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Urban design to enhance flood risk resilience in Tebessa city, Algeria.

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الحمد لله كما ينبغي لجلال
وجهه وعظيم سلطانه

Dedications

I would like to dedicate this modest work;

To my father, my mother, and my grandfather.

To my brother

To my sisters

To all TALBI family, especially my uncles

To my close friends

To all those who fight ignorance and strive for knowledge, I dedicate this humble work.

TALBI Sarra

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Abstract

This research demonstrates how urban design can enhance urban resilience to flood risks, particularly under current and future climate change conditions, and develops an illustrative case for an urban resilience experiment in an Algerian city, the city of Tebessa, which occupies a strategic position in the extreme east of Algeria, a crossroads city on the border of the desert and Tunisia. Over the past two decades, flood risk management has evolved from structural defenses to a broader approach based on resilience. The latter emphasizes the ability to resist, recover, adapt and transform in response to flooding events.

This thesis is divided into three parts: Firstly, the analysis of the urban environment of Tebessa city using machine learning models (XGBoost, Random Forest, KNN) to predict vulnerability to flooding; Secondly, the study of environmental climatology to forecast future rainfall and water levels in the Wadis using GIS; Thirdly, to highlight the relationship between urban expansion and flood risk over the period 1990 to 2023. This research also simulates urban development scenarios in the area covered by land use plan no. 9A. The final results show that the integration of modularity, redundancy, diversity, efficiency and connectivity in urban design considerably enhances the resilience of Tebessa city, the subject of this research, to flood risks.

Key words: Urban design - urban resilience - flood risk - vulnerability – Tebessa city – machine learning- urban environment .

Résumé

Cette recherche démontre comment la conception urbaine peut renforcer la résilience urbaine face aux risques d'inondation, en particulier dans les conditions actuelles et futures du changement climatique, et développe un cas illustratif pour une expérience de résilience urbaine d'une ville algérienne qui est la ville de Tébessa qui occupe une position stratégique à l'extrême Est de l'Algérie, c'est une ville carrefour à la frontière du désert et de la Tunisie. Au cours des deux dernières décennies, la gestion des risques d'inondation a évolué des défenses structurelles vers une approche plus large basée sur la résilience. Cette dernière met l'accent sur la capacité à résister, à se rétablir, à s'adapter et à se transformer en réponse aux événements d'inondation.

La présente thèse élaborée en trois moments : Primo, l'analyse de l'environnement urbain de la ville Tébessa à l'aide de modèles d'apprentissage automatique (XGBoost, Random Forest, KNN) pour prédire la vulnérabilité aux inondations ; Secundo, l'étude de la climatologie environnementale pour prévoir les précipitations futures et les niveaux d'eau de l'Oued à l'aide du SIG ; Tertio, faire ressortir la relation qui existe entre l'expansion urbaine et les risques d'inondation de la période de 1990 à 2023. Cette recherche simule également des scénarios d'aménagement urbain dans la zone couverte par le plan d'occupation des sols n° 9A. Les résultats montrent en définitif que l'intégration de la modularité, de la redondance, de la diversité, de l'efficacité et de la connectivité dans la conception urbaine, renforce considérablement la résilience de de la ville de Tébessa objet de cette recherche face aux risques des inondations.

Mots clés : Conception urbaine – résilience urbaine - risque d'inondation - vulnérabilité - ville de Tébessa - apprentissage automatique - environnement urbain.

الملخص

يوضّح هذا البحث كيف يمكن للتصميم الحضري أن يعزز القدرة على الصمود الحضري في مواجهة مخاطر الفيضانات، لا سيما في ظل الظروف الحالية والمستقبلية لتغير المناخ، ويضع حالة توضيحية لتجربة في الصمود الحضري في مدينة جزائرية، وهي مدينة تبسة، التي تحتل موقعًا استراتيجيًا في أقصى شرق الجزائر، وهي مدينة مفترق طرق على الحدود بين الصحراء وتونس. على مدى العقدين الماضيين، تطورت إدارة مخاطر الفيضانات من الدفاعات الهيكلية إلى نهج أوسع نطاقاً يعتمد على المرونة. تركز المرونة على القدرة على المقاومة والتعافي والتكيف والتحول استجابةً لأحداث الفيضانات.

تنقسم هذه الأطروحة إلى ثلاثة أجزاء: أولاً، تحليل البيئة الحضرية لمدينة تبسة باستخدام نماذج التعلم الآلي (XGBoost، Random Forest، KNN) للتنبؤ بمدى التعرض للفيضانات؛ ثانياً، دراسة المناخ البيئي للتنبؤ بمستويات الأمطار ومستويات المياه في الوادي مستقبلاً باستخدام نظم المعلومات الجغرافية؛ ثالثاً، تسليط الضوء على العلاقة بين التوسع العمراني ومخاطر الفيضانات خلال الفترة من 1990 إلى 2023. كما يحاكي هذا البحث سيناريوهات التنمية الحضرية في المنطقة التي يغطيها مخطط استخدام الأراضي رقم 9 أ. تُظهر النتائج في نهاية المطاف أن دمج النمطية والتكرار والتنوع والكفاءة والفعالية والترابط في التصميم الحضري يعزز إلى حد كبير قدرة مدينة تبسة، موضوع هذا البحث، على الصمود في وجه مخاطر الفيضانات.

الكلمات المفتاحية: التصميم الحضري – المرونة الحضرية – مخاطر الفيضانات – الضعف – مدينة تبسة –التعلم الآلي – البيئة الحضرية.

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ACRONYMS

LUP	Land Use Plan
UDMP	Urban development Master Plan
GCF	Green Climate Fund
XGBoost	Extreme Gradient Boosting
RF	Random Forest
k-NN	k-Nearest Neighbor
ML	Machine Learning
UR	Urban Resilience
DRR	Disaster Risk Reduction
UD	Urban Design
CRF	City Resilience Framework
URF	Urban Resilience Framework
RCN	Resilient City Network
SDGs	Sustainable Development Goals
UN	United Nations
UNDRR	United Nations of Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
NDCs	Nationally Determined Contributions
NAPs	National Adaptation Plans
RH	Risk Hazard
FRA	Failure Risk Analysis
EOP	Emergency Operation Plan
QPE	Quantitative Precipitation Estimation
GIS	Geographic Information System
DEM	Digital Elevation Model
MNDWI	Modified Normalized Difference Water Index
NDWI	Normalized Difference Water Index
NDVI	Normalized Difference Vegetation Index
NDBI	Normalized Difference Building Index
BFR	Building Footprint Ratio
FAR	Floor Area Ratio

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General introduction

GENERAL INTRODUCTION

Context of the study

A natural catastrophe is a significant physical occurrence that affects both biotic and abiotic components of the ecosystem. Certain events have the potential to occur abruptly or gradually (Messner & Meyer, 2006). And from one location to another, the hazard's impact and severity may differ dramatically. According to (Rose, 2004) any nation's economy, developed or developing, will be negatively impacted by deaths, material losses, and environmental damage. It will have a long-term effect on a developing or undeveloped nation's progress. After a calamity, especially floods, every ecosystem experiences an unanticipated change in its biotic and abiotic parameters (A. Balasubramanian, 2005).

Floods, hurricanes, cyclones, and storms are mostly caused by atmospheric meteorological conditions (Holling, 1973). Their consequences will be felt in practically every aspect of the world, regardless of whether they are caused by one or several environmental segments of the planet. A body of water that overflows the river channels is called a flood (Solomon et al., 2007). Since disasters are a constant source of natural hazards on Earth, it is important to research their origins, impacts, and mechanisms. Among all the natural catastrophes, floods have the most potential to cause environmental harm (Leichenko, 2011a; Guhathakurta et al., 2011). Floods are seen as economic and social calamities as well (El-Masri & Tipple, 2002). Certain severe natural occurrences across a drainage basin are linked to floods (A. Balasubramanian, 2005). Storm-water drainage may be the cause of floods in metropolitan areas. The fraction of precipitation that makes it to the streams is known as runoff. Runoff turns into a steam flow when it enters a stream. It is a catchment's or a watershed's whole discharge. According to (A. Balasubramanian, 2005) Relatively significant flows that surpass the natural pathways created for the runoff are referred to as floods; The river stage is the elevation at which water moves through streams.

Since then, a technical perspective has dominated flood research and policy, but in the past few years, the socioeconomic and social aspects have gained importance because of intensified and expanded land use, rising potential for damage in flooding areas, and an increase in conflicts between socioeconomic land use and flood protection policies (Schanze, 2002). Over the past few years, there has been a paradigm shift away from technical flood protection and toward flood risk management. This includes the development of a risk analysis methodology that considers the costs and benefits of various flood risk management strategies, as well as the benefits and drawbacks for society. The foundation of this approach is an investigation of flood damage (Messner & Meyer, 2006).

Risk has always been a part of city life, and many centuries-old cities have demonstrated their resilience in the face of natural disasters, resource shortages, and violence. Global factors emerging at the city level in the twenty-first century, such as terrorism, disease epidemics, economic fluctuations, and climate change, present additional difficulties. As more people reside in cities as centers of economic activity, opportunity and innovation. But cities are also places where stresses accumulate or sudden shocks occur that can lead to social collapse, physical collapse or economic deprivation. That is, unless the city is able to withstand, and urban risks are increasing (Zhang & Li, 2018a). In addition, risks are becoming increasingly unpredictable due to the complexity of urban systems and the unpredictability of many risks, most notably climate change (ARUP, 2015). The evaluation of potential hazards and the implementation of strategies to mitigate them will remain crucial components of urban planning and design. Furthermore, cities must make sure that their investment choices and growth plans strengthen rather than weaken the city's resilience (MacKinnon, 2015).

> *"Understanding resilience requires being able to connect it to other attributes that can be determined, at least in part, by observation." Martin-Breen & Andries (2011) Resilience: A literature review. The Rockefeller Foundation: New York City, p. 11 (Patrick & J.Marty, 2011)*

The term "resilience" has become incredibly popular in academic and policy debate in recent years, and there are many reasons for this sharp increase in popularity (Meerow & Newell, 2015). Socio-ecological resilience theory is a particularly relevant method to addressing future climate uncertainties because it recognizes that systems are continually evolving in nonlinear ways (Meerow et al., 2016). causing some to argue that it is better than similar but more delicate ideas like "vulnerability" (Weichselgartner & Kelman, 2014).

Resilience in particular has become a desirable viewpoint when discussing cities, as they are frequently conceptualized as extremely complex, adaptive systems (Batty, 2008a). In just two decades, the percentage of urban people on the earth has increased from 10% in 1990 to over 50% due to unprecedented urbanization (UNDESA, United Nations Department of Economic and Social Affairs, 2009).

However, what does the phrase "urban resilience" actually mean? The Latin verb resilio, which meaning "to bounce back," is where the word resilience gets its etymology " (R. J. T.

Klein et al., 2003). Since it's an intellectual idea, its definition and history are less clear (Adger, 2000; Lhomme et al., 2010; Pendall et al., 2010; Rega & Bonifazi, 2020). The conceptual fuzziness of resilience is advantageous because it allows it to serve as a "boundary object," a shared idea or object that resonates with various "social worlds" and, as such, can promote interdisciplinary scientific cooperation (Star & Griesemer, 1989). Since the definition of resilience is flexible, stakeholders can agree on a common language without necessarily agreeing on a precise definition (Brand & Jax, 2007a). However, because of its ambiguity, resilience may be hard to operationalize or to create measures or indicators for that can be applied generally (B. Klein, 2016; Wardekker et al., 2020).

Urban resilience must first be defined by defining what is meant by "urban." Depending on the field or theoretical framework used to view it, this can differ greatly (Salat, 2017). In addition, 14 of the 25 publications propose that "networks" make up urban systems. Others still describe cities as being made up of networks and systems. For example, (Desouza & Flanery, 2013) view "cities as networked complex systems." Cities are defined as "complex and dynamic metasystems" made up of "dynamic linkages of physical and social networks" by (Godschalk, 2003a).

consisted of "dynamic connections between social and physical networks." Although the nomenclature and emphasis used in the literature vary, urban systems do in fact comprise a conglomeration of ecological, social, and technical components. For instance, cities are frequently sites of interaction between natural and human patterns and processes, which develop to create a "urban ecosystem" or SES, according to research on urban ecology (Alberti et al., 2003; Resilience Alliance, 2010). The phrase "socio-technical networks" is frequently used in the literature on urban and sustainability transitions to highlight the relationships between social and technical system interactions (Shahabi et al., 2020; Meerow et al., 2016). However, the dynamics of technological development are rarely taken into serious consideration in SES studies (Smith & Stirling, 2010). Given that socio-technical networks frequently have a significant impact on the robustness of the SESs in which they are situated, this is problematic. As a result, some academics—such as (Ernstson et al., 2010)—demand that cities be conceptualized as intricate socio-ecological systems made up of networks that are socio-technical as well as socio-ecological.

The research on urban resilience is incoherent in this regard because the spatial and temporal scale taken into consideration also significantly influences how urban resilience is characterized (Alberti et al., 2003; Ernstson et al., 2010; Brown et al., 2012). Through system interactions such as the trade of resources, water, energy, capital (of many forms), and the like, globalization processes have entwined cities with remote locations and areas (Armitage & Johnson, 2006; Davoudi et al., 2012). The "hinterland" and the city are heavily dependent on one another, making it difficult to draw precise borders between them. Some studies of urban resilience have demonstrated how these social, ecological, and technical systems transcend the boundaries of the city proper in order to acknowledge its multi-scale aspects (Ernstson et al., 2010; Desouza & Flanery, 2013). But a lot of people don't; and according to (Feliciotti, 2016) the timescale of action, examines discrepancies in the way different definitions handle temporal scale.

Creating the connection between a location's setup and operation. Nonetheless, our comprehension of the resilience of urban areas is still lacking, and urban planning and design are ill-prepared to provide guidance on how to successfully create places that benefit people, the environment, and the economy. We are in dire need of a novel theoretical solution that is also practically applicable to address this difficulty. Our solution, which is based on seeing urban form as a complex adaptive system in and of itself, is to bring together the domains of resilience and design. Based on these considerations, we attempted to develop a framework that, by learning from the guidelines that produced successful and adaptable places in earlier studies, encourages an urban design practice that designs places much less and much better, with implications for policy-making. Rather of serving as an ideological platform, our approach is:

1) Theoretical: having learned to identify the recurrent factors that increase the problem of flooding and its relationship with resilience according to the previous studies through the urban design parameters.

2) Practical: It promotes a revised place-building process and offers the analytical and assessment instruments needed to give the right design to the future city, making it a crucial resource for planners and designers.

Problematic

The planet currently confronts a significant challenge from dangerous shocks and mutations. In accordance with the rising climate variability, the warmer atmosphere increased the evaporation of water surfaces and held more water, increasing the intensity of the rainfall, and the frequency of extreme events has increased in cities; As a result, these changes increased the effectiveness of natural hazards already observed: The twentieth century has seen a rise in the frequency of large floods (Foudi & Osés, 2014a). Due to the fact that 50% of the world's population lives in urban regions, large-scale natural catastrophes threaten the security, stability, and sustainability of cities and result in significant economic and human losses. This complicates the management of big hazards in cities (Lak et al., 2020; Meerow et al., 2016); cities and urban systems must thus be able to recover more quickly from shocks and pressures caused by the environment (Leichenko, 2011b) as well as inadequate catastrophe management in urban areas (Cutter et al., 2008a).

In urban areas, the impacts of climate change are expected to lead to an increase in the frequency of urban hazards. Today, several factors complicate major risk management in cities (Almeida et al., 2020). Major hazards causing significant social, economic and environmental damage worldwide, particularly in highly vulnerable urban areas (Hochrainer-Stigler et al., 2020).

The concept of urban resilience has developed in response to this situation, as it allows us to understand the behavior of an area as a system of systems, improving its response to climate-related extreme events, and as a system of systems (Almeida et al., 2020); In this regard, stability and readiness are seen as crucial elements of urban resilience, enabling cities and metropolitan regions to take preventative action in the face of unanticipated catastrophes (Lak et al., 2020), Due to the fact that the idea of urban resilience emerged in reaction to this circumstance, "resilience thinking" has also emerged as a crucial idea that has changed how people see solutions for vulnerable places (Leichenko, 2011b), resilience is a concept "revolving around the capacities of urban environments to absorb disturbances, recover from shocks, self-organize, adapt and transform" (Zhang & Li, 2018).

Recently, there has been persistent near exponential rise in the number of publications targeting a more comprehensive knowledge of urban resilience, with the idea being differently defined (Brand & Jax, 2007a).

In particular, the governments have placed a lot of emphasis on resilience from a technological and scientific standpoint and as a defense against risk. In this way, it has solidified its place in the public policy arsenal and educated a wide spectrum of policymakers from across the globe (Cabinet Office, 2011), through various practices, which we mention at three scales are:

Worldwide scale, there are some of the world's best practices to enhance urban resilience to major hazards:

a)- *The Sendai Framework for Action on Disaster Risk Reduction 2015 – 2030* (UN, Sendai, Japon, 2015): which stand on four priority actions: understanding disaster risks, strengthen disaster risk governance to better manage risk, invest in disaster risk reduction for resilience, and strengthen disaster preparedness for effective response and "building back better" during recovery, rehabilitation and reconstruction.

b)- *Green Climate Fund* (UN, Frankfurt School, 2016): The result of a consensus involving 194 governments and launched at the end of 2011, the Green Climate Fund (GCF) is the financial mechanism of the United Nations Framework Convention on Climate Change. The Fund's objectives are to: limit or reduce greenhouse gas emissions in developing countries, help vulnerable communities adapt to the impacts of climate change already being felt;

Continental scale, there is the Action Plan for the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 in Africa (African Union, 2015); which stand on seven goals set by the Sendai Framework are as follows: Significantly reduce disaster mortality on the continent by 2030; Significantly reduce the number of people affected by disasters in Africa by 2030; Reduce, by 2030, direct economic losses due to disasters as a proportion of gross domestic product; Significantly reduce, by 2030, the disruption of basic services and the damage caused by disasters to critical infrastructure, including health and education facilities, in particular by strengthening their resilience; By 2020, significantly increase the number of countries with national and sub-national/local disaster risk reduction strategies; Significantly improve international cooperation with developing countries by 2030, providing appropriate and continuous support to complement national efforts to implement the Sendai Framework; And significantly improve people's access to multi-hazard early warning systems and disaster risk information and assessments by 2030.

National scale, a few national attempts have been made to optimize urban resilience to major hazards:

a)- *The Action Plan for the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 in Algeria* (UNISDR, 2015): for a Resilient Algeria Achieving Disaster Risk Reduction in Arab Countries: National Study on Good Practices; This national study summarizes Algeria's efforts in planning for greater disaster resilience; Algeria's national study identifies three entry points giving impetus to DRR efforts: Political will and institutional capacities, early sectoral commitment, and Regional and international partnerships.

b)- *National biodiversity strategy and action plan 2016-2030* (MERE, 2017): For sustainable economic and social development and adaptation to climate change, SPANB was conducted under the aegis of the Ministry of the Environment and Renewable Energies (MERE) with a view to developing a vision and lines of Action for biodiversity in Algeria, The SPANB is structured around four strategic orientations, summarized as follows: Adapting the institutional, strategic and legislative framework, Development, sharing and valorization of knowledge and know-how for inclusive sustainable development, Conservation and restoration of Algeria's natural capital, and Enhancing biodiversity for a green economy.

d)- *Responsibility, a culture of peace, diversity and plurality at the service of sustainable development in Algeria* (MAE, 2019): to monitor and evaluate the implementation of the Sustainable Development Goals (SDGs) in Algeria. The 2030 Agenda for Sustainable Development is the result of a consensus of the international community (the United Nations system) around a vision of the world that aims:

*Eradicate poverty in all its forms, everywhere in the world.

*Eradicate hunger, ensure food security, improve nutrition and promote sustainable agriculture.

*Enable all people to live in good health, and promote well-being for all at all ages.

*Achieve gender equality and empower all women and girls.

*Ensuring equal access to quality education for all, and promoting lifelong learning opportunities.

*Guarantee access to water and sanitation for all, and ensure sustainable management of water resources.

*Guarantee access for all to reliable, sustainable, modern and affordable energy services.

*Promote sustained, shared and sustainable economic growth, full and productive employment and decent work for all.

*Build resilient infrastructure, promote sustainable industrialization that benefits all, and encourage innovation.

*Reduce inequalities within and between countries.

*Make cities and human settlements inclusive, safe, resilient and sustainable.

*Establish sustainable consumption and production patterns.

*Take urgent action to combat climate change and its repercussions.

*Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

*Strengthen and revitalize the global partnership for sustainable development.

*Preserve and restore terrestrial ecosystems, ensuring their sustainable use, manage forests sustainably, combat desertification, halt and reverse land degradation and halt biodiversity loss.

*Promoting peaceful and open societies for sustainable development, ensuring access to justice for all, and building effective, accountable and open institutions at all levels.

Algerian cities, like all cities in the world, are exposed to major risks resulting from the effects of climate change and greenhouse gases, which determine the risk of both natural and industrial origin. And when we talk about the risks that affect Algerian cities in general, we find several types of risk that threaten our cities (Law N° 04-20 of December 25, 2004 on the prevention of major risks and disaster management in the context of sustainable development).

The Wilaya of the city of Tebessa, like other cities around the world, faces a major challenge in terms of shocks, adverse changes and major risks to the city's security and sustainability; The city of Tebessa is located in a watershed is characterized by a dense hydrographic network consisting mainly of ravines and gullies (Wadis) that cross the existing urban fabric of the city (Report of the UDMP intercommunal Tebessa-hammamet-elkouif-bekkaria-boulhaf dyr the final phase, 2018), such as: *Wad Rafana* , *Wad Nagues* , *Wad Zaarour* , *Wad segui* ,*Wad El anba* , *Wad Elgnater soud*, *Wad ELmizab* and *Wad chabrou*.

The city of Tebessa ranks first in terms of the number of buildings constructed on flood-prone areas, with 1 7236 constructions (National Economic and Social Council, 2003). According to the latest statistics, flooding is the number one natural hazard threatening the city of Tebessa (Directorate of Civil Protection, 2021).

Dealing with the issue of urban resilience in the city of Tebessa is an interesting undertaking, as we note that this city is of particular interest to urban policies, which have gone so far as to give it an event-driven consecration (the creation of 05 new urban poles in the Wilaya of Tebessa following Executive Decree N° 11-237 and Executive Decree N° 11-239 of July 9, 2011 declaring the operation relating to the construction of public housing and accompanying facilities in certain Wilayas to be in the public interest). With this in mind, a large number of projects have been launched, including major housing programs and facilities within these new urban centers:

- 5 700 LPL housing units + public facilities, at pole N°28 DOKKANE.
- 3 240 AADEL housing units, 440+100+250 LPA housing units and 1000+200 LPL housing units + university campus at pole N°03 BOULHAFDYR...etc.

Despite the fact that these urban poles have undergone well-studied urban design and exploited attempts such as the ORSEC plan (executive decree N°19-59 of 02/02/2019) and the general prevention plan (law N° 04-20 of 12/25/2004), but the most common interest recently is the vulnerability of the urban fabric of these poles to flood risks, based on the recording of significant losses caused by seasonal precipitation, such as: the incident recorded on 25/10/2021 of Pole N° 03 of BOULHAF-DYR exactly at the level of the 3 240 AADEL housing program which were handed over to their beneficiaries on 07/08/2021. This made it difficult for the population to adapt to such conditions.

So, thinking about new concepts for protecting urban fabrics or a city like Tebessa is not a purely technical gesture, but an opportunity to solve problems of risk management methods and urban design.

The essential question we have been addressing throughout our research is that of:

- **How can enhance the urban resilience of Tebessa city against flood risk through the urban design parameters?**

Or:

- **To what extent can urban design, with its multiple parameters, contribute to enhance urban resilience and improving environmental performance in the city of Tebessa in the face of flood risks?**

Another secondary questions can also guide this research:

- **What is an effective way to assess the urban resilience of the urban fabric against flood risk?**
- **Will urban resilience become a new imperative in Algerian cities to reduce flood risk?**

Other questions may also guide us, such as:

- **What conceptual parameters can contribute to urban resilience in order to reduce the risk of flooding?**
- **How can urban design achieve urban resilience objectives?**

In order to answer these questions, we have identified two assumptions, which we hope are the most relevant:

Assumptions

Following the content of the study context, two distinct assumptions are formulated to demonstrate the main statement of the present thesis.

ASSUMPTION 1: Through environmental conditions.

Participation promotes not only the production of sustainable development factors, but also the improve urban design through environmental parameters only (Wadis, precipitation ... etc.) according to the flood susceptibility mapping of the city, to make the city of Tebessa more resilient permanently and to assimilate the disturbances and risks of recurrent flooding or future.

ASSUMPTION 2: Through the spatial morphology of the urban fabric.

The conservation and protection of cities require the emergence of urban design that allows the adaptation and anticipation of disasters related to floods through the spatial morphology of the urban fabric only (Urban structure: roads, the shape of open spaces, infrastructure, buildings, and plot layout ...etc) that can control these risks and reduce losses.

Objectives

To make this a reality, and to provide insights into the research question and problem in question, we have adopted an essential objective, which is to target the conceptual parameters that influence the vulnerable urban fabric in order to reduce flood risk and optimize urban resilience in the following ways:

- On the environmental level: Understand the phenomenon of flooding and the impact of environmental parameters on the optimization of urban resilience, in order to ensure sustainable environmental regulation and promote the ecosystem elements of the city of Tebessa.
- On the urban level: identify parameters for enhancing urban design, and find an effective way to assess urban resilience, particularly urban fabrics. This will help to mitigate vulnerability problems on the one hand, and improve systematic testing and subsequent argumentation on the other. This will lead us to a proposal for the urban design of the city of Tebessa to optimize urban resilience against flood risks.
- On the Architectural level: find a contribution and a reflection on how to adapt and reduce flood risks and losses in order to ensure the ecological comfort of constructions.

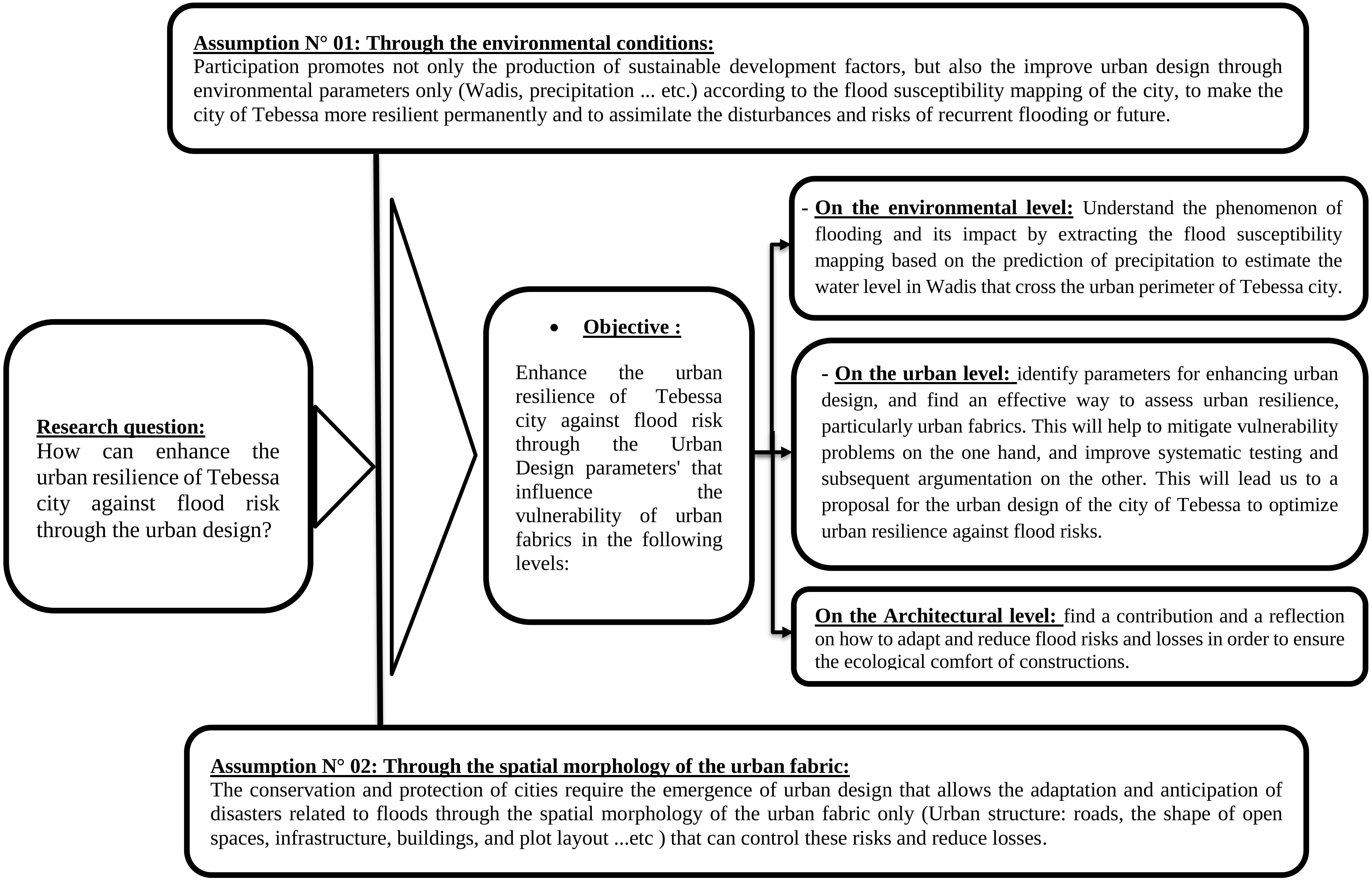


Figure 1 Research question, assumptions and objectives.

Thesis structure and research approach

The current thesis report begins with a general introduction, then consists of two main parts, the first section contains two chapters and the second section contains three chapters, a total of five chapters, and at the end the conclusion appears.

