BATTLING URBAN FLOODS: SPATIAL PLANNING, EDUCATION AND PREVENTION INITIATIVES FOR ENHANCING RESILIENCE

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Abstract
Floods are the number one natural disaster on the planet, according to UN indicators, and constitute a multifaceted issue that causes complex consequences, affecting many sectors of the economy. Flooding can often cause major property damage and threaten human health, especially in densely populated urban areas. The intensity and frequency of flooding phenomena in urban areas are a reality that is taking on ever greater dimensions both in Europe and throughout the world. Although they are not new phenomena, their frequency and intensity show an alarming increasing trend due to climate change.

The entanglement of flood risk in urban areas with the concept of urban resilience is a long-standing issue in the research community. Although flood risk in urban areas has been extensively studied in terms of its technical characteristics, the field is clearly lacking regarding the holistic approach to mitigating the effects of flood events both in terms of protecting human life and material losses, which includes the spatial planning, prevention infrastructures but also the citizen engagement.

Prevention using new artificial intelligence technologies, providing the correct information, and improving infrastructure through a more environmental approach are the basic tools to reduce the effects of flood phenomena and strengthen the resilience of an area.

The purpose of this paper is to highlight the aforementioned condition and at the same time the necessity of a holistic approach and integrated planning through soft actions (spatial planning, education, early warning systems through intelligent agents) to shield urban resilience.

Key words: *urban foods, resilience, prevention initiatives, spatial planning, citizen engagement*

Introduction

Floods are the number one natural disaster on the planet, according to UN indicators. They are higher in frequency and in disasters than both fires and earthquakes and hurricanes. Floods can cause injury, loss of life, significant economic costs, damage to the environment and cultural heritage, as well as resettlement of citizens. The economic cost of hydrological events in the EU between 1980 and 2017 amounted to around €166 billion. This is about one third of the damage caused by climate change related events (https://www.eca.europa.eu/Lists/ECADocuments/SR18_25/SR_FLOODS_EL.pdf).

The risks of flooding and water quality degradation in developing and developed countries are related to:
- pollution of surface and groundwater with urban waste water and the discharge of solid waste;
- intense urbanization and, at the same time, inadequate urban planning
- soil erosion and sedimentation
- the alteration of river banks, especially in steeply sloping areas such as hillsides, which are subject to landslides after the rainy season (Tucci, 2007).

Flooding is a multidimensional problem that causes complex impacts affecting many sectors of the economy, (Luo et al., 2021; Mavhura, 2019; Zhu et al., 2022). Often floods can cause major property damage and threaten human health, especially in densely populated urban areas. Urban flooding has negative impacts on people in both developed and developing countries (Bertilsson et al., 2019; Luo et al., 2021; Zha et al., 2021; Zhu et al., 2022).

The intertwining of flood risk in urban areas with the concept of urban resilience is an issue that has long been of concern to the research community. Although flood risk in urban areas has been extensively studied in terms of its technical characteristics, the field clearly lacks in the area of a holistic approach to mitigate the impacts of flood events both in terms of protection of human life and material losses, which includes spatial planning, prevention infrastructure and citizen engagement.

1. The main causes of increased urban vulnerability

Throughout history, the cities have determined the speed and the quality of change. Cities are the incubators of new economic activities and patterns of life. Thus, the city is not a static concept but a system in constant flux. That is to say that within the city, some economic activities may decline or even disappear, while others may develop and flourish (Samourkasidou, 2020· Lambrianidis, 2002).

Today, most cities in the developed world face a number of challenges arising from the globalization, the internationalization of economies, the de-industrialization, the migratory and the refugee flows, and the critical environmental pressures such as climate change. At the same time, each city's history, identity and distinct national and urban policies, accompanied with the above-mentioned factors, are shaping the new geography of cities, changing both their urban and socio-economic structure (Vitopoulou et al., 2015).

According to the United Nations Concept Paper on Urban Vulnerability (UNEP, 2007), the vast majority of environment-related problems are found in cities. Urban centers face a range of risks and impacts not only within their narrow core but also in their wider functional area.

The main causes of urban vulnerability are the following:
- Population growth
- The pressure to acquire land
- Urbanization and over-concentration of population in urban areas
- Climate change
- Economic growth and ever-changing economic conditions
- Rapid technological progress
- The exacerbation of social inequalities
- Globalization
- Waste of natural resources
- War conflicts and subsequent refugee and migration flows
- The rise of pandemics and health crises

2. Risks of Flooding

Floods are not always the result of rainfall. Other causes of flooding are:
- From fire
- From earthquake
- From water sources
- From surface water and drains
- From groundwater.

