Spatial Dimension of Flood Risk

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ABSTRACT **In order to more successfully prevent the occurrence of floods and to mitigate their negative impact and numerous consequences, the Flood Risk Management (FRM) approach has been adopted in many European countries. Risk identification and assessment are the initial activities within the framework of FRM. This chapter analyses flood risk assessment from the supra-national to the individual buildings scale, describes different relevant assessment methods, and discusses the interconnectedness of flood risks at different spatial levels. Urban flood risk assessment is recognised in this chapter as being particularly complex, due to the variety of present factors, interrelations between physical and human components in the urban environment, and interrelations with other spatial levels in terms of floods. By analysing different scales of urban flood risks, it has been argued that further work in the development of risk assessment methodologies is especially necessary at the neighbourhood level, having regarded the significance of this spatial scale for successful flood management.**

KEYWORDS flood risk, assessment, mapping, spatial scale, urban areas

1 Introduction

The flood, defined as "temporary covering of water and land not normally covered by water" (European Commission, 2007, Article 2), represents one of the most common manifestations of natural phenomena with often significant consequences and negative effects on the human environment. It is expected that, in the future, flood occurrence will increase due to climate change manifestations (such as extreme precipitation, sea level rise, and the rapid melting of snow), land use changes, continual transformation of natural into built environments, and numerous other human activities, technological failures, and the combination of all these factors. In recent years, in order to prevent the occurrence of floods more successfully and to mitigate their negative impact and numerous direct and cascading consequences, the Flood Risk Management (FRM) approach has been adopted in the political agenda in many European countries.

"Flood risk management (FRM) aims to reduce the likelihood and/or the impact of floods" (Simonović, 2012, p. 14). At the same time, FRM is about learning to live with flood risks, i.e. learning to "accept some degree of risk in return for the benefits to be derived from using land subject to flood risk" (Yoshiaki & Porter, 2012, p. 62). In wider terms, flood risk managment aims "to achieve the right balance between the economic, social and environmental dimensions of flood risk reduction, both today and into the future" (Klijn, 2009, p. 11), and therefore is directly related to sustainable development and the promotion of "the long-term health of associate ecosystems, societies and economies" (Sayers et al., 2013, p. 6).

In general, the FRM procedure can be described by four sets of activities represented in the form of circular process (Fig. 1.1).

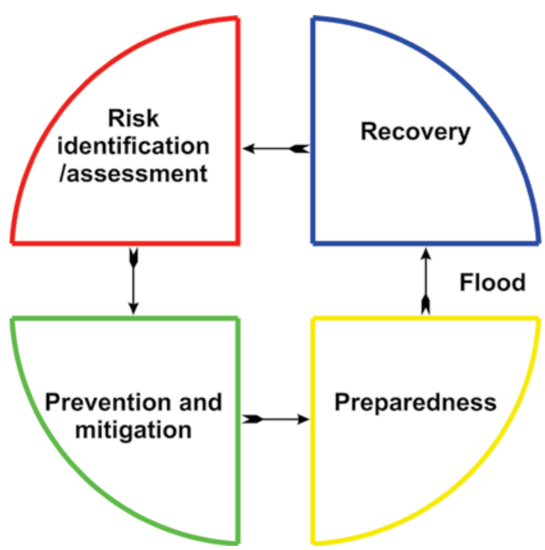

FIG. 1.1 Key groups of activities of flood risk management *(Image by author)*

The first group of activities – *risk identification and assessment* – relates to the recognition and monitoring of the flood risks and includes: collection and analyses of data in different formats and obtained from different sources; development of databases; assessments of hazards, vulnerability and exposure; integrated flood risk assessment; presentation and dissemination of assessment results; development of different flood risk-related maps, and others. All subsequent flood risk management procedures and measures, such as the identification and implementation of structural and non-structural protective measures, building the preparedness for future flood events, or drafting the recovery plans, are informed by the flood risk analysis results. At the same time, risk assessment also informs and is informed by some other fields such as land use planning, basin management, environmental management, or stakeholders' engagement, etc. Both flood risk assessment and flood risk management together belong to the wider Integrated Flood Management (IFM) approach.