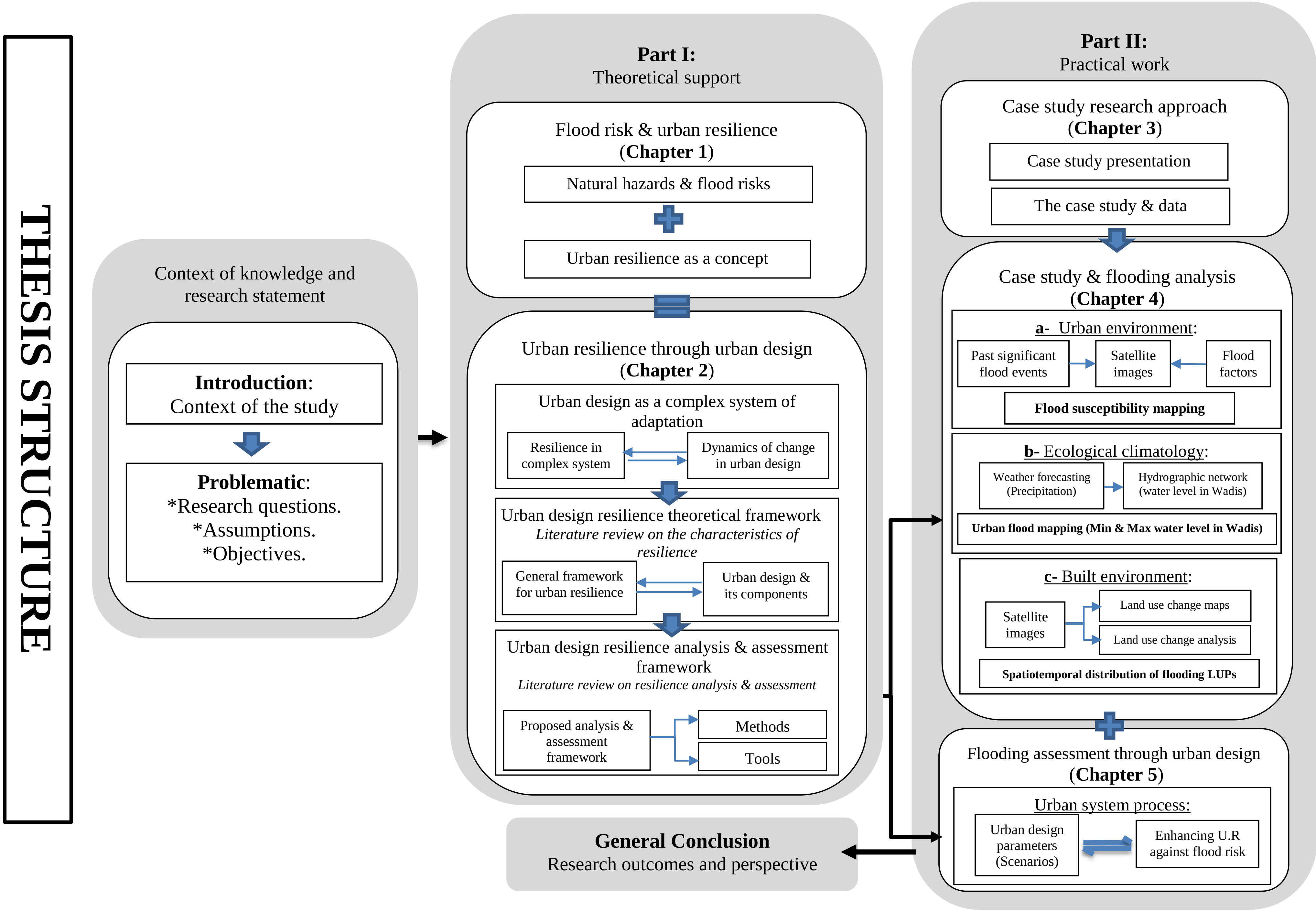
Chapter 1 introduces the natural hazards, especially flood risks, as well as the factors that cause them and their impact on the environment, concerning the methods that have been used to reduce them, in addition to the concept of urban resilience and its relationship to reducing the risk of floods based on previous studies as a state of the art.

Chapter 2 deals with the concept of urban resilience through urban design, discussing urban design as a complex adaptive system according to its dynamics of change. This part is based on a literature review of the characteristics of resilience to define the theoretical framework of urban design resilience according to its components; Simultaneously, the previous literature reviews are discussed in terms of methods and tools for analyzing and assessing urban design resilience through proposed analysis and assessment framework.

Chapter 3 begins with a description of the research region, Tebessa city; Algeria, including its features and constituents. The methodology part then goes over the several factors that, based on earlier research, make the city more vulnerable to flooding. This leads to the division of this chapter into two sections: (i) case study presentation; and (ii) case study and data.

Chapter 4 defines the scope of the study, which focuses on the analytical elements of this field in relation to flood risks. In order to try to identify areas of vulnerability to find initial solutions to the concept of urban resilience through urban design, the current chapter of the case study analysis “Tebessa City” is divided into three sections that are aligned according to the previous chapter and are arranged as follows: 1) Urban environment; 2) Ecological climatology, and, 3) Built environment.

Chapter 5 focuses on the impact of urban design criteria on flood risk and urban resilience in the current and future climates. This chapter deals with the assessment of flooding through urban design parameters that have a major role on urban resilience against flood risk in the land use plan N° 9A of the city of Tebessa; In the course of the study, sections are based on environmental and parametric approaches and 3D simulated models to thoroughly understand the relationships between study components.


THESIS STRUCTURE
Context of knowledge and research statement
Introduction: Context of the study
Problematic: *Research questions. *Assumptions. *Objectives.
Part I: Theoretical support
Flood risk & urban resilience (Chapter 1)
Natural hazards & flood risks
Urban resilience as a concept
Urban resilience through urban design (Chapter 2)
Urban design as a complex system of adaptation
Resilience in complex system
Dynamics of change in urban design
Urban design resilience theoretical framework
Literature review on the characteristics of resilience
General framework for urban resilience
Urban design & its components
Urban design resilience analysis & assessment framework
Literature review on resilience analysis & assessment
Proposed analysis & assessment framework
Methods
Tools
Part II: Practical work
Case study research approach (Chapter 3)
Case study presentation
The case study & data
Case study & flooding analysis (Chapter 4)
a- Urban environment:
Past significant flood events
Satellite images
Flood factors
Flood susceptibility mapping
b- Ecological climatology:
Weather forecasting (Precipitation)
Hydrographic network (water level in Wadis)
Urban flood mapping (Min & Max water level in Wadis)
c- Built environment:
Satellite images
Land use change maps
Land use change analysis
Spatiotemporal distribution of flooding LUPs
Flooding assessment through urban design (Chapter 5)
Urban system process:
Urban design parameters (Scenarios)
Enhancing U.R against flood risk
General Conclusion
Research outcomes and perspective

PART I

Theoretical support

Introduction

More than ever, a number of cities worldwide are subject to the inevitable occurrence of man-made or natural disasters that almost always have lethal outcomes (Lak et al., 2020). The primary causes of the catastrophic accelerating climate crisis and global warming are human activities, particularly insensitive urban fabrics, anarchic urban development, and massive and rapid urbanization. As a result, the earth is more vulnerable to and severely confronted with natural disasters (Leichenko, 2011b). Among these risks that threaten cities, we mention floods, which have become a constant threat to their stability (Ben et al., 2003).

According to (Rozalis et al., 2010), flooding is regarded as a serious natural hazard with an incalculable coverage of losses. According to (Wu et al., 2002), flooding is caused by high precipitation and snowmelt, which causes rivers to overflow from their usual borders and temporarily submerge territory that was not previously covered by water. River flooding is the category for this kind of flooding. According to (Tehrany et al., 2013), there are two more forms of coastal and flash floods. However; Flash floods pose a serious risk to both human life and infrastructure, including highways, trains, and metropolitan areas. Floods can introduce infections into urban areas and result in microbial growth and illnesses because of the potential damage caused by such catastrophes, which can have a significant financial impact (Youssef et al., 2016).

Urbanization has drawn increasing attention from environmental specialists in the twenty-first century. By the 20th century, however, this ratio had sharply increased, with half of all people on Earth believed to be urban inhabitants (Buckley et al., 2008). In 1990, just 15% of people on Earth lived in cities (Fonseka et al., 2019). Over half of the world's population lives in urban regions like cities and towns. According to UNFPA (UNFPA (United Nations Population Fund, 2018), a significant portion of urbanization in Africa and Asia is expected to result in serious social, economic, and environmental issues. By 2030, this figure is expected to reach approximately five billion people. Rapid urbanization has resulted in a drastic decrease in the amount of green space relative to the growth of impermeable area due to the massive increases in population and buildings in cities (Valy, 2010). The risk of flooding has grown in many locations due to population growth, the rapid expansion of urban development, and valley side construction (B. Feng et al., 2021). According to Choubin et al. (Choubin et al., 2019), this issue has a detrimental impact on both the environment and human population because it degrades the land's quality, increases material and human losses, and has an impact on human health and biological control (Kikegawa et al., 2003; Meineke et al., 2014).

Recent years have seen a significant expansion in urbanization and climate change, which has resulted in a number of environmental issues and heightened risk of natural catastrophes (Bates et al., 2010). Urbanization tends to raise the potential for residual damage and the worth of flood losses avoided, yet development that is encouraged may benefit society in part financially. Revisions to the hydrological study, however, may result in lower or higher benefit estimates as well as a reduction in the standard of defense that floodplain dwellers experience. It will be easier to prevent complacency about flood dangers if flood frequencies in protected urban areas are periodically reevaluated (Thompson et al., 1991). According to (Tehrany et al., 2013) Unplanned urbanization growth is predicted to increase the likelihood of flood disasters.

According to (Wardekker et al., 2020), resilience is defined as a strategy or set of strategies that can handle the high degrees of unpredictability associated with complex urban difficulties. Due in part to its potential application to a wide range of urban dangers and issues, resilience has drawn attention, notably in urban studies (Meerow & Newell, 2015; Salat & Bourdic, 2012). Its positive implications could also have played a role; according to (McEvoy et al., 2013; Carmona, 2003) "strengthening resilience" offers a policy framework that is noticeably more positive than "reducing vulnerability." In reality, cities and global network organizations of cities have adopted the idea (Zimmermann et al., 2016). Ecology and complex adaptive systems research (Holling, 1973) are largely responsible for the notion of resilience. These fields study the stability of ecosystems and a system's ability to bounce back after shocks or disturbances. Since then, a variety of scientific domains have used it (Brand & Jax, 2007a; Meerow et al., 2016). In this regard, the concept of urban resilience came to reduce the risk of flooding especially in urban area like cities (Community Resilience Group, 2015). According to (Brand & Jax, 2007a), the adaptability of the resilience concept may facilitate its use by practitioners as a "border object," linking the many domains, industries, and parties participating in the urban system. But it can also impede practice by providing insufficient guidance and support to manage resilience and incorporate it into municipal planning (Puchol-Salort, O'Keeffe, Van Reeuwijk, et al., 2021). In fact, critical literature contends that resilience is frequently used as a catch-all term for future-proofing in practice without a precise definition or explanation of how particular system features or interventions might enhance it (Davoudi et al., 2012; Albert, 1999).

However, the term "resilient city" is not easily achieved because of its political connotations, which make it a contentious and divisive phrase. The word embellishes and hides an inherent contradiction, which is the major source of the problem (Salat & Bourdic, 2012). In this context, Cities are complicated, interconnected systems that are very susceptible to risks from environmental disasters. Cities are very vulnerable to flooding due to the same characteristics that make them appealing and viable, such as their linked infrastructural systems, population densities, architectural designs, and gathering spaces (Godschalk, 2003a). Through this challenge; One aspect of the urban ecology that affects a city's overall resilience is its physical layout. Urban design, however, "does not exist in isolation, but within a framework of rules and regulations, actors and agents, networks and local cultures," even though it may be "the most tangible dimension of cities" (M. Marcus et al., 2019).

Chapter I
Flood risk & urban resilience

I.1. Introduction

Nowadays the world faces a major challenge against harmful shocks and mutations according to the increasing variability of climate, the warmer atmosphere increased the evaporation of water surfaces and held more water that increases the intensity of the rainfall, and the frequency of extreme events has been more aggressive in cities; as a result, these changes increase the effectiveness of natural hazards already been observed: the frequency of great floods has increased during the twentieth century (Foudi & Osés, 2014a).

The large-scale natural disasters provoke security and stability, and sustainability of cities and cause serious human and economic losses according to several causes in this decade that complicate the management of major risks in cities, because 50% of the global population lives in urban areas (Lak et al., 2020; Meerow et al., 2016); Urban areas, roadways, and railroads are just a few examples of the infrastructure that is seriously threatened by flash floods. Because of the potential for severe damage from these calamities, floods have the potential to introduce infections into urban areas, where they can lead to microbial development and diseases (J. Taylor et al., 2011), that’s why cities and urban systems need to be able to quickly bounce and to be more resilient from climate-related shocks and stresses (Leichenko, 2011b), and also disaster mismanagement in urban regions(Cutter et al., 2008a).

In this regard, stability and preparedness are considered important keys to urban resilience, supporting urban areas and cities to be proactive in the face of reactive events (Lak et al., 2020), because the concept of urban resilience has developed in response to this situation, moreover, “resilience thinking” has become a necessary concept that brought a new perception as a solution to the vulnerable areas (Leichenko, 2011b), as it allows us to recognize the behavior of the city as a complex system, it involves several factors such as social, economic, ecological …and many processes and objects are interdependent in space and time, this complex system becomes vulnerable when one of these subsystems is not functioning, damaged or unable to adapt to new challenges (Narieswari et al., 2021; Zhang & Li, 2018a), if this situation is not properly solved it can be devastating or fatal (Narieswari et al., 2021; Zhang & Li, 2018a). However, it is difficult to translate resilience from a scientific idea into workable municipal initiatives. The study of resilience is dispersed among a number of academic domains, and perspectives on it change over time and throughout disciplines (Leichenko, 2011a). The adaptability of the resilience concept may facilitate its use by practitioners as a "border object," linking the various domains, industries, and parties participating in the urban system (Brand & Jax, 2007b). Resilience is a general phrase for future-proofing that is frequently used without a precise definition or explanation of how particular activities or system features might make it better (Davoudi et al., 2012). This may result in ad-hoc policymaking, where decisions made to adapt resilience to the local environment are made in an implicit, non-deliberate, and possibly unsuitable manner for the objectives and requirements of the community (Wardekker et al., 2020).

The current chapter on flood risks and urban resilience research aims to better understand the flood risk vulnerability, perception, and preparedness through the previous studies, this understanding will be useful to formulate methods of controlling floods through urban resilience as a contemporary concept that helps reduce flood problems. Accordingly, the two sections of this chapter are organized as follows; 1) Natural hazards and flood risks; 2) Urban resilience as a concept.

I.2. Natural hazards and Flood risks

I.2.1. Conceptual tensions and definition

I.2.1.1. Flood risks and natural hazards

A natural disaster is a significant physical occurrence that affects both biotic and abiotic components of the environment. Certain events have the potential to occur suddenly or gradually (A. Balasubramanian, 2005). And the notable natural disasters on Earth are: tsunamis, cyclones, tornadoes, storms, earthquakes, volcanic eruptions, and floods …etc. In addition to this, the ecosystem is also suffering more severely from desertification, forest fires, landslides, and droughts; These are all worldwide occurrences, and there isn't a region on Earth where these natural dangers don't exist (El-Masri & Tipple, 2002).

A hazard's impact and degree of intensity might differ greatly from location to location, whether a nation is developed or developing, material losses, environmental damages and death will have a significant impact on its economy. It will have a long-term effect on the growth of a developing or underdeveloped country. Following a disaster, such as a flood, every ecosystem will experience an unanticipated change in its biotic and abiotic parameters (A. Balasubramanian, 2005).

Floods, hurricanes, cyclones, and Storms are mostly caused by atmospheric meteorological conditions. Their consequences will be felt in practically every aspect of the world, regardless of whether they are caused by one or several environmental segments of the planet (UNISDR, 2017).

Floods are one of the dangers that incite cities, as defined by the American Planning Association, which characterizes as: “a physical state or phenomenon that has the risk of causing death, injury to people or the economy, infrastructure damage, agricultural loss, damage to the region and its territories, disruption of commerce and services, or other kinds of harm or loss (Department of Environmental Protection - State of New Jersey, 2009)

Over the world, flooding has emerged as the most common natural hazard that may cause serious environmental, social, and economic harm, particularly in metropolitan areas where there is a high risk of flooding (W. Xu et al., 2021).

The possibility of flooding that poses risks to one's life, health, property, resources, and ability to use a natural floodplain is known as a flood hazard. The following factors make up its physical characteristics: places or regions impacted, chance of occurrence and frequency, speed of flood onset, and severity (duration, size, and extent of the flood) (Department of Environmental Protection - State of New Jersey, 2009).

According to (A. Balasubramanian, 2005); The flood is a body water that overflows the river channels and certain extreme natural occurrences over a drainage basin are linked to floods; In urban areas, floods may be due to storm-water drainage. The portion of precipitation that makes it to the streams is known as runoff. Runoff turns into a steam flow when it enters a stream. It is a catchment's or a watershed's whole outflow. Relatively significant flows that surpass the natural pathways created for the runoff are referred to as floods. The river stage is the elevation at which water moves through streams.

The volume, length, and speed of water moving through these pathways define a flood; A river basin's network of streams drains the precipitation that the Catchment zone collects. Flooding results when a river's tributaries' combined flow of water exceeding the river's channel capacity (Messner & Meyer, 2006).

I.2.1.2. A complementary definition

I.2.1.2.1. Vulnerability

The sensitivity of the impacted socio-economic and ecological systems, or, more generally put, their potential to be injured by a dangerous event, determines the actual amount of flood damage of a given flood occurrence (Cutter, 1996). In general, the more vulnerable element is, the more exposed it is to a hazard, and the more susceptible it is to its forces and impacts, the more likely it is that it will be harmed. As a result, data on these variables—which can be described in terms of element-at-risk indicators, exposure indicators, and susceptibility indicators—are necessary for any investigation of flood vulnerability. Natural and social science indicators are quite important in this sense (Messner & Meyer, 2006).

a) Indicators of element at risk

The set of components that flood occurrences have the potential to affect is the subject matter of any examination of flood vulnerability (Glade, 2003).

The number of social, economic, or ecological units or systems that are at risk of being impacted by all types of hazards in a particular area is indicated by element-at-risk indicators. These include people, homes, businesses, economic production, private and public buildings, public infrastructure, cultural assets, ecological species, and landscapes that are either situated in or connected to hazardous areas (Füssel & Klein, 2006).

The extent of damage can be assessed in monetary and non-monetary units, reflecting the overall maximum probable flood damage, based on information about which and how many elements are at risk of being affected by flood occurrences. Another name for this is harm potential. Additionally, exposure and susceptibility indicators are always tied to element-at-risk indicators and play a vital role in the study of flood vulnerability since every element at risk is exposed to and susceptible to flood occurrences to varying degrees(El-Masri & Tipple, 2002 and Messner & Meyer, 2006).

b) Indicators of exposure

The exposure indicators according to Messner Frank and Meyer Volker (Messner & Meyer, 2006); There are two types of them that need to be identified. The initial one is required to represent the type of exposure to various components that are at danger. The position of the various elements at danger, their elevation, their proximity to the river, their proximity to places that will be inundated, the return times of various types of floods in the floodplain, and similar information are all provided by indicators. When combined, these indicators provide information on the likelihood of flooding in floodplains as well as the danger to the different components that are susceptible to flooding. The second category's indicators concentrate on broad aspects of floods, such as their length, speed, sedimentation load, and depth of inundation; When taken into account together, they show the extent of flooding as well as how it is distributed over time and area. Exposure indicators provide detailed information about dangerous risks to the different components that are at risk.

c) Indicators of susceptibility

The degree to which an element at risk reacts instinctively to a threat is measured by susceptibility indicators. The study of (Messner & Meyer, 2006) relates susceptibility indicators to the affected ecological, economic, and social systems or to individual unit of these systems. Sensitivity in the limited sense refers to a significant set of measures that measure the absolute or relative impact of floods on certain items at risk in relation to social and economic systems. For instance, a common concern in damage analysis and study is the effect of inundation depth and flood duration on structures, with the aim of identifying building categories with comparable susceptibilities. And this make sense, because single-story structures often sustain more (relative) damage than multi-story buildings, and because wooden dwellings are far more vulnerable to floods than stone ones.

In a broader sense, indicators of susceptibility relate to system characteristics and encompass the social context of the formation of flood damage, particularly the knowledge and readiness of those impacted by the flood about the risk they live with (prior to the flood), their ability to deal with the hazard (during the flood), and their capacity to withstand its aftermath and recover (after the flood event). As a result, the three pertinent sets of indicators relate to people's and social systems' capacities and methods for readiness, coping, and recovery (Ben et al., 2003).

Many studies have been conducted on the susceptibility of social systems in a larger sense, and several indicators have been proposed in this respect. First of all, indicators of awareness and preparedness for individuals and communities show how well-informed and equipped threatened individuals and communities are to handle dangerous situations. Examples of these indicators include the number of households protected from the physical effects of flooding by technological measures, the number of individuals insured against flood damage, the number of individuals prepared to act in disaster management, and the caliber of flood protection measures and disaster management organizations (Tapsell et al., 2002). Second, because general socioeconomic indicators are frequently correlated with an individual's and social system's capacity to deal with the effects of floods, coping indicators include general data on age, poverty, structure, gender, race, social relations, education, institutional development, and the percentage of the population with special needs (Ben et al., 2003). Technical system indicators are included in this category as well since the social effect of floods is closely linked to the vulnerability of lifelines and basic infrastructure, which sustain the population's basic requirements supply. Technical susceptibility indicators identify vulnerabilities unique to floods and the capacity of socio-technical systems, such as electricity supply, waste water treatment, drinking water supply, and communication networks, to tolerate the effects of flood occurrences (Messner & Meyer, 2006). Thirdly, social susceptibility in a more general sense also has to do with the actors' capacity to withstand the effects of the danger and restore the pre-existing circumstances. This element is intended to be measured by recovery markers. Among others, Indicators include the amount of money that impacted families and communities have saved up, the capacity to replace lost goods, the cohesiveness of social structures, and the outside assistance from friends, the government, and private donors. Moreover, the long-term effects of flooding on general health conditions and living standards can be quantified in terms of time or space, taking into account the amount of time needed to return to pre-hazardous circumstances (Proag, 2014).

Many susceptibility indicators indicating the impact of floods on economic units and systems, such as enterprises, sectors, and economic production regions, do exist, despite the fact that less study has been done on economic systems and their susceptibility to floods in a broader sense; The key indications pertain to readiness, coping, and recovery tactics and techniques, much like in the case of social systems. Indicators of economic preparation provide information on the social and technical readiness of economic actors and systems, including flood insurance and the capacity to shift output to alternative sites; And the ability of actors to deal with flood disasters is measured by coping indices (Thompson et al., 1991). Recovery indicators eventually provide data on long-term effects like as productivity, competitiveness, and insolvency as well as the amount of time needed to return to pre-crisis circumstances (Iorhen, 2021).

There are detrimental biological effects of floods in addition to the regular occurrences and important role that floodplain ecosystems play in the environment; Ecological systems can be severely disturbed, particularly if the floodwater is contaminated or if substantial sedimentation processes take place (Haase, 2003). It seems sense to discuss ecological systems' vulnerability to flooding as a result; While relating susceptibility to specific biological units is counterproductive, it makes sense to develop susceptibility indicators in a more comprehensive context about ecosystems as a whole. These metrics may be obtained from the discussion of ecological resilience. A system's ecological resilience is its capacity to withstand changes or shocks from the outside world and continue to exist (Holling, 1973). The degree of change or disruption that a system can withstand, its ability to self-organize and adapt, and the speed at which it returns to equilibrium following a disturbance are all significant markers in this context (Pimm, 1984).

Identification of the most significant relationships between expected flood damages and the exposure and susceptibility characteristics of the affected socio-economic and ecological systems is the task of vulnerability analysis, which comes after the most significant indicators for elements at risk, exposure, and susceptibility in a narrow and a broader sense have been identified and quantified. The development of anticipated harm to an element at risk is shown by typical outcomes based on susceptibility and exposure characteristics. As a result, the wide meaning of vulnerability stated above can be clarified. The qualities of a system that characterize its susceptibility to damage can be used to define vulnerability. Referring to the entire spectrum of potential flood risks, it may be articulated in terms of functional correlations between projected damages involving all elements at risk and the sensitivity and exposure characteristics of the affected system (Messner & Meyer, 2006).

I.2.2. The connection between flood damage and vulnerability

In order to estimate the advantages of flood protection measures beforehand and, thus, assist policy decisions, flood damage analysis attempts to quantify flood damages for certain future scenarios with distinct flood occurrences and flood policies. The idea of damage potential is important in this situation. The greatest amount of damage that might happen if a region is flooded is represented by its damage potential. In many cases, a vulnerability factor is derived for the most important vulnerability indicators having a substantial impact on the degree of damage produced during a flood event. Vulnerability aspects must be taken into account in these analyses in order to estimate the proportion of the damage potential which will finally materialize, i.e., to determine expected damages (Glade, 2003).

Such a factor is used in some vulnerability analyses to quantify the expected damage reduction for multiple categories of elements at risk. It is derived from expert knowledge and empirical data on flood damages and then expressed on a scale between 0 (no loss at all) and 1 (total loss); The exposure indicator "inundation depth" is the most crucial vulnerability indicator for assessing damages in current flood damage evaluations (Elsner et al., 2003).

I.2.3. Types of floods

Different topographical features and weather patterns have an impact on the variables that increase the risk of flooding. As a result, three scenarios highlight the different kinds of flood danger (Department of Environmental Protection - State of New Jersey, 2009):

a- *Rainfall flood*: the possibility of flooding brought on by the water level and small streams.

When precipitation pools on the surface of the ground or flows over it instead of infiltrating into the soil or draining through the current infrastructure and conventional drainage systems, surface water flooding occurs.

b- *River flood:* Risk of river flooding.

When a river's capacity is exceeded by the amount of water entering from nearby land, flooding occurs.

c- *Coastal flood:* Risk of coastal flooding.

Elevated tides and erratic weather patterns can cause sea flooding.

I.2.4. Classification of damages

Flood affects fall into two categories: direct effects and indirect consequences. Assessing the losses and damage also involves classifying the repercussions into tangible and intangible categories. This classification is the most often used in the literature, despite variations in interpretations and the definition of what is considered direct or indirect (Rose, 2004).

- The direct impacts occur when water comes into direct contact with the materials that are exposed; the indirect effects are the consequence of the direct impacts, and they occur at different scales (spatiotemporal). Moreover, affects that can be readily measured in monetary terms are referred to as tangible effects, whereas effects pertaining to products that are not traded on the market or for which a value cannot be determined are referred to as intangible effects; (Figure 2), (Foudi & Osés, 2014a).
- Direct and tangible: damage to buildings and equipment, possessions, costs associated with cleaning, infrastructure (such as sewage and road systems), livestock, and agricultural produce...
- Direct and intangible: damages and losses to property, people, and cultural assets...
- Indirect and tangible: Public services such as water, power, public service, and transportation flows are disrupted.
- Indirect and intangible: overcoming the aftermath of an event, learning how to avoid flooding, changing one's decision-making or perception of danger,... (Rose, 2004).

Because of the manner that flood risk affects ecosystems, the effects on wellbeing are not always negative. Given that the characteristics of the flood and societal perceptions of the services will influence the way it functions (Foudi & Osés, 2014a).

Furthermore, flow processes are more indicative of catastrophic costs than inventory procedures. The flow statistics therefore make it possible to record the duration of the outage and the return of the activity. (Foudi & Osés, 2014a).

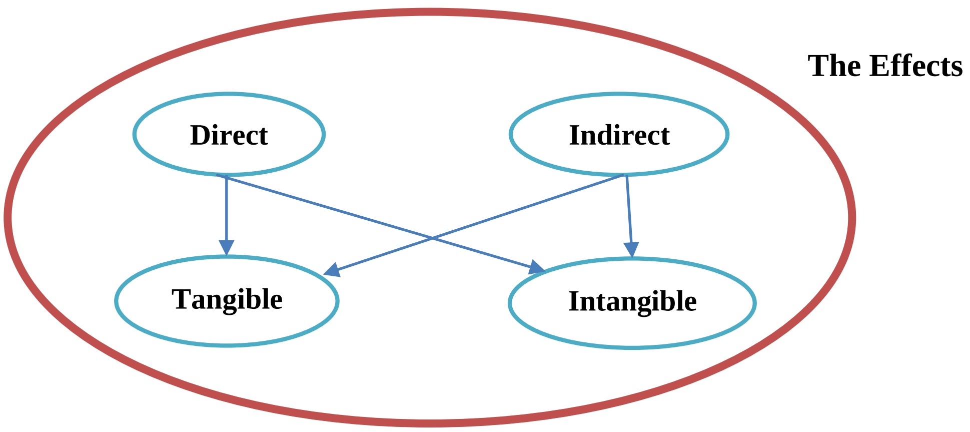


Figure 2 Classification of flood damage, (Foudi & Osés, 2014a)

I.2.5. Causes of flooding

Flooding in general comes due to both physiographic and meteorological factors. And according to (A. Balasubramanian, 2005) the important physiographic factors are:

- Land use and land cover: Runoff is also influenced by an area's land cover and land use. Overland movement is always encouraged by built environments and bare terrain. In this context, the goal of human land alteration through farming, deforestation, and urbanization is to maximize rainfall runoff.
- Slope of the catchment: More overland movement is invariably encouraged by a steep slope.
- Type of soil: The soil's texture and composition determine infiltration levels. More water will seep into sandy and alluvial soils than into silty and clayey soils.
- Storage facilities of surface water: Ponds and lakes have large capacity to store water and prevent flooding.
- Natural and artificial drainage: Among the contributing issues include improper land use, channelization of natural waterways, and obstruction of drains by constructions.

According to (Iorhen, 2021; A. Balasubramanian, 2005); The major climatic factors are:

- Presence of a large catchment zone: large catchment zones will undoubtedly result in higher runoff, which will cause flooding.
- Antecedent Precipitation Index (API): is a measurement of the soil moisture content that existed before to the storm.
- Variation of atmospheric pressure: any variation in the atmospheric pressure can be contribute to any movement of storms.
- Intensity, form and duration of precipitation: The main cause of flooding is intense rainfall. Prolonged periods of low-intensity rainfall can also result in prolonged floods and flooding.
- Direction of a storm movement: The storm's trajectory is one of the most distinctive factors that causes flooding. Should the storm proceed downstream, it will exacerbate the river discharge's magnitude.
- Low temperature and high humidity: Low temperature and high humidity slow down the environment's rate of evapotranspiration.

I.2.6. Environmental impacts of floods

Streams naturally experience flooding, and the majority of floods are dangerous; They might demolish houses and other assets, remove the topsoil, and leave the area desolate. Also, Random and intense floods can cause enormous losses if people are not ready. The land may be inundated by rivers, lakes, or seas (Aldardasawi & Eren, 2021).

Flash floods' water moves quickly, and they possess the ability to uproot trees, move boulders, demolish buildings, and completely collapse bridges. These waters carry away massive volumes of garbage. Therefore, there are many ways that floods affect the ecosystem (A. Balasubramanian, 2005).

Floods can have an impact on the geomorphology, sedimentology, population, society, and economy. A typical, natural stream's configuration may alter due to flooding, and it may produce fresh rills and creeks. The loose topsoil may be removed and the slope altered by the erosive power of the floods, it is also capable of rolling the boulders out of the way. Floods cause severe sediment transfers; Depending on where they occur, floods can kill thousands of people and destroy entire settlements (Kulkarni et al., 2014).