In addition, flooding can also be caused by human activity. Indicative examples are the following ones:

By failure/misfire of a technical infrastructure. For example, when dams fail due to faulty construction or maintenance, or when they collapse due to heavy rainfall.

The development and building of infrastructure in flood-prone areas, such as along rivers, near river deltas, in coastal zones or near torrents, has led to an increase in flood vulnerability because the natural resilience of these ecosystems has been compromised. In addition, permanent structures such as bridges can cause problems by blocking the flow of water, resulting in increased water levels upstream of a river.

Deforestation, especially of peri-urban forests due to intensified urbanization and excessive logging, leads to the lack of sufficient number of trees to absorb the quantities of water from heavy rainfall and the inability to reduce the flow of water in the urban landscape.

In urban areas, surfaces made of impermeable materials, such as roads, squares and other concrete infrastructure that do not allow water to penetrate the ground, predominate. As a result, water accumulates and floods in low-lying areas if not properly directed. Also, a direct result of intense urbanization and the covering of the natural land surface with materials such as asphalt and concrete, is the replacement of natural streams by artificial ones. This results in an increase in the speed of water flow due to the lack of friction within the smooth artificial surfaces and the subsequent difficulty in managing it. Urbanization therefore increases surface runoff more than would occur on natural ground. The high proportion of impervious urban surfaces practically prevents rainwater from seeping down to the ground and increases the amount of run-off water (Lekkas, 2000· Ganoulis, 2003).

In addition to the loss of human lives and the significant material damage they may inflict, the effects of floods can also cause environmental impacts, impacts on the economic activity of an urban area and impacts on human health. The real costs of flooding therefore go beyond the purely economic element and may include factors such as loss of confidence in authorities or a greater burden on long-term support services such as clinical stress and anxiety (Kopsida, 2019).

3. Urban Floods

Floods are defined as the overflow of water in areas not covered by water and occur in various forms, namely:
River Floods
Urban Floods
Flash Floods
Coastal Floods
Dam-failure Floods
Floods from melting snow
Aboveground water floods

In many cases there may be a combination of the above categories. For example, among the above-mentioned types of flooding, **Urban Flash Floods** are one of the most important and dangerous forms. Such floods were the one that hit Mandra, Attica in 2017 and the one that recently occurred in Volos in September 2023.

Picture 1: View of Volos from the flood of 2023
Source: https://www.reader.gr/ellada/ti-symbainei-ston-bolo-treis-meres-meta-ti-foniki-plimmyra-etoimoi-na-paixoyme-mehri-kai

Picture 2: View of Mandra Attica from the flood of 2017
Source: https://dasarxeio.com/2017/11/19/51295/

This type of flooding is the most common in the Greek and Mediterranean area and can cause great damage in a very short period of time. Their main characteristics are a mixture of natural and man-made causes. More specifically, they are caused by intense and heavy rainfall, where their intensity and duration play a decisive role in their generation. At the same time, the topography of the area and the distribution of the land surface are also considered to be crucial factors. Soil condition includes soil type, the amount of moisture in the ground and the amount of soil in relation to the rocks, while land cover includes natural vegetation and anthropogenic cover. Soil morphology refers to the slopes of the area. The steeper the slope, the faster water flows in the event of heavy rainfall. This in turn causes a lower degree of penetration and a higher probability of flooding (Diakakis and Deligiannakis, 2012).

4. Mitigation of Impacts and Losses

In general, the destructive action of floods in urban areas has the following phases (Emmanouloudis, 2021):
A. Awareness phase
B. Warning phase
C. Evacuation phase
D. Safe protection phase

Urban flooding is a major problem in many parts of the world as it is one of the most naturally catastrophic events that take place every year, especially in coastal and riverside cities. Urban flooding, as a natural disaster, cannot be avoided. However, losses resulting from flooding can be mitigated through proper planning and management (Eldho et al., 2018).

4.1.The case of inflatable dams

As mentioned above, urban flooding causes damage mainly to structures, both public, such as roads and bridges, and private, such as homes and businesses. For these reasons, it is considered necessary to manage flooding episodes by utilizing modern flood protection measures for the wider urban environment in order to reduce the impact of the flooding episode as well as the cost of restoration.

