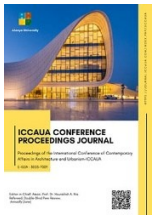

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How can urban resilience manage the Wadi floods: Case of Oued El Harrach in Algiers

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A b s t r a c t

The safety of people and ecosystems is seriously threatened by severe weather events and natural catastrophes. To guarantee that every community benefits from a safe, sustainable built environment, social and economic factors must be considered in resilient urban planning. The commune (municipality) of El Harrach is situated in the east of Algiers and traversed by the same-named river. With growing urbanization throughout the years, El Harrach is strategically located overlooking the Bay of Algiers. However, a number of threats persist, such as the chemical pollution and the risk of flooding. Through this study, we will explore the advantages and limits of urban resilience against the risk of flooding in El Harrach region using a combination of two urban analysis methods: SWOT (for the risk analysis) and NBS (for the proposed alternatives). The results will also be presented in the form of GIS maps in order to suggest future decision-making in the land use regional plan framework.

K e y w o r d s : Urban resilience; flood risk; Algiers; SWOT analysis; NBS method.

1. Introduction

The safety of people and ecosystems is seriously threatened by extreme weather events like heat waves, flash floods, prolonged droughts, and severe thunderstorms. The impacted regions' economic stability is also at peril. These catastrophes result in significant material destruction in addition to the terrible human casualties. They interfere with millions of people's everyday lives and impact vital infrastructure.

This requires providing careful consideration to how structures and the urban environment might be planned to accommodate the various needs of users while merging in with their surroundings (Holling, 1973). For example, using sustainable, locally sourced materials can help buildings' carbon footprints while boosting the local economy. Since sustainability and resilience are seen as inherently connected (Fitzgibbons & Mitchell, 2019, (Amen 2021; Amen and Kuzovic 2018b; Aziz Amen 2022; Al-Dujaili, and Amen 2018)), this paper will focus on the resilience as a strategy to manage and control floods in a sustainable and adaptative ways.

As for the urban scale, several researchers turned to explore the capacity of cities to heal from disasters (Meerow et al., 2016) and highlight the need for integrated, equitable strategies that combine structural and non-structural measures to mitigate vulnerabilities and enhance adaptive capacities (Meerow & and Newell, 2019).

The city of Algiers, capital and metropole, is rich in human, economic and urban resources, and still possesses significant natural resources that have recently been developed. After the development of the “Sublette's” park, which began in 2011, it is now the turn of the banks of Oued El Harrach, which takes its name from the same municipality.

Despite these initiatives, and others in progress, these surroundings are still threatened by the risk of flooding and water pollution from industrial discharges. We will ask the following questions in this work, namely: **How can urban resilience control the risk of flooding on the banks of oued el harrach? Are the planned measures adapted to NBS methods?**

This article aims to explore the environnemental concern of resilient planning in Algiers especially with flood risks in the oued el Harrach banks and analyses the governemental urban planning of the banks which began in June 2012.

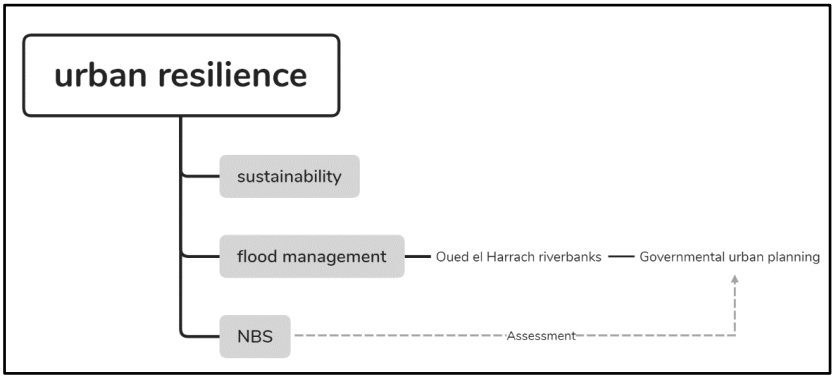

Figure 1. Structure of the Study (Developed by Authors).

2. Urban resilience and flood risk management

Resilience is a concept that dates back to ancient times, when local community needs and the environment molded architecture. Architectural techniques have been evolved to address local issues in various parts of the world, reflecting a thorough awareness of the climate and available resources.

Rapid urbanization in cities and industrialization in the 20th century frequently caused these traditional principles to be neglected in favor of contemporary design that prioritized aesthetics and quick functionality. The main goal of building design was to satisfy contemporary comfort standards, frequently at the expense of increasing environmental hazards.