In this regard, and according to (A. Balasubramanian, 2005) it can be said that floods affect the environment by:

- Housing damages and loss human lives.
- The main instances of environmental damage caused by floods include the destruction of commercial and industrial properties.
- The inflow of storm water into sanitary sewers.
- The combination of sewer overflows and the promotion of disease vectors.
- The spilling of sewers over the streets, delays in public transportation.
- The negative effects on aesthetics.
- The disturbance of wildlife habitat.
- The economic losses resulting from the washing away of crop lands, and the pollution on water ways and receiving water bodies.

Floods have an impact on human health in various locations, and the two biggest effects of the environment on life are the emergence of epidemics and the transmission of diseases carried by water; Disease vectors are carried by floodwaters. There will be an effect from the upstream to the downstream. Malnutrition, acute respiratory infections, measles, and various forms of diarrhea are the illnesses to be feared (Aldardasawi & Eren, 2021).

Additionally, justified is the sudden rise of communicable diseases and numerous drowning deaths may occur during a severe flood, it primarily affects the most vulnerable groups in society, including young children, the elderly, and the ill. Also, hypothermia, or the loss of body temperature brought on by extended submersion in water and exposure to wind, is the most prevalent medical condition among the survivors (Gautam & Van der Hoek, 2003).

Severe shortages of food and food grains might result from floods, and Organic, inorganic, and hazardous contaminants are all widely dissolved in and transported by water. In addition, Floodwaters can shorten these elements' residency times in a matrix, increasing their mobility over land and water resources. Storm water pollution in metropolitan areas has a wide range of erratic and scattered sources. Within municipal bounds, residential, commercial, and industrial activities, parking lots, and highways all contribute to pollution. Floods will negatively impact soil fertility; It is inevitable for manures, fertilizers, and soil humus to leak out of their respective areas (Aldardasawi & Eren, 2021).

Large-scale siltation in ponds, lakes, and tanks will result from soil erosion, this is one of the main reasons for reservoir sedimentation is flooding. It regulates and restricts the amount of area that can be used to store water, increases outflow, and causes flooding; Millions of goods, including homes, crops, and cattle, can be destroyed by floods; It is widely acknowledged that flooding is one of the most common, pervasive, and catastrophic natural hazards in Asia's highly populated areas. During the monsoon season, flooding in many areas of the Indian Subcontinent reaches disastrous levels; One famous example from history is the erosion of the Harappan (Indus) Civilization as a result of several significant floods in the Indus River (Gautam & Van der Hoek, 2003).

Extremely large-scale disasters have happened in the past, and floods will always pose a threat; Annually, about 5 million people worldwide are impacted by floods that are officially recognized. Year after year, the rate likewise rises; Proportionately more money is also spent on flood assistance (A. Balasubramanian, 2005).

I.2.7. Methods of controlling floods

Experts in meteorology, hydrology, geomorphology, and engineering analyze the origins, consequences, management, and mitigation of floods. In order to manage floods and lessen their effects, several strategies are used; They are mainly attempted (A. Balasubramanian, 2005):

- Construction of reservoirs, natural detention basins, river channels, inter-basin water transfer, levee and flood wall construction, diversion canal construction, bank stabilization, best agronomic practices, afforestation, and catchment zone management are some ways to modify the flood.
- Flood control procedures, such as flood plain management, structural modifications, flood proofing, disaster preparedness, flood forecasting, and flood warning, are implemented to alter the susceptibility to flood damage.

- Additional strategies for mitigating losses include flood prevention, public health, emergency evacuation, flood insurance, and tax exemptions.

The effects of a disaster can be mitigated. To lessen the negative effects, one must comprehend the nature of the hazard; Finding high-risk or flood-prone locations is a critical component of flood control measures (Soleimani-Alyar et al., 2016).

An integrated hydrological and meteorological study can be used to map the areas of a river basin that are susceptible to flooding, it is necessary to approach flood management with particular aims, objectives, and techniques based on the location, area, drainage systems, and frequency of floods in basins.

Controlling future floods primarily depends on evaluating past floods; Estimating the likely future runoff rates and associated features (water depths and velocities) using information from rainfall patterns, terrain, soil hydrology, land use patterns, and the morphology of natural and artificial river channels is the first stage in assessing the risk of flooding; As a result, maps illustrating the limits of flood damage will be created. These maps of hazard zonation will undoubtedly aid individuals in organizing and managing flood situations, it facilitates the dispersing of water, the creation of gravel beds, the growth of shelter belts, the treatment of land, the management of trees, fencing, and the building of flood walls (Mandych, 2007).

There will always be floods despite flood controls; However, it can prevent all death and lessen the loss. It requires scientific and political effort to lessen the effects of natural risks; Globally (Soleimani-Alyar et al., 2016).

I.3. Urban resilience as a concept

I.3.1. Conceptual tensions and definition

I.3.1.1. Definitions of urban resilience and understanding

In order to gain a deeper understanding of resilience, many studies from various fields have provided definitions of the concept in chronological order, starting in 2000 and ending in 2023. These definitions have led to the conclusion that resilience is an adaptive concept that can change depending on the field and time.

First, In ecological systems’ Resilience is not determined by the stability of the populations that make up the system or even by the system's ability to maintain a stable ecological state, but rather by how well it operates (Naeem et al., 1999), It is difficult to monitor since an ecological system's resilience depends more on how it is used than on the stability of its subsystems or even on its capacity to adapt to a variety of habitats (Adger, 2000; (Pimm, 1984), in addition, Resilience is a system's capacity to tolerate disruptions or to endure as much inconvenience as is reasonable before modifying its structure by changing the guidelines, boundaries, and parameters that control behavior (Adger, 2000).

In the agricultural and biological and environmental sciences, Resilience is the capacity of cities and their environs to adjust to change before adjusting to a new state of structures and practices (Alberti et al., 2003); To maintain a specific dynamic system, urban governance must also possess the transformative ability to deal with uncertainty and change (Ernstson et al., 2010).

In social science; “Stress adaptation to climate change, effective risk internalization, and speedy recovery from negative consequences” (Henstra, 2012).

In environmental science; urban studies, and social science; “Is the ability of an urban system—and all of its socio-ecological and socio-technical networks—to adapt to change, quickly transform systems that limit current or future adaptive capacity, and maintain or quickly return to desired functions in the face of disruption.” (Meerow & Newell, 2015)

In earth and planetary sciences, and according to Meerow “The ability of the environment to tolerate shocks and carry on with business as usual afterward is referred to as resilience” (Meerow et al., 2016), Resilience is hence a notion that “centers on the ability of urban settings to change, absorb shocks, disrupt, recover, and self-organize” (Zhang & Li, 2018b), Thus resilience is a concept that “The ability of an urban area to endure a variety of shocks and strains and to adjust to novel environmental circumstances.” (Reu Junqueira et al., 2021).

In urban science, "The capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience" is how the Resilient Cities Network defines "urban resilience." (SACN-Cities-Network, 2022).

Recently, “Resilience is the quantifiable capacity of any urban system, together with its people, to continue operating despite shocks and strains while constructively adapting and changing in the direction of sustainability is known as urban resilience.” According to (Vasilevska & Slavkovic, 2023).

After gathering all of these definitions, we can state that, generally speaking, urban resilience is seen as a positive attribute that centers on the capacity to tolerate systemic changes in the city and preserve equilibrium (TALBI et al., 2022).

The city's ability to adapt to flood hazards and withstand them is becoming increasingly appealing. Even when hazards are identified, risk minimization and vulnerability are typically not big issues until after such tragedies have occurred (W. Xu et al., 2021).

I.3.1.2. A complementary definitions of urban resilience

One reason for the challenge in defining resilience is the wide variety of stakeholders and the various fields in which the notion is applied, such as ecology, psychology, physics, and so on. The main definitions of resilience are summarized in Table 1.

Table 1 Definitions of Resilience.

Author	Definition
(Alberti et al., 2003)	Cities' capacity to adapt to change, build new buildings, and rebuild after it.
(Godschalk, 2003b)	A robust system of social connections and physical systems
(Rose, 2004)	makes a distinction between adaptive resilience—the system's ability to withstand difficult circumstances—and natural resilience, which is tied to typical conditions.
(Campanella, 2006a)	a city's ability to avoid destruction
(Norris et al., 2008)	a group of adaptable abilities capable of preserving system functionality and compatibility during a crisis
(Lamond et al., 2009)	includes the notion that communities and cities need to be able to bounce back fast after both big and little disasters
(Cote & Nightingale, 2012)	Positive or negative system characteristics give birth to resilience, which becomes a normative perspective.
(Romero-Lankao & Gnatz, 2013)	The ability of urban inhabitants and systems to endure a variety of risks and pressures
(Sharifi & Yamagata, 2018)	One of the aspects of urban sustainability that aims to preserve human-environment interactions across time is resilience.

I.3.1.3. Source of Resilience

A city's resilience is influenced by a variety of causes, and no two cities have the same innate ability to recover. Some of these are hard to alter since they are products of more significant political and economic realities. For instance, a city with a strong, diverse economy would recover far faster than one that is weak or highly specialized (Campanella, 2006a).

Additionally, planning and designing may significantly increase a city's resilience. A city may weather a crisis with a low death toll provided its emergency management and evacuation procedures are well-practiced. Cities may lessen their risk by making investments in planning and executing hazard mitigation strategies. By establishing the Federal Emergency Management Agency Mitigation Directorate in 1993 (FEMA pub 1, 2010), the federal government institutionalized hazard planning. Seven years later, the Disaster Mitigation Act was passed, providing state and local governments with financial incentives and technical support to plan ahead and lessen the effects of disasters. After the terrorist events of 2001, many of these efforts were shelved, but things might change again. Hurricane Katrina, according to a recent article by David Godschalk, "hammered home a simple but irrefutable lesson: Acting beforehand to mitigate natural hazard impacts is much more effective than picking up the pieces afterwards" (Overly, 2021). This also applies to corporate enterprises. In The robust Enterprise, Yossi Sheffi makes the case that recognizing possible "high-impact/low-probability disruptions" is essential to creating a robust company. Increasing essential infrastructure's "redundant capacity" is also important (Sheffi & Jr, 2005). When applied to cities, this may entail planning many escape routes, setting up a standby power grid or communications system for disaster management staff, or setting up shelters and food and water caches at the local level.

But eventually, people are what make cities and businesses resilient. A company is only as creative as its management and staff. A city can only withstand as much as its people can. Throughout history, resilient citizens have made urban resilience possible. When the German Luftwaffe began bombing London every day and night at the beginning of World War II, the city's "Blitz spirit" allowed people to continue living. The industrial East End and Buckingham Palace were bombarded, seemingly bridging the class gap. Ministers in the government, who believed that the explosions would result in widespread anarchy and a decline in morale, were thankfully shown to be incorrect. Following the September 11, 2001 terrorist attacks in New York, spontaneous candlelight vigils and unofficial monuments fostered a tangible sense of community and camaraderie that persisted until the August 2003 blackout, which was notably different from the 1977 "Night of Terror" due to a comparable power loss (Campanella, 2006a).

Following the 1985 earthquake in Mexico City, a completely new kind of resilience surfaced. A calamity tests a government's legitimacy and authority, showing the flaws in political leadership and, in certain situations, even shocking abuses of power. These kinds of disclosures have the power to spark political change. Following the earthquake, the Mexican government rebuilt important infrastructure systems, sometimes at the price of providing city dwellers with the necessities of food and shelter. The earthquake also revealed evidence of corruption, which inflamed unrest even more: it destroyed newly constructed municipal buildings that were shoddily constructed and revealed police station vaults that stored torture evidence. All of this had the effect of inciting the people of the capital to demand political responsibility and a realignment of priorities for reconstruction. "Within days of the earthquake people began to organize on their own and reclaim the city for themselves by taking over the business of recovery and reconstruction without assistance from government authorities," (Sapountzaki, 2014) wrote in The Resilient for All. Their efforts made sure that things like housing and healthcare were regained or restarted. A commitment to constructing affordable homes, new political leadership, and long-lasting political reforms were the results of grassroots movement.

Remarkable tales of civic fortitude have been told in New Orleans. The people who live in the damaged Lower Ninth Ward, where over 60% of the population is African American, have been struggling for the opportunity to rebuild. Katrina also severely damaged and completely submerged the working-class Vietnamese American neighborhood of Versailles in east New Orleans; houses, shops, and the vast market gardens around the neighborhood were all devastated. But thanks to a shared history, the social fabric held. An incredible level of collective resilience was made possible by this. According to the New York Times, the Vietnamese.

> "*established community groups to rebuild, with the [local] church serving as the central office. A single crew fixes and purges the homes. Some schedule acupuncture treatments to reduce stress and tetanus injections to avoid sickness. during the families that come by during the day to check on the property, another crew goes grocery shopping and prepares rice and spicy stews. Friends and relatives take turns driving each other to and from work, church, or even to and from the Texas cities where they are temporarily residing."* (Page 22 of Hauser, *2005; (Campanella, 2006a)*.

The Vietnamese community's ties to New Orleans were strengthened by surviving the disaster rather than eroded. "My people say homeland now; they mean New Orleans. Before Katrina, when we said homeland, we meant Vietnam," a local priest told the Times-Picayune (Truitt, 2012).

Others were not as fortunate to have such a close-knit social network. In addition to being among the poorest, many of the hardest-hit neighborhoods in New Orleans also had high rates of drug use, gang violence, and other socioeconomic issues including a failing public education system. It will be tough for those who are already fighting for their lives to recover after such a severe blow. Many of these New Orleanians already have extremely low levels of resilience.

After fleeing to the Superdome and Convention Center, a large number of the flooded areas' occupants were evacuated to locations outside of New Orleans; however, it is still unclear how many individuals went and how many will return. Early in October 2005, one of the first thorough polls of the New Orleans evacuee population was carried out using data from the American Red Cross. It was found that around 50,000 families, or 39% of the evacuee population, most of whom were Black and impoverished, had no intention of returning. If this is true, it will be the biggest American internal migration in a generation. Communities all around the country will be affected by this distribution, but none more so than New Orleans (Campanella, 2006a).

If the residents of a city are mostly responsible for its ability to recover, then it is a very bad day indeed if they disappear. Strangely, the people most affected by the disaster have a major portion of the responsibility for restoring New Orleans to its former state as a vibrant, genuine metropolis rather than a theme park. Visitors and conference attendees may contribute much-needed funds, but the people who live in the Lower Ninth Ward, Centilly, New Orleans East, and other impoverished neighborhoods are the real heart of the Big Easy, bringing with them their customs, music, mannerisms, and speech patterns that have made New Orleans special (Truitt, 2012).

Their geographical dispersion makes it very challenging to organize grassroots movement. Implementing a campaign similar to the one that assisted in Mexico City's reform will be challenging if the prospective coalition is dispersed around the country and has limited ways to communicate with one another. According to some critics (e.g., (Overly, 2021), federal authorities have refused to share basic information on the whereabouts of evacuees. The absence of temporary housing inside the city boundaries and other obstacles that some have perceived as "transparently designed to discourage the return of Black residents to the city" have prevented even those families from returning (Overly, 2021). Alternatively, as the Associated Press recently stated, "Hurricane Katrina may prove to be the most brutal urban-renewal project that black America has ever experienced."

I.3.2. The relationship between vulnerability and resilience

According to (Sapountzaki, 2014), the studies of vulnerability and resilience assessment in regard to one or more natural disasters are illogical. In the actual world, responses to multi-risk situations usually result in complicated features that we refer to as vulnerability and resilience. Therefore, risks of poverty, social isolation, earthquakes, floods, and epidemics cannot be the only factors considered in policies aimed at increasing resilience. Resilience policies can only address the entire range of risks that an actor faces; the actor is ultimately responsible for determining the priorities, objectives, and other aspects of those risks. Creating a mindset of high risk is the primary strategy for increasing resilience.

High risk perception is the primary component of "good resilience," which includes: (a) a focus on pro-active resilience prior to disasters; (b) equal concern for natural or globalized risks as well as chronic risks; (c) equal concern for vulnerabilities both now and in the future; (d) rebalancing one's own vulnerability without shifting it to others; and (e) learning to avoid additional vulnerability resulting from others. For high risk perceptions, risk education, training, knowledge, and research are essential. Therefore, risk learning need to be included into regular teaching programs and courses at all educational levels; the corresponding curriculum ought to cover vulnerability and resilience in addition to hazard and risk. Moreover, governmental agendas as well as those of civil society groups should incorporate claims and aspirations related to risk and vulnerability minimization; A portion of the duty for the publication and distribution of risk information should fall to the mass media (Pasteur, 2011).

I.3.3. Dimensions of resilience

I.3.3.1. Community resilience

Prioritizing community resilience implies placing more emphasis on what communities can do when they collaborate. It entails enhancing community capabilities as opposed to emphasizing susceptibility to misfortune or catastrophic occurrences (J. Twigg, 2007). Resilience is defined by Tainter and Taylor (J. Taylor et al., 2011) as the capacity to bounce back from adversity and accomplish sustainable goals (Zhou et al., 2015).

Since it is associated with more local competency, social support, and resources as well as a lower chance of trauma and misunderstanding, the idea of "community resilience" is almost generally seen as beneficial (Nanditha, 2022). Community resilience is defined by the Communities Advancing Resilience Toolkit (CART, 2013) as "a strategy to support and foster enhanced disaster preparedness and community recovery from such events" and as "the ability of community members to take deliberate, purposeful, and collective action to alleviate the detrimental effects of ad- verse events" (Pfefferbaum et al., 2013).

As a result of its emergence from the interdependencies of social, economic, environmental, and physical systems, community resilience is described by Walpole and others (2021) as "a complex concept to measure" (Loerzel & Dillard, 2021).

Resilience is "the ability of individuals and communities to deal with a state of continuous, long-term stress; the ability to find unknown inner strengths and resources in order to cope effectively; the measure of adaptation and flexibility," according to Ganor and Ben-Lavy (Ganor & Ben-Lavy, 2003), who also define it as "the ability of a community to stick together and to help itself as a group, as well as the families and individuals in its midst."

According to Norris and colleagues (Norris et al., 2008), social capital, economic development, community competence, and information and communication are the four essential components of adaptive capacities that come together to form a disaster preparedness plan. These factors are the foundation of community resilience (Pfefferbaum et al., 2013; Norris et al., 2008). They see resilience as both a theory and a metaphor (in relation to individuals and their surroundings). According to Norris et al., community resilience is a collection of abilities and tactics that support efficient catastrophe preparedness and response.

Building community resilience is a process that takes time to master. It necessitates long-term activity planning, execution, monitoring, and evaluation. It necessitates an organized investment that makes advantage of the community's innate potential, values, and resources. The organization's people, institutions, capital, services, and all other natural resources are among its resources.

Six fundamental components are listed by Ganor and Ben-Lavy (Ganor & Ben-Lavy, 2003) as making up community resilience:

- Communication: It is important for communities to share information in real time about the risks they face, the services they can offer, and the resources they may use.
- Cohesion: People in a community must help one another and make sure that the weaker members receive special attention.
- Coping is the capacity of the community to react or go on without delay. The ability to cope requires the existence and effective operation of institutions created specially to address trauma and offer support during emergencies.
- Cooperation: Rather than waiting for outside help, communities must rely on their own resources and abilities. At the local level, a community must have higher levels of accountability.
- Credo: This is the community's vision for a better, more promising future. It is seen as a ray of hope.
- Credibility: The community needs a new kind of leadership that is more creative and centered on grassroots leadership that comes from inside the community and that represents the community's objectives and distinctiveness rather than one that is based on the traditional politics of the community (Ganor & Ben-Lavy, 2003).

Just as every community is different, so too are the patterns of resilience. Every community demonstrates a different degree of communal resilience. There are several measures that have been devised by specialists in different sectors to quantify this resilience of communities. The American Red Cross Community Resilience Assessment Tool and the Transcultural Community Resilience Scale (Nanditha, 2022) are two examples of the scales.

Conjoint Community Resiliency Assessment Measure (Leykin et al., 2013), People (Kammouh & Cimellaro, 2018), Community Resilience Index (CRI) (Justice Institure of British Columbia, 2020), and so on. Each scale includes unique dimensions or domains for measuring community resilience. The CoBRA (Community-Based Resilience Analysis) tool was created by the UNDP Drylands Development Centre and is an additional analytical tool. It is a technique that uses certain indicators to gauge the resilience of a community. There are four goals for the CoBRA methodology:

- To determine which catastrophe resilience attributes are most important to a particular community
- To evaluate the community's accomplishments of these traits both during the evaluation and the preceding crisis or disaster
- To determine the tactics and traits of disaster-resilient households
- to determine which services or interventions are most suited for enhancing community resilience to disasters (UNDP Drylands Development Centre, 2016).

Measuring community resilience may assist in resolving issues and inadequacies as well as enhancing current practices to foster resilient communities. It can also be used to assess a community's current state of disaster risk reduction and preparedness. It is possible to create resilient communities by studying the practices of high-performing communities and adapting their lessons learned to create model communities.

According to Norris et al. (Norris et al., 2008), communities may improve their resilience to disasters by implementing the following five steps:

- When it comes to fighting calamities, communities rely heavily on their financial resources. In order to reduce social vulnerability and bridge the gap between the existing inequities, communities must improve their economic resources. It is important to establish economic variety so that after a crisis, community leaders can concentrate on allocating resources fairly.
- Participation from the community is encouraged at every stage of the mitigation process. They ought to have access to the community's social capital as well. In order to utilize community resources wisely, they should be incorporated into the response strategy.
- Pre-existing organizational networks and relationships are essential for the quick mobilization of emergency and continuous support services for victims of disasters. Systems must communicate with one another in order to carry out programs swiftly and effectively.
- In the wake of disasters, interventions that can strengthen and safeguard innate social support networks must be created. This has the potential to improve community resilience and foster greater social cohesiveness among its members.

- According to Norris, and Pfefferbaum (Norris et al., 2008; Pfefferbaum et al., 2013), communities should be adaptable and concentrate on creating dependable and trustworthy information and communication tools that work in the face of uncertainty.

According to Borkowska and Laurence (Borkowska & Laurence, 2021), catastrophe research links the collective efficacy derived from more cohesive neighborhoods to greater community resilience, which is manifested in speedier recovery times following natural disasters. According to (Nanditha, 2022), when people band together and support communities, they are able to understand the problem, their parts in it, and how it gives their life purpose. Additionally, she claims that people in underdeveloped countries already have informal networks and that they frequently provide a hand to one another (Rolland, 2020).

Multiple stakeholders, linked systems, multidimensional risk and contexts, and resilience capacities are the essential components of resilience-building (United Nations, 2010)

Six pillars are discussed by (Nanditha, 2022) as being crucial to constructing community resilience. Among them are:

- People: According to Lerch (Lerch, 2017), the community's members have the ability to foresee the future and develop its resilience. The people in the community determine what has to be done to build community resilience. Since they are the main community stakeholders, they are in charge of and accountable for fostering resilience.
- Thinking in terms of systems: Communities are intricate, linked systems made up of different subsystems. They face challenges from outside sources that also have an impact on them. Communities that are resilient benefit not just their constituents but also the world social-ecological system.
- Adaptability: A resilient community is able to adjust to changes, but because the problems that communities confront are ever-changing, adaptation is a continuous process in communities.
- Transformability: When confronted with significant obstacles, a community must constantly adapt and change. The resilience as a whole may be threatened if the adaptation process moves slowly and the problems become more than the person can handle. According to resilience research, transformability is dependent on three factors: capacity for transformational change, alternatives for transformational change, and acceptance.

- Sustainability: In order for ecosystems, future generations, and other communities to benefit, community resilience must be maintained.

Courage: Courage is a crucial quality that one needs to face difficult circumstances, and it should exist on both an individual and a communal level. The capacity to take chances and foster community resilience is provided by courage (Lerch, 2017).

I.3.3.2. Institutional resilience

Understanding, controlling, and directing the socioecological system have been the main goals of recent resilience techniques (Walker et al., 2006). This method suggests a self-sufficient system with interwoven socio-ecological and human-natural systems. According to this theory, the urban system is shielded from outside pressures and shocks by internal regulating mechanisms. Among these crucial systemic capacities is institutional capacity. According to Hodgson (Hodgson, 2006), the term "institution" refers to the set of regulations that influence social and economic interactions as well as human conduct. Institutions can be overt or covert, official or informal. They lessen ambiguity, establish social norms, which anticipate conduct and promote interaction (Campbell, 1998). Institutions control the interactions between actors and systems in regard to managing environmental stresses. According to Huntjens et al. (Huntjens et al., 2012), institutions define and control access to urban systems, make choices about urban management, and help information move between local organizations, employers, families, and other actors.

Sustainable urban growth is hampered by political, cognitive, and functional disruptions brought on by weak urban management and governance institutions (Grabher, 1993). Sufficient institutional capabilities foster both internal urban system management and adaptive efficiency (Hodgson, 2006). The urban development management system's linkages and procedures are supported by institutions (Keck & Sakdapolrak, 2013). They establish policies, urban planning, and decision-making frameworks at the municipal level. Urban resilience is largely dependent on institutional planning capability, particularly the ability to plan for emergency scenarios (Campanella, 2006a). Preparing, mitigating, recovering, and responding are the four phases that Coaffee and O'Hare (Coaffee & O'Hare, 2008) define in what they refer to as generic anticipatory planning for crises.

According to Sharifi and Yamagata (Sharifi & Yamagata, 2018), two crucial institutional elements in creating a resilient city are leadership and planning. Land ownership, scenario-based planning, use of pressure factors, common planning, collective memory, active planning, degree of flexibility, zoning regulations (the acceptable rate of development in at-risk areas),

identification of requirements based on assessment of risks and vulnerabilities, human habitation in high-risk areas, risk analysis and risk mapping, control of unauthorized development, and more are among the associated powers.
They come to the conclusion that effective urban management and governance entails the following: a targeted government strategy; public involvement; accountability and independence; interpersonal and organizational trust; inter-organizational cooperation; political stability; leadership ability; emergency evacuation and management procedures; urban networks at various levels (regional, national, and transnational); and transparency.

Planning capacity is therefore a key institutional component in this approach, which views cities as open, cohesive, and diverse systems with community stakeholders at the center of planning and planners as creative and innovative actors (Collier et al., 2013).

Despite being separate aspects, institutional capacity and governance are linked to other resilience-related aspects. Therefore, it's critical that communications inside and between enterprises be of a high caliber. Stronger links between different system components and the development of social capital are two ways that effective leadership fosters resilience (Irani & Rahnamayiezekavat, 2021a). Decisions and plans made by urban managers can gain more legitimacy and support when the public is included in the decision-making process. Decentralization and a focus on regional innovation can simplify organizational bureaucracy and increase the efficiency of organizational operations. The community's ability to handle a crisis is increased when public engagement is encouraged, local and regional forces are mobilized, and ideas, opinions, and experiences are freely exchanged (Norris et al., 2008). Building a coherent network of people and institutions improves the public's ability to learn and trust, as well as people's desire to engage, stay prepared, and handle difficult circumstances (Chandra, 2011).

Cities need resilient governance to be resilient. In order to do this, it is critical to develop a responsive city where residents may actively participate in urban planning procedures by using technology. Policymakers, government specialists, urban planners, and architects must all play different roles in order to create responsive city designs (B. Klein, 2016).

According to (Irani & Rahnamayiezekavat, 2021a), obtaining resilience requires upholding justice and human rights as fundamental ideals. They contend that building a framework based on justice and rights for those who are vulnerable, figuring out why ideal justice and actual justice differ, upholding the rights of all social groups, and empowering marginalized communities to access justice and rights are all necessary for building resilience.

I.3.3.3. Economic resilience

The economic component focuses on the economic aspects of neighborhoods and cities, such as employment, the range of economic resources and jobs, the number of enterprises, and household income. The economic dimension also shows how a city or neighborhood is doing in respect to the world economy. Diverse economies, strong creative potential, dependable infrastructure, and a trained labor force are characteristics of resilient cities (Adger, 2000).

Economic development, sustainable livelihoods, physical capital, health services, access to education, and employment opportunities have all been found to be critical components of economic resilience (Pfefferbaum et al., 2013). In particular, the quantity and variety of economic resources matter. (Adger, 2000), for instance, demonstrated how reliance on finite financial resources led to diminished resilience and income distribution disparity.

A disaster's impact on wellbeing extends beyond its physical devastation and immediate negative impacts on people's lives and possessions. The impact on well-being is also correlated with an economy's capacity to recover, rebuild, and reduce financial losses. This capacity, also known as macroeconomic resilience, is made up of two parts: dynamic resilience, or the capacity to rebuild and repair, and instantaneous resilience, or the capacity to avert significant losses. Microeconomic resilience, which is represented in the distribution of failures, household vulnerability, pre-disaster income, and capacity to withstand shocks, also has an impact on well-being (Irani & Rahnamayiezekavat, 2021a).

The structure of an economy and its degree of stability and security are both considered aspects of the economic dimension of resilience. Employment rates, work opportunities, and job skills are some of these structural components (Cutter et al., 2008a). Strong and diversified economies help cities weather crises better than ones that are weaker (Campanella, 2006a). Thus, fostering an environment that is favorable to business as well as expanding the potential for commerce, industry, and production all help to foster resilience (Localize, 2020).

A community's capacity to draw in and keep jobs while fending off the negative impacts of the recession is demonstrated by domestic investment and economic diversification (Irani & Rahnamayiezekavat, 2021a). Important indications of economic resilience have also been discovered, including high tax revenues and robust economic networks capable of drawing and retaining a local workforce (Localize, 2020). A society's ability to weather economic downturns can be strengthened by the presence of sizable enterprises and corporations (Sherrieb et al., 2010). The engagement of the public and private sectors in business growth, promotion of collective action, integration into the regional economy, and economic collaboration with other regions and nations are other significant aspects (Sharifi, 2016).

The significance of fair income distribution and sustainable incomes as critical components of economic resilience is emphasized by other scholars. For example, Norris et al. (Norris et al., 2008) view social resilience as including economic development. They contend that the fundamental components of economic resilience are the equal distribution of resources, the reduction of catastrophe risk and vulnerability, and the quantity and variety of economic resources. However, cities may not be able to achieve sustainable revenues if they are dependent on finite natural resources (Adger, 2000).

According to Rose (Rose, 2004), resilience at the macro, and micro levels of economic systems during times of crisis and inherent resilience are what lead to economic resilience. He goes on to suggest that market resilience is a prerequisite for economic resilience. The ability of the economic system to control the risk associated with economic equations might help microeconomic players in the market become more resilient and re-empowered to engage in the economy. Economic actors can be supported in times of need and risk can be reduced via resilient economic systems.