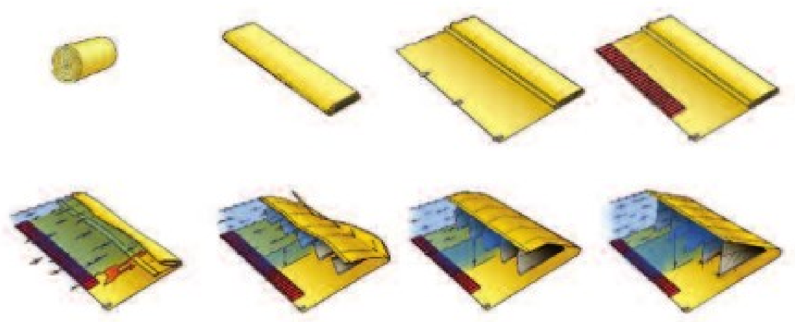
Since the late 1950s, the pioneering construction of inflatable dams was introduced to the scientific community (Imbertson NM, 1960). Inflatable dams are structures that provide new methods for confining a body of water and flood control. They are innovative measures of protection against flood events by replacing permanent structures such as earthen levees or timber barriers or non-permanent structures such as sandbag levees.

Picture 3: Building protection from flood waters Source:Quick Dam, 2020

Particularly for the urban environment, sandbags are a common response to flooding to protect the properties. However, their placement has proven unsatisfactory and this is because they require expertised labor and equipment. In addition, they are time-consuming interventions, especially considering that the time available to provide at least temporary flood protection in flood-prone areas is limited. Furthermore, these structures can quickly become saturated and structurally weakened and even fail, since they pose a problem in terms of removal after flood waters recede (Dery & MegaSecur Inc., 1999).

The simplicity of the inflatable dam concept and proven reliability are key qualities that make them acceptable solutions to multiple problems (Zhang et al., 2002). Inflatable dams can be either temporary or permanent structures. They are installed at short notice in the event of rapidly rising flood waters or threatening conditions. They are flexible to use because they can be folded and moved from one place to another without requiring special conditions for their installation, and can be easily stored using small storage space. In addition, they have easy repair processes, low cost, high durability, adaptability to adverse conditions as well as being environmentally friendly structures (Dery and MegaSecur Inc., 1999; Mason, 1998; Xueqing, 2007).

The innovation of inflatable dams is that they use the flood water itself as a filling element, creating a wall. When the water reaches it, the structure gradually rises as the water level increases, causing the dam to lift with it in a simple and effective way. As a result of this function, the flooded area is separated from the area that needs to be protected (Dery, 2004). The dam works by blocking and/or diverting the flow of water, helping to prevent flooding and property damage.



Picture 4: Stages of inflatable dam development WaterGate Source: MegaSecur Inc., 2018b

4.2. The use of Artificial Intelligence

Artificial Intelligence (AI), with the support of digital humanoids, is an important tool for flood risk management and mitigation. The methodology of an integrated approach to monitoring and responding to a flood event through AI is as follows[8]:

Step 1°: Data collection and analysis

For each river or stream basin, a combination of information is used, including both satellite and sensor data and historical data from Fire Administration and municipal records.

Step 2°: Flood risk categorisation

A Register of streams and rivers is created for each study area, with a ranking of flood risk in descending order. The information collected is used to create it and machine learning algorithms are used to derive the hierarchy. In this way, it is established in order of importance which watercourses are the most dangerous in order to determine the flood risk zones, which are related to the distance from their riverbed.

Step 3°: Install early warning systems

Taking into account the above-mentioned Register, early warning systems are installed, with the aid of Artificial Intelligence, following the risk hierarchy and the range of flood risk zones

[8] See Kravari K. (2023) https://www.tovima.gr/print/green/ta-12-eksypnacrvimata/

of each watercourse. At the same time, the use of warning systems that are not powered by electricity and are not connected to mobile phones is being considered, as such systems often become inoperable during extreme events. As an alternative, sirens are installed which rely on hydro-generators for their operation.

Step 4°: Input of "intelligent agents" to further refine the risk

These are AI programs that can take decisions or perform a service. These digital "humanoids" operate without human intervention, taking into account various parameters such as population density, infrastructure, protected areas, etc. In this way, they specify and "photograph" the most critical areas for protection.

Step 5°: Urban planning and land use

Based on the flood risk categorization and the high flood risk zones of the watercourses, it is examined whether there are critical and vulnerable areas for protection. If such areas are identified, measures related to land use change, specialized protection techniques or, in extreme cases, relocation of settlements are proposed.

