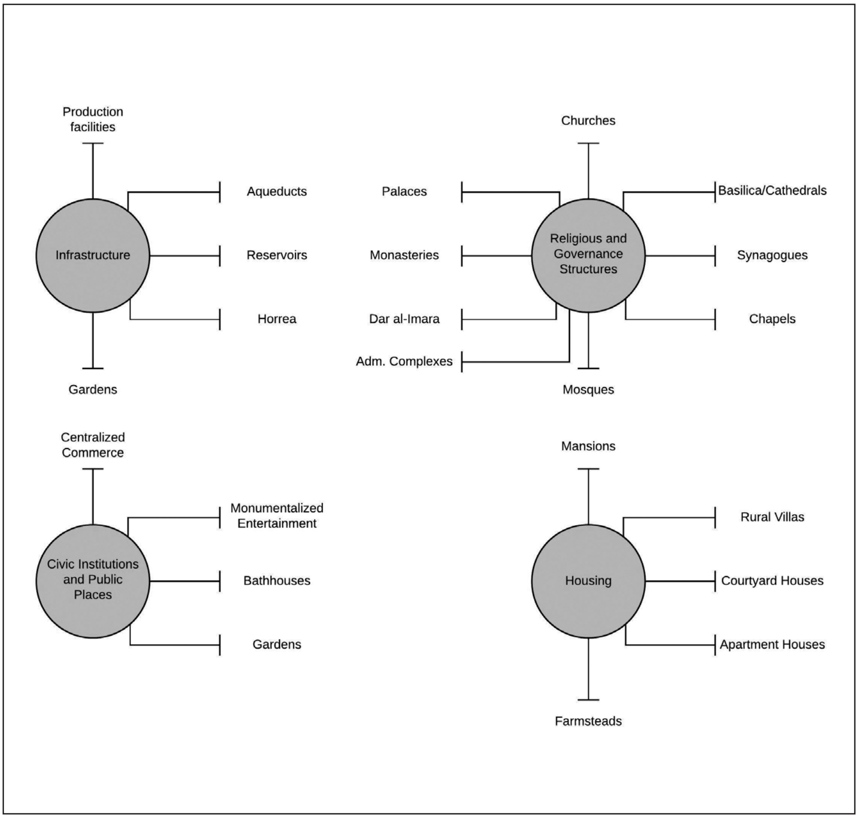

Fig. 4. List of proxies.

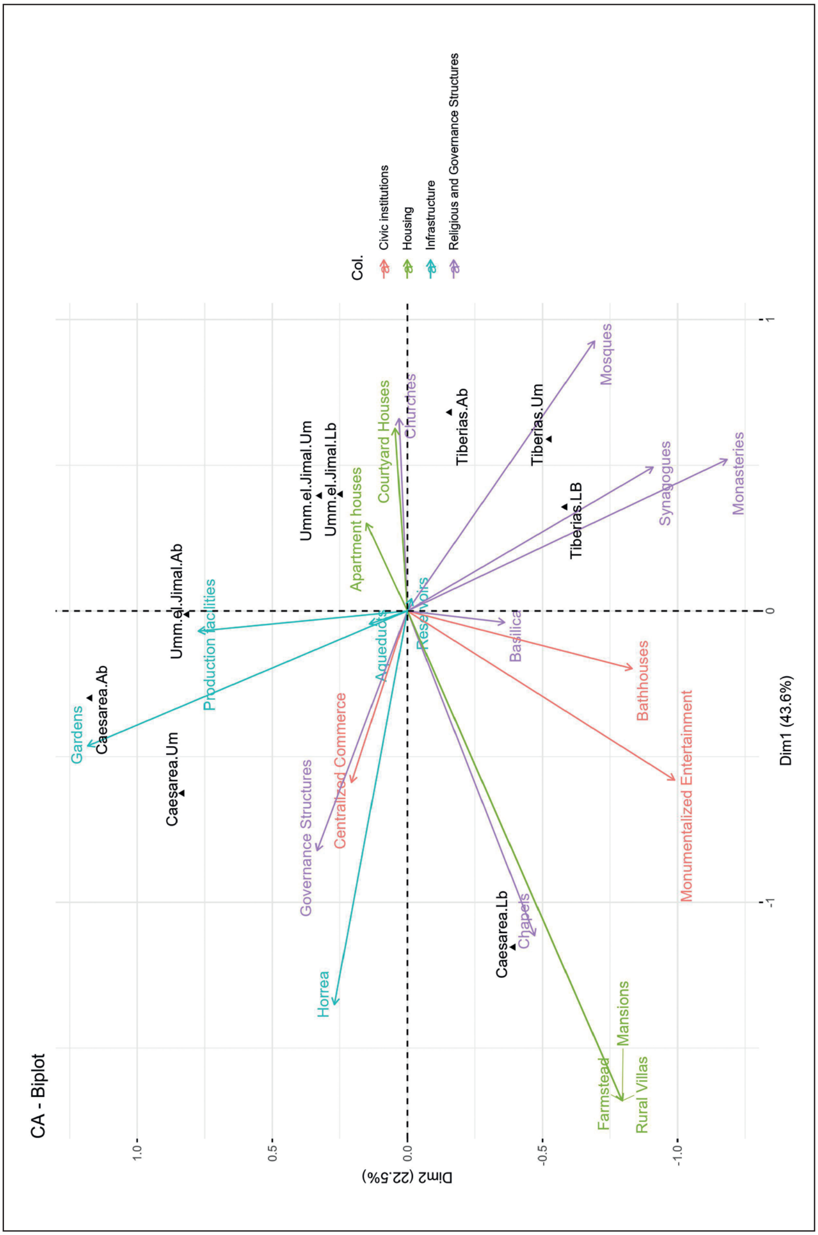

Fig. 5. CAbiplot.