I.3.4. Transformative resilience

Exploring transformative resilience's shift across time, sectors, and settings is necessary since it's a dynamic, multifaceted, and place-specific notion. Thus, according to (Asadzadeh et al., 2022); The majority of transformative resilience papers were shared between 2015 and 2021 as a result of a sharp increase in records after 2020. In the post-2015 era, transformative resilience has become a focal point of international policy and academic initiatives on sustainable development, climate change adaptation, and disaster risk reduction due to the swift changes in global dynamics and the incapacity of dominant resilience approaches to guide safe, inclusive, and sustainable pathways. Consequently, the primary cause and explanation for this tendency may be the incorporation of transition and change in resilience research and policy narratives. Trusting conservative coping and the reformative adaptive skills of resilience may lead to opposing consequences, increase innate vulnerabilities, and produce maladaptive pathways, as overwhelming empirical findings in the academic literature have demonstrated (Torabi et al., 2018). Policy literature recognized the transformational potential of resilience measures on an urban and regional scale through UN objectives (e.g., the SDGs, the "Paris Agreement," and the "Habitat III") and science-policy reports (e.g., the SREX and the GAR).

According to (Ernstson et al., 2010) "bibliometric" study, the majority of previous research on transformational resilience has focused on environmental studies. Significantly less attention has been paid in the literature to other crucial subjects including public administration, urban studies, business economics, and geography. Although there is a strong correlation between the need to adopt intentional modifications and execute sustainable approaches to address climate change and the increased attention given to environmental concerns (Rega & Bonifazi, 2020). More varied environments are required to support the study, characterization, and application of transformational resilience. Among the primary concerns that are underrepresented in the analysis are governance and planning, which are crucial to the global objectives to propel the shift toward fundamental transformational resilience in the context of development, climate change, and natural catastrophes. Furthermore, the Global South predominates in the evidence of social-environmental inequality and unsustainable development trajectories supporting the need for a fundamental shift in resilience planning and practice, while the unfair geographies of transformative resilience frequently belong to the Global North. Transformative resilience is a new idea that offers the chance to create creative local capacity-building theories and methods. Through their use in understudied regions like cities in the Global South (Africa and Asia-Pacific) and through co-creative approaches in partnership with marginalized and underrepresented groups in local case studies, these could advance our understanding of sustainable resilience development (Ziervogel et al., 2016).

The field frequently defined transformation as a long-term alteration of urban systems in the context of natural and climate-induced hazards in the development phase (2000–2015). This was the most widely used concept to drive transformative resilience (often as incremental change) of complex socio-ecological systems during the genesis phase (1996–2000) (Bristow & Healy, 2018). The concept's appeal in the relevant literature expanded in the second period (2015–2021) as it was positioned transformation in UN policy agendas and science-for-policy reports. Overall, the study revealed that the four primary theme areas of vulnerability and climate change adaptation, urban and regional catastrophe resilience, sustainable management and institutional transformation, and the COVID-19 pandemic have largely shaped the development of the transformational resilience concept. The predominate focal areas and directions of the literature are indicated by these groupings. In the first cluster (vulnerability and climate change adaptation), for instance, future research might concentrate on a fundamental change in the traditional institutions, policies, and strategies that create maladaptive pathways and present spatiotemporal vulnerabilities in the context of global climate change. The second cluster of study on urban and regional resilience may focus on mindset modifications with the goal of creating a system lens that enables leaders and decision-makers to identify the boundaries of possibilities and innovation for transformation in their own settings. In order to improve and educate policy, more research on the third category (sustainable management and institutional transformation) should concentrate on systemic strategies that facilitate the shift to sustainability. This needs to improve knowledge of institutional and management system discourses, structures, instruments, and practices across a range of contexts and sizes. Even though our study contains some terms from the fourth cluster (the COVID-19 pandemic), which is a relatively new context for transformative resilience literature, more research is necessary to determine the gaps, challenges, and needs for innovation in leadership that have emerged from the COVID-19 pandemic context with municipal and community stakeholders at different scales and locations (Asadzadeh et al., 2022).

Although transformational resilience takes on new forms in the face of global shifts, including reasons, discourses, and orientations, conceptualizing it is still difficult. Unlike the conservative and reformative conceptions of resilience, transformative resilience does not include conceptualization efforts that support the investigation and elucidation of underlying capacities that contribute to a fundamental shift of various systems toward resilience and long-term sustainability. Consequently, the essential words that have been derived from this work might serve as a starting point for future research aimed at conceptualizing transformational resilience processes and capacities in various development, climate change, and natural catastrophe settings at various scales. The grouped core themes in the pertinent literature point to the pathways and interactions needed to develop and strengthen transformational resilience (Nalau & Verrall, 2021).

I.3.5. Resilience transitions

Three significant case studies were used by (Ernstson et al., 2010) : New Orleans, Cape Town, and Phoenix. These cities were chosen because they highlight some of the most difficult problems associated with modern urbanization, such as rising sea levels and climate change, growing resource access disparities, disputes over water use between urban expansion and agriculture, and energy use and urban sprawl. This research tries to expand the theoretical conversation on urban resilience by combining ideas from geography and sociology with insights from the author's research in these places to make four arguments:

- The first argument demonstrated how cross-scale interactions might be important in causing changes in slow variables that push urban systems beyond thresholds since urban socioecological processes frequently operate at multiple scales;
- The second argument based on geographic research to situate cities inside "systems of cities" and to reframe cross-scale interactions as interdependent social and technical networks that link cities and maintain flows of information, matter, and energy;

- Third argument based on research showing cities are intense centers of invention with significant effects on the economy, technology, and social structure;
- In the context of the politicized urban environment, the fourth argument explored ways to harness urban innovation to make urban government more proactive in addressing interconnected social-ecological concerns and responsive to ecosystem dynamics.

I.3.6. Resilient city

Even when used as a long-term goal, the term "resilient city" is deceptive. It's a word that means every part of a city may become concurrently robust, meaning they can all overcome or overcome their vulnerabilities. Resilient city buildings, however, are not something that resilient inhabitants identify with. (physical and other) (ARUP, 2015).

The Resilient City is utopia because vulnerability and resilience are mutually reinforcing. In the urban system, the two properties share a residence. It is impossible for an urban community of resilient people to ever stop being vulnerable. Conversely, documentary evidence demonstrates that resilient individuals may, and most likely will, result in susceptible urban physical structures, institutions, and/or communities; this is known as collective vulnerability. Documentary evidence suggests that the opposite is also valid: institutions may create societal and individual fragility, and strong governments may put additional strain on weak and disadvantaged social groups. Therefore, the greatest policy goal that the "Resilient City" idea can give is to increase the resilience of some elements or players in the city while decreasing the vulnerability of others. Additionally, the phrase "Resilient City" equalizes the rights of the most and least vulnerable residents of the city with relation to resilience (Sapountzaki, 2014).

Resilience's mode of operation is the foundation of the symbiotic link between resilience and vulnerability in urban environments. Because of its limited resources, its employment requires a lot of individual and communal fight in the urban arena. It is clear that actors that deprive individuals or groups from their own resources for resilience limit the latter's potential to lessen vulnerability (Sapountzaki, 2007). Furthermore, vulnerability transference (in time and space) to other actors is one of the fundamental resilience functions. As a result, as certain players become more resilient, others become more vulnerable (ARUP, 2015).

Identification of the resilience function type, the origin of the resilience (i.e., where/whom it originates from), and the "journey" and destination of the levered vulnerability are necessary for assessing the resilience effect on vulnerability. Resilience, defined as an actor's internal rebalancing of their own vulnerability characteristics, may be advantageous to them since it enables them to successfully adapt to changing resource availability and combination of dangers faced situations. It accomplishes this without endangering other actors—individual or group. While resilient behavior normally benefits the resilient actor, it may have negative effects on other people. Resilience is a technique of transference of vulnerability (Wardekker et al., 2020).

Resilience may revive "vulnerability justice" in the city and/or spur institutional changes in this direction if vulnerability moves from the underprivileged and vulnerable to the wealthy and safe or responsible institutions. Conversely, if vulnerability moves from the wealthy and political elite to the already disadvantaged and impoverished, then vulnerability disparities will only get worse (Sapountzaki, 2014).

Megacities' slum sections and squatter/illegal settlement zones are breeding grounds for hazards, weaknesses, and resiliency. Individual resilience is preferred by the people living in these deprived neighborhoods above community resilience (Sapountzaki, 2007). Instead of focusing on extreme event risks, each of their separate resilience tactics targets chronic risks, such as personal economic or income vulnerability, rather than human, physical, housing, or health vulnerabilities. When such chances present themselves, they create two distinct plans to counteract acute crisis vulnerability by appealing to remote, safer locations, as well as long-term vulnerability.

Governments and authorities that are resilient take into consideration their financial and political susceptibilities. Since mitigation measures are expensive and unpopular, these authorities seldom have the opportunity to plan for them in advance of disasters. Public authorities may find that pre-disaster risk reduction is a feasible alternative only in the event of populations with high risk perceptions. Seismic design building rules typically get tighter following seismic disasters, and this is not by accident (Sapountzaki, 2007).

Authorities and state institutions vacillate between addressing their economic vulnerability and their authority vulnerability throughout the post-disaster recovery phases. The majority of the time, they put local social concerns and the majority of disadvantaged people last in favor of macroeconomic goals at the national or regional level. When their vulnerability grows, the latter resort to their own resources for material and intangible resilience. Land property rights are among the most important of these; those who feel reliant on them prevent any changes to the urban pattern, not even those that lessen the vulnerability of the urban structure. Institutions exacerbate societal and individual vulnerabilities in a vicious cycle of events, and many people oppose collective resilience—at least when it comes to urban vulnerability mitigation plans. The only way to end these destructive cycles of vulnerability transference is to raise risk perceptions (Sapountzaki, 2014).

The slogan "Resilience in the City" should be used instead of "Resilient City," as it is up to the urban community to decide which is more important: resilient institutions and resilient citizens, or individual and collective resilience (i.e., the resilience of the physical and other structures in the city) through democratic processes like consensus building. This modification strengthens the concept's political undertones and might greatly activate citizens to become more capable vulnerability managers (Sapountzaki, 2014).

I.3.7. Resilience approach

Resilience approaches are strategies that aim to leverage a society's adaptive resources and capacities to address change-related issues. These methods place more emphasis on a society's inherent ability to overcome damages than they do on outside interventions. Numerous scales, including national, regional, metropolitan area, local, and household, can be used to evaluate resilience. Policymakers should be aware of this distinction since resilience assessment measures can be helpful in choosing actions and options.

Four methods to urban resilience are identified by (Pendall et al., 2010): route dependency, equilibrium, systems views, and long view. The equilibrium method is predicated on the idea that, similar to other systems, urban systems too have states of equilibrium that are susceptible to disturbance from both internal and external sources. The fundamental idea behind this method is that, given the system's capacity to take in and adjust to outside fluctuations and changes, any disruption in its equilibrium can lead to the system reaching a new one. The systems perspective entails a four-phase process of continuous adjustment, with each phase having a different relationship to the three dimensions of change: the system's ability to access accumulated resources; the actors or variables within the system's internal association; and resilience, which is the system's susceptibility to stresses and shocks. Phases of imaginative and adaptable reactions are associated with high resilience.

The impacts of choices and plans on phenomena and occurrences are the main emphasis of the path dependency approach. According to this perspective, agents' activities and coincidental circumstances lead to equilibrium or imbalance (Irani & Rahnamayiezekavat, 2021a).

Resilience over time is a problem that is addressed by the long view method. In a system, equilibrium or imbalance can be attributed to a sequence of decisions and actions made at various points in time in addition to present events and activities. Therefore, a historical perspective on the phenomena is necessary to have a deeper understanding of the topic.

Sharifi and Yamagata explore resilience and its applications in ecological, socio-ecological, and engineering systems. In the field of engineering, resilience pertains to a system's capacity to withstand external disruptions and regain equilibrium (Sharifi & Yamagata, 2018).

The engineering principles of stability, efficiency, consistency, predictability, and reversibility to the prior condition are strongly associated with this (Holling, 1973). According to (Zipperer et al., 2011), there is a stable equilibrium in this method.

The ecological approach places a strong emphasis on a system's unpredictable nature and capacity to adapt to disturbances in order to maintain its essential operations. By absorbing fluctuations or dangers and adjusting to them, the system employs a multiple-equilibrium model to generate a new state of equilibrium that moves it toward a better state (Holling, 1973). According to this method, resilience serves as a gauge for a system's capacity to withstand stresses and shocks from the environment; as a result, the system has to have the capacity to govern and manage these shocks. The adaptive state and future of the system can be determined by its assets and resources (Holling, 1973). The ecological approach places a strong emphasis on the system's self-organization, nonlinearity, and uncertainty (Alberti et al., 2003). Stated differently, this strategy highlights the system's capacity for self-organization and the potential to draw lessons from mishaps in order to make things better.

The system must be able to absorb, learn from, and repair disasters in order for the socio-ecological approach to work (Cutter et al., 2008b). According to this method, people are primarily responsible for transforming the world and having an impact on how ecosystem dynamics evolve in both the local environment and the biosphere overall (Chelleri, 2012) .The four phases of an adaptive system are described by (Holling, 1973) as follows: a quick phase of development and exploitation; an extended phase of accumulation, monopolization, and structure conservation; a rapid phase of breakdown or release; and a brief time of renewal and reconstruction.

Galderisi (Galderisi, 2014) distinguished four approaches in her summary of the theoretical literature: hazards and disasters (the resilience of local regions and areas against risks and disasters); economy (the resilience of the city's economic systems at the regional level and its production capacity); ecology and sustainability (the capacity of the ecosystem and social ecology); and climate change (the ability of cities to cope with climate change).

According to another perspective, resilience is a system's capacity to anticipate, take in, fix, and adjust to both known and new dangers (Cutter, 1996; Holling, 1973). A three-pronged strategy to resilience was presented by (Figueiredo et al., 2018), (Table 2). According to this paradigm, there are three techniques that are better than the other three: catastrophe risk reduction, sustainable livelihood, and socio-ecological. These strategies are complementary, which means that national policy frameworks must be used in addition to local initiatives.

Table 2 Three Fundamental Approaches to Resilience, (Irani & Rahnamayiezekavat, 2021a).

Approach	**Definition of Resilience**	**Typical Scale of Analysis**	**Most Common Concepts**
Disaster risk reduction	The capacity of a system, group, or civilization that is subjected to risks to withstand, absorb, adapt, and recover from such impacts quickly and effectively by maintaining and regaining its fundamental structures and functions (United Nations, 2010).	National and Global	Hazard Disaster Disaster risk
Socio-ecological	The extent to which the system can adapt while maintaining its ability to manage structure and function; the degree to which the system can self-organize; and the potential to develop and enhance learning and adaptation (Holling & Goldberg, 1971).	Communities and Cities	Shocks Stresses
Sustainable livelihoods	a capability that permits families and communities to endure shocks and pressures while maintaining a minimal threshold condition (Frankenberger, 2020).	Households and communities	Vulnerability

The national level policies and initiatives are the main focus of the catastrophe risk reduction strategy. The planning and financial commitments required by national governments to generate and get resources that can increase urban resilience must be made.

The socio-ecological approach views the city as an ecological social system and places emphasis on the urban scale. This systemic approach addresses the linkages between different system components and the mechanisms of change, all of which are based on a holistic perspective of the city. According to this theory, cities are flexible social and technological systems made up of many parts, and the right arrangement of these parts may raise people's standard of living. Changes are dynamic and systematic, meaning that modifications to one element may result in modifications to other elements (Balawejder et al., 2021). Put another way, a comprehensive strategy is needed for the examination of urban resilience.

The Food and Agriculture Organization (FAO) and Oxfam developed the sustainable livelihood strategy, which places a strong emphasis on household resilience (Irani & Rahnamayiezekavat, 2021a). This method views individual and family well-being as a crucial aspect of resilience. This strategy is suitable for nations with high rates of social inequality and poverty. According to the research that is currently available, one of the main causes of human vulnerability is personal wealth (Irani & Rahnamayiezekavat, 2021b).

Poor households have extremely low levels of employment, health, and access to infrastructural services. They also reside in susceptible places and have little access to disaster protective gear. These elements raise the degree of vulnerability and support focusing on enhancing the living circumstances for the occupants. Alternative methods concentrate on the neighborhood level. This is founded on the understanding that varying levels of vulnerability and resilience are produced by geographical social inequality and discrimination (Cutter et al., 2008a).

I.3.8. Resilience assessment according to the previous studies

It is essential to understand the various approaches taken in these studies to distinguish between conceptual and analytical efforts in light of earlier research on urban resilience according to the previous studies. By doing this, it will be possible for subsequent research to provide a direction for further exploration. To further describe some of the most current literature reviews, we extract the following items from the table below (Table 3): Subject, Method, Tool, and Use Area as reported by the study's author.

Table 3 Analytical urban resilience in recent literature reviews, (TALBI et al., 2022 and Büyüközkan et al., 2022).

Reference	Subject	Method	Tool	Application area
(Beceiro et al., 2022)	Nature-Based Solutions / Resilience assessment framework	Statistics	1D-2D modeling	Porto
(W. Xu et al., 2021)	Flood resilience	Analysis method (ISM-ANP)	evaluation network model (ISM-ANP model)	03 Chinese cities (Wuhan, Nanjing, and Hefei)
(Ghouchani et al., 2021)	Urban resilience	Statistics	Exploratory Factor Analysis	/
(Feofilovs & Romagnoli, 2020a)	Disaster Risks	Modeling, MCDM	SD Model, multi-criterion analysis	Latvia
(L. Li et al., 2020)	Policymaking	Modeling	SD Model, Simulation, Sensitivity Analysis	Beijing, China
(L. Li et al., 2020)	Green Infrastructure	MCDM	AHP	Ghent, Belgium
(Xun & Yuan, 2020)	Urban resilience evaluation	MCDM	Intuitionistic trapezoidal fuzzy numbers, TOPSIS, sensitivity analysis	Dalian city, China
(Iturriza et al., 2020)	Climate Change	Modeling	Delphi, SD model, pilot test, simulation	Kristiansand, Norway
(Feofilovs & Romagnoli, 2020b)	Urban Flood Resilience	Modeling	System dynamics (SD) model	Latvian Municipality
(Moghadas et al., 2019)	Urban Flood Resilience	MCDM	AHP, TOPSIS	Tehran, Iran
(Zhang et al., 2019)	Disaster Risks	MCDM	Delphi Method, AHP	Shenzhen, China
(L. Da Silva et al., 2019)	Sustainability	Statistics	Descriptive Analysis	Sao Paulo, Brazil
(Iturriza et al., 2019)	Urban Resilience	Modeling	Delphi method, SD model	Norway, Spain, UK
(Brunetta & Salata, 2019)	Disaster Risks	Statistics	Clustering analysis, sensitivity analysis	Turin, Italy

Despite all the changing definitions, urban resilience is still seen as a key concept in preparing cities for disasters and unanticipated events brought on by extreme weather brought on by climate change.

In particular, flood disasters have an impact on city stability for a number of reasons, which may be divided into two groups (BENSON, 1964):

1st / Accelerator factors: are things like the following that make floods in cities happen more quickly:

- Climate change.

- Topography characteristics: Altitude, Drainage area, Main-channel slopes, Channel geometry, Length of the basin, Orientation, Shape factor, Storage area, Stream order, Soil and geology, Forested area, and Basin rise.
- Hydrologic characteristics.
- Runoff and runoff/precipitation ratios.
- Location.
- The meteorology characteristics: Temperature, Wind, Rainfall, Snow, and Evaporation.

2nd / Exacerbating or aggravating factors: Among these is the way that urban design exacerbates and intensifies floods in urban areas.

- Urban design.
- Vulnerability of urban fabrics.
- Land use.
- Fast urbanization in flood zones.

I.3.9. Risks from natural hazards

To improve organizational resistance to natural disasters, the following risk data is required (Figure 3):

- Understanding the connections between different environmental dangers, such as the way that excessive precipitation may lead to floods, as well as the likelihood and regularity of the natural catastrophes that should worry people the most;
- Understanding the main impacts that different types of natural catastrophes are expected to have on infrastructure operators and operations;
- Understanding of the indirect effects of risks, including those brought on by disruptions to vital supply chains and other infrastructure-related operations; and
- knowledge of the risks that the company faces, their primary consequences, and their aftereffects, which include reliance on additional infrastructure and essential service providers (Cabinet Office, 2011).

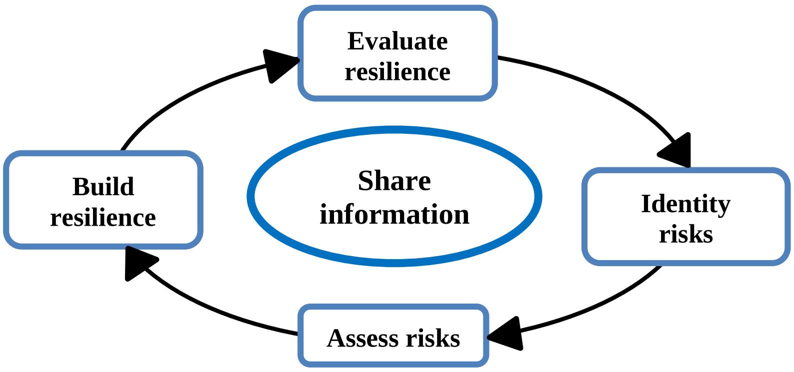


Figure 3 Flood Resilience Standards, (Cabinet Office, 2011).

I.4. Conclusion

Urban resilience is a "new perspective on thinking" that has come into being. Around the turn of the century, it was used in planning as a notion that supports measures to deal with stresses like flood danger and to respond by revitalizing and reinventing communities. Addressing the causes and effects of significant global crises requires resilience. Resilience is a strategy that promotes a holistic perspective of an urban system, comprehending the linkages between a city's spatial layout, physical assets, functions, and socio-economic components. For this reason, it is seen as a solution to the difficulties facing the city.

Resilience is a fundamental concept in urban development that forms the cornerstone of several strategic interventions and investments in major global development organizations. It is both a feature of sustainable urban development and a catalyst for development in general. At the city level, resilience compares the metropolitan region to a dynamic, complex system that is always in need of comprehensive, coordinated solutions to various difficulties.

The concept of resilience has become essential in this context. Experts working under the direction of the National Economic and Social Council in 2015 made recommendations in "From the challenge of resilience the requirements of the emergence of the Algerian economy," which encourages the adoption of resilience as a positive trait in our cities to resist against this kind of hazard. The Algerian government has also begun updating its laws to keep up with global trends in order to maintain the concept of resilience as an effective solution for our cities and to motivate the potential to transform vulnerable cities into resilience cities. through examining Law No. 04-05, which amends and completes Law No. 90-29 concerning development and urbanism, and substitutes it with the First Draft of the Law No. 13 / CNL-DG / 2020 of August 2 about urbanism, which is created by the Algerian National Housing Fund. that acknowledges the idea of urban resilience as essential to maintaining its cities. and going over the urbanism-related laws. This Act's goals are to establish a new urban planning system and a unique urban domanial regime. One of the goals of this legislation is to "Affirm the resilience of urban spaces to the risks of natural and technological disasters." The basic principles on land use and management help to apply and protect the fundamental rights provided by the Constitution.

There are several ways to research the idea of urban resilience in Tebessa, however we can sum it up as follows based on the previously listed studies:

- **a.** Statistics method: This method can employ a variety of methods, such as latent Dirichlet allocation, variational Bayes, and exploratory factor analysis.

b. Multi-criteria decision-making (MCDM): This method can make use of the Delphi Method, AHP, TOPSIS, and other technologies.

c. Analysis method: The evaluation network model (also known as the ISM-ANP model) is the tool that may be employed in this procedure.

d. Modelling method: This method can make use of the following tools: Sensitivity analysis AHP, GIS, SD Model, Simulation, and so on.

In order to improve comprehension and proficiency with the idea of urban resilience, this study established a number of characteristics for assessing urban flood resilience and created an assessment framework based on the three levels:

1. Urban design level:

This level addresses urban resilience from the perspective of designing Algerian cities in general, and Tebessa in particular, by examining the instruments currently in use to design the city's urban perimeter and identifying any gaps in the attempts to mitigate the financial and human losses caused by floods through a variety of factors, including the size of the city, its buildings, runoff water, planning procedures and strategies, infrastructure, orientation, land use, drainage areas, urbanization, structure, and the city's framework, all of which can have an impact on storm water flow. This level also assists in identifying solutions that lessen the negative effects of flood risk in order to increase Tebessa City's resilience.

2. Legislative level:

This level only addresses urban resilience from a legal perspective by conducting a thorough analysis to identify any gaps in the legislative declaration provided by presidential decrees, laws, directives, and other documents that the Algerian government has released throughout time, including some of the exploitative attempts such

- The law N° 83-03 of 05/02/1983 relates to the protection of the environment.
- The executive decree N° 85-231 of 25/08/1985 fixed the conditions and modalities for the organization and implementation of interventions and assistance in case of disasters.
- The law N° 04-05 of 25/12/2004 relating to the prevention of major risks and the management of disasters within the framework of sustainable development.
- The executive decree N°19-59 of 02/02/2019 set out the terms and conditions for the preparation and management of emergency organization plans.

This research offers recommendations for improving Algerian cities' urban resilience, particularly Tebessa's, against flood hazards so that Tebessa becomes a resilient city.

3. Natural level:

At this level, flood hazards—a common natural hazard that poses serious environmental, social, and economic problems worldwide, particularly in urban areas—are treated as the element that poses the greatest danger to the stability of cities in terms of their resilience.

This level offers a thorough examination of flood issues and identifies any gaps using a variety of criteria, including topography, evaporation, precipitation, rainfall, altitude, forest area, and sol and geology. In order to make Tebessa a resilient city, this research offers solutions for the city's flooding issues and raises urban resilience against flood hazards.

Chapter II

Urban resilience through urban design

II.1. Introduction

The International Strategy for Disaster Reduction (United Nations, 2005), presented the Framework for Action 2005-2015 at the World Conference on Disaster Reduction in Hyogo, Japan. The conference's objective was to drastically minimize disaster loss by 2015 in terms of human life, as well as the social, economic, and environmental resources of nations and communities. Five action priorities were listed in the Hyogo Framework for Action:

- Make sure that disaster risk reduction has a solid institutional foundation for execution and is prioritized both nationally and locally.
- Determine, evaluate, and track the risks of disasters and improve early warning.
- At all levels, cultivate a culture of safety and resilience by using knowledge, creativity, and education.
- Minimize the fundamental risk variables.
- Enhance emergency readiness for a successful response at all levels.

According to (International Strategy for Disaster Reduction, 2005); Communities' approaches to risk reduction and catastrophe management have advanced significantly as a result of HFA. Furthermore, it has advanced the Millennium Development Goals. HFA was compiled into five theme areas in a study for the Department for International Development (DFID, 2007), such as: Risk assessment, Disaster preparedness and response, Governance, Knowledge and education, and Risk management and vulnerability reduction.

HFA was replaced with the Sendai Framework for Disaster Risk Reduction (SFDRR). On March 18, 2015 (United Nations, 2015b), during the Third UN World Conference held in Sendai, Japan, it was accepted. It makes an effort to provide direction for multi-hazard management of catastrophe risks in development across all sectors and at all levels. There are four priority areas in the Sendai Framework:

- Investing in disaster risk reduction for resilience.
- Strengthening disaster risk governance to manage disaster risk.
- Enhancing disaster preparedness for effective response and building return better in reconstruction, recovery, and reconstruction.
- Understanding disaster risk.

Through the last conclusion of the previous chapter, and according to (Alessandra, 2018); this work is based on the Urban design level as one of the important perspective to enhance the urban resilience in our cities; Considering the concept of resilience is still relatively new notion in the language of urban planners, and it will take some time before it becomes established and useful. The resilience of cities is rarely discussed as a matter of urban form and resilience, and the scholarship pays little attention to the role of the micro-scale morphological structure of cities in building resilience. This is partially because urban design, both as a discipline and as a profession, relies on the medium of urban form to act in the urban system. As a result, the notion of resilience in urban design is devoid of both a precise knowledge of the spatial attributes that contribute to a place's resilience and particular evaluation instruments that address the characteristics of urban form in connection to resilience. Given the existing resilience of cities, this poses a significant challenge for urban designers.

To address this challenge, the present chapter aims at a) build a common ground between urban resilience and urban design by understanding the relationship between urban design and urban resilience according to the previous studies; b) formulate a theoretical framework that focuses on how urban design contributes to the development of urban resilience by reviewing, consolidating, and combining existing knowledge on urban design and urban resilience theory. Accordingly, the three sections of this chapter are organized as follows; 1) Urban design as a complex adaptive system; 2) Urban design resilience theoretical framework ;3) Urban design resilience analysis and assessment framework.

II.2. Urban designs as a complex adaptive system

II.2.1. Setting the scene for the need for urban resilience

Cities face many types of disruptions that could threaten their infrastructure, economy, natural environment, or communities. Acute shocks in most cases are sudden, and intense. Chronic pressures that gradually destroy a community's cohesiveness, such high unemployment rates, inadequate social safety nets, and unequal public transit systems, worsen the effects of sudden shocks (Leichenko, 2011b).

The ability of a city's institutions, businesses, neighborhoods, and people to endure, adjust, and develop in the face of both acute shocks and ongoing stress is known as urban resilience; A city can enhance its overall trajectory and the well-being of its communities, infrastructure, natural environment, and economy by fortifying its fundamental fabric and expanding its comprehension of the threats that jeopardize its stability (SACN-Cities-Network, 2022).

Globalization, urbanization, and climate change are megatrends that have an impact on urban resilience. Urban resilience in South Africa also entails addressing the triple danger of poverty, inequality, and unemployment in addition to a host of other social evils, the spatial legacy of apartheid, corruption, and the theft of public funds (Enrique Peña Nieto, 2016).

Cities must be seen as systems made up of people and locations that frequently undergo rapid change when viewed through the perspective of urban resilience. Therefore, in order to be resilient to urban challenges, cities must consider both their strengths and their weaknesses holistically, engaging with the most vulnerable citizens of their communities on a meaningful level. Urban resilience should be planned for by addressing problems and coming up with solutions in a way that is inclusive, risk-aware, place-based, integrated, and forward-thinking. Cities can reap numerous benefits, or "resilience dividends," by employing an urban resilience approach. These benefits include maximizing the value of every Rand invested, lessening or even preventing the effects of shocks and stresses on the city's population, economy, and physical environment, and enhancing quality of life (SACN-Cities-Network, 2022).

II.2.2. Urban resilience in comparison with disaster risk reduction and sustainability

Urban resilience is sometimes conflated with disaster risk reduction (DRR) and sustainability. While some ideas from DRR and sustainability are incorporated into urban resilience, the names are not interchangeable. These two ideas are transcended by urban resilience "with a holistic and proactive approach." (United Nations, 2015b).

Additionally, resilience tries to find methods for systems to survive and thrive even in an unbalanced world, whereas sustainability strives to bring the world into long-term balance amid the loss of natural resources. Similar to DRR, resilience focuses on developing a proactive and integrated plan to address both acute shocks and chronic stresses, whereas DRR aims to minimize the damage caused by natural catastrophes. Resilience, in its simplest form, is the ability to take revolutionary steps to improve cities over the long and short terms, in addition to coping mechanisms and adaptive tactics (SACN-Cities-Network, 2022).