Step 6°: Develop stream-specific flood simulation models

Taking into account meteorological observations and hydrological measurements of the wider area, predictive accuracy is obtained as to which areas on both sides of the watercourse will be flooded, which area of the risk zone will be "submerged" and under which specific intensity and duration of rainfall. In each application of the model, depending on the predicted rainfall, it is checked which areas will be affected by the critical areas for protection identified.

Step 7°: Flood risk organisationand planning

The "intelligent agents" are responsible for checking the suitability of the machinery and their technical adequacy, the correct distribution of the intervention teams (spatially and temporally), the automated operation of the flood water discharge gates, the continuous monitoring of the water level in the beds and the static adequacy of the embankments and their possible damage from mammal nesting in them, etc.

Step 8°: Preparation - readiness of populations.

Using AI-powered communication tools (e.g. chatbots or automated voice services) and taking into account flood simulation models, specific instructions are given to the population, depending on the target group they belong to (elderly, vulnerable etc.), the area where they are located (single-storey, two-storey houses, schools, etc.) and the type of flood risk zone in which they are placed (very high, high, medium, etc.). The guidance is further specified in the case of people who are temporarily in a risk area, e.g. at a concert, sport event, etc.

Step 9o: Post-flood impact assessment

The risk management model includes the assessment of post-flood impacts. With the support of AI, it is possible to continuously monitor the evolution of pollution after the flooding in order to monitor the quality of groundwater aquifers and when they will be suitable for drinking and irrigation, etc.

Step 10o: Educate populations against flood risk

It is conducted in an experiential way using Augmented and Virtual Reality technology. The aim is, through these exercises, to enable the trainee citizens to face a flood risk and act accordingly when the critical moment arises.

5. Flood resilience and the role of spatial planning

To reduce the underlying causes of flooding and ensure the continuation of the development process, cities should prioritize risk-based land use planning. Globally, urban centers are at high risk of flooding, not only from frequent and severe hydro-meteorological events and sea level rise, but also from rapid, extensive and often unplanned urban development that goes beyond the construction or improvement of drainage infrastructure. Spatial planning (urban/traffic planning, land use planning, etc.) based on risk management is therefore vital for cities in both developed and developing countries.

Urban form, i.e. the way urban areas are designed and built, together with the urban cultures and lifestyles of citizens, can influence the occurrence and intensity of climate change. Of particular interest is the case of compact cities, which are widely accepted as representing a sustainable urban form and the most appropriate for climate change mitigation (Pizzaro, 2009). These cities are expected to experience the impacts of climate change more severely due to their characteristics such as high density, high traffic loads, traffic congestion, problematic urban layout, lack of open and green spaces, abandoned building stock and high poverty rates (Salata and Yiannakou, 2013).

But just as civil procedures can create increased exposure to risks, they can equally facilitate reduction. The importance of spatial planning in this role is now widely accepted. Spatial planning offers many opportunities for flood management at all stages of the disaster risk management cycle. Cities have used numerous spatial planning tools to manage flooding with varying degrees of success. Examples include regulatory plans, building codes, zoning (to identify floodplains or open spaces), building codes (to ensure flood-resistant structures), etc. (World Bank, 2017).

The effectiveness of planning is easier to be understood by considering what the consequences of its absence will be. For example, rapid, unplanned development has occurred in cities that have subsequently proven to be more vulnerable to natural hazards worldwide. While building practices and controls exist in almost all countries, their implementation can be inconsistent which leads to unregulated and unplanned development regardless the risk management plans and practices.

In a resilient city, its fundamental functions should be continued, under all circumstances, even immediately after a flood. In addition to providing flood protection for the city as a whole, cities should ensure that the integrity of public services and functions is protected, for example not only regarding technical infrastructure such as public transport, tunnels or bridges, but also regarding hospitals, schools, etc.

Involving citizens and stakeholders as early as possible in the planning process is vital and increases the resilience of a city. It should be noted that multifunctional solutions for water resilience and storage and flood protection are increasing in frequency, popularity and influence (Kopsida, 2019).

The integration of flood risk management into the land use planning process is challenging and requires coordination between many stakeholders and institutions, formal and informal, for comprehensive decision-making. Similarly, resilience requires a combination of large and small-scale measures, both private and public. Aligning decision-makers and city managers at all levels is therefore considered crucial and can help accelerate the implementation.