The spatial dimension of flood risk has been recognised as one of the main challenges in flood risk assessment, besides "temporal dimension of flood risk and adaptation", "new means to describe the occurrence of flood hazards", and "definition of flood risk – from one to several hazards" (Åström, Arnbjerg-Nielsen, Madsen, Rosbjerg, & Friis-Hansen, 2015, p. 4). Considering flood risk as a necessary basis of flood management, this chapter analyses specificities regarding flood risk assessment from the supra-national to the individual buildings scale and describes the interconnectedness of flood risk at different spatial levels. Urban flood risk assessment has been recognised in this chapter as particularly complex, due to the variety of present factors, interrelations between physical and human components in the urban environment, and interrelations with other spatial levels as they relate to floods.

2 Flood Risk

Since the beginning of the 21st century, Europe has been affected by a series of massive flood events. In August 2002, heavy rainfall triggered flood waves along large river systems and caused the death of 110 people in parts of Austria, the Czech Republic, and Germany (Risk Management Solutions, 2003). In the late spring and summer of 2007, a series of extreme rainfall events in England and Wales caused the occurrence of a number of major flood episodes that led to 14 fatalities and affected over 55,000 homes and 6,000 businesses (Marsh & Hannaford, 2007). In 2012, the floods in Krasnodar Krai in southwest Russia, that occurred as a result of the equivalent of five months of rain falling overnight, caused 114 deaths and adversely affected about 30,000 people (Hays, 2013). In May 2014, massive rainfall affected the territory of the Republic of Serbia and caused the rapid and huge rise of the level of water in several large rivers. The catchment of the river Sava was the most heavily affected. Consequently, three immediate effects followed: sudden flooding that led to the destruction of houses, bridges,

FIG. 2.1 The town of Obrenovac in Serbia, which was heavily affected by flooding in May 2014 *(Image by Vesna Urošević, 2014)*

and parts of roads; high-intensity flooding of urban (Fig. 2.1) and rural settlements; and increased flow of underground water that activated landslides. The floods caused 51 deaths and affected about 1.6 million people throughout 38 municipalities in the Republic of Serbia, of which about 32,000 were evacuated during the flooding events (Kern, Vučković Krčmar, Toro, & Jeremić, 2014). Other floods occurred in Athens in 2017 (Smith, 2017), and in France, Germany, and Spain in 2016 (EM-DAT: The Emergency Events Database, n.d).

In the period from 1973-2002, floods caused a total of 264 disasters in Europe, each with at least 10 deaths, affecting at least 100 people, and requiring national or international assistance (Hoyois, & Guha-Sapir, 2003), while the total number of registered floods in Europe in the period between 1990-2016 was 493 (Source: EM-DAT: The Emergency Events Database, n.d.). The ueven temporal distribution of floods and the increasing number of flooding events in recent times (Nones, 2017) indicate that, despite flood protection measures, the probability of the occurrence of floods is increasing. In order to prevent or mitigate negative flood impacts, it is necessary to consider the experience from past flooding events, and to carry out the analysis of *risk* regarding future flood occurrence and impact.

Risk can be defined through its three main determinants: hazard, vulnerability, and exposure (Roaf, Crichton, & Nicol, 2009). When a hazard does not have a negative impact on the human environment, it cannot be considered that it will lead to a disaster, where the value of risk in this case equals zero to minimum (Kron, 2005; Bell, Greene, Fisher, & Baum, 2005; Armenakis, Du, Natesan, Persad, & Zhang, 2017). In the built environment, the risk of floods increases due to the hazards originating from human activities (such as land use changes, land surface sealing, occupation of flood plains for new developments and reduction of retention areas, weak engineering practice at various spatial scales in the built environment, etc.), climate change manifestations, and some other natural processes (like the natural erosion of river channels).

"An element at risk of being harmed is the more vulnerable, the more it is exposed to a hazard and the more it is susceptible to its forces and impacts" (Messner & Meyer, 2005, p. 3). In general, vulnerability is higher in those areas in which floods did not occur in the past, but are probable in the future, i.e. in those areas where previous flooding events did not result in learned lessons (Blanksby, 2012). Vulnerability to floods also increases when the built environment is subjected to changes that are not systemically verified or controlled, when flood control systems and mechanisms are not established or properly maintained, as well as when a social vulnerability is high (for various reasons). Besides hazards and vulnerability, the potential damage caused by flooding also depends on the exposure characteristics of an area. These characteristics can be represented in a number of ways, from land-use type, to buildings and assets, to the number of people residing or working in potentially affected areas (Poussin et al., 2012).