At the same time, the three aspects of resilience against disaster risk; are defined by (Lhomme et al., 2010), to place the strategy in a temporal trajectory aimed at: "give ourselves the means to manage the jolts of the urban system subject to numerous disturbances or to make adaptations at the margin (short-term resilience), but also to keep this system on the ideal trajectory of sustainability leading to transformations in urban forms and fabric (long-term resilience)."(Figure 4).

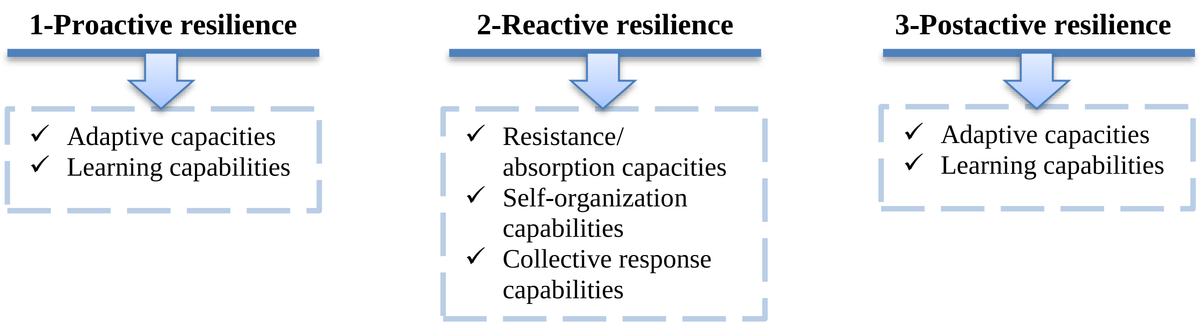


Figure 4 The Three aspects of resilience, (Lhomme et al., 2010).

II.2.3. Exploring the design of urban systems

This section aims to investigate how resilient, change-adaptive, and innovative the urban fabric can be on various scales. In order to achieve this, a variety of urban form considerations may be necessary, including building type, street layout, open space configuration, land use distribution, and transportation infrastructure. Thus, since the early writings of the German and Italian schools, urban form in urban morphology has been historically conceptualized as a collection of morphological components (Kropf, 2009). Specifically, the Caniggia and Maffei (1979) classification of streets, plot series, plots, and buildings, as well as the tripartite subdivision of townscape elements proposed by Conzen (1960) in town plan (with streets, plots, and building-plans), building form, and land utilization, became widely accepted and applied in urban morphology (Alessandra, 2018).

But as Dibble (2016) recently noted, despite the fact that "the existing lexicon is not only lacking in physical, geometric-based definitions, but is not capable to universally characterize all types of urban form," too frequently these classification systems are taken for granted in the analysis of urban form (Dibble et al., 2019). Some writers bemoan the fact that contemporary post-war urban fabrics are not adequately captured by conventional definitions of urban form components (Albert, 1999). Others draw attention to the fact that current definitions of significant morphological elements contain some ambiguity and fuzzy language (Caniggia , Maffer, 1979). Nonetheless, it is imperative to identify clearly defined morphological components as part of the current work's mandate in order to address the five determined features that are provided in relation to urban form (Alessandra, 2018).

In trying to overcome these constraints, some have attempted to include the morphological traditions of (Conzen, 1960). putting forth creative interpretations of the compositional hierarchy of urban form and proposing new, more general classifications of the fundamental morphological elements and their interactions (Dibble et al., 2019). Accordingly, five morphological components and aggregates were identified as a result of the selection of those that are: 1) universally observable in any settlement, regardless of location, time, and type urban setting (urban, suburban, village, rural, traditional, and modern); 2) spatially and geometrically unequivocal when identified and represented on a map; and 3) objectively measurable in their physical and geometrical dimension. Plots, street boundaries, streets, blocks or buildings, and sanctuary zones are among them (Kropf, 2009).

The five attributes of modularity, redundancy, diversity, efficiency, and connectivity are associated with the various morphological components, and a new definition that takes into consideration their cross-scale interdependencies is provided (Forgaci & Timmeren, 2014). The fact that, as previously mentioned, is what motivates the decision to associate assets mostly with qualities (Alessandra, 2018). "An analysis of spatial patterns is more likely to be attainable than a comprehensive system-wide description of processes, given the complexity of the processes that shape urban environments." (Kropf, 2009); However, these assets have a direct impact on the four performances of robustness, recovery, adaptability and transformability of the urban form. As a result, it was decided to limit the attention to a few scales for each attribute, drawing on the body of knowledge in the fields of urban morphology, sustainability science, network science, and urban geography in addition to the previous literature.

II.2.3.1. Modularity

The theme of spatial modularity is primarily discussed in resilience literature in terms of "safe to fail" infrastructure networks (such as power, water, and communication networks). This refers to the existence of relatively decentralized and compartmentalized systems that, in the event of a random failure, can quickly isolate faulty modules or components, preventing cascading damages to the wider network. When it comes to urban form, a modular urban structure is one in which various morphological elements are arranged into groupings that are highly linked and function as cohesive units despite being relatively independent (Alessandra, 2018). The idea that cities may be understood as wholes composed of a nested hierarchy of components, with each component assembling with similar-scale components to build higher-level coherent wholes in an ascending hierarchy, is a fundamental tenet of most theories of urban morphology. Lower-level components are in fact contained inside or framed by the urban form that each morphological scale represents: streets enclose buildings, buildings enclose street or street edges, street edges consist of a sequence of plots, and plots consist of buildings and/or open spaces, creating a compositional hierarchy. Following (Kropf, 2009), "A building is both a composition of rooms and an element that is part of a plot; the levels of the compositional hierarchy are defined in two directions, from below by the domain of its potential parts and from above by the position of the element as a part in a composition.". (Salingaros, 2000) asserts that the ability of the hierarchy's levels to communicate with one another is largely dependent on the presence of enough intermediate levels between the biggest and smallest levels to allow for feedback to cycle up and down.

A system with a variety of interacting scales may, in fact, regulate itself as it can utilize slow processes to formulate quick processes and fast processes to experiment with and introduce new ideas (Salat & Bourdic, 2012). Therefore, modularity in the urban form is enhanced when every level in the compositional hierarchy can be easily recognized both as a whole and as a collection of lower-level pieces. On the other hand, this is lessened when certain structural levels are absent or underrepresented, as happens when one entity takes up many levels simultaneously (for example, a structure consisting of only one room, or a plot taking up a whole city block). This phenomenon is referred to as coextension by Kropf (Kropf, 2009). The coextension of some parts to higher or lower levels, according to the author, is a locally repeated occurrence in urban forms since it results from separate morphological development processes. In fact, any morphological pattern should be anticipated to exhibit some degree of coextension. But if it spreads too widely, it might lead to the disappearance of a level in the hierarchy and significantly reduce form flexibility. Plot sizes, for instance, tend to vary somewhat in traditional textiles, but they rarely extend to the width of street boundaries. Similar to this, building sizes may differ, although streets will hardly ever coextend to the size of buildings. Plot sizes, for instance, tend to vary somewhat in traditional textiles, but they rarely extend to the width of street boundaries. Similar to this, street margins come in many sizes, but they almost never extend to building sizes. A building might be big or tiny, but it is extremely unusual for a building to extend to its sanctuary area.

Because of this, modularity is essential at all sizes. The more modular a fabric is, the more easily its sub-structure may undergo internal configuration changes (such as deletions, additions and replacements) without suffering significant consequences. A fine-grained plot structure is associated with more spatially distributed, locally based, and direct forms of territorial control, which enable the implementation of quicker, more immediate, and less expensive adaptations in response to contextual change. Examples of these adaptations include entrance setbacks, gate placement, new entrances, and the conversion of garages and rear entrances into main entrances. (Salingaros, 2000) studied this aspect of plots in terms of territorial control. In addition, street edges that are divided into numerous small plots tend to be more persistent than those that only have a few large plots because of the higher difficulties typically associated with assembling smaller plots (Ryan, 2005). This ensures that modularity is maintained over time, which is a prerequisite for structural complexity and, consequently, efficiency. Several studies (Porta et al., 2012) have supported this theory, linking fine-grained land parceling to an increased urban environmental complexity.

For other morphological scales, the same holds true. (Feliciotti et al., 2016) state that the transition between worlds is structurally more favorable for informal encounters and experience adaptations when street margins are marked by several plots. Likewise, a higher degree of synchronization with streets is made possible by the presence of distinct street boundaries inside blocks. "A street front becomes more versatile if it can adapt over time to the character of the street; if, on the other hand, it is linked to a whole block, its capacity to change and adapt is restricted, its lifespan shortened, with implications on character and quality of life," (Romice et al., 2016). In contrast, loss of modularity occurs when the urban grain is worn down, as in the case of monolithic edges/blocks found in modern urban development. A single plot can occupy an entire building or street edge, making it particularly uninteresting and resistant to adapting to changing contextual factors (social, economic, and technological), as well as less likely to exhibit emergent properties for which they were not originally intended. Lastly, sanctuary regions that are created all at once as monolithic pieces have a limited ability to react gradually to their surroundings and often reject cues for adaptation. Although this is uncommon in historical frameworks, it is a common characteristic of many large-scale, single-ownership developments (Adams et al., 2013) and post-war urbanization. All lower levels in the compositional hierarchy of urban form completely vanish when this occurs (Alessandra, 2018).

II.2.3.2. Redundancy

Redundancy is a well-established attribute in resilience literature, and studies in various domains and with various assets (human, natural, social, economic, etc.) have examined its role in reducing the impact of disruptive events (Ahern, 2011). The issue of redundancy in urban form, however, has only just begun to be addressed (Salat & Bourdic, 2012), mostly from the standpoint of streets and other infrastructure networks. Plots, however, are a key component of urban form redundancy as they serve as the starting and ending points of most journeys. At this size, redundancy is determined by the locations that each city user may choose from and the routes they can take to get there. (Mehaffy et al., 2010) argues that the redundancy of connective ties between origins and destinations allows for the combination of journeys, enhancing personal choice, and the optimization of more efficient paths.

This is especially crucial at the street level, where a redundant transportation network can sustain a wider range of trip types under more varied conditions. Conversely, street systems with purely tree-like street layouts, or those with redundant connections, direct traffic down fewer paths. Because they need to be maneuvered up and down, they become susceptible to component failure and become locally separated even if their parts are spatially near together (Salat & Bourdic, 2012). However, because redundant street networks contain secondary pathways, they are more resilient to demand surges (J. Da Silva et al., 2012) and suffer only mild deterioration from the random failure of one or more nodes/links (such as an accident blocking a street) (Salat & Bourdic, 2012). Redundancy and connectedness are related, but they are not the same thing. For example, a street network might be internally connected without necessarily being redundant; redundancy is only raised when connections increase the number of possible pathways between destinations.

II.2.3.3. Diversity

Successful cities are virtually always recognized having a highly varied and multipurpose urban fabric. This characteristic is most noticeable in historic cities, where gradual changes allow the fabric to organically evolve over time, striking a balance between the need to maintain a distinctive identity and character and adding new components in response to evolving needs. Therefore, a resilient urban fabric has to strive to convey variation at every morphological scale (Alessandra, 2018; Albert, 1999).

In fact, it is thought that diversity is essential to explaining why certain areas have the innate ability to "continue to succeed despite changes in economic conditions, technology, and culture." (Montgomery, 1998). Many academics support the idea of variety in urban design literature (Jane Jacobs, 1961), as a stimulant for other cherished urban characteristics like diversity, sociability, and economic vibrancy. Diversity in the urban form is defined geometrically as variability in the size and shape of urban components, or functionally as the availability of multiple unique functions in close proximity. Diversity is linked in both situations to increased possibility for sustaining a range of uses and activities as well as more intensive use of available space (Jabareen, 2006).

At the plot scale; The ability of a plot to support different land uses is often investigated in terms of geometrical and spatial features (Dovey & Pafka, 2017; Caniggia , Maffer, 1979).

as a stimulant for other cherished urban characteristics like diversity, sociability, and economic vibrancy. Diversity in the urban form is defined geometrically as variability in the size and shape of urban components, or functionally as the availability of multiple unique functions in close proximity. Diversity is linked in both situations to increased possibility for sustaining a range of uses and activities as well as more intensive use of available space (Q. He et al., 2018). Areas with many small plots have a higher possibility to apply alternative tactics than areas with bigger (and consequently fewer) plots, "thereby ensuring variety in the resulting environment," because each plot symbolizes the position of an actor acting in the urban realm (L. Marcus, 2011). Small plots do, in fact, promote diversity in forms, uses, and tenure in addition to creating more active frontage (Wood & Dovey, 2015). Lastly, the size of the plot can be used to predict the turnover of buildings because larger plots have a higher frequency of building demolition than smaller ones. Where individuals have more influence over the planning, construction, and upkeep of their own surroundings and buildings alter more gradually through minor modifications (Mikael, 2022).

At the building scale; Building size is often seen as a useful measure of diversity. While larger and more complex building shapes can be accommodated by large buildings (De Bellefon et al., 2021), smaller building sizes are linked to less diversity in building shape and size as well as a higher linear extension of interfaces to block area. This, in turn, results in more varied and intense opportunities for interaction between buildings and streets (Carmona, 2003). In fact, "small buildings" are one of the four essential prerequisites for urban diversity according to Jacobs (Jane Jacobs, 1961), and they are also essential for fostering social diversity and other forms of diversity. In this context, Akkelies van Nes (Akkelies van Nes, 2007) conducted a comparative study on a number of Amsterdam buildings and discovered that while Modernist and contemporary samples were typified by larger buildings and lower functional diversity, historic and late 19th-century buildings were typically smaller and featured a higher diversity of uses. According to Alessandra (Alessandra, 2018), programmatic planning ideologies that sought to increase urban open space and decrease the area devoted to streets resulted in the introduction of superblocks, or exceptionally large buildings, into traditional fabrics, which otherwise kept building sizes small. As a result, even though diversity is typically increased by the presence of numerous small and short buildings (Jane Jacobs, 1961), greater diversity of building types and land uses may be encouraged and facilitated by "a range of lock sizes (including small blocks) rather than a single repeated building size" (Carmona, 2003).

At the street scale; The degree of variation in the type of interface between public (streets) and private (plot) space, which is dictated by the form of the transition between the public and private realms, determines diversity at the scale of street margins. A diverse range of interfaces (with respect to transparency, setback, permeability, etc.) is "fundamental for practices of production, exchange, consumption, and reproduction," (Alessandra, 2018). According to their research, "while retail and hospitality functions generally require a direct and transparent connection to passing trade, commercial and industrial functions often require stricter mediation of access, and residential prefers a setback," high levels of interface diversity obliquely enable greater functional mix (Wood & Dovey, 2015). Areas with a uniform interface type, on the other hand, disturb diversity of any kind. According to (Alessandra, 2018; Kropf, 1996), a significant number of post-war developments lack street-facing plots and buildings, or important visual relationships between buildings and the public realm are hindered by high hedges and large setbacks.

II.2.3.4. Efficiency

Salat and Bourdic (Salat & Bourdic, 2012) argue that the development of complex systems is always focused on increasing organizational effectiveness. But as previously said, this process necessitates a rise in structural complexity rather than a need for simplicity. The same is true of cities and urban forms; as they change over time, they move toward higher organizational spatial complexity at all scales, which makes them increasingly structurally efficient.

Salat (Salat, 2017) asserts that the distribution and differentiation of morphological components and connections in cities are not random or concentrated around average values, but rather evolve towards a specific form of organization where a long tail of small, common, and frequent components and links is matched by a decreasing number of large, specialized, and rare ones. In some situations, this relationship can be represented by a power law. This enforces a structure in which increasingly fewer big, specialized components counterbalance a huge pool of common, tiny, and regularly dispersed components, links, and/or functions. (Kendall & Teicher, 2000a) argues that this imbalance across scales is essential to comprehending the dynamics of urban transformation because it permits the general shape to remain relatively stable despite change.

For several real-networks, power law distributions have been found (for a review, see (Clauset et al., 2009)). The first of several power-law distributions shown to be associated with the distribution of city size in the setting of cities (Pickett et al., 2011). Since then, a large number of power law correlations have been discovered in urban areas, including those between the size of a city and its physical infrastructure (Jiang & Claramunt, 2002) and its CO_2 emissions (Oliveira et al., 2014). Using whole urban regions as aggregate units of analysis, the majority of these researches compared them (Pickett et al., 2011). But in the last few years, a number of writers (Salat, 2017) have begun to focus more on smaller spatial scales, and in particular, on how spatial components are distributed within urban areas (Batty, 2008b); plots (Salat & Bourdic, 2012); streets (Porta et al., 2012); and transportation networks (Salat, 2017).

Plots: An efficient urban structure, for instance, has a fine-grain plot pattern with a wide range of sizes, with a long tail of tiny plots offset by a small number of large ones (Bourdic & Salat, 2012). Salat (Salat, 2017) asserts that "many small blocks and small lots of diverse sizes make up an evolving resilient city". Because of the variety of actors and investment opportunities they can support, the urban fabric can be easily reconfigured, divided, or consolidated at different peace while still remaining more adaptable and innovative (Wood & Dovey, 2015). While small plots are ideal for small businesses and activities, larger plots provide the ideal environment for more specialized functions. Grain sizes can work in concert with one another on both larger and smaller production and consumption scales, drawing and attracting each other in turn (Wood & Dovey, 2015). This is necessary to meet the various needs that people have as they change over time. Small plots are ideal for housing more prominent buildings and specialized functions that are expected to last for longer periods of time, while larger plots resist more incremental change and are home to cheaper, more adaptable ordinary buildings.

The phrase "a multiplicity of interconnections at different scales and through scales" (Salat, 2017) describes another recurring pattern at the street scale. In other words, an effective network can meet the demands of both human-scale and walkable accessibility within the local area and relatively unrestricted and rapid movement between distant destinations. According to (Salat & Bourdic, 2012; Porta et al., 2012), such a network should be designed with a few primary routes that extend out to the larger metropolitan and regional environment, many urban main streets that connect districts and neighborhoods, and large number of dense small streets. Scale-free networks of connections are, in fact, the most efficient in terms of accessibility, energy and resource consumption, and flow distribution throughout the day (Bourdic & Salat, 2012). While it is mostly missing, if not reversed, in the majority of post-war developments, this scale-free structure seems to be more noticeable in traditional urban fabrics (Salat, 2017).

II.2.3.5. Connectivity

Connectivity is a central attribute in urban design literature (Carmona, 2003), Although connectivity is viewed as a double-edged sword in the literature on resilience, in urban design it is considered essential to successful cities as it fosters sustainable mobility, place-making, and quality of life (Laura, 2015; Ewing et al., 2006). The degree to which various urban locations are connected to one another both internally and externally to their surroundings is known as spatial connectedness. According to Porta (Porta et al., 2012), more connection promotes greater intensity of social and commercial activity and makes it easier for people to move about and move things. Furthermore, connection fosters increased interaction among components of the urban fabric and encourages the creation of novel patterns and functionalities (Dhar & Khirfan, 2017).

Various geometrical characteristics of blocks have been attributed by various writers to connection. For instance, (Jane Jacobs, 1961) considers compact and short blocks as essential components of interconnected urban fabrics. Like thus, (Stangl, 2015) observes that since "a block is an impenetrable area, its restriction of travel through the environment increases with block size... However, a small block size "relates more directly to the objectives of good connectivity". Indeed, according to (Mora et al., 2017), "smaller blocks enable pedestrians to walk around thus providing better access, while larger buildings restrict a direct route between the origin and destination of a walking or cycling trip."

As "the essential connective tissue of urban public space - from the macro-scale of entire cities to the micro scale of circulation within buildings" (Marshall, 2005). In fact, (Bourdic & Salat, 2012) state that "a critical aspect of transport resilience is the connectivity of the street network." Enough intersections increase the number of routes that can be taken, shorten travel times and traffic bottlenecks, and improve pedestrian accessibility. Accordingly, highly connected street networks have short street segments and frequent intersections, a higher incidence of three- and four-way intersections, and few dead-end streets (Marshall, 2005). In this sense, street connectivity depends on the configurational properties of the network, that is, the way different routes are linked to each other. Comparable networks lead to finer-mesh circulation and ease of movement both inside and across places. In contrast, locations that are geographically near together end up being locally separated when cul-de-sacs are the norm and junctions are few and far between. Additionally, the availability of direct and convenient routes increases with network connectivity.

Urban major streets have a crucial role in connecting at the sanctuary area scale, influencing the size and layout of these spaces through their junction patterns. (Porta et al., 2012) state that they should be spaced apart enough to provide a variety of internal, safer, and quieter local pathways typical of more residential regions, but still sufficiently close to one another to facilitate transit between various areas at speeds that are generally pedestrian-friendly. Because of this, the resultant network can handle vehicle traffic at its edges while maintaining protected areas with less traffic (Mehaffy et al., 2010). According to a recent study by (Porta et al., 2012), main streets that bordered sanctuary areas often met at intervals of no more than 400 meters before the invention of the vehicle and professional planning paradigms. This indicates that the streets reflected "the limitations of pedestrian movements and the self-organizing logic of social urban life". The same study also discovered that this distance was more than twice as great in modern cities as it was in traditional ones because of new planning regulations and the introduction of automobiles. This increased the area of sanctuary areas four times, which had a significant negative impact on accessibility and connectivity.

II.2.4. Urban design: perspectives and applications

According to (Holling & Goldberg, 1971), there are similarities between urban systems and ecological systems, This meant that the urban form could be conceptualized as a multi-layered spatial-temporal system that was characterized by multiple adaptive cycles organized into a Panarchy, regulated by discrete cycles of growth, decay, and reorganization, and influenced by the interaction of emergent bottom-up processes and conservative top-down mechanisms. In this context, It is now possible to prove that urban design exhibits the four essential characteristics of complex adaptive systems—systems interaction, historical succession, spatial interlocking, and non-linear structure—that were described by (Holling & Goldberg, 1971).

- First, systemic interactions may be said to characterize urban form as each urban environment can be thought of as consisting of a fundamental core of spatial components connected to each other via sets of same-scale (part-to-part) and cross-scale (part-to-whole) links.
- Second, the urban form is a dynamic entity prone to several cycles of change and significantly impacted by its historical development and prior states, as demonstrated by the Territorial Development Cycle and the Burgage Cycle; Urban form has a historical aspect in this way.

- Third, the Panarchy describes how changes in the spatial structure of urban settlements are shaped over time by a variety of intangible contextual factors, but that urban form also has "its own weight and inertia, that work to oppose social, economic, and political factors" (Gauthier & Gilliland, 2005), so it's not just a passive product. It is dependent upon the form's own geometrical and configurational characteristics. Furthermore, spatial position is important since objects, events, and actions are constantly placed in space (Werlen, 2017). "Everything is related to everything else, but near things are more related than distant things," according to the first law of geography (Tobler, 1970). As a result, morphological events are spatially intertwined: geometry and position influence both the absolute changes of objects and the relative changes of surrounding items.
- Fourth, changes occur both top-down and bottom-up as a result of the synergy between slow and fast processes in the urban form. These changes can be brought about by external events, such as the Industrial Revolution or other significant technological advancements, by economic booms or recessions, by the cumulative effects of internal adaptation pressures, or by the scaling-up of small-scale processes. Because "rules of interaction change as the system evolves producing unexpected results," outcomes are thus never totally predictable (linear) nor wholly chaotic (random) but rather non-linear across scales (Feliciotti, 2016).

The observation of these features, as proposed by (Holling & Goldberg, 1971), extends the more general view of urban systems as prime examples of self-organizing complex adaptive systems and suggests that urban design, even when examined at finer scales, is in fact a complex adaptive system itself; Thus, it makes sense to apply a resilience paradigm to the analysis and evaluation of urban form in all of its morphological manifestations, and this is a worthwhile endeavor.

II.2.5. Dynamics of change urban design

The dynamic system of systems known as the urban environment is created by the interaction of many physical and non-physical elements that contribute to the construction and evolution of cities (Sharifi, 2019). For this reason, any analysis of urban form resilience needs to take into account a thorough, integrated approach and shouldn't be done in isolation from deciding variables and determining factors (Sharifi, 2019). In this perspective, the dynamics and metabolism of all urban systems are modeled using the System dynamics technique

(Feofilovs & Romagnoli, 2021).

A system's behavior can be explained using system dynamics, which provides a framework for the system's behavior and uses feedback loops to drive the system's behavior (Papachristos, 2019). The scope and scale of research employing the system dynamics approach for studying urban areas vary and cover a wide range of examined aspects: some are centered around the urban area in general; while others are focused on specific aspects of the urban area and primarily addressed to one discipline, such as technology, environment, health, and economic and other areas. The most common themes covered by system dynamics models for urban systems in the literature include urban sustainability, the energy sector in urban transportation, urban economy, urban regions and urban water supply systems (Feofilovs & Romagnoli, 2021).

An example of a study applying the system dynamics approach to the urban system is found in the study of Ombretta Romice, Sergio Porta, and Alessandra Feliciotti (Romice et al., 2018). The work focuses on the realms of design to that of resilience, an accomplishment possible only when treating urban form as a complex adaptive system; On this basis, the innovative place-making approach “Master Planning for Change” which, by learning from the rules that have generated adaptable and successful places in history so far, calls for an urban design practice that designs far fewer and far better places, with consequent of implications for policy making. Far from being an ideological statement, this approach stands on 1) evidence-based: it applies the lessons it has gained from studying cities from history to the present to develop the resilient cities of the future. 2) Practical: It promotes a revised place-building process and offers the means to implement it, making it a crucial resource for designers and legislators or policy-makers.

According to (Seville, 2009), It is imperative to include additional resilience tactics, including as development setbacks, water-tight building designs, and a well-practiced evacuation strategy. Because resilience is dynamic, it necessitates ongoing attention to detail and effort to reach maximum potential resilience under the current conditions.

II.3. Urban design resilience theoretical framework

II.3.1.Urban resilience general framework

The City Resilience Framework (CRF) is shown in Figure 3. This innovative framework was created by Arup with funding from the Rockefeller Foundation and is based on in-depth urban study. The plan formulation process is supported by the CRF, which serves as a framework for comprehending the intricacy of urban systems and the factors that influence a city's resilience.

The Resilient Cities Network, which is made up of cities dedicated to constructing and funding urban resilience, promotes the Urban Resilience Framework (URF). More than 100 cities worldwide have made considerable use of the URF architecture.

The CRF includes four essential components of urban resilience, as shown in Figure 5: Infrastructure and environment; economy and society; leadership and strategy; and health and well-being. Three main drives provide the foundation for each dimension.

The following are some of the principles of the Resilient Cities Network approach:

- Understanding resilience requires considering the city as a system.
- The common elements of the city system that need to be taken into account while constructing urban resilience are outlined in the City Resilience Framework (CRF).
- The CRF serves as the foundation for stakeholder involvement in the creation of a resilience strategy.

Figure 5 City resilience framework, *(*Urban Resilience Program - Resilient Cities Network, *2022)*

II.3.2. Urban design and its components

The CRF does recommend that there be communication between the state and its residents with the goal of knowledge transfer between the parties and that multiple stakeholders be knowledgeable, competent, and have access to information. Therefore, the question is not so much whether top-down or bottom-up approaches to growth are superior, but rather how to best combine the two in order to get the desired outcome. In an ideal world, they would come together in the center, with the top-down strategy assisting in resource channeling and the bottom-up approach creating and executing the framework.

II.3.2.1. Resilience building

The Resilient Cities Network emphasizes that in order for cities to become resilient, funding must be directed on initiatives that maximize benefit relative to each Rand expended. High-impact solutions provide a number of advantages, including better jobs, more equitable access to essential services, and infrastructure that is climate resilient. The ideal way to conceptualize resilience is as a process that includes several facets of sustainability, including integrated risk management, smart city development, catastrophe preparedness, and climate change adaptation (Jane Jacobs, 1961).

Resilience building is essentially the practice of addressing certain issues or areas at the same time in order to lower risk and improve resilience in the city. A comprehensive strategy is necessary to better understand the interdependencies between shocks and stresses in order to build urban resilience. Even if shocks and pressures are unpredictable, it is possible to build resilience and make the required adjustments by using the knowledge and experience that is now available to identify weaknesses and potential vulnerabilities (Feliciotti et al., 2016).

The ideal time to gauge the size of a problem or difficulty is after a shock event occurs because it is impossible to gauge it beforehand. A city can only work to overcome its weaknesses using all available information and the best available predictive capabilities, and become more resilient as new realities arise.

Chronic stress is typically associated with poverty, inequality, and high unemployment rates in South African cities. Furthermore, elements like the efficacy of the government and the provision of fundamental services could be considered long-term stressors. Therefore, reducing current and future risks requires developing resilience in the face of these systemic problems. In a world where change is the only thing that can be forecast with certainty, building resilience is a dynamic process. Resilience is not the same as sustainability in this regard because sustainability has objective standards for achievement (Enrique Peña Nieto, 2016).

Urban resilience is about how cities prepare for present and future change, and preparing for this change requires the integration of agendas like climate change adaptation, climate change mitigation, disaster risk reduction, biodiversity, and so on. These are some of the key concepts that were highlighted during eThekwini's 100RC process. Equity, poverty alleviation, and sustainable development. Governance and political issues are also crucial to the resilience story. Given the ongoing problems with development and governance that cities like eThekwini face, it appears that resilience should be viewed as a step in a larger process of transformation rather than as a destination in and of itself. Resilience may also need to be decreased in some systems and enhanced in others in order to facilitate transformation. For a systemic strategy to be meaningful and effective, it will be necessary to address several related resilience challenges at the same time (SACN-Cities-Network, 2022).

II.3.2.2. Resilience plot

Plots are essential for diversity and play a multitude of roles both vertically and horizontally, which makes them an invaluable tool for constructing resilience. However, because functions frequently vary, a plot's geometry becomes essential to its ability to support various functions throughout time (Kropf, 1996; Ryan, 2005).

Specifically, a complex and efficient scale-free structure is characterized by a long tail of small plots balanced by fewer large plots. Small plots are preferred by creative industries of all kinds because they are more adaptable and can be used for a variety of purposes (Wood & Dovey, 2015). At the same time, a few larger plots provide the ideal environment for more specialized uses (Salat & Bourdic, 2012). The ability of places and people to easily self-organize and reorganize is promoted by the statement that "a variety in sizes of plots provides investment opportunities for every budget and every investor, which creates a diversified market with a multiplicity of actors." This increases the likelihood that similar functions are provided in different ways simultaneously, and hence redundancy: if one fails, others can survive (L. Marcus, 2011). As further forms of diversity develop over time, this also makes it possible for a greater degree of mixing to arise in terms of building values, layouts, sizes, and ages,… etc. (Jane Jacobs, 1961).