In the same line, the engagement of local communities and citizens in using social media and other digital platforms is a structural element of urban resilience and climate change management. Iterative participatory processes, experiential and interactive learning and the use of open data help to steer projects (technical and intangible) towards the most appropriate, efficient and socially acceptable solutions. Raising citizens' awareness by investing in education, communication and information dissemination is essential to improve the resilience of a community and increase its preparedness.

6. Sponge Cities

Realizing the need to plan cities that are more resilient to flooding, the scientific community concluded that in addition to all the above, the natural absorption capacity of each city should be increased.

This approach aims to create a water management system that acts like a sponge to absorb and store rainwater and then direct or release it for reuse where possible. Its implementation requires a series of infrastructure and structures that promote the development and interconnection of 'blue' and 'green' spaces in the urban environment. Indicatively, adding gardens on rooftops, planting trees in abandoned areas, changing planning regulations to reduce overcrowding, encouraging the use of gravel over concrete in parking lots and/or streets, creating green facades on buildings, creating rain gardens, etc. can all contribute to changing the map from grey to green and enhancing its "spongy" character (Liu, Jia and Niu, 2017).

In conclusion, the city's ability to absorb excessive rainfall, a sponge-like capacity, enables it to manage the large amount of rainwater and thus the risk of a flood event and to mitigate its effects (Liu, Jia and Niu, 2017).

Picture 5: Park Yanweizhou in Jinhua – A sponge city
Source: turenscape.com

Conclusions

The city is a complex and complicated system that is not easy to protect. It is exposed to a multitude of risks, challenges and changes of a geomorphological, economic, social, technological, political and institutional origin, which are particularly challenging to address either individually, as a whole or as a single threat. The concept of resilience exists over time in every city and the degree and mechanisms by which it is achieved varies.

The increasing number of urban floods seriously threatens sustainable urban development and human security, leading to significant loss and damage in both developed and developing countries. However, the impacts of flooding can be avoided to a significant extent with proper planning, targeting prevention and awareness of citizens.

The human factor is present in all phases of a flood event, both at the level of its development and at the level of management. Through preparation and training, the risk of human losses can be mitigated. However, coordination of all stakeholders (citizens, citizens' groups, municipalities, regions, etc.) is required. New technologies, such as augmented reality and electrically autonomous hazard warning systems, are capable of providing greater safety, particularly in panic circumstances.

The use of inflatable dams as a means of protection and response to flood events aims to reduce damage and thus the cost of restoration. Their design addresses the time factor, enabling them to be installed quickly even if the event is ongoing. They function like traditional dams, separating the flooded area from the impervious area. In addition, with the technological advances of recent years, AI can be a powerful element in the toolbox of scientists for a more effective and targeted response to flooding in urban environments.

Cities, especially compact ones, face a number of serious problems, such as high traffic loads, congestion, lack of open and green spaces, neglected building stock, anarchic and often arbitrary building, etc., which determine their degree of vulnerability. One of the risks to an urban environment is flooding, which is exacerbated by the above-mentioned problems. Integrated spatial planning that takes account of all parameters and involves the public, using all modern tools and methods, is a key factor in mitigating the impact in terms of both human losses and material damage. For this reason, in recent years, and in response to climate change, the sponge city model has been particularly developed.

In conclusion, the measures that can be taken to mitigate the effects of a flood event can be divided into two categories: intangible (soft actions and plans) and tangible (technical infrastructure) ones.

References

Bertilsson, L., Wiklund, K., de Moura Tebaldi, I., Rezende, O. M., Veról, A. P., & Miguez, M. G. (2019). Urban flood resilience – A multi-criteria index to integrate flood resilience into urban planning. Journal of Hydrology, 573, 970–982. https://doi.org/10.1016/j.jhydrol.2018.06.052.

Dery, D. (2004). Flood control barrier (Patent No US20040071510A1). https://patents.google.com/patent/US20040071510.

Dery, D. & MegaSecur Inc. (1999). Flood control barrier (CIPO Canadian Intellectual Property Office Patent No. WO 99/49143).

Diakakis, M. and Deligiannakis, G. (2012). Floods in Greece – A statistical and spatial approach. Natural Hazards, 62 (2).