To determine the risk of floods for a human environment, different spatial scales need to be assessed, from supra-national to the level of individual buildings.

2.1 Flood Risk Assessment

As explained in the previous section, and shown in Fig. 1.1, flood risk management activities are implemented within the cyclical, continuous process, following the initial flood risk assessment activity. Therefore, the activities within the flood risk management cycle primarily depend on introductory assessments of flooding events and their consequences. On the other hand, the actualisation of the assessment of the risk of floods and of their consequences depends on the availability of different types of data and the specific needs that inform the assessment procedure. For example, the scope, and details and methods that are used during the assessment carried out by local flood risk management teams are different from the assessment methodology and assessment scope set for national teams. To effectively explain these differences, de Moel et al. (2015) have established the flood risk assessment hierarchy from supra-national, to macro (national), to meso (regional), to micro (local) scale.

Monitoring the data on precipitation, water flows, and the formation of long sequences of data are necessary for hydrologic calculations and the preparation of hydrologic models, which precede the successful implementation of flood protection measures. In cases in which there is an insufficient sequence of data, different models can be used, from hydro-meteorological, to prognostic, to river basin models, to hydrological, and to stochastic models that enable generating multiple variables (water flows, precipitation) from multiple sites (Marković, Plavšić, Ilich, & Ilić, 2015).

At any spatial scale, flood risk assessment starts with the development of adequate hydrological models. On the basis of obtained results, the maps representing flood hazards are made, and, subsequently, the parameters regarding vulnerable population and assets, possible damages, etc. are defined. According to the probability of different flooding events, for defined time periods, as well as the corresponding damage, flood risk diagrams can be drawn; e.g., rivers stage-damage relationships diagram developed by Shaw (1994, p. 471).

Flood hazard maps are followed by the design of flood risk maps. While maps of threats indicate geographical areas that may be affected by flooding, depending on applied scenarios, flood risk maps provide information on potential damaging consequences of those scenarios for the same geographical areas. Here, all elements that are at the risk of flooding in a certain area (referred to as flood risk receptors) should be identified, and the types of impacts should be defined. Nonetheless, this is a very complex task that includes many influences and uncertainties, such as the number of inhabitants, the impact of floods on social and economic spheres, etc., and thus requires the use of data from different sources (e.g., spatial plans, statistical databases, etc.). Usually, flood risk is represented in maps as low, medium and high risk by using different colours of graphical presentation.

In the design process of the maps of flood hazards and flood risks at least three different scenarios are considered. The first scenario deals with high probability floods and return periods ranging from 10 to 50 years. The second scenario considers medium probability floods and a recurrence interval of 100 years. In the third scenario, low probability extreme events and long recurrence periods of 500, to 1,000, to even 10,000 years, as well as the potential floods caused by damages to dams and embankments, that correspond to mentioned return periods, are examined. According to the hydraulic calculations, flood hazard maps are drawn for every given scenario in such a way as to present borders of flooded areas and water levels, by using different graphical representations.

3 Flood Risk at Large Spatial Scales

3.1 Supra-National Level

At the supra-national level, flood maps are usually not very detailed, and their resolution ranges from 1-10 km. Here, the global models for flood hazard assessment can be used, and the consequences of floods are presented by the gross domestic product loss or the size of the affected population. Flood risk assessment at the supra-national level also allows for the monitoring of the effects of climate change and population growth.

Supra-national flood risk management is coordinated by international organisations and bodies, such as the United Nations, the World Bank or the European Commission. For managing and monitoring the large rivers whose basins are spread over the territory of several countries, different international collaboration agreements have been made and organisations have been established to manage flood risks.