These days, the focus is on designing built environments that not only endure natural calamities but also develop in an environment that is constantly changing. Considering sustainable developments that are more resilient to both natural and man-made disasters is also essential (Zeng et al., 2022).

Algiers witnesses a growing risk of flooding recently due to climate change, urban sprawl and soil artificialization.

With the Sendai framework 2015-2030 that Algeria signed, the public investment turned to funding projects to develop riverbanks into green esplanades and promenades, sometimes in collaboration with foreign construction companies (such is the case for el Harrach with a Korean company) under the patronage of the wilaya of Algiers.

Since we discuss the flood risk management from a resilient perspective, we aim to analyse the strategies of flood management applied by the Algerian authorities and the organizations in charge with the project of El Harrach riverbanks development.

The objectives of resilience encompass not only the control of flood risk when it occurs but also the prevention of its occurrence. For this reason, Algeria created the governomental institution ECOLOH in 2023. Their missions are to preserve ecological and biological diversity and strengthening recreational, educational and research activities.

2.1.Flood management risk and GIS:

Every significant catastrophe has frequently resulted in technological advancements in the realms of architecture and urban planning. One tangible illustration of this progression is the growing use of sophisticated software to simulate the possible effects of a disaster on a building.

The aim of this paper was to develop the strategical parts of the Wadi riverbanks in GIS in order to represent the flood risks management. Since we lack of data, this step was regrettably cancelled.

2.2. Nature based solutions NBS:

In terms of sustainability facing the natural calamities, NBS seems to be a suitable strategy to preserve the urban environment from consequences of flood risks. According to De Olivera (Lemes de Oliveira, 2025), human-nature relationships well established are essential for a good quality of life. Even the plurality of definitions and nature based solutions over years and regions, we noticed an increasing link from citizens to nature. Since Covid 19, people are more expressive for their need to green urban environnement.

Green infrastructure (GI)—such as urban wetlands, permeable pavements, and green roofs—has emerged as a cost-effective tool for flood mitigation. Studies show GI can reduce stormwater runoff by 20–40% in cities (Nou & Charoenkit, 2020). The early warning systems can also improve real time responses and quick decisions made.

These reasons led us to choose the NBS as a stragety to analyse the urban planning in the river bank explained in the next part of the paper (analysis results).

2.3.Study case

This municipality is located in the Eastern part of Algiers (15km), bordering the sea to the north and the other communes of East Algiers in the surrounding area. It is crossed by national roads, the train line and the oued. The latter forms a delta starting in the south and ending to the sea in the North.

Figure 2. view over Algiers from Saint Raphael balcony (public garden) in 2007.

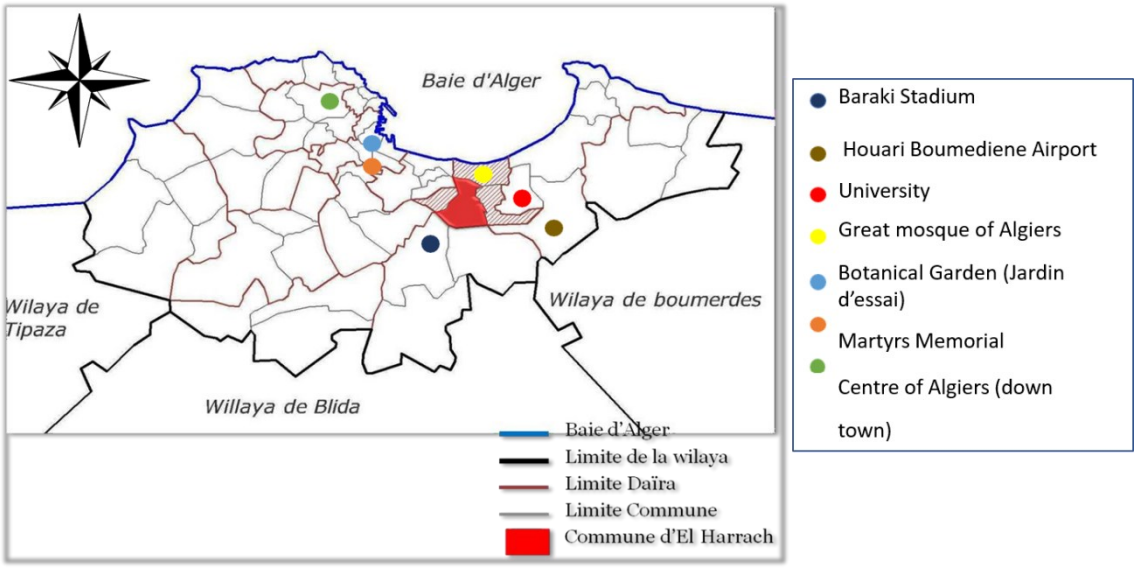

Figure 3. Map of El Harrach municipality. (Developed bu the authors).