Plots function largely as proper modular elements because each one is occupied by an independent function and is subject to an autonomous ownership regime. They are distinct from one another in terms of function and geometry, but they are also somewhat connected to one another because they all rely on the same network (Feliciotti et al., 2016). However, plot geometry has a major influence on modularity at the plot scale: larger plots are more unfavorable than smaller plots due to their varying capacities to aggregate or disaggregate (Kendall & Teicher, 2000b). Moreover, simpler shapes—usually rectangular—are better adapted to encourage the formation of cohesive wholes. Plot accessibility is crucial for connectivity because, for the majority of trips, plots serve as the starting point and the ending point. Greater availability of distinct and independent destinations that may be reached in a short amount of time or distance is implied by a higher number of accessible plots, which leads to stronger internal connectedness (L. Marcus, 2011).

II.3.2.3. Resilience street

Streets serve as the boundary between public and private domains since they sit between plots (Henshaw, 2014). The variety of street borders reflects the diversity of the streets that border them, but the degree of "constitutedness" of the street, the spacing between street intersections, and the grain of the individual plots can all affect how easily or slowly this "synchronization" occurs (Akkelies van Nes, 2007); that is the degree to which streets and building fronts are closely related both aesthetically and functionally. This typically results from a slow process of adaptation over time that boosts diversity: street fronts become an integral part of the complexity of the urban landscape when there is good responsiveness between the hierarchy of streets and plot pattern, which in turn boosts efficiency (Feliciotti et al., 2016). However, streets were purposefully constructed to be "un-constituted" in many post-war developments, reducing them to large-scale iterations of a limited number of types. This led to a severe reduction in the variety of urban interfaces and an incompatibility between plots and streets; Also, street edges act as connectors between plots and streets, also regulate the connections between other urban features (Henshaw, 2014). Thus, street edges are essential to modularity because the degree of autonomy and interdependence among modules depends in part on how permeable their borders are to various kinds of flows (Quinan & Alexander, 1981). emphasized the importance of edges and interface components in the construction of cohesive wholes. Street edges can, once more, be "soft" and porous to exchange (active fronts, arcades, etc.); on the other hand, they can limit interaction (setbacks, etc.) or even prevent any joining (high fences, blank fronts with no access points, etc.); in this latter case, adjacent modules can be isolated even though they are physically close to one another (Feliciotti et al., 2016). The amount of street edge permeability also depends on how many or how few access points there are. For this reason, it becomes crucial for connection, especially at the local level. Because several relatively small plots make a greater number of tightly spaced access points possible, there are more accessible destinations, which is good for social life (Romice et al., 2016). In any case, street importance determines the appropriate level of permeability for street boundaries. More permeability is needed at street margins that front major thoroughfares in order to facilitate ongoing interaction between public and private areas. On the other hand, streets that are primarily residential can afford less permeability because they do not require the same level of trade (Feliciotti et al., 2016).

II.4. Flood risk analysis and Urban design resilience assessment framework

II.4.1. Reviewing urban resilience characteristics

The various elements that contribute for making them resilient, as well as the programs and policies that control risk. For design purposes, the index has been frequently used to assess the resilience of cities today (Figure 6).

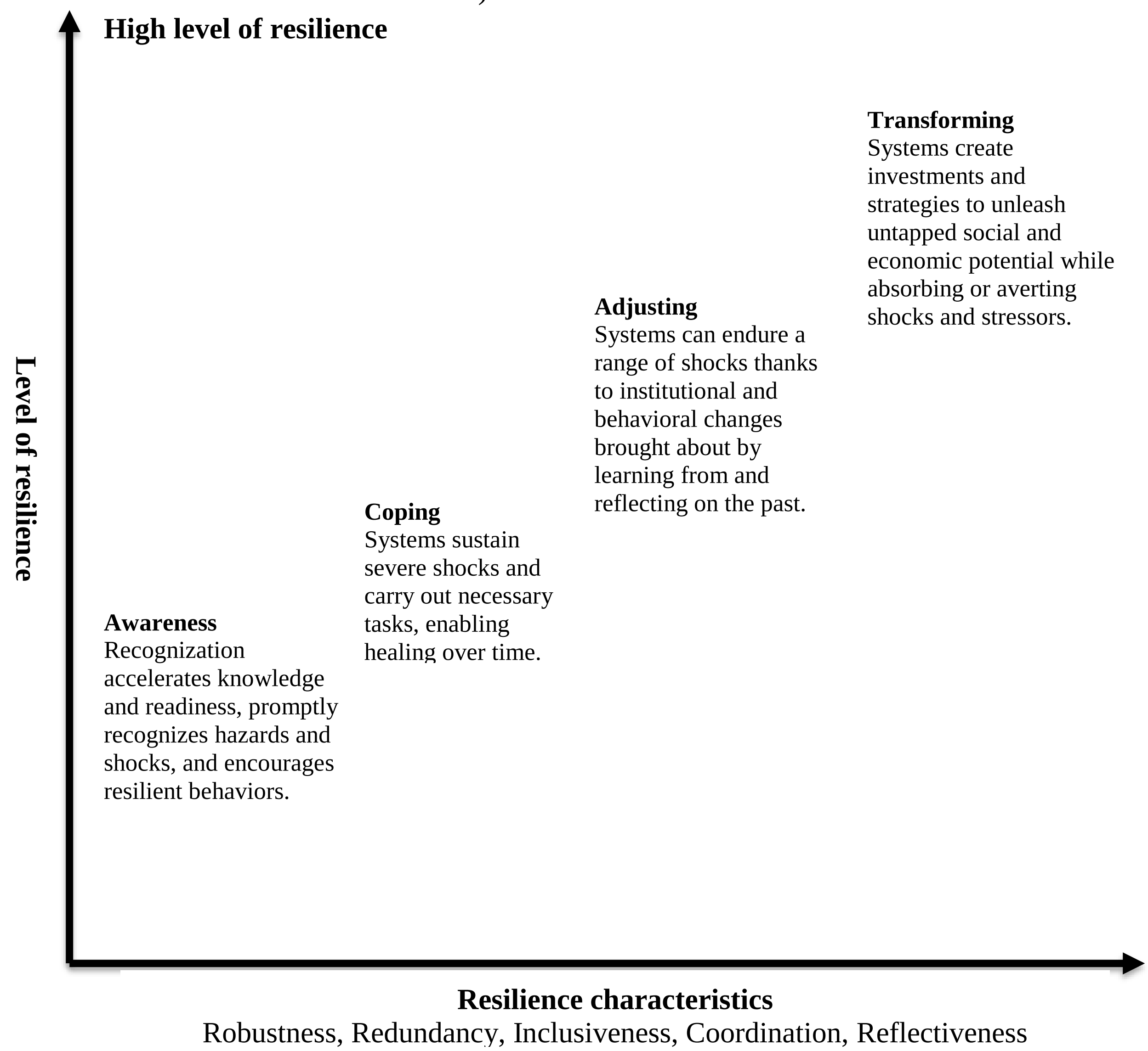


Figure 6 Resilience characteristics drive the continuum of the World Bank's urban system resilience framework, (United Nations, 2021).

In the same way, the World Bank has created a framework for urban resilience that includes the following features that serve as a baseline and can be used to construct interventions:

- Robustness is the stability and robustness of urban systems and infrastructure.
- Ensuring equitable benefits from resilience initiatives for the most vulnerable individuals is known as inclusion.
- Coordination; Encourages coordinated reactions to shocks and stresses.
- Reflectiveness is known as systems' ability to adapt and change in response to common knowledge and experience.
- Redundancy: Managing resilience risks in urban systems by using several routes.

The framework may be used to evaluate whether urban initiatives contain these qualities at the operational level and to evaluate the overall impact of the project on strengthening urban resilience along a five-stage continuum at the level of the urban system (United Nations, 2021).

II.4.2. International policy frameworks influencing the resilience and risk of cities

Urban risk reduction and resilience strategies differ greatly throughout cities worldwide, depending on national policies and central government backing. To differing degrees, national policies in several nations are modeled after international policy frameworks. This section explores four globally recognized policy frameworks that address development, catastrophe risk reduction, and climate change. We evaluate their approaches to the risk and resilience issues that cities currently and in the future must address. Collectively, these frameworks offer a broad vision for urban resilience, the kinds of objectives cities ought to pursue, and an all-encompassing view of what cities may accomplish, in spite of their notable historical-cultural, socio-economic, political, and geographic/geophysical distinctions (United Nations Development Programme, 2021).

II.4.2.1. The sustainable development goals

The SDGs are non-binding international agreements between nations to advance development across 17 objectives by 2030. The pledge to 'Leave no one behind' encapsulates a commitment to equitable development along with 169 specific aims. (United Nations, General Assembly, 2015) Though SDG 11 - Sustainable Cities and Communities - focuses explicitly on making cities inclusive, safe, resilient, and sustainable, most goals and targets have some connection to the resilience agenda. Target 11.5 draws emphasis to the necessity of lowering the financial and human costs associated with disasters in urban areas:

> *"11.5 By 2030, drastically cut the number of fatalities and impacted individuals, as well as the direct economic losses associated with disasters—including those related to water—in relation to the world's gross domestic product, with an emphasis on safeguarding the underprivileged and those in precarious situations" (United Nations, General Assembly, 2015).*

Other Sustainable Development Goals (SDGs) that specifically address risk mitigation and urban resilience include:

- Goal 11.3 Increase the ability for participative, integrated, and sustainable human settlement planning and management in all nations by 2030, as well as inclusive and sustainable urbanization.
- Goal 11.b Develop and implement holistic disaster risk management at all levels in accordance with the Sendai Framework for DRR 2015–2030. By 2020, significantly increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters.
- Goal 1.5 Increase the poor's and those in vulnerable situations' resilience by 2030, and lessen their exposure to extreme weather events linked to climate change as well as other shocks and disasters related to the economy, society, and environment.
- Goal 3.d Enhance every nation's ability to identify and manage threats to national and international health, with a focus on developing nations in particular.
- Goal 13.1: Make all nations more resilient and capable of adjusting to risks and natural disasters associated to climate change.

This agenda is strongly related to a number of other aims and indicators, such as the SDGs 9 and 2 on infrastructure provision and food security.

An urban lens can help all of these, and they can all gain by having a clear urban perspective. Although the idea of urban resilience was present prior to 2015, its position as a fundamental component of sustainable development was solidified when it was added to the 2030 Agenda as a stand-alone target (Leitner et al., 2018).

II.4.2.2. The New Urban Agenda

Out of the Habitat III conference in 2016, the UN created the New Urban Agenda, which is centered on the ideas of sustainability, resilience, equity, and smartness (United Nations

(HBITAT III), 2016).

Environmentally sustainable and resilient urban development is one of the three pillars of the New Urban Agenda, along with two other pillars that center on social and economic objectives. The agenda's articles 65 through 80 contain the signatories' promises to put these pillars into action. The majority of these publications have implications for resilience, risk mitigation, and development; however, articles 77–78 may most directly address these topics:

> *"77. In accordance with the Sendai Framework for Disaster Risk Reduction 2015–2030, we pledge to strengthen the resilience of cities and human settlements, including by developing high-quality infrastructure and spatial planning, adopting and putting into practice integrated, gender- and age-responsive policies and plans, and using ecosystem-based approaches. We also intend to mainstream comprehensive and data-driven disaster risk reduction and management at all levels to lower vulnerabilities and risk, to help households, communities, institutions, and services plan for, respond to, adapt to, and quickly recover from the consequences of hazards, including shocks or latent pressures, particularly in risk-prone areas of formal and informal settlements, including slums. We will encourage the construction of resilient and resource-efficient infrastructure, including the renovation and upkeep of slums and informal settlements, in order to lower the risks and effects of disasters. In collaboration with local government agencies and other relevant parties, we will also push for actions to reinforce and remodel all vulnerable housing stock, including that found in slums and informal settlements, to increase its resilience to natural catastrophes."*
>
> *"78. We pledge to support the shift from reactive to more proactive risk-based, all-hazards, and all-of-society approaches. Examples of these include promoting ex ante investments to prevent risks and build resilience and increasing public awareness of risks, all the while ensuring prompt and efficient local responses to meet the immediate needs of those impacted by natural and man-made disasters and conflicts. This should involve incorporating the "build back better" ideas into the post-disaster recovery process in order to incorporate*

> *environmental and spatial measures, resilience-building strategies, and lessons learned from previous catastrophes into future planning. It should also involve raising awareness of new hazards." (United Nations (HBITAT III), 2016).*

Crucially, the majority of the New Urban Agenda's precise goals are predicated on other international agreements, including the Paris Agreement, Sendai Framework, and SDGs. SDG 11 for "planning, construction, development, management, and improvement of urban areas" is specifically accelerated by the agenda (United Nations (HBITAT III), 2016). The agenda acknowledges that the majority of urbanization in the ensuing decades will occur in low-income countries and integrates urbanization into development policy and practice.

The Action Framework for the Implementation of the New Urban Agenda was developed since the New Urban Agenda does not address the issue of implementation. The framework, which is not legally obligatory, encourages five areas where national action might be implemented to help local urban areas: Urban planning and design; urban economy and municipal finance; urban legislation, rules, and regulations; national urban policies; and local implementation (United Nations (HBITAT III), 2016).

II.4.2.3. The Sendai Framework for Disaster Risk Reduction

A wide commitment to minimizing disaster damage and losses is outlined in the Sendai Framework for Disaster Risk Reduction, which is correlated with the SDGs' accomplishment. The purpose of the Sendai Framework, which has four priority areas, seven targets, and 38 indicators, is to encourage and track Member nations' reported progress in disaster risk reduction. The Sendai Framework's central idea of resilience is discussed in regard to the hazards of disasters (United Nations, 2015b). Investing in disaster risk reduction for resilience is the focus of Priority 3, which also has a specific aim (d) pertaining to the efficacy of these investments:

> *"(d) By 2030, significantly lessen the damage that disasters do to vital infrastructure and the interruption of essential services, such as health and educational facilities, in part by strengthening their resilience." (United Nations, 2015b).*

While the concept of resilience is understood to cut across all contexts (rural and urban), sectors, and scales (local, national, regional, and global), the framework explicitly states in its guiding principles that local government empowerment, responsibility, and involvement are essential to lowering the risk of disaster (United Nations, 2015b).

Through its Making Cities Resilient initiative, the United Nations Office for Disaster Risk Reduction (UNDRR) created an extra reporting framework for local governments in 2017. As a diagnostic, reporting, and planning tool, the Disaster Resilience Scorecard for Cities was created as part of the campaign and is based on ten principles (UN Office for Disaster Risk Reduction, 2017):

1. Make plans for resilience to disasters
2. Recognize, comprehend, and apply existing and potential risk scenarios
3. Boost resilience in terms of finances
4. Aim for resilient urban planning and development
5. Preserve natural buffers to strengthen the defensive qualities provided by natural capital
6. Increase the resilience of institutions
7. Recognize and enhance the resilience of society
8. Boost the resilience of the infrastructure
9. Assure efficient disaster relief
10. Quicken your recuperation and rebuild stronger

Local governments can evaluate urban resilience and create resilience action plans that align with the Sendai Framework targets with the help of the scorecard. To ensure coherence between both objectives and minimize reporting duplication, their key indicators are included in national-level reporting, and the Sendai Framework reporting system is linked to SDG goal 11.b (UN Office for Disaster Risk Reduction, 2017):

> *"11.b. By 2020, significantly increase the number of cities and human settlements that adopt and implement integrated policies and plans aimed at inclusion, resource efficiency, climate change mitigation and adaptation, and disaster resilience. Additionally, develop and implement holistic disaster risk management at all levels in accordance with the Sendai Framework for Disaster Risk Reduction 2015–2030." (United Nations, 2015b).*

Currently, the initiative is being carried out under the name "Making Cities Resilient 2030." Apart from the scorecard and action planning, the program facilitates the execution of resilience plans by cities, with an emphasis on enhancing cross-sector governance frameworks and financing accessibility.

II.4.2.4. The Paris Agreement

Although urban environments are not explicitly addressed in the legally binding Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), clauses 7.1 and 8.1 make resilience and hazards clear (United Nations, 2015a).

> *"7.1 In light of the temperature goal mentioned in Article 2, the Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change. The purpose of this goal is to contribute to sustainable development and ensure an adequate adaptation response."*
>
> *"8.1 Parties acknowledge the role that sustainable development plays in lowering the risk of loss and damage as well as the significance of preventing, mitigating, and addressing loss and damage related to the unfavorable effects of climate change, particularly extreme weather events and slow onset events." (United Nations, 2015a).*

The agreement places planning and execution of mitigation and adaptation under national jurisdiction. Urban resilience and hazards are specifically addressed in the technical guidelines that assist nations in creating Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) that are submitted to the UNFCCC (United Nations, 2015a).

Resilience in urban contexts is defined in the NDC planning process as climate change resilience. According to the NDC technical standards, nations should support local delivery, engage in multi-stakeholder consultations, integrate local authorities in NDC implementation, and collaborate with current urban policies. On the other hand, the rules presuppose that a successful mitigation policy will increase city resilience (UN-HABITAT, 2020). A 2016 UN-Habitat analysis reveals that 113 of the 164 original NDCs included urban components (UN-HABITAT, 2017). Of them, 75 countries included urban adaptation programs that prioritized the following major sectors for adaptation (in order of importance):

1. Security of food.
2. Preservation of biodiversity and ecosystems.
3. Water resource management.
4. Hazard and misfortune.

5. Medical and healthcare.
6. Management of land usage.

In order to promote adaptation, UN-Habitat's NAP human settlement technical guidelines specifically address urban and human settlement issues in the creation and implementation of NAPs as well as more widely (Nicola et al., 2016).

It is implicitly expected that reduced vulnerability leads to urban resilience, and a NAP with an urban-focused component would accomplish this (M. Marcus et al., 2019). International agencies are also offering technical support to incorporate urban adaptation and resilience priorities and targets into the NAP process (M. Marcus et al., 2019; United Nations, 2021).

The significance of urban resilience is central to these four policy frameworks and global goals, which have produced a set of standards, evaluation instruments, and a lot of top-down administrative and technical expertise. The idea of urban resilience as a reaction to disturbance—which is primarily thought to be external—emerges from these aims. The ways in which risk arises from and is produced by the urban system are not well understood (Evans & Reid, 2013).

II.4.3. Flood risk analysis framework

Many expert groups have made significant strides toward directing the creation of these frameworks (Winograd, 2005). The approach attempts of (B. L. Turner et al., 2003) to align vulnerability analysis with scientific concerns about global environmental change and sustainability. They have resulted from years of practice and study on resilience, the effects of climate change, and risks and hazards (Cutter, 1996). Understanding the effects on and reactions of the impacted system or its components requires more than a narrow emphasis on perturbations and stressors, as this work's main lesson acknowledges (Dennis, 1999; Showalter et al., 1990). The risk-hazard (RH) is a classic reduced-form framework that has influenced vulnerability research.

In various respects; Essential Components of risk-hazard analysis based on the sustainability theme broadens and refocuses the scope of vulnerability analysis (Cutter, 1996; Füssel & Klein, 2006; Rechkemmer & Von Falkenhayn, 2009). It focuses primarily on coupled human-environment systems, whose sustainability and susceptibility depend on the interaction between the biophysical and human subsystems as they are impacted by processes that operate at various spatiotemporal (and functional) scales. We determine that the following components, especially those targeted at promoting sustainability, should be included in any vulnerability analysis:

- Stressors and perturbations that interact, as well as the order in which they occur;
- Exposure that goes beyond the existence of a disturbance and a stressor, such as the way the linked system is exposed to risks;
- The connected system's sensitivity to the exposure;
- The system's ability to adapt or respond (resilience), taking into account the dangers and repercussions of a delayed or subpar recovery;
- the reconfiguration of the system following the answers (i.e., modifications or adaptations), and;
- Scalar dynamics and nested scales of linked systems, risks, and their reactions.

Apart from these fundamental components, research from (B. L. Turner et al., 2003) indicates that the vulnerability analysis's methodologies and emphases are most helpful for decision-making (Rechkemmer & Von Falkenhayn, 2009; Cash et al., 2003) when they:

- Enhance the standard perturbation-stressor-to-consequence method by focusing on the desired results and moving backwards toward the perturbation or stressor, hence increasing the requirement for stakeholder involvement;
- Profile differential vulnerability: regardless of how the system may be constrained, subsystems and parts of the connected system are seldom equally susceptible;
- are aware of the nonlinear and stochastic components interacting with the coupled system to produce unexpected or surprising results;
- Pay attention to how institutions that function as structures or stressors impact the sensitivity and resilience of systems;
- Determine which dubious causal structures influence vulnerability and examine the cause-and-effect relationships that allow them to function;
- Provide suitable measurements and metrics for tests, models, and assessments; and
- Establish institutional frameworks that connect vulnerability studies to decision-making processes, emphasizing the importance, reliability, and validity of the data generated.

A framework Unveiled: Intricacy Concise and Presented A thorough vulnerability study should ideally take the system as a whole into account. But this is an unattainable goal. The utilization of "reduced" vulnerability assessments is always necessary due to real-world data and other restrictions. Analysts must, however, continue to recognize that vulnerability is rooted in a complex coupled system with linkages that function at many spatiotemporal scales and frequently involve stochastic and nonlinear processes. Ignoring this bigger picture might result in the discovery of "response opportunities," which, if taken up, could have major unforeseen implications or "surprise" effects (Stern & Fineberg, 1996; Kates et al., 2000).

Building a framework for flood risk analysis according to the previous studies:

The framework offers the general classifications of elements and connections that make up a coupled system's susceptibility to risks (B. L. Turner et al., 2003); According to (Dennis, 1999; Robert, 1985; Foudi & Osés, 2014b; B. L. Turner et al., 2003), The goal of the foundational Risk hazard framework (Figure 7) was to comprehend the effect of a hazard in relation to exposure to the hazard event and the entity's dose-response (sensitivity) (Robert, 1985). Previous quantitative implementations of this model in environmental and climatic impact evaluation mostly focused on exposure and susceptibility to disturbances and pressures (Ausubel & Biswas, 1980; B. L. Turner et al., 2003) and proceeded from the risk to the consequences (Robert, 1985).

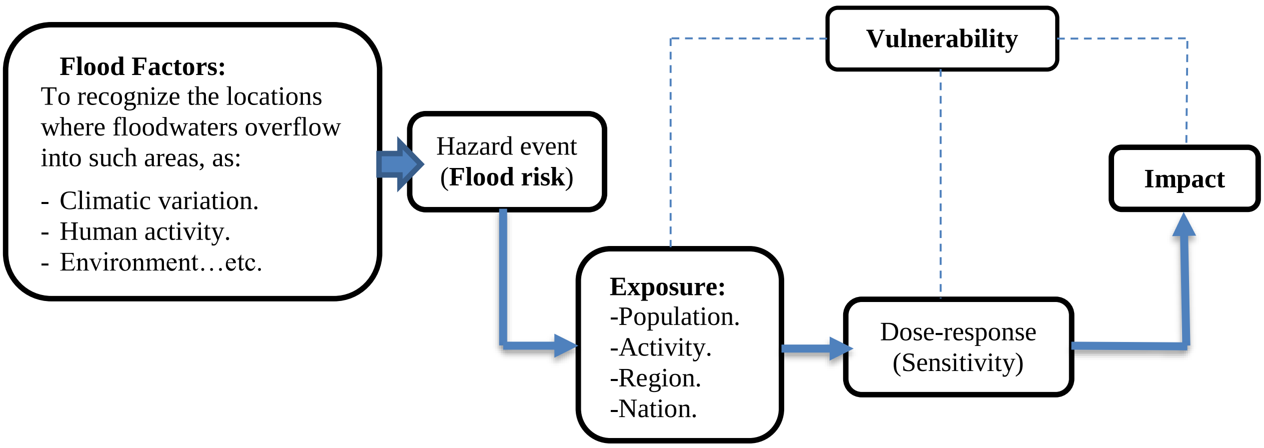


Figure 7 Flood risk analysis framework, (Dennis, 1999; Robert, 1985; Foudi & Osés, 2014b; B. L. Turner et al., 2003).

The following framework (Figure 7) summarizes the different steps taken in the next chapters for analyzing the flood risk of our case study, which is started by recognizing flood factors as a first step to select the zonation of where floodwaters overflow into such areas to distinguish between natural and man-made accelerators and aggravators factors (Arnaud-Fassetta & FORT, 2011), such as: Climatic variation, Human activity, and environment …etc, The impact model variations in one or more characteristics of factors affects a specific population, activity sector, or region of the country and 'causes' impacts, or changes in state that would not have happened in the absence of the factors, according to the most basic assumed relationships to detect the vulnerability of the study area (Robert, 1985).

Based on (Ministry of Ecological Transition and Solidarity, 2020), Failure Risk Analysis FRA involves identifying potential failure risks for the system under study, bearing in mind that each system is unique. The aim is to protect the receiving environment, and to act on flood risks in order to reduce their impact: loss of human life, socio-economic losses, illness, destruction of infrastructure, dispersal of local economic development players, cessation or decline of activities, unemployment... These few examples also demonstrate that the impacts of flood risks are multidimensional as well as subtle.

Detailed risk analysis in 3 steps:

1. ***Cause-and-effect analysis**:* analyze the causes of the risk, determine the consequences, identify the main causes and factors.
2. ***Qualitative assessment**:* evaluate the consequences of the risk, assess the probability of occurrence, present the risk map.
3. ***Quantitative assessment**:* estimate and evaluate scenarios, assess risk distribution, determine human, socio-economic and financial consequences (Ministry of Ecological Transition and Solidarity, 2020).

Identifying flood risks:

Risk identification is the starting point for risk analysis; In detail, risk identification involves formalizing knowledge of the terrain, in order to identify the areas and buildings most vulnerable to flooding. These vulnerabilities then need to be characterized. The real aim of this approach is, on the one hand, to target the areas to be treated as a priority, and on the other, to provide a response to reducing vulnerability that is adapted to the local context.

The methods available to carry out risk identification work include:

- Past significant events and satellite image analysis.
- Field visits.
- Surveys of the local population and/or participatory mapping.
- Analysis of urbanization plans and land use patterns.
- Vulnerability analysis of urban fabrics.

This work is related to the next part, which is:

1- FLOOD ZONE MAPPING / FLOOD SUSCEPTIBILITY MAPPING

The simplest way to avoid flooding is to avoid exposing yourself to it. To do this, you need to avoid building, living or carrying out activities in so-called flood zones, which can be identified on a special map called a flood zone map or flood susceptibility mapping. The design of this map requires precise topographical surveys and hydraulic modeling to determine how floods inundate these areas.

2- INSTALLATION OF FLOOD MARKERS

It's important to remember that floods also occur in areas that are supposed to be non-floodable. Consequently, since there is no such thing as zero risk, regardless of the area, it is prudent to make regular observations by installing flood markers in so-called strategic areas such as streams, rivers, hydrographic networks, frequently or easily flooded areas, but also on various public or private buildings such as Quays, Bridges and historical monuments. The data provided by these markers must be studied in order to anticipate possible flooding, such as the effects of climate change, precipitation, and rainfall, as well as the impact of fast urbanization, Land use, and land cover...etc.

3- LIMITING RUNOFF

Discharging water reduces the risk of flooding in a given area, but transfers it to downstream areas. Instead, it's more effective and less dangerous to implement a slow-down management strategy through appropriate urban design that directly contributes to reducing flood risks within urban areas. Recommended ways of limiting runoff include preserving and restoring areas with a high water retention capacity; designing and maintaining ditches; and designing small water retention basins (This section will be further explained in the next titles).

II.4.4. Challenges in urban resilience assessment

According to the research of (Saja et al., 2019) in the review of social resilience studies; mentioned that resilience measuring tools to calculate the dynamic interactions between social and other dimensions are not yet captured; Also, the research of (Cutter et al., 2008) declared the current research applying multiple equilibrium regimes in models with socio-economic components are still limited. Often quantitative indicators for the assessment of resilience among different scenarios are used to facilitate the comparison in different contexts (Asadzadeh et al., 2015); One method of capturing multidimensionality is to combine indicators that show several urban area characteristics into a single score known as a "index" (Apreda, 2016), through applying a composite indicator-based method. This method is often used for assessing the performance of sustainability, human development, innovation, corruption, and competitiveness (Becker et al., 2017); Nonetheless, one of the most well-known Sendai

Framework indicator issues are that they are utilized to identify global trends in the reduction of losses and disasters at the current state of use (United Nations, 2015b); In this regard, they used to calculate the impact of short-term disasters but do not offer enough data to develop long term strategies for prevention disaster and risk reduction (Feofilovs & Romagnoli, 2021).

The challenges in urban resilience assessment, according to Cariolet J. M (Cariolet et al., 2019), discovered that it is difficult to apply pertinent variables or indicators in a way that is workable and feasible for each urban system. As a result, it is recommended that a systemic approach be integrated into the development of urban resilience mapping. Computer simulation tools for resilience assessment are moving toward the systemic approach and are trying to apply quantitative techniques that explain how system variables are related to one another. Short-term, realistic and accurate models are typically those created for single systems, such as hospitals (Pishnamazzadeh et al., 2020), energy supply systems (P. He et al., 2019), and water supply systems (Quitana et al., 2020). However, resilience is still a distinct measure for different components of the urban system because most models don't seem to be able to capture the resilience of the entire system at this stage of development (Feofilovs & Romagnoli, 2021).

According to (Saja et al., 2019); There are more models in modern computer-based simulation tools that include several facets of overall resilience in hybrid models. For example, in the study of (Steinø & Veirum, 2005), Despite their notion of parametric design drawing inspiration from the CAD world, their experiments to now have not included the use of CAD technologies to parametric urban design. Conversely, they have made it clear that they view parametric urban design as a framework for thinking about design that can be used with both CAD and analog working methods. However, there are clear benefits to using CAD tools for parametric urban design, making it interesting to explore. Scenario creation is one such use, where CAD might help with the configuration and reorganization of many design scenarios.

Additionally, (Weichselgartner & Kelman, 2014) research, mentioned there are two main issues with the resilience hypothesis and its present implementation. Firstly, an excessive number of initiatives aimed at enhancing resilience in and for cities rely on unquestioned presumptions about society, which essentially forces a technical-reductionist framework onto intricate networks of interactions, values, and significance. Rather, what is needed is a "critical resilience-thinking through locality and marginality". Secondly, the current quantitative production style that reduces resilience to a single city measure conceals far more than it reveals. Specifically, local customs and knowledge-making traditions can be used to identify social plurality, cultural heterogeneity, and geographic difference. Decontextualized top-down knowledge on resilience, produced in a particular science-policy setting with specific institutional arrangements, provides a severely limited guide to urban policy and practice and may have significantly less value in problem-solving than pursuing co-designed bottom-up knowledge and tools (Asadzadeh et al., 2015).

As the previous studies make clear; This does not mean that the term "resilience" should be completely removed from urban planning and design agendas. Bringing together knowledge and experience from many sources is a crucial first step. This entails combining several fields of expertise and methods by which authorities, the public, and scientists work together to produce information that is not only socially sound, actionable, and suitable in its context, but also based on sound science. Resilience's conceptual ambiguity and disconnection from people's real-world experiences will be addressed by combining a variety of information, creating a clear operational definition, and establishing tangible baselines (Cutter et al., 2008).