The United Nations (1991) document, *Mitigating natural disasters: Phenomena, Effects and Options - A Manual for Policy Makers and Planners,* is the pioneering international strategy that provides guidelines for the implementation of three main groups of activities, including: risk assessment, planning and decision making, and effective implementation of strategies for risk reduction. The strategy was launched following the designation of the first International Decade for Natural Disasters Reduction 1990-1999 by the United Nations General Assembly. In that period, the *Yokohama Strategy and Plan of Action for a Safer World* (1994) was adopted, as well as the *Guidelines for Natural Disaster Prevention, Preparedness and Mitigation*. In 1999, the United Nations Office for Disaster Risk Reduction (UNISDR) was established to facilitate the implementation of the *Disaster Risk Reduction Strategy*. Later, the UNISDR brought the *Hyogo Framework for Action 2005-2015* (UNISDR, 2005), the *Guidelines for National Platforms for Disaster Risk Reduction* (UNISDR, 2007), and the *Sendai Framework for Disaster Risk Reduction 2015-2030* (UNISDR, 2015).

In the European Union, *Flood Directive* (European Commission, 2007) deepened the flood risk management approach and set three types of activities to be undertaken by the member states by the year 2015:

- preliminary flood risk assessment (Fig. 3.1), where the goal is to assess the level of flood risk in every water basin district or unit of management, and to select those areas for which flood mapping and risk management plans will be developed;

- flood mapping that includes the development of flood hazard maps according to three scenarios for floods with low, medium, and high probability, as well as the development of flood risk maps that present the potential adverse consequences according to the taken scenarios.

According to the EU Flood Directive, both flood hazard and flood risk maps should be revised every six years;

- development of flood risk management plans, with indicated objectives for concerned areas and the measures foreseen to reach these objectives (European Commission, 2007).

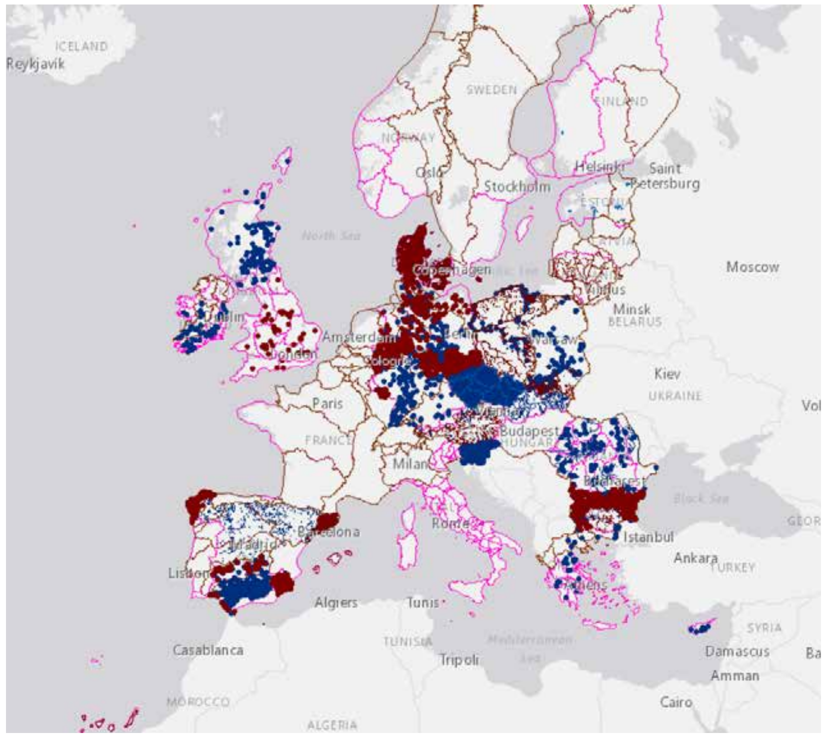

FIG. 3.1 Preliminary flood risk assessment in Europe *(Image by European Environment Agency, 2018)*

Following the completion of the first cycle of implementation of the EU Floods Directive, Nones (2017) carried out an analysis of the results of implementation in eight European countries and noted that, when it comes to the consideration of flood risks, there exist notable area-specific and methodology-related differences. This situation is explained by the absence of standardised nomenclature or agreed practices for flood mapping at global, regional, and sometimes even national scales, requiring stronger collaboration between authorities at different levels, from local to international (Nones, 2017). In addition, there is a need to continuously embody the latest scientific findings into the flood risk management strategies in order to reduce the uncertainty regarding risk factors, as well as to raise the level of flood awareness at all administrative levels and in society as a whole (Nones, 2017).

Despite the noted inconsistencies and the need for further advancement, different European countries and regions have made significant progress in contemporary flood risk management to date.