Eldho, T. I., Zope, P. E., & Kulkarni, A. T. (2018). Urban Flood Management in Coastal Regions Using Numerical Simulation and Geographic Information System in P. Samui, D. Kim, & C. Ghosh (eds.), Integrating Disaster Science and Management (pp. 205–219). Elsevier. https://doi.org/10.1016/B978-0-12-812056-9.00012-9

Emmanouloudis, D. (2021). Scientific Note: LESSONS LEARNT FROM RECENT FLOODS IN EUROPE. EUROPEAN COMMISSION Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO).

Ganoulis, J. (2003). Risk-based floodplain management: A case study from Greece. International Journal of River Basin Management, 1(1), 41-47.

Imbertson N.M. (1960). Automatic rubber diversion dam in the Los Angeles River. Journal of the American Water Works Association, 52, 1373-1378.

Kopsida, A. (2019). Urban Resilience and Natural Disasters: Floods. Master Thesis, Athens: NTUA.

Lambrianidis, L. (2002). Economic Geography. Athens: Patakis Publications (In Greek).

Lekkas, E. (2000). Natural and technological disasters. Athens: Access PrePress (In Greek).

Liu, H., Jia, Y. and Niu, C.W. (2017). "Sponge city" concept helps solve China's urban water problems. Environmental Earth Sciences 76(14):473. DOI:10.1007/s12665-017-6652-3.

Luo, P., Xu, C., Kang, S., Huo, A., Lyu, J., Zhou, M., & Nover, D. (2021). Heavy metals in water and surface sediments of the Fenghe River Basin, China: Assessment and source analysis. Water Science and Technology, 84(10–11), 3072–3090. https://doi.org/10.2166/wst.2021.335.

Mason, D. (1998). The Inflatable Rubber Dam in Water Resource Management. Water Resources. https://wisa.org.za/document/the-inflatable-rubber-dam-in-water-resource-management/.

Mavhura, E. (2019). Analysing drivers of vulnerability to flooding: A systems approach. South African Geographical Journal, 101(1), 72–90. https://doi.org/10.1080/03736245.2018.1541020.

Pizzaro, R. (2009) "Urban Form and Climate Change: Towards Appropriate Development Patterns to Mitigate and Adapt to Global Warming", in Davoudi, S., Crawford, J. & Mehmood, A. (eds.) Planning for Climate Change: Strategies for Mitigation and Adaptation for Spatial Planners, London: Earthscan, pp. 33-45.

Salata, K.-D. and Yiannakou, A. (2013). Spatial planning for adapting urban areas to climate change: Issues raised from a case study in the city of Thessaloniki. 13th International Conference on Environment, Science and Technology (CEST2013), Athens 5-7/09/2013.

Samourkasidou, E. (2020). Urban transformations in Eastern Mediterranean port cities (19th-20th century). PhD Thesis. University of Thessaly (In Greek).

Tucci, C. E. M. (2007). Urban Flood Management (WMO/TD-No. 1372). World Meteorological Organization. http://www.wmo.int/apfm.

United Nations Environment Programme (2007) Cities and Urban Vulnerability in the context of Urban Environmental Management, Concept Paper.

Vitopoulou, A., Gemenetzi, G., Giannakou, A. and Tassopoulou, A. (2015). Sustainable cities: Adaptation and resilience in times of crisis. Athens: ASSOCIATION OF GREEK ACADEMIC LIBRARIES (In Greek).

World Bank (2017). Land Use Planning for Urban Flood Risk Management. UFCOP. https://openknowledge.worldbank.org/server/api/core/bitstreams/6876079a-5970-5f8f-aa29-aa025768c7d9/content.

Xueqing Z. (2007). Flexible structures. Internation Water Power & Dam Construction. www.waterpowermagazine.com.

Zha, X., Luo, P., Zhu, W., Wang, S., Lyu, J., Zhou, M., Huo, A., & Wang, Z. (2021). A bibliometric analysis of the research on Sponge City: Current situation and future development direction. Ecohydrology, 14(7), e2328. https://doi.org/10.1002/eco.2328.

Zhu, W., Cao, Z., Luo, P., Tang, Z., Zhang, Y., Hu, M., & He, B. (2022). Urban Flood-Related Remote Sensing: Research Trends, Gaps and Opportunities. Remote Sensing, 14(21), 5505. https://doi.org/10.3390/rs14215505.

www.eca.europa.eu/Lists/ECADocuments/SR18_25/SR_FLOODS_EL.pdf

www.neasmyrni.gr

www.statistics.gr (Greek statistical authority)

www.tovima.gr/print/green/ta-12-eksypnacrvimata/