3. Material and Methods

The following scheme is a roadmap to explain the methodology used in this paper and the important points that were discussed after in the results section.

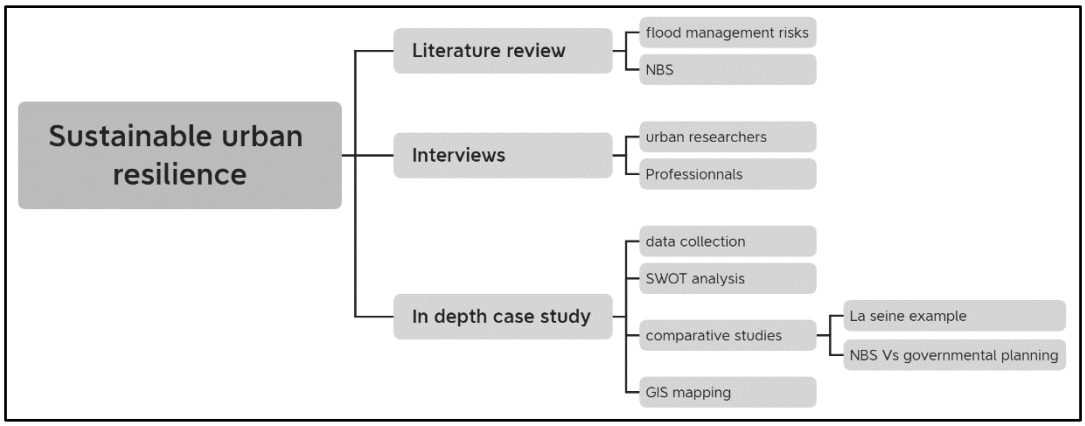

Figure 4. Methodology chart. (developed by authors).

The municipality gave us the land use plan of el Harrach commune (called in Algeria POS plan d'occupation du sol in French).

According to the flooding map , the risk is very high in both banks of the oued (in red) in the central part of the region and medium risk between El harrach and the surrounding communes (in orange, fig. 5).
Mostly, the organization in charge of the project of the banks development:
- Implement a green area called “esplanade”,
    - Clean up the Wadi El Harrach riverbed, monitor its flow and water quality, and carry out regular and ongoing sanitation and waste removal operations,
    - set up flood warning systems (forecasting and alert systems).

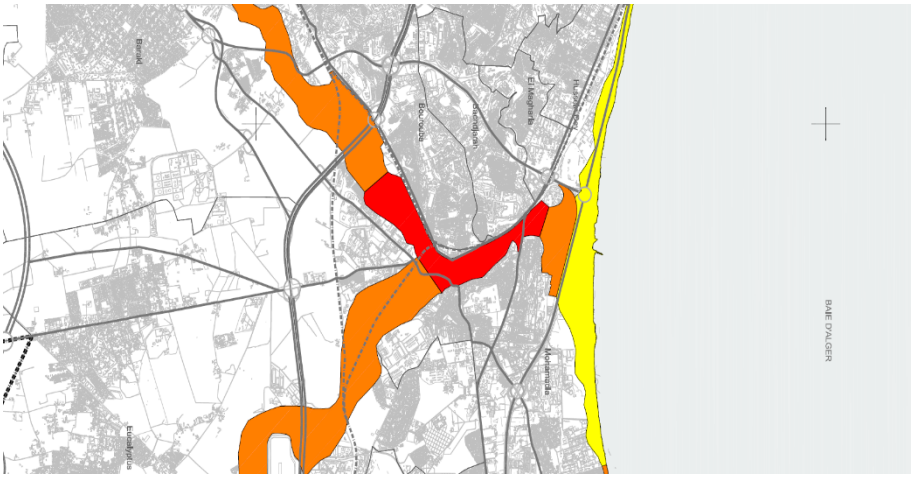

Figure 5. Flood map of flood risks. (URBAB, 2010).

4. Results and discussions:

The following part will discuss the several results of our analysis. Beginning with the site analysis through SWOT that confirmed that the Wadi is a great natural opportinuty for the site but misses diverses amenities such as the socio-cultural facilities.

4.1. SWOT Analysis results:

Table1. Matrix of El Harrach site analysis according to SWOT. (developed by the authors).