3.2 National Level

According to de Moel et al. (2015), flood risk assessment at the national level can be driven by different goals. In the US, for example, the primary objective is to determine the boundaries of the national insurance programme, while in the UK the objective is to warn the public about the risks, and to define the total risk to which the country is exposed (de Moel et al., 2015). Because of the great number of floods, the priorities in flood risk management in Spain are assigned to "optimizing the available resources in such a way as to obtain the greatest benefits in terms of risk reduction" (Martínez, 2015, p. 7). On the other hand, the main reasons for risk mapping in the Netherlands are the assessment of climate change impact and the facilitation of decision-making regarding the risk management strategies. In addition, actual Dutch flood risk management policy aims to enable additional protection in those areas in which a large number of victims, failures in critical infrastructure, or major economic and environmental damages potentially occur (Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2014). In the Republic of Serbia, the *National Disaster Risk Management Program* was presented following the massive flooding events that affected the country in the spring of 2014, in which numerous serious consequences clearly demonstrated a need for the systemic redefinition of the existing concept of flood management. The Action Plan for the implementation of the aforementioned program (for the period 2016-2020) was released in 2016 (Vlada Republike Srbije, 2016). Here, the concept of risk management is based on six components for disaster risk management, and flood risk management represents its integral part. The National Program makes institutional capacity building a top priority and a precondition for successful risk management, followed by the identification and monitoring of the risks.

The resolution of risk maps intended for national spatial level ranges from 100m to 1km. The models used to determine national risk maps are usually two-dimensional hydraulic models with certain simplifications. National risk maps, in addition to the flood risks, also provide an insight into climate change effects and population growth.

3.3 Regional Level

Usually, risk assessment maps for regional levels are made for the entire watercourse network and the recurrent period of 100 years (e.g. Fig. 3.2). Both stochastic models that consider spatial dependence between different measurement spots and the precipitation-rainfall models with climatic scenario data can be used for that purpose. Flood risk assessment at the regional level is used to check the effects of the undertaken measures or for studying future development according to the different scenarios of climate change. The resolution of regional risk assessment maps ranges from 25 to 100 metres.

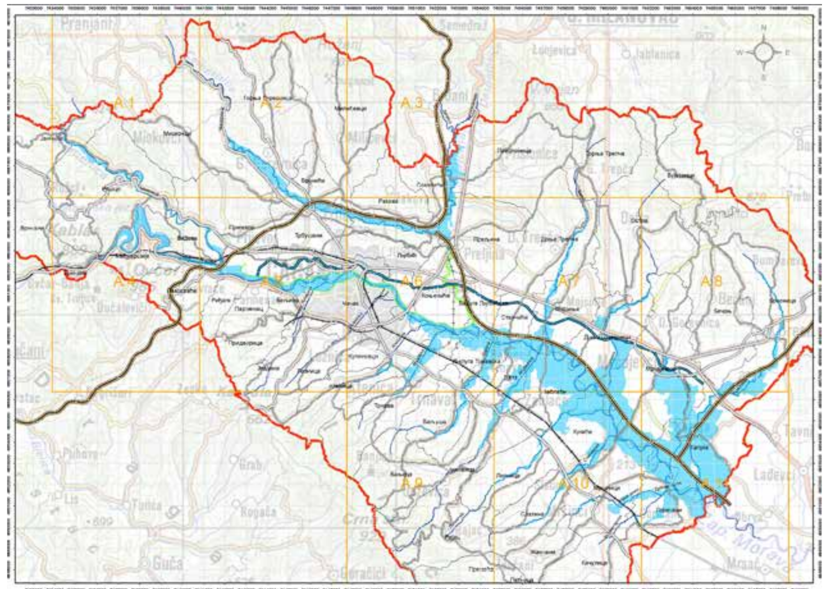

FIG. 3.2 Atlas of threats from large watercourse in the territory of Čačak, for the recurrent period of 100 years *(Image by Jovanović et al., 2014)*

4 Urban Flood Risks

Flood occurrence is, above all, related to extreme meteorological and hydrological events. Nevertheless, the floods in urban areas can also occur as a consequence of storms, or tsunamis, and/or due to a range of human activities, such as land conversion, land surface sealing, building in floodplains, inadequate sizing and maintenance of sewage and drainage systems, etc. In urban areas, where risks to people and properties are greatest, flood risk management should be aligned to all types of flooding and the interactions between them (Blanksby, 2012).