Emerging questions for more research point out some of the difficulties in putting various resilience strategies into practice. These new concerns must clearly recognize that resilience transcends environmental and development processes and that resilience should be used to enhance sustainability rather than undermine it. In actuality, the function of various socioeconomic contexts in which behaviors are engaged in and the manner in which they relate to fundamental social practices must be addressed by scholars as well as policy and practice decision-makers (Weichselgartner & Kelman, 2014).

Therefore, much greater knowledge is required on the kind of interventions that work best for boosting resilience in various contexts as well as the best approaches to develop, carry out, and sustain them. To further define and operationalize creating urban resilience, which extends beyond program timetables and supports long-term organizational learning and action, more study is required. An essential part of this is analyzing theoretical and practical viewpoints, which are required to comprehend resilience-related practical knowledge in a way that promotes knowledge realization and guarantees that knowledge leads to action. In order to include the individuals best qualified to oversee, manage, and assess the procedures in the process of building resilience, it would also be beneficial to look at the skills that enable the application of results. Understanding what is and is not unique to urban settings of various sizes is one aspect of that, and it will also help with comprehending the benefits and drawbacks of disaster risk reduction and resilience building in various urban contexts (Davoudi et al., 2012).

II.4.5. Urban design resilience assessment framework

The assessment of urban design resilience continues to be a developing field of study, "How urban systems and more specifically their spatial form can be understood in terms of a resilience framework" is a topic that is gaining attention (L. Marcus, 2011). Among them, Alessandra's (Alessandra, 2018) study is noteworthy since it was one of the first to directly connect ecological theories—developed by (Holling, 1973)—to spatial-morphological processes. In his work, the author extends the Textural Discontinuity Hypothesis, which is used in ecology to explain patterns of discontinuity and clustering found in biological organisms, to analyze the complexity and heterogeneity of the built environment. The author argues that, just as the heterogeneity of an ecological landscape is linked to the resilience of an ecosystem both now and in the future, changes in the size of built landscape elements can be analyzed, and that these changes can be used to compare different stability states of the system before and after shocks.

The notion of "spatial capital" (L. Marcus, 2011) and the rich history of Space Syntax research (Wilkinson et al., 2010) have been built upon by (L. Marcus, 2011; Cloete, 2012), who have attempted to translate the four characteristics of resilience in complex adaptive systems—change, diversity, self-organization, and knowledge—into spatial variables of accessibility (local and global integration in Space Syntax) and spatial diversity (degree of land division into parcels). Lastly, (Salat, 2017) Salat draws a link between the tradition of studies on urban complexity developed in urban geography (Pickett et al., 2011) and shows that the morphological structure of several cities exhibits hierarchical configurational order and allometric regularities similar to those found in biological and ecological systems. Salat makes a connection to the ecological discourse on resilience when he says that scaling laws may assist planners and urban designers in creating more resilient cities, just as they are a useful tool for comprehending resilience and change in ecological systems. In contrast, (Ernstson et al., 2010; Ben et al., 2003; Guo et al., 2020) investigated the resilience of urban form using four major "measures": social, environmental, physical, and economic resilience. Each of these "measures" was evaluated using one or two indicators (Table 4). These instances serve as important models for evaluating resilience in urban form, and further study is necessary to build upon them if urban planners are to make a significant contribution to creating environments that can successfully navigate the problems of growing urbanization.

Table 4 Four dimensions of resilient urban design, (Ernstson et al., 2010).

Environmental	Green space	✓ Green space coverage.
	Public transport accessibility	✓ Public transport stations.
Physical	Density	✓ Population density/hectare. ✓ Floor area and coverage ratio.
	Street layout and building types	✓ Building floor plans. ✓ Building and street sections.
Economic	Property value in urban context	✓ House heat maps across the city.
	Property values over time	✓ Historical prices. ✓ House prices since 1990.
Social	Land use and social amenities	✓ Section use ✓ Ground floor use ✓ Social amenities
	Tenure	✓ Housing tenure statistics

As stated by Carpenter et al. (Carpenter et al., 2001), "specify which system configuration [or indeed configurations] and which disturbances are of interest" (p: 766) is the first stage in a resilience evaluation. This entails defining the focal system, or the pertinent temporal and spatial scales at which the measurement is made, as well as the range of perturbations that the system has encountered over time by giving a description of the processes and events that have contributed to the system's shaping and transformations.

According to the Resilience Alliance (Resilience Alliance, 2010), the system delineation phase entails a thorough examination of the events and processes taking place both inside and outside of the system under investigation, the identification of key organizational scales, and the conceptualization of various stages in the system's evolution at various scales and across various domains (social, economic, institutional, etc.). Thus, even while the physical domain—more precisely, the urban form system—is the subject of current research, it's crucial to recognize the ways in which morphological changes are influenced by social, economic, cultural, and political changes as well. Therefore, defining the focus system's temporal and geographical bounds is a crucial step that comes before the evaluation itself. Urban morphology research, which holds that the evolution of urban form can only be understood in connection to the important contextual processes that create and are shaped by it, also frequently holds this perspective (Oliveira et al., 2014; Jażdżewska, 2022).

In the present study, the creation of multi-scale historical timelines is the suggested approach for defining the spatial and temporal limits of the focus system and pinpointing the primary activities taking place both inside and outside of it; as well as "what is an appropriate time span over which to examine this system" (Resilience Alliance, 2010), using timelines in system ecology and resilience theory (Resilience Alliance, 2010). Timelines are also used in urban morphology, where they identify major morphological periods in the development of the built environment and serve to augment the study of urban form with the reconstruction of major socio-cultural, economic, and political-institutional processes (Kropf, 2009). They also make it possible to visualize the relationship between morphogenetic and socio-economic processes over time. Timeline utilization in this study will enable the definition of events around the system under investigation and the iterative refinement of the focused system's limits in terms of both space and time (Alessandra, 2018).

The empirical evaluation of urban form resilience comes next. Since resilience can only be inferred indirectly through linked observable and quantifiable surrogates or proxies, it cannot be directly observed or represented by standard aggregate measures, according to Carpenter et al. (Carpenter et al., 2001). Proxy indicators, in contrast to traditional indicators, quantify observable changes in certain parameters that are related to the phenomena under investigation at different times, rather than directly addressing the phenomenon itself (Siregar, 2018; S. J. Taylor & Letham, 2017). The majority of the assessment frameworks support this viewpoint, which is consistent with the theoretical framework and confirms that the ability to deploy various resilience performances depends on fundamental attributes possessed by the system. Despite the diversity of approaches, these frameworks frequently involve the use of proxy measures (ARUP, 2015; FAO, United Nations, 2016). Main contextual factors affecting the investigated area over the period considered at different scales (policy, economy, society) can be discursively linked to the study of various spatial configurations over time through the use of resilience proxies, a quantitative method, and the use of multi-scale timelines, a qualitative research method.

Building a framework for Urban design resilience assessment according to the previous studies:

Throughout this section, an attempt was made to formulate an integrated urban resilience assessment framework aimed at detecting the specific contribution of urban design to the resilience of cities. Based on the previous studies of resilience assessment (Alessandra, 2018), a qualitative approach founded on the use of multi-scale timelines, which enables the attainment of a deeper comprehension of the system under investigation, to identify the borders both temporally and spatially of specific area. Also, the quantitative approach, based on the urban design systems described in Chapter 2, which attempts to evaluate each of the five resilience attributes (Modularity, redundancy, diversity, efficiency, and connectivity) using a variety of components of urban design that enable the spatial characterization of urban system forms at various morphological scales (Table 5).

The previously mentioned methods and analytical instruments aim to offer essential instruments for evaluating the many aspects of urban resilience. However, by combining various methods from various traditions, it became clear that, in the field of urban design knowledge, there are still certain gaps that need to be addressed and would call for more research. In fact, whereas time-line analysis is already widely accepted among urban scholars—especially in the field of urban morphology (Kropf, 2009)— The assessment of urban resilience qualities using parameters has shown where particular morphological scales lack appropriate assessment techniques and where just a few indicators exist for certain of the indicated resilience traits. In contrast to variety and connection, characteristics like efficiency, modularity, or redundancy have not yet been properly examined in relation to the structure of cities. Even though it is outside the purview of the present work, more research is required to close this gap. When it comes to resilience, "the methodologies developed in ecology are not yet suitable for application to complex systems other than ecosystems, like cities," even though many of the indicators that are frequently used in urban design research already have their roots in biology and ecology (Wardekker et al., 2020; Sapountzaki, 2014). Utilizing metrics created in the domains of network analysis and complexity sciences is an additional option. Using the same methodology employed to analyze social networks, brain networks, or computer networks, community recognition techniques, for instance, may be applied to the modularity of street networks. Once more, it is critical to consider the particular topological limitations and characteristics of spatial networks while making this shift (i.e. topographical capacity, metric distance, planarity).

This work presents an assessment framework for urban design resilience that aims to support evidence-based, well-informed design interventions as well as post-implementation monitoring of urban design projects, the lack of which is bemoaned by both system ecologists (Ahern, 2011) and urban designers (Wardekker et al., 2020). The framework can be used to quantify existing urban environments or evaluate project outcomes, taking into account both the projects' current state and future changes. To confirm the framework's application and explanatory capacity in the examination of resilience, tests in actual urban settings are necessary to confirm its validity (or at least a part of the city). CHAPTER V of the current thesis is to attempt to do so for a chosen case study, based on the methodology described in this chapter and the indications.

Table 5 Urban resilience parameters assessment, (Alessandra, 2018).

	Building	**Plot**	**Street**
Modularity	/	/	Street-edge granularity
Redundancy	/	Redundancy index	Local meshedness
Diversity	Building size	Accessible plot Density, Plot-size heterogeneity	Street-edge Interface matrix;
Efficiency	/	Plot-size Distribution	Street – length distribution
Connectivity	Building section; building size Building face Length; Compactness;	/	Topological connectivity Metric connectivity Street connectivity

II.5. Conclusion

It is essential to recognize that there are challenges associated with implementing a cogent resilience architecture. These include the possibility of conceptual "stretching," the mixing of normative and empirical applications, and the danger that the term's increasing use will cause it to be viewed as "the solution," a magic bullet for communities and organizations finding it difficult to deal with a range of outside "threats."

Finally, because resilience protects a radical challenge to the status quo, this study confirms Davoudi's opinion (Davoudi et al., 2012) that the resilience "turn" represents how design should be "prepared for innovative transformation." Using a resilience framework is therefore not something that should be done lightly. Resilience provides design theory and practice nothing less than a paradigm shift, challenging the underlying assumptions of modern design methods. The acceptance of "ontological uncertainties" in resilience debates, for instance, ensures that "blue-print" designing (Wilkinson et al., 2010), while important, is no substitute for "great leadership and a culture of teamwork and trust which can respond effectively to the unexpected" (Seville, 2009). This highlights how resilience as a radical concept clearly challenges designing's linear assumptions.

This focus recognizes the value of the capacity for improvisation and inventiveness while highlighting some of the drawbacks of an overly regimented approach to resilience. The human dimension—which is based on an intuitive, "sense-making" approach to unfamiliar or chaotic situations—may ultimately be the crucial challenge in an era of profound uncertainty, regardless of the broader institutional or strategic implications of applying the resilience framework to the theory of design and practice (Cote & Nightingale, 2012). And determining the flooding potential of a region using linear, surface and relief morphometric parameters is a useful approach for assessing the influence of congruent river systems on the flooding of the main Wadis.

Making changes to a city's urban shape requires a lot of effort and resources. Therefore, the ability of a form to endure in response to shifting needs is also necessary for sustainability. Numerous studies showing the varying degrees of success with which city forms responded to structural change over time (Brand & Jax, 2007a; Campanella, 2006b; Wardekker et al., 2020) support the claim that "there are urban forms that appear 'inherently' more resilient to change over the long run than others" (Ernstson et al., 2010; Guo et al., 2020). According to this research, the resilience of the urban ecosystem as a whole is influenced by the arrangement of different spatial parameters of cities such as buildings, streets, and plots, as well as their associations with the five typical characteristics of modularity, redundancy, diversity, connectivity, and efficiency; Therefore, the aim of this part is to develop a knowledge-interface between resilience thinking and urban design by concentrating on urban form and morphological analysis. Urban designers have the ability to manipulate a city's shape, which is what makes it unique, in order to affect its resilience. In this way, the elements and systems that have been described here might be used as guiding principles for both the construction of new urban forms and the intervention of current ones. According to (Gupta & Ghose, 2015), "resilience, as a design principle, was an implicit part of traditional construction knowledge"; knowing how form interacts with resilience at various sizes might aid in the rediscovery of this knowledge.

Cities, like all systems, depend on complex and multi-scale interactions between the institutional, physical, and human materials of which they are composed. According to (de Moel et al., 2009), many resilience research is being constructed around these pillars. Consequently, some of the previously mentioned analytical methods and tools were selected to provide basic tools for assessing many aspects of urban resilience; therefore, the work was divided into two sections, analytical and assessment, where the comprehensive analytical approach section to flood risk combined three main levels, the most important of which are:

i) Urban environment; which studies the factors that lead to the location and relative size of flooding areas according to past significant events in the city (RCEP, 2007; Xu et al., 2021);

ii) Ecological climatology; which examines weather forecasting and its relationship with the hydrographic network that exists or crosses the urban fabric to detect future flood risk (M. D. Turner, 2014; Bonan, 2002), and;

iii) Built environment; which looks at Land use change over different periods (timeline), and how it affects flood risk (Feng et al., 2021; Adams et al., 2013);

While the Urban Resilience Assessment section relies on scenarios that aim to support evidence-based urban design interventions that focus on urban design components such as buildings, streets, and plots, as well as their association with modularity, redundancy, diversity, efficiency, and connectivity, in addition to post-implementation monitoring of urban design projects, to infer their resilience indirectly through these observable and measurable parameters.

In order to enhance the understanding of resilient urban design and assess its resilience against flood risk. These add a temporal, user-centered dimension to the understanding of changes in urban design. They offer significant insights into the relationship between the physical environment and human practices across spatial and temporal scales, including aspects of quality of life (Montgomery, 1998).

PART II

Practical work

Introduction

Urbanization has drawn increasing attention from environmental specialists in the twenty-first century. In 1990, only 15% of people on Earth were considered to live in cities; by the 20th century, however, this number had sharply increased, with half of all people thought to reside in cities. (Buckley et al., 2008; Fonseka et al., 2019). Over half of the world's population lives in urban regions like cities and towns. According to UNFPA projections, this number will increase to almost five billion by 2030. Additionally, a significant portion of this urbanization in Africa and Asia will result in serious social, economic, and environmental issues. (UNFPA (United Nations Population Fund, 2018).

Rapid urbanization has resulted in massive increases in both population and building stock in cities, which has drastically decreased the amount of green space relative to the growth of impermeable areas (Valy, 2010). The risk of flooding has increased in many locations due to population growth, rapid urban development, and valley side construction (B. Feng et al., 2021; Choubin et al., 2019), Because it degrades land quality, increases human and material losses, and interferes with biological control and human health, this issue has an adverse impact on both people and the environment (Kikegawa et al., 2003; Meineke et al., 2014).

Today, analyzing and assessing the city's current situation has become a necessity in order to be able to extract the gaps in this area, identify the city's vulnerability areas in order to draw attention to risk and hazard issues, foresee necessary actions within the framework of urban initiatives, and reduce exposure to these risks in order to design fragile cities into robust ones (B. L. Turner et al., 2003).

The transition from a natural to an artificial landscape during urbanization has a substantial impact on the transport and storage of precipitation water at the ground surface within a particular watershed (Booth, 1991). Paved impervious materials reduce the rate of surface infiltration by preventing water from penetrating naturally. Excess precipitation will swiftly travel as overland flow toward a stream channel when the rate of precipitation exceeds the maximum rate of infiltration. This will contribute to the short-term stream response and may cause floods and soil erosion (Dingman & Dingman, 2015).

Historical records and the findings of flood modeling are two popular data sources used to evaluate the influence of urbanization on flood risk. Early research uses historical field measurements from rainfall gauge stations and river gauges to relate urbanization to the amount and frequency of urban flooding (Anderson, 1978).

More recently, it has been demonstrated by sophisticated nonstationary flood-frequency models that urbanization significantly affects the increasing frequency and magnitude of floods (B. Feng et al., 2021). Complex flood models can now be applied because of the quick advancement in computing power. In order to simulate flood discharge in catchments at various levels of urbanization, (Bronstert et al., 2007) developed a multi-scale, process-oriented coupling difference model. They also developed a set of relationships between land use and flood peak flows under various storm scenarios. (Banasik & Pham, 2010) used a rainfall-runoff model for a small watershed to simulate flood hydrographs under two historical land use situations in different years and one hypothetical land use scenario.

(Al-Ghamdi et al., 2012) used rainfall-runoff models to estimate flood peak discharges under historical land use patterns in various years. They discovered that urbanization had a significant impact on peak discharge increases. Three anthropogenic variables (urbanization, flood defense, and other variables) were used in numerical modeling by (Yin et al., 2015) to estimate flood hazards. Using a hydraulic model (Yu & Lane, 2006; Huang et al., 2017) simulated the inundation area and average depth for land use circumstances in three distinct years in fluvial flood scenarios. Remote sensing photos taken with various sensors served as the primary source of land use data and were assessed for flood modeling (Verbeiren et al., 2013).

Like every other city in the world, Tebessa city faces significant challenges from shocks, dangerous mutations, and significant threats to the sustainability and security of the city (URBA-BA, 2018). And according to (National Economic and Social Council, 2003) The city of Tebessa ranks first nationally in terms of the number of buildings constructed in flood-prone areas, with 1,7236 constructions. In this context, dealing with the issue of urban resilience in the city of Tebessa is an interesting undertaking, this city is of particular interest to urban policy-makers, who have even gone so far as to give it an event-based consecration. Measures taken in recent years to protect the city from flooding have mainly involved recalibrating and developing the Wadis that run through the urban environment. The most important works began in 2006 (Department of Sanitation and Environmental Protection, 2014).

This part generally aims to get to know the field of study, as well as to conduct some applications on it, which generally addresses both the analytical and evaluative aspects of this field against flood risks. It also allows us to detect the vulnerability zones in order to address the attempt to find initial solutions to the concept of urban resilience through urban design.

Accordingly, the current part of case study 'Tebessa city' analysis and assessment is divided in three chapters are organized as following: 1) the first chapter includes the presentation of case study and collecting data; 2) the second chapter deals with 'case study and flooding analysis'; and 3) the last one deals with 'flooding assessment through urban design'.

Chapter III

Case study research approach

III.1. Introduction

The city is a human invention par excellence and is highly complex. It is a living environment that is rooted in the division of space and time that differentiates it from its rural surroundings (Gérard-François, 2012). Founded by the domestication of the world, it is a privileged place for structures, processes and internal and external flows of materials, energy and information (Moriconi-Ebrard & Perez, 2017). The city is an ecosystem open to the environment it transforms, and which transforms it retroactively (Dumont, 2010). It favors diversity, proximity, accessibility and concomitance, while at the same time giving rise to diversity, concentration, congestion and differentiation (Gérard-François, 2008). All these characteristics do not make the city easy to understand; on the contrary, they could fuel lengthy debates on the possibility and means of controlling its organization and regulating its structures, processes and flows. A historical perspective is therefore useful, if not necessary, for a comprehensive understanding of the city and urban development processes (Perez et al., 2019).

The city is not only a product (with an urban morphology) resulting from the action of a human community, but it is also a long-term process. On the one hand, cities maximize human relations; on the other, cities are born, flourish, suffer, regenerate and sometimes die (Perez et al., 2019; Gérard-François, 2012).Accelerated urban population growth and spatial explosion are major features of today's cities. The scale of this phenomenon around the world means that the concentration of population in so-called "developing" countries is of particular importance. Under the dual effect of migration from rural areas and a high urban birth rate, these conurbations are growing in size and pace (Dumont, 2010).

Tebessa City, like every other Algerian city, has seen tremendous, fast urban growth that has severely fragmented space and resulted in significant changes to the environment and the built environment. The Urban Development Master Plan was updated by Tebessa's local government in 2012 (URBA-BA, 2018), to deal with the Tebessa commune's land availability issue for potential future urbanization; In contrast, Tebessa, which was named #1 among Algerian cities, is plagued by regular flooding hazards (National Economic and Social Council, 2003), Furthermore, the geomorphological features of the city, such as the intricate hydrographic network encircling the city's perimeter, increased the risk of flooding in this region (Talbi et al., 2023).

Tebessa City has recently seen a number of natural disasters, most notably floods of differing sizes in various areas caused by unpredictable seasonal precipitation (ANGIRE, 2019); These occurrences have resulted in minimal damage because urban runoff and small streams have overflowed (Sanitation and Environmental Protection Department (DAPE), 2013). However, heavy rainfall has severely affected many neighborhoods and housing estates, which has caused traffic jams and sporadic accidents (Wilaya de Tébessa Water Resources Department, 2018), including the deaths and building collapses reported in the Civil Protection data. As a result, in environmental and water management, reducing flood damage by simulating urban flood susceptibility in watersheds is crucial (Siahkamari et al., 2018).

The current chapter first provides a description of the study area, with its characteristics and components, the city of Tebessa, Algeria. Next, the methodology section explains the various factors that increase the flood problem in the city according to the previous studies. Accordingly, this chapter divided into two titles are: i) case study presentation, and ii) the case study and data.

III.2. Case study presentation

III.2.1. Regional situation

Since the administrative partition in 1974, the city of Tebessa has had the unique distinction of serving as the seat of a border state. Located in the northeastern part of the wilaya, it functions both as the municipality and district of Tebessa administratively (Figure 8).

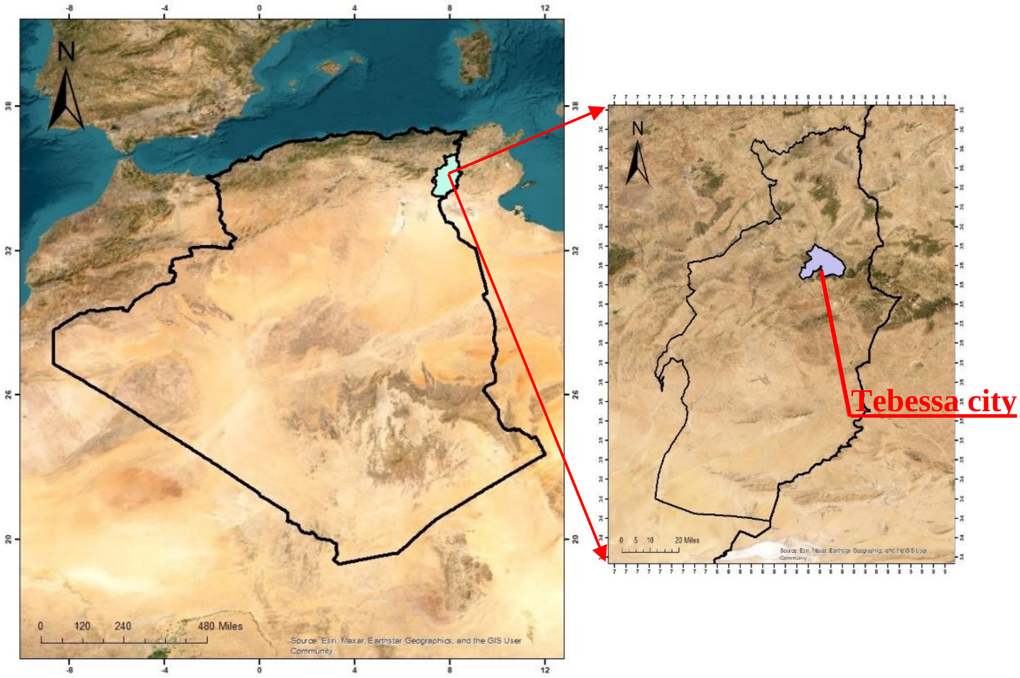


Figure 8 Location of Study area.

(Maps drawn by the authors from Google Satellite imagery, 2023)

Tebessa's administrative boundaries are shared by:

- To the north with the municipality of Boulahaf-dyr,
- To the northeast with the municipality of El-Kouif,
- To the northwest with the municipality of Hammamet,
- To the south with the municipalities of El Ma-labiod and Ogla El-Melha,
- To the east with the municipality of Bekkaria,
- To the west with the municipality of Bir Mokaddam (URBA-BA, 2018).

The approximate surface of the city is 184 km². Geographically speaking, it is contained inside the Tebessa wilaya's larger context:

- To the east by Tunisia, with a distance of 280 km from the capital, Tunis,
- To the west by Khenchela and Oum El Bouaghi,
- To the north by Souk Ahras,
- To the south by El Wadi (URBA-BA, 2018).

III.2.2. Astronomical characteristics

Approximately 8.11 degrees east longitude and 35.4 degrees north latitude are where Tebessa City is located. The city is situated in the hot temperate zone (Mediterranean), which is distinguished by a continental climate (HADJLA, 2016).

III.2.3. Topography

The study area topography is marked by distinctive feature, mostly defined by mountains in the south, such as ANWAL mountain, DOKKANE mountain, and others. Apart from the untamed landscape, the area has lowlands symbolized by the MERDJAH Plain, which extends from the city's eastern to western borders. This plain stays elevated on average by about 800 meters above sea level (URBA-BA, 2018).

III.2.4. Geology

Many features of the city are shaped in large part by the region's geological structure. This covers the way the city is growing, the locations and layout of buildings, and even the height of the structures. These variables are influenced by the hydrographic network, the geotechnical characteristics of the soil, and the distribution of vegetation (URBA-BA, 2018).

III.2.5. Hydrography network

The city of Tebessa is characterized by a rich hydrographic network consisting mostly of canyons and valleys, which locals call “fills”. The city's current urban fabric is closely intersected by these waterways. Wad Rfana, Wad Al-Naqus, Wad Zaarur, Wad Al-Saqi, Wad Al-Anba, Wad Al-Ganater Sud, Wad Al-Mizab, and Wad Shabro are some of the well-known fillings in the region (Wilaya de Tébessa Water Resources Department, 2018) (Figure 9 and Table 6).

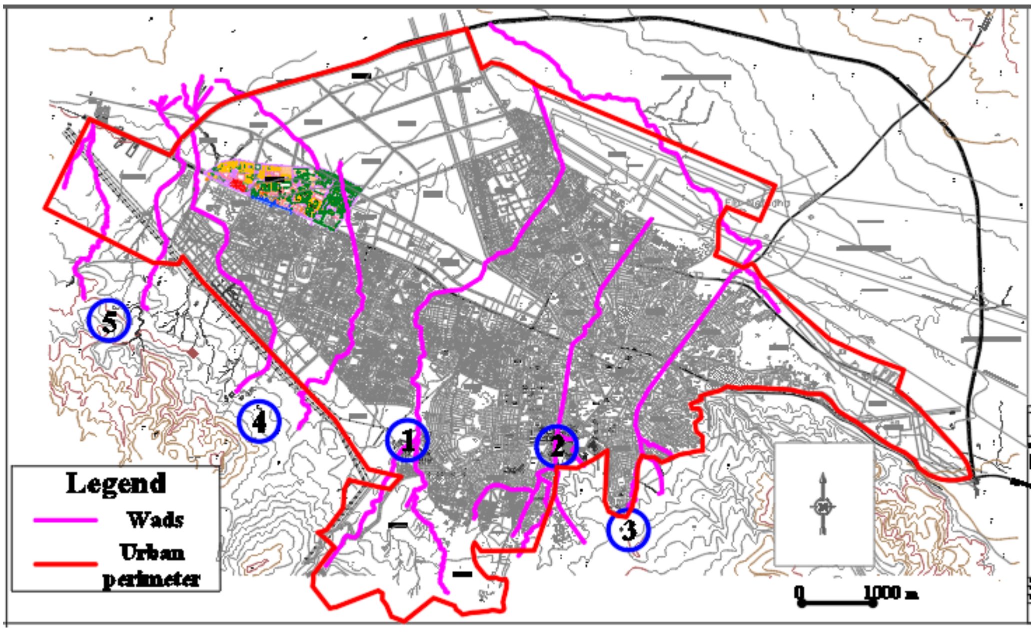


Figure 9 Intercommunal UDMP Tebessa-Hammamet-Elkouif-Bekkaria-Boulhaf Dyr the final phase.

Table 6 The Existing Wadis in the study area *(Tebessa city).*

N°	Wads	Length (km)	State
01	EL ANBA	19	Ever-flowing
02	SEGUI	12.5	Ever-flowing
03	RAFANA	9	Ever-flowing
04	NAGUES	9	Ever-flowing
05	ZAAROUR	7	Ever-flowing
06	EL GNATER SOUD	/	Ever-flowing
07	CHABROU	/	Ever-flowing

Source: The direction of civil protection of the wilaya of Tebessa,2023.

III.2.6. Geographical configuration and climate

Tebessa City's topography and geographic layout provide an environment that is favorable to flooding. The city is especially susceptible to catastrophic flooding occurrences since it is tucked away at the foot of a mountain range and crossed by numerous wads (National Agency For Integrated Water Resources Management, 2019).

III.2.7. Rainfall patterns

The bioclimatic zone of the research area is moderate semi-arid, with distinctive precipitation patterns. This area normally receives 400 to 500 mm of rain per year. Nonetheless, there are notable seasonal and inter-annual fluctuations in precipitation in the area. The average annual rainfall can be as high as 480 mm in years that are beneficial, but it can drop as low as 130 mm in years that are not suitable (URBA-BA, 2018).

III.2.8. Historical overview of the city of Tebessa

Tebessa is a crossroads of civilizations, a territory where the influence of cultural cross-fertilization is expressed. Each civilization that has settled here has left its mark on the area in terms of traditions, dominant ideologies, lifestyles and, in short, culture, but it has also appropriated cultural references from civilizations that came before it (GHERZOULI, 2014); Ancient Thevest, with 21 centuries of urban life behind it, was Roman, Byzantine, Vandal, Muslim, Turkish and French. Each period of its history has left its mark on the town's heritage. Historically and archaeologically rich, Thevest is a unique site with many monuments of great archaeological value. As a result of sociological, economic and strategic factors, the town of Tebessa's urban development has mainly taken place from prehistoric times to the present day (Castel, 1914).

The spatial and chronological development study of the city's urbanization comes to highlight the city's potential for expansion and its development prospects. This is based on the natural data associated with its location. It also comes with the aim of describing the evolutionary signs of urban and architectural heritage areas as a tool for consolidating memory by showing the development of the city and analyzing the reasons that helped it (Julien, 1962). According to historians, the various eras that passed through the city of Tebessa can be summarized in the chronological axis of civilizations in this city that shown below (Figure 10).