Strengths	Weaknesses
Strategic location: Close proximity to Algiers, the airport, and major infrastructure. **Presence of the El Harrach oued:** Potential for landscaping and recreational development. **Good accessibility:** Well-connected to road networks. **Multimodal transportation:** Wide range of transportation options (bus, tramway, metro, train). **Economic dynamism:** Presence of well-established industrial and commercial zones.	**Water and air pollution:** Negative impact on the environment and public health. **Aging infrastructure:** Several facilities require renovation. **Lack of diverse amenities**, particularly socio-cultural facilities. **Insufficient green spaces and ecological continuity:** Quality of life affected by dense urbanization. **Inadequate pedestrian and cycling mobility**: Lack of appropriate infrastructure. **Social inequalities and unequal access to public services**: Some neighborhoods are less well served than others.
Opportunities	**Threats**
El oued rehabilitation projects: Improvement of the environment and enhancement of the riverbanks. **Government support:** Urban planning policies (PDAU 2035) promoting urban renewal. **Green economy development:** Potential for ecological and sustainable initiatives. **Proximity to strategic infrastructure:** – The Great Mosque of Algiers (to the north) – The Baraki International Stadium (to the south) – Houari Boumediene International Airport	**Risk of flooding and landslides:** Impact on vulnerable neighborhoods near the wadi. **Ongoing environmental issues:** Continued pollution and inadequate waste management. **Urban pressure and high density:** Leading to congestion and noise pollution. **Seismic risk:** El Harrach is located in Zone 3 according to the 2003 Algerian Seismic Building Code (RPA 2003).

Figure 6. View on the wadi riverbank.

The upper part of the riverbanks are now designed into esplanades according to the land plan of the municipality. The maps confirmed that the development of the section of the " upper watercourse " flowing through agricultural land, near the Bentalha locality (Baraki commune), is well advanced.

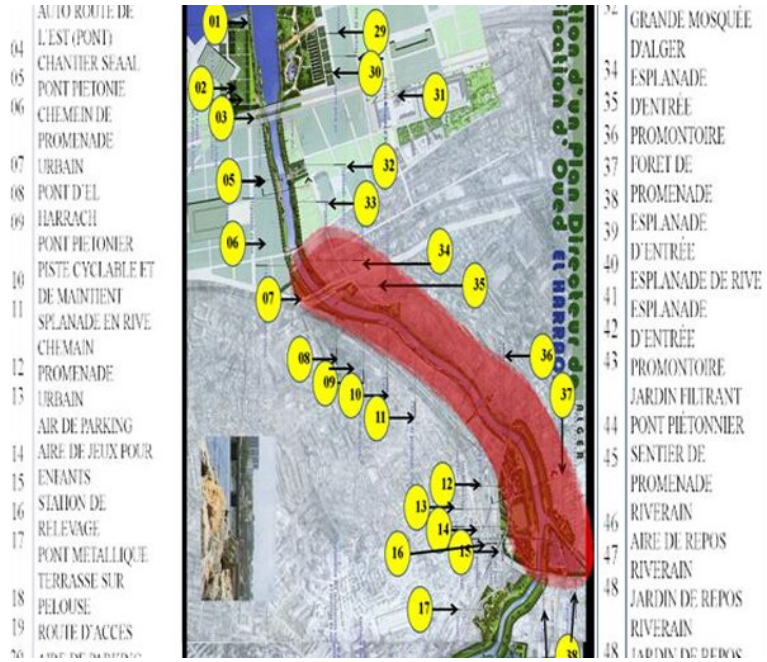

Figure 7. Part of el Harrach land plan. (El Harrach municipality, 2012).

4.3. Interview results

According to Mr Brahimi's interview:

- El Harrach region is in a high risk of flooding since 1954, three minor rising water levels happened (no human causalities) but the authorities have registered this area in the flood risk regions.
- The current Algiers urban plan development (PDAU) and the recent land occupation plan of El harrach (POS) recommended 300 meters of riverbanks.
- There is a citizen satisfaction from the banks project.
- There is also a focus on cyclist-friendly infrastructure.
- In the university, we had a French partnership for workshops and academic contests.
- Unfortunately, we were not able to contact the Korean company who worked about the riverbanks project in El harrach.

4.5. NBS Results:

The region of El Harrach benefits from a blue and green urban spaces. That are nowadays developed as a recreational areas for citizen of Algiers in general (not only of El Harrach commune) beside to "Sablette" park, the wadi of el Harrach was abandoned for years because of the industrial emissions that cause an olfactory pollution.