Flood risk assessment on an urban scale is based on data regarding terrain configuration, existing hydrological constructions, land use, infrastructures, buildings, etc. and their position. The provision of detailed information at this level is important because local flood hazard maps and flood risk maps (e.g. Fig. 4.1 and Fig. 4.2) inform flood risk management and urban development. During the assessment, detailed hydraulic models are used to obtain information regarding the depth of water, the velocity, and the duration of the flooding event. In addition, the objects that can be affected by flooding are considered, thereby allowing for precise estimation of the potential damage for every single element. The resolution of urban risk assessment maps ranges from 1 to 25 metres.

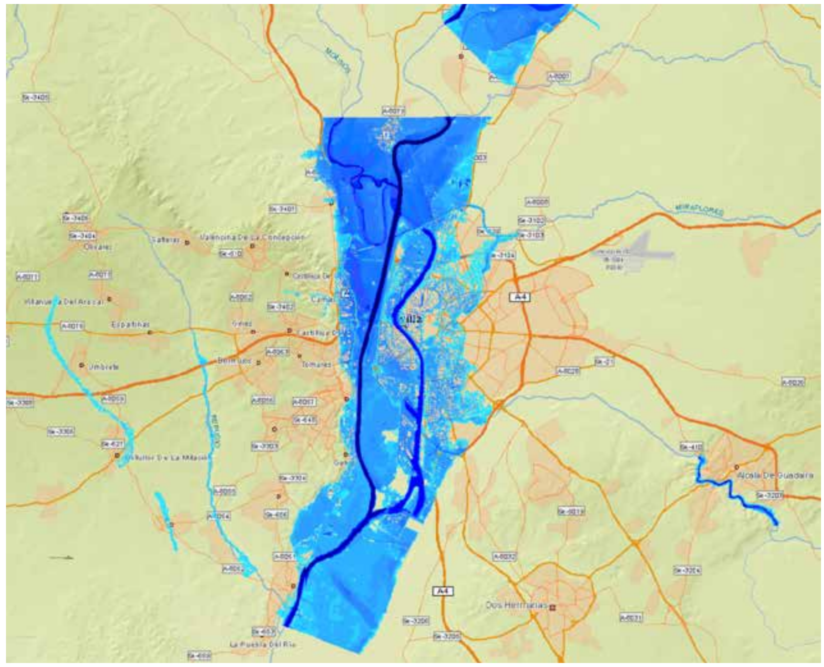

FIG. 4.1 Map of hazard from fluvial flooding over a recurrent period of 500 years, City of Sevilla *(Image by Sistema Nacional de Cartografía de Zonas Inundables (SNCZI) – Inventario de presas y embalses (IPE), 2018)*

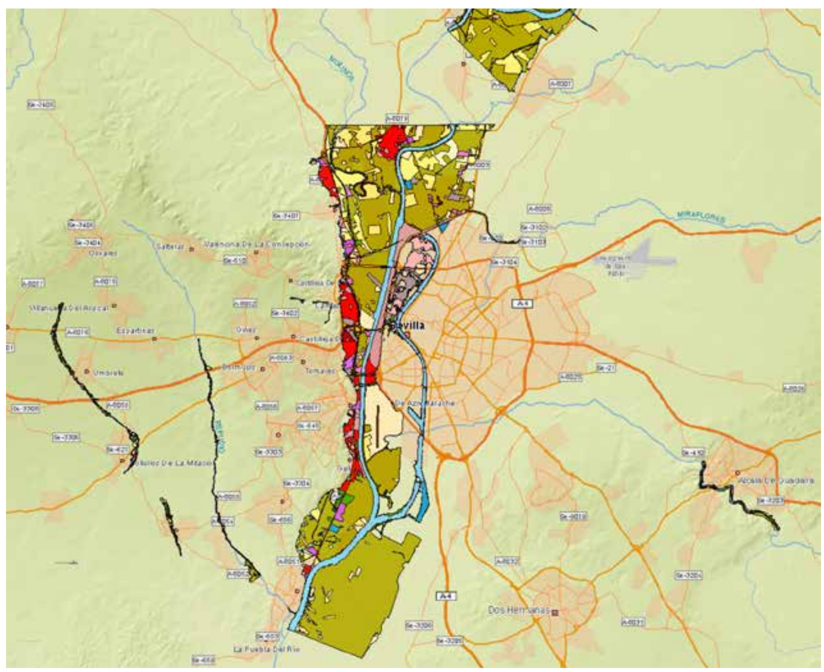

FIG. 4.2 Map of risk from fluvial flooding for the economic activity over a recurrent period of 100 years, City of Sevilla *(Image by Sistema Nacional de Cartografía de Zonas Inundables (SNCZI) – Inventario de presas y embalses (IPE), 2018)*

Jha, Bloch, and Lamond (2012) have illustrated the approach to urban flood risk management by distinguishing between catchment, city, neighbourhood, and building scales. Similarly, Escarameia and Stone (2013, p. 22) have argued that, when considering urban flood risk, it is necessary to observe flooding as "multi-(spatial) level interacting systems which are made up of various components that act as input-output units, including positive or negative feedback loops". Flood management measures differ between the levels of observed urban systems, and only when an integrated approach to all levels has been established, a full effect of flood risk management plan can be accomplished.

As a flood wave can be formed at a certain distance from the urban area, it is necessary to first consider the flood risks from the catchment, and, in that way, to tackle the flood problem closer to its core (Jha et al., 2012). In the framework of integrated flood risk management, the analyses related to the river and water catchment may also extend to regional, national, or supra-national scale.

In the assessment of the risk from floods on urban level, Armenakis et al. (2017, p. 2) have argued that the risk maps are not sufficient to define the risks, and that it is necessary to develop an approach "for the determination of location-based risk indices due to flooding by integrating flood maps, socio-economic parameters, and impact on infrastructure and services". Such an observation confirms the relevance of integrating urban planning and design measures with the flood management, and furthermore the necessity to include other stakeholders in this process, from citizens to local policy makers and different institutions. Similarly, Ran and Nedovic-Budic (2016) have proposed a conceptual framework for spatially integrated policies. According to these authors, the territorial integration between spatial planning (SP) and flood risk management "focuses on consistency (horizontal integration) and alignment among spatial scales (vertical integration)" (Ran & Nedovic-Budic, 2016, p. 71). The key issues that need to be addressed in territorial integration relates to finding the ways of "sharing and exchanging information among neighbouring jurisdictions and overlapping jurisdictions because the SP spatial hierarchy differs from that of FRM" and checking "the consistency and conflict among spatial policy levels" (Ran & Nedovic-Budic, 2016, p. 71).

An integrated approach to flood risk management is further connected with the resilience approach. According to Mileti (1999, p. 32-33), "local resiliency with regard to disasters means that a locale is able to withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life and without a large amount of assistance from outside of community". A resilient city, as argued by Godschalk (2003), implies a sustainable framework consisting of physical systems and human communities. It also refers to a territorial entity whose components are able to not only resist, but also to adapt to surprises and changes in regular conditions. In contemporary terms, resistance to floods is, for this reason, combined with the adaptability of the built environment, primarily of its human component. Accordingly, the approach of 'protecting from the water/floods' has evolved into the approach of 'living with the water/floods'.

Therefore, the assessment of the risk of floods in urban areas should also include the assessment of community coping capacity, community vulnerability, community hazard, etc. To that end, different methodologies to measure the aspects of resilience of communities to the floods, such as socioeconomic characteristics, social activity dynamics, experience and perception regarding floods, flood management knowledge, etc. have been proposed (e.g., Bell & Blashki, 2013; Kablan, Dongo, & Coulibaly, 2017; Roder, Sofia, Wu, & Tarolli, 2017).

4.1 Neighbourhood Scale

Neighbourhoods represent one of the community components in the network of resilient cities. Although bottom-up initiatives can be used to shape flood management strategies and policy development (Zevenbergen, Veerbeek, Gersonius, & Van Herk, 2008), flood risk assessment at the neighbourhood level has not been given sufficient attention to-date, and a "clear integration between flood resilience and urban design practices at the neighbourhood level has yet to be established" (Serre, Barroca, Balsells, & Becue, 2016, para. 5). The relevance of assessing the flood risks at the neighbourhood level is underpinned by the fact that not all parts of a city are subjected to the equal vulnerability and exposure to the floods (Ojikpong, Ekeng, Obongha, & Emri, 2016; Armenakis et al., 2017). In disadvantaged neighbourhoods and in those areas that are subjected to more intensive climate change manifestations, the assessment of flood risks is an objective priority.