According to the Algerian Space Agency: "analysis of Alsat-2A images taken on 12/15/2015, shows that landscaping is almost complete. These leisure and recreation facilities, which include rest and sports areas, cycle paths, pedestrian walkways and water features, have been completed".

The study confirms that the development plan of El harrach banks respected the nature based solutions and enhanced the region's natural potential. Unfortunately, we were not able to create GIS maps to represent the results due to the lack of data about El Harrach region and lack of time.

Figure 8. El harach riverbanks before and after development. (Source: Algerian space agency, 2015).

5. Conclusions

1. El Harrach banks development project is one the opportunities for Algiers to safeguard a natural urban environment thanks to the recent studies and ecological solutions applied.
2. Citizen in Algiers particularly are asking for more green and public areas, the need for recreational natural urban areas in developing countries is highly discussed after the pandemic of Covid 19.
3. The strategical development and urban plans in Algeria are closely similar to those in France, Algiers has a great opportunity to benefit from previous experiences of flood risk management in natural framework (and in other countries).
4. Regrettably, the lack of access to data for researchers and the public (citizen) hinders risk management studies. We aim to develop further studies with more quantitative results in the future in the framework of risk management in urban areas.

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Conflict of Interests

The Authors declare that there is no conflict of interest.

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Appendix

Interview questions and responses:

Q1 (Opening): Good morning Mister Brahimi, Could you tell us about your academic or professional background and what led you to work on urban resilience and flood risks?

A: I have 44 years of professional experience. I had a PhD in Urban Design in Scotland and have been teaching at EPAU (Algerian school of Architecture), where I helped launch the postgraduate program. I also held the position of a chair of the pedagogical council and was the founder of the Sergy-Pontoise competition.

I have worked on urban projects in collaboration with Mr. Rahmani. My work on urban issues began years ago with an engineer friend (Mr. Attari). From that collaboration, I began introducing these subjects into fourth- and fifth-year architecture students, and since 2003—following the Boumerdes earthquake—I've been communicating these issues to both students and public authorities.

My focus has been on natural risks, such as earthquakes and floods, as well as anthropogenic risks.

Q2: Do you consider the flood risk to be a major threat in the vicinity of Oued El Harrach?

A: Absolutely. Since 1954, there have been two or three events where water levels rose by nearly one meter, flooding the entire area of El Harrach.

There are engineers at USTHB (Houari Boumediene university in Algiers)—such as Ms. Daoudi, a specialist in flood risks in wadis—who have studied these phenomena.

Wadis, artificial lakes, and dams—all these infrastructures carry the risk of urban flooding.

Q3: What is your opinion on the planned developments in the framework of the PDAU? Which regulatory or technical tools would you use if you were an engineer or urban planner?

A: We worked on the 2015 PDAU, but subsequently it was the POS that was applied. Current regulations now require a 300-meter safety zone.

Preventing vulnerability is above all about avoiding fatalities—which can occur in seconds.

We need to study economic, social, and political feasibility.

Anti-seismic regulations and coastal development frameworks are being used and should be integrated into planning.

Q4: In your opinion, what are the potentials (natural, economic, social, etc.) of the municipality of El Harrach? Can it become a resilient municipality that can easily adapt to changes caused by natural disasters? Why?

A: At the moment, the local municipal president has initiated rehabilitation efforts, and residents seem satisfied.

The development of metro stations is underway, which will help attract investment. Property values are expected to increase. There is also a focus on cyclist-friendly infrastructure and residents are excited about.

From a political standpoint, there's an effort to encourage Algerian investors under a 50/50 partnership scheme with national stakeholders.

Q5: Which tools or software have you used—or would have liked to use—in your research?

A: We used Robot for seismic calculations. For flood-related studies, we worked with anti-flooding standards and examined the technical details of ground floors, such as the design of doors and windows.

We also had a partnership with France, where students worked on joint workshops—both in Algerian and French sites—as part of their academic exercises.

Q6: As a teacher, what key aspects should be taken into account for more resilient and adaptive urban planning?

A: Research by Adel Souami in this field is ongoing.

Inclusion is essential: projects must be integrated into their environments. We should prioritize planting trees to provide shade and protection from sun and rain, and create more natural and public green spaces rather than focusing solely on built facilities.

We should also provide wind protection using eco-friendly materials.

Reducing car usage in favor of pedestrian and cycling areas is crucial.

Urban planning and architectural design should proceed in parallel.

We must prioritize child-friendly spaces and encourage artistic expression.

Appropriate urban furniture is also important.

Closing: we thank you sir for yout time and information

A: Thank you Miss, whish you all the luck for your conference.