Nevertheless, some efforts have been made to develop methods and tools that would support flood risk assessment at this urban scale. De Risi et al. (2013) have presented an integrated modular probabilistic methodology for predicting flooding risks in a Geographical Information System (GIS) framework. Using the example of informal settlements, the authors have tested the methodology where the determination of risks starts from the definition of rainfall probability curves (climate modelling), continues through the development of flood hazard maps (hydrographic basin modelling), to fragility (vulnerability) of a settlement portfolio (structural modelling), and to the final development of risk maps (De Risi et al., 2013). In addition, the utilisation of GIS systems has been proposed to examine the social vulnerability assessment of flood risk (Fernandez, Mourato, & Moreira, 2016), while Sy et al. (2016) have demonstrated the relevance of a participatory approach in mapping and collecting information on flooding from the local population (participatory-GIS).

In another recent study, Serre et al. (2016) presented a method for assessing urban neighbourhoods' resilience to flooding by integrating flood risks with urban regeneration planning. The results from this research reveal that a number of urban design measures involving transportation infrastructure, land use (open public spaces), and buildings can be used to improve neighbourhood's resistance, absorption, and recovery capacities.

4.2 Building Scale

At the scale of a building, risk assessment relates to existing buildings, where the primary goal is to reduce possible negative consequences, and to new buildings, where the goal of assessment is to achieve flood resilience (Bowker, Escarameia, & Tagg, 2007). According to Escarameia and Stone (2013), in both cases, special attention should be assigned to the so-called hotspot buildings that enable community functioning, and to smart shelter structures that provide a survival place for flood victims.

In the case of existing buildings, risk assessment refers to the assessment of exposure and vulnerability of the building structure. Here, characteristics such as the applied structural system, quality of construction, and materials used are particularly relevant, especially in the case where evacuation is not planned. In addition, for evacuation purposes, the existence and position of exit gates and routes are important. All mentioned building features are assessed in relation to the parameters of the intensity of floods (depth, velocity, and duration of the flood event). To assess the risk of floods to individual buildings, different methods such as orthophotos, sample surveys, laboratory tests (De Risi et al., 2013) etc. can be used. The results aim to provide information regarding potential damage and negative effects on people, i.e. to inform the protective measures.

Flood risk assessment for new buildings is largely informed by the risk from floods at the location in which a proposed building will be constructed. The aim is to determine different design measures that range from wet proofing, to dry proofing, to raising or moving structures, to floating and amphibious structures (Escarameia & Stone, 2013), etc.

5 Conclusions

Flood risk management is an approach adopted in most countries of the European Union and is at the process of adoption in candidate countries. Although based on common procedure and measures defined by the *European Floods Directive* (European Commission, 2007), the approach is largely dependent on national and regional conditions and regulations. As floods often affect several neighbouring countries, the development of cross-border collaboration is vital for successful flood risk management at any spatial scale.

Understanding the risk from floods represents a prerequisite for successful risk management and its integration into a systemic resilience approach. This work has shown that the flood risk is assessed using various data and methods that correspond to the assessment needs and the level of detail required for a specific spatial scale. Nevertheless, the risks from floods at different spatial scales are narrowly interconnected, and the complexity of causal relations is best visible at the urban scale. By analysing different scales of urban flood risks, it has been concluded that further work in the development of risk assessment methodologies is especially necessary for the level of a neighbourhood, having regarded the significance of this spatial scale for successful flood management.

In order to prevent the occurrence of flood-related disasters in human environments, it is equally necessary to simultaneously assess flood risk at different spatial scales, and to cover different scales and aspects of the planning and design of those environments. Furthermore, the assessment of flood risk determinants in human environments relates to both physical structures and community components. Within the approach of resilience, this means that the assessment of the human component and its adaptive capacity is equally significant as the assessment of the characteristics of urban infrastructure, characteristic of individual buildings, etc. All of the aforementioned issues result in greatly complex flood risk assessment processes and require a profound coordination and deep engagement of different stakeholders in assessment procedures, again at different spatial scales.

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