The city of Tebessa is a major urban center, forming the face of an entire region, known for its wealth of historical, cultural and religious sites. This is due to the succession of different civilizations over time (URBA-BA, 2018; Julien, 1962). Briefly mention among them:

a-Primitive times and Roman occupation (Prehistory- 4th century A.D)

***Prehistory*:** Long before the historical period, the Tebessa site was inhabited by peoples whose passage can be seen in several places, such as dolmens, cromlechs erected on nearby mountains or Stone Age remains, such as carved flint from numerous workshops (Figure 11). Various civilizations occurred during this period , including:

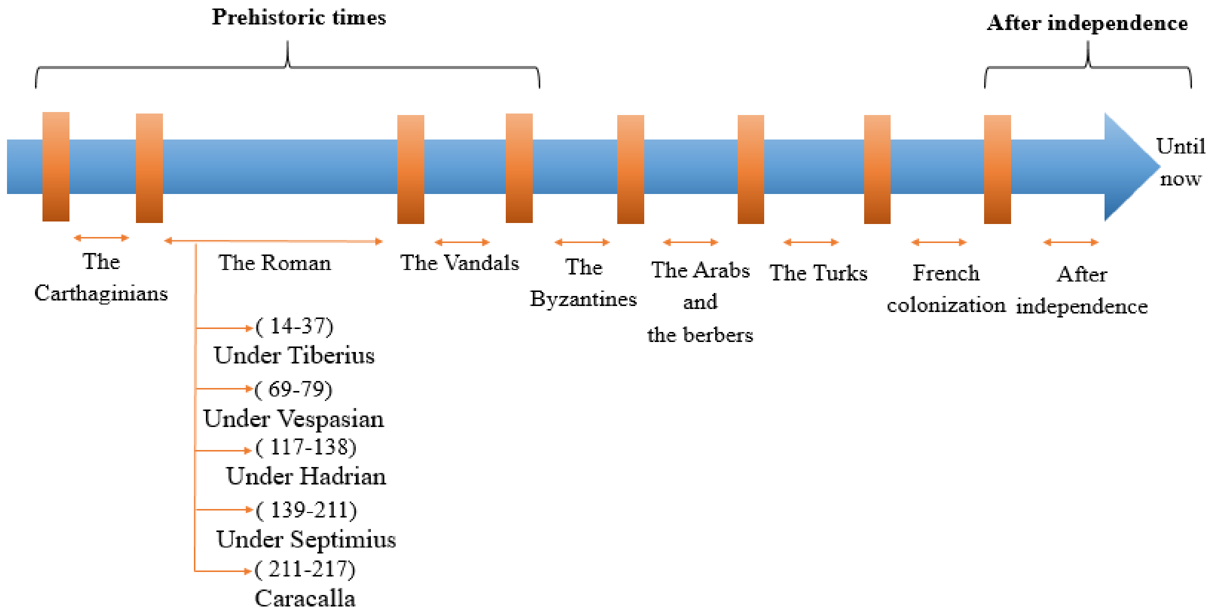


Figure 10 The chronological axis of civilizations in the city of Tebessa, (URBA-BA, 2018)

***Greek*:** The ancient THEVEST seems to have been known to the Greeks as HECATOMPYLE (Castel, 1914, URBA-BA, 2018).

***Carthage*:** Around the 3rd century B.C., a Carthaginian incursion to the south gave rise to a first commercial and military centre. first commercial and military center; however, the indigenous city at the foot of the foothills of the *Aurès* did not keep the Phoenicians for more than 50 years, and only tombs on the northern slopes of *Djebel OZMOR* are of Punic origin (URBA-BA, 2018).

***Rome*:**

The history of the country remains confused until the annihilation of CARTAGE and THEVESTE, after having known several successive dominations of hordes, tribes or passing armies, sees the arrival of the first Latins in the 2nd century BC. J. C (Castel, 1914) .

During this period, the axes of the Roman city were drawn, and some important buildings were constructed that still bear witness to this day (URBA-BA, 2018).

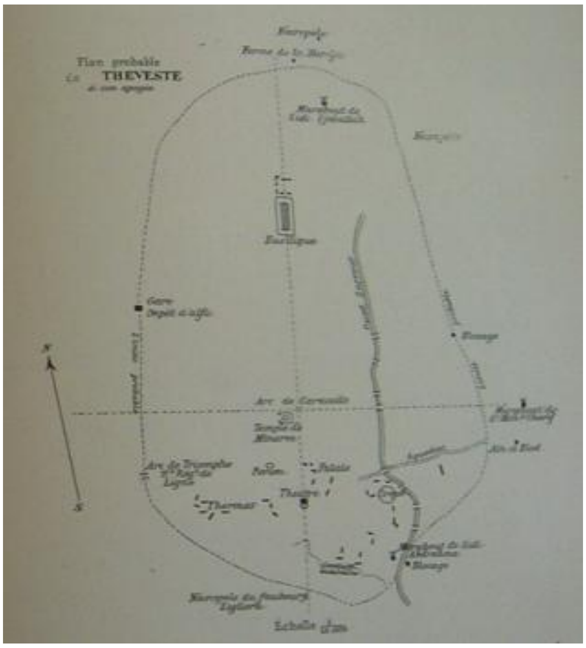


Figure 11 Old map of the city of Tebessa, (Castel, 1914)**.**

b-Vandal and Byzantine occupation (5th century A.D- 6th century A.D):

Vandals**:** Some aspects of Roman life have been preserved, but the town slowly withered away, frequently mutilated by Moorish incursions that encouraged the inhabitants to fortify themselves. The many scattered towers found in Tebessa date from this period (Castel, 1914).

Byzantine**:** This second founder of THEVEST had a Byzantine citadel built, forming the nucleus of the modern city, but the Moors began to rise up, and the city was surrounded by a second wall. The history of Tebessa became confused until the Arab invasion in 647, and the country never recovered (URBA-BA, 2018); Figure 12.

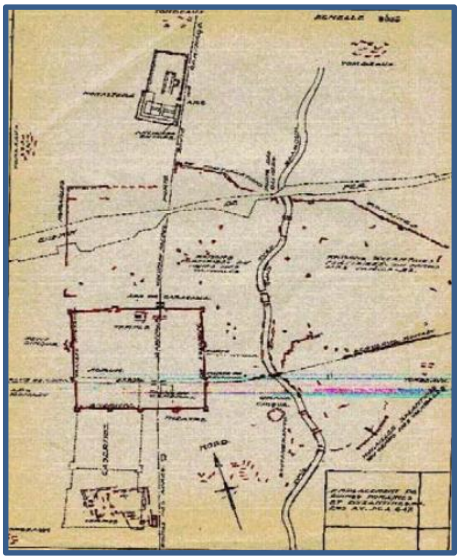


Figure 12 Tebessa City map, (Castel, 1914)**.**

c-Muslim and Turkish occupation (7th century A.D- 19th century A.D):

The Muslims penetrated TEBESSA in the 7th century AD, after the siege of the city where the Christians were entrenched, the Roman THEVESTE became the Muslim Tebessa, after a short Berber domination, under the KAHINA, the Arabs remained victorious at the beginning of the 8th century (Castel, 1914, Julien, 1962).

Around 1573, Tebessa came under Turkish sovereignty until the arrival of the French.

After battles between the Turks of Algiers and Tunis, with tribes serving both sides according to their interests, Algiers was taken in 1830 (URBA-BA, 2018); Figure 13.

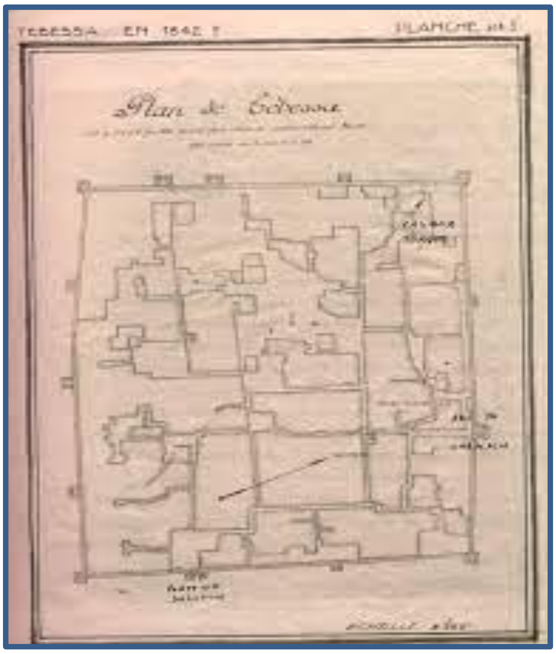


Figure 13 Tebessa City map, tracing the roads in 1842 , (Castel, 1914)**.**

d-French occupation:

During the French period, the town was greatly enlarged, the center within the ramparts was reorganized, the courtyard was a road around the center and the old street grid was largely respected, although most of the houses were replaced by colonial constructions at the time, partly with traditional Arab-Muslim type houses with courtyards inside (URBA-BA, 2018); Figure 14.

Figure 14 Tebessa City map in 1856, (Castel, 1914)**.**

e-After independence:

Immediately after independence, Tebessa was chief town of the Daïra of the Wilaya of Annaba and it wasn't until July 1974 that it became a Wilaya administrative center.

According to urban planning instruments such as the Land Use Plan and Urban Development Master Plan, the square has become a place for gathering, relaxation, illicit trade (URBA-BA, 2018).

III.2.9. Historical monuments of the city of Tebessa

According to archaeological studies, the city of Tebessa has known life and human presence since more than 12 000 BC. It played an important role as an active commercial center in commercial exchanges with Carthage. In this context we mention some of the historical monuments of Tebessa city that still exist until now (Ministry of Culture, 2007).

a- Triumphal arch of Caracalla:

The construction process of this landmark began in the year 211-212 AD and was completed in 214-215 AD. It has four facades, each adorned with 4 cylindrical columns. The Arch of Triumph is at a horizontal distance of 400 meters from the Amphitheater to the northwest (Ministry of Culture, 2007), (Photo 1).

Photo 1: Historical monuments: Triumphal arch of Caracalla, (Ministry of Culture, 2007).

b- Byzantine wall:

Tebessa, with its fortifications, forms a rectangular enclosure 320 meters long and 280 meters wide, flanked by fourteen towers at the corners and sides, and pierced by three gates (Photos 2 and 3). The gate formed by Caracalla's triumphal arch to the north. Solomon's Gate to the east, and the small postern called Ain Chahla to the south. The walls of the enclosure are nine to ten meters high and vary in thickness from 1.50 to 2 meters. At around seven or eight meters above ground level, there is a crenellated walkway, accessed by three staircases at each of the three gates. The towers are 15 to 17 metres high, and contain a ground and first floor, separated by an ashlar cross vault (URBA-BA, 2018).

Byzantine wall is one of the most important and largest landmarks of the city of Tebessa. It was built in the decade of the Patriarch Solomon in the year AD 535 to protect the city and confront the enemies, and the following area is 8,9 hectares (Castel, 1914), (Photo 2).

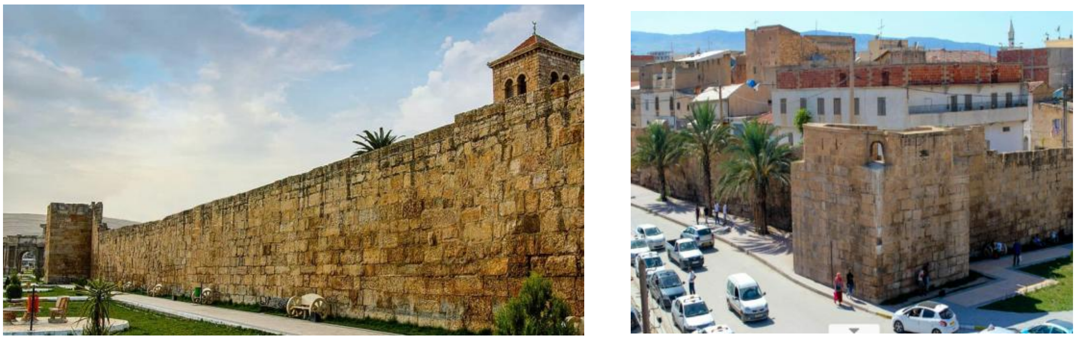


Photo 2: Historical monuments: Byzantine wall and towers, (Ministry of Culture, 2007).

Photo 3: Historical monuments: Salomon gate, (Ministry of Culture, 2007).

c- Church:

This landmark was built with the beginning of the French occupation in 1845 and is located within the Byzantine wall near the northwest corner (Castel, 1914), (Photos 4, 5).


Photos 4, 5: Historical monuments: Church, (Ministry of Culture, 2007).

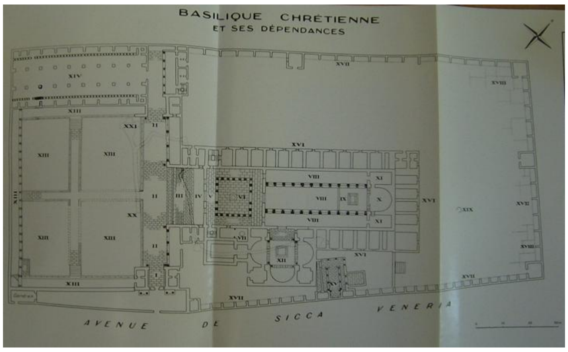
d- Temple of Minerve:

This landmark was built after the triumphal arch of Caracalla in the years (69-79) during the reign of Emperor Vespasian and is located at a distance of 55 meters from it. It consists of two parts, a prayer hall and a sanctuary, which is the temple of the goddess Minerve, the goddess of knowledge (Ministry of Culture, 2007), (Photos 6, 7).


Photos 6, 7: Historical monuments: Temple of Minerve, (Ministry of Culture, 2007).

e- Basilica:

The Roman Byzantine church is located 620 meters north of the Triumphal arch of Caracalla, at the end of the Cardomakismos axis. Its area is estimated at 1,8 hectares. It was built to be a court, a square or a public forum that hosts many activities of public interest (Castel, 1914), (Photos 8, 9).



Photos 8, 9: Historical monuments: Basilica, (Castel, 1914).

f- Amphitheater:

Built in the year 73 AD or 89 AD; It can accommodate more than 7000 spectators. It was used as a stadium or theater and sometimes for wrestling games between knights and prisoners of war or with predatory animals. This Amphitheater is located south of the city's honor, 150 meters from Solomon Gate, east of the castle in which the ancient city is located (Ministry of Culture, 2007), (Photos 10, 11).

Photos 10, 11: Historical monuments: Amphitheater, (Ministry of Culture, 2007).

III.3. The case study and data

III.3.1. The urban planning instruments that include the city of Tebessa

Urban expansion is governed by many laws that specify the conditions for urban planning and subjecting the use of land to regulatory rules that determine the urban character of the city in terms of the type of land use, the height of the buildings, the area, and the green areas and facilities included in the residential neighborhoods...etc., and work to organize, create or transform built and unbuilt properties. Rational and economic management of lands, as well as effective environmental preservation, can only be achieved by establishing a legal framework that sets limits on the actions of others in the field of development and reconstruction (Iglouli, 2020), In this context, the Algerian legislator worked to issue a set of laws that came to regulate lands through urbanization tools, especially the Urban Development Master Plan, and the Land

Use Plan under Law N° 90-29 on urban planning and development (Official Journal of the Algerian Republic, 1990).

III.3.1.1. Urban Development Master Plan (UDMP)

Law N° 90-29 organized the Urban Development Master Plan in the second section of its third chapter in Articles 16 to 30, in order to become familiar with the various rules regulating the Urban Development Master Plan. Therefore, we consider it necessary to address the concept of the UDMP.

Article 16 of Law N° 90-29 defines the Urban Development Master Plan as: “a tool for general planning and urban management, which determines the basic directions for the urban development of the municipality or municipalities concerned, taking into account development designs and development plans, and sets the reference formulas for the land occupation plan.” (Official Journal of the Algerian Republic N° 84, 2004); We conclude from the content Article 16: The Urban Development Master Plan is a means of general planning and urban management that specifies the basic directions for the urban development of one municipality or several neighboring municipalities united by common factors (Iglouli, 2020), such as the spread of several municipalities in a specific urban fabric, or their participation in a drinking water distribution network and means of urban transportation. Public or other major structures and equipment.

The plan also takes into account all development designs and development plans. It maintains and respects the directions of the land occupation plan and sets its reference formula for the use of the land and its aesthetics, present and future (Nedjai, 2012); Therefore, the directive plan for development and reconstruction expresses the organization, framing and management of the construction activity (Iglouli, 2020). This plan was originally drawn up to regulate the use of land and organize the reconstruction processes, under penalty of signature. Penalties for violating it, which is stipulated in Article 10/2 of Law N° 90-29. Also, the master plan is a tool of a predictive nature, established for a period of 20 years, and is subject to opposition by others (Article 10/1 of Law N° 90-29), the master plan is a means that specifies the conditions for the forms and results related to the expansion of residential blocks over a 20-year horizon. It specifies the main directives for the urban development of the concerned municipality or municipalities and sets the reference formulas for the land use plan. Here the technical aspect of the Urban development master plan appears, and it also consists of a technical report. Maps, graphs and statistics (Official Journal of the Algerian Republic, 1990).

The Urban development master plan is a mandatory plan for all municipalities, as stipulated in Article 24 of Law N° 90-29, which states: “Every municipality must be covered by an Urban development master plan, the project of which shall be prepared on the initiative of the President of the Municipal People’s Council and under his responsibility.” (Official Journal of the Algerian Republic, 1990).

Article 17 of Executive Decree N° 91-177 (Official Journal of the Algerian Republic, 1991a), amended and supplemented by Executive Decree N° 05-317 of September 10, 2005, stipulates the content of the master plan for development and reconstruction, which consists of:

1 - An orientation report in which the following is presented:

a- Analysis of the current situation and the main possibilities for development in view of the economic, demographic, social and cultural development of the territory concerned.

b- The proposed development department, taking into account the directives in the field of urban development, coastal protection, and reducing natural and technological dangers.

2- Codification specifies the rules applied to each area included in the sectors; This codification states:

a - The predominant allocation of lands, when necessary, and the nature of the activities prohibited or subject to special procedures, especially those stipulated in the Coastal Environment Plan stipulated in Law N° 02-02 (Iglouli, 2020) relating to the protection and development of the coast.

b- The general density resulting from the land occupancy coefficient.

c- Easements required to be maintained, modified or created.

d- Areas in which land occupation plans interfere with the reference boundaries associated with them, by highlighting the areas of interference in the existing urban fabric and the areas of the areas required to be protected.

e- Determine the location and type of major equipment, basic facilities, services and works, and also determine the construction conditions in Chapter Four of Law N° 90-29.

f- Areas and lands exposed to natural hazards, especially seismic fractures, landslides, landslides, mudflows, soil compaction, liquefaction, collapses and floods.

g - Areas to protect areas and lands exposed to technological risks represented by basic institutions and facilities, especially chemical and petrochemical facilities, fuel and gas transportation channels, and energy transmission lines.

h- Seismic areas and their classification according to their degree of susceptibility to earthquake risk.

i- Major risks included in the general plan for prevention and special plans for intervention.

3 - Graphic documents that include the following diagrams:

a- A plan of the existing reality that highlights the currently constructed framework, and the most important roads and various networks.

b- Configuration plan between the following limits:

-Permanent and reconstructible sectors designated for future reconstruction and non-reconstructible sectors, as specified in Law N° 90-29.

- Some parts of the land: the coast, agricultural lands with high or good agricultural potential, and lands with a prominent natural and cultural character.

- Areas included in land occupation plans.

c- Plan of easements that must be maintained, modified or created.

d- An equipment plans that highlights road traffic lines and the most important means of delivering drinking and disinfecting water, as well as identifying the locations of collective equipment and public utility facilities.

e- A plan specifying the areas and lands exposed to natural and/or technological hazards: and special plans for intervention.

- Protection areas for institutions, facilities or equipment that involve technological risks are determined in accordance with applicable legal and regulatory procedures.

- Areas and lands exposed to natural and/or technological hazards are registered in the master plan for development and reconstruction based on the proposal of the regionally responsible reconstruction departments according to the forms that dictated the approval of the plan.

III.3.1.2. Land Use Plan (LUP)

The land use plan is the second tool for urbanization that was introduced in Law N° 90-29 alongside the master plan for development and reconstruction, according to which the rights to use land and construction are determined (Official Journal of the Algerian Republic, 1990), and therefore the land occupation plan is within the framework of the directives of the master plan for development and reconstruction. In turn, it is a means Binding on every municipality of the country or part thereof (Iglouli, 2020).

Law N° 90-29 regulated the land use plan in the third section of Chapter Three thereof, in Articles 31 to 38. Executive Decree N° 91-178 of May 28, 1991 (Official Journal of the Algerian Republic, 1991b), sets forth the procedures for its preparation and approval and the content of the documents related to it, which Amended. It was completed pursuant to Executive Decree N° 05-318 of September 10, 2005 (Official Journal of the Algerian Republic, 2005).

The land use plan, as defined in Article 31 of Law N° 90-29, is: “The plan that specifies in detail, within the framework of the directives of the master plan for development and reconstruction, land use and building rights.” (Official Journal of the Algerian Republic, 1990).

It is a means of detailing and implementing the general and general directives contained in the master plan. It specifies in detail land use rights, and specifies the minimum amount for urban development (Iglouli, 2020), and the maximum amount of permitted construction, expressed in square meters of built-up floor outside the building, or in cubic meters of volume. It sets the rules related to the external appearance of buildings, determines easements, identifies neighborhoods, streets, memorials, sites and areas that must be protected, renewed and repaired, identifies the locations of agricultural lands that must be preserved and protected, and identifies green spaces and sites designated for public facilities (Official Journal of the Algerian Republic, 1990). The land use plan specifies in detail how to organize and implement land use operations, methods of reconstruction, construction standards, and how to distribute roads and easements throughout. Territory of the municipality or municipalities concerned (Iglouli, 2020).

According to (Official Journal of the Algerian Republic, 1990);The land use plan shares several characteristics that characterize the urban development master plan, the most important of which are:

- -The land use plan was originally created to regulate the use and organization of the construction process in light of amended and supplemented N° 90-29.
- - Land use plan is a detailed and accurate plan of its connection to real estate ownership.
- - The land use plan, like the urban development master plan, can be invoked. In front of others in accordance with Article 10 of Law N° 90-29, amended and supplemented;
- - The land use plan covers all or part of the municipality only, which is stipulated in

Article 34 of Law N° 90-29, which states: “Every municipality or part of it must be covered by a land use plan....”.

As for the urban development master plan, it covers the entire municipality, which is confirmed by Article 24 of Law N° 90-29, which states: “Every municipality must be covered by a master plan for development and reconstruction....”

The land use plan aims to achieve the basic objectives of urban development (Official Journal of the Algerian Republic, 1990), and these objectives are stipulated in Article 31 of Law N° 90-29, which are as follows:

1 - It specifies in detail the organization of land use and the determination of building rights therein.

2 - Specifies the minimum and maximum quantity of permissible construction, expressed in square meters (m2) of the floor built outside the building or in cubic meters (m3) of sizes, and determines the types of permissible buildings and their uses.

3 - Sets the rules related to the external appearance and aesthetic aspect of buildings.

4 - It determines the public space, green spaces, and sites designated for public facilities and facilities of public interest, as well as the layouts and features of traffic roads.

5 - Identifying neighborhoods, streets, memorials, sites and areas that must be protected, identified, restored and repaired, in addition to controlling traffic routes and distributing roads of various types and specifications.

6 - Determine infrastructure networks such as potable water, natural gas or sewage, waste disposal places...etc.

7 - Determines the locations of agricultural lands that must be preserved and protected.

III.3.2. Urbanization

A city's potential for expansion and the limits of its development are thus highlighted by the study of its urban development, which is based in part on the natural data associated with its location and location, as well as in part on how it reads the history and sociology of its society and demonstrates the trends and axes of growth. Our examination of the geographical and historical evolution of urbanism provides an answer for this; Accordingly, Tebessa city is the largest urban area in the Wilaya, its size and spatial volume, which continue to grow rapidly, make it a highly heterogeneous space, giving rise to spatial, functional and even structural dysfunctions and anomalies (URBA-BA, 2018).

The city of Tebessa has been affected by rapid and massive urbanization growth that has dramatically disrupted space, leading to profound spatial and environmental transformations. The local authorities in Tebessa revised the Urban Development Master Plan in 2012 (URBA-BA, 2018), to address the issue of land availability for future urban expansion in the Tebessa commune; The urban perimeter of the city therefore witnessed a significant expansion as a result of the rapid urbanization of the city in response to population growth, especially during the 1970s, which was characterized by the demographic explosion. Between 1977 and 2018, the city's population rose from 62 639 to 200 256. Regarding the urban fabric, its area increased from 1 637 hectares in 1988 to 4 843,65 hectares in 2018 (HADJLA, 2016), (Figure 15).

<u>Before 1842:</u> The beginning of the episodes of urban development was the colonial core represented by THEVEST of the Roman era, surrounded by the Byzantine wall, then the Arab-Islamic neighborhoods with narrow paths. This stage was also known for the construction of the first facilities in addition to the ancient Turkish mosque, thus building the city. What is distinctive about this stage is that it goes back to the Romans, the Byzantines, then the Muslim Arabs and the Turks. The area of the city at that time reached 8.9 hectares.

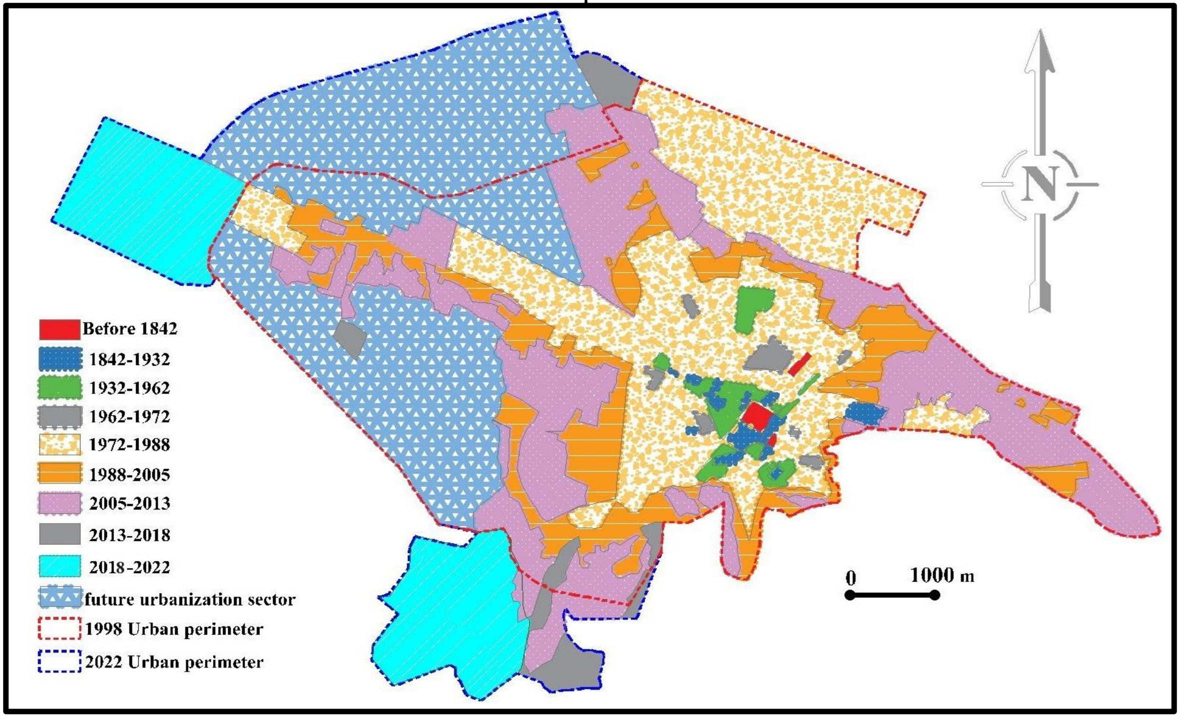
<u>For the second stage 1842- 1932:</u> With the fall of the city under occupation, the French colonial fabric took on a chess geometry with the establishment of the military barracks inside the Byzantine wall to the southern side in the year 1852, the military quarter, the church, the hospital, the railway line, public parks, and the municipality. The French replaced some Arab buildings with colonial ones. The urban area reached 53.35 hectares, and with the aim of controlling and organizing the expansion of the city’s urbanization, the colonial authorities issued.

<u>The third stage 1932- 1962:</u> In this stage, urbanization moved along two axes, east-west and north-south, in accordance with the directives of the development plan for the year 1931, taking an organized form by intensifying construction to occupy the spaces existing within the empty spaces of the previous stage. The area of the urban perimeter reached... The end of the stage is about 126.05 hectares, an increase of 136 percent in 30 years.

<u>The fourth stage, 1962-1988:</u> witnessed a gradual densification of the urban fabric with a change in the type of housing units, the concentration of third sector activities, and the expansion of the city towards the north, east and west along national roads N°10, 82, 16 and 08. This was followed by the expansion of the city towards the south and south-east. From the old city (slums, as is the case in the *Al-Jorf* neighborhood and the *Al-Mizab* neighborhood), in

a deteriorating situation, to the north and west, neighborhoods within the framework of development and self-construction plans, this fabric extending around the core has left vacant areas and intermittent exploitation of the urban space.

Figure 15 Intercommunal UDMP Tebessa-Hammamet-Elkouif-Bekkaria-Boulhaf Dyr the final phase.



Source: The Direction of urbanism, architecture, and construction of the Wilaya of Tebessa, and the author, 2022.

<u>The fifth stage 1988-2013:</u> In advanced stages, the expansion included the areas surrounding National Road N° 10 in the industrial zone and the collective housing neighborhoods and around National Road N°16 (the airport and residential subdivisions), and finally the urban expansion worsened towards the north and west (Fatima Al-Zahra neighborhoods, 325 homes; And 134 dwellings) and this is under the influence of topographical obstacles to the south, and looking at the city’s location it becomes clear to us that this expansion was at the expense of flat agricultural lands in addition to some of the slopes of the mountains that border it to the south at the expense of modern geological formations dating back to the third and fourth periods. It is noted that consumption The area is excessive, especially after the year 2004, which extended longitudinally along the axis of National Road N° 10 leading to Constantine and also towards the south, as in 2013 the urban area reached an area of 2,998 hectares.

<u>The sixth stage 2013- 2023:</u> This stage witnessed an expansion of the urban perimeter

based on the review of the Urban Development Master Plan, as the urban area of the city increased to 4,843.65 hectares. The plan only included expansion areas, including urban poles N° 28 and 09A, for example: 5700 LPL housing units + public facilities, at pole N°28 ..etc.

III.3.3. Factors of flooding in the city of Tebessa

The ability to recognize the Zones exposed to floods depends first on a good understanding of the places where floodwaters cover their boundaries (Foudi & Osés, 2014a), using aerial photographs, remote sensing (Q. Feng et al., 2015a), and fieldwork in parallel, to assess flood risks in the city of Tebessa.

The morphological analysis of the region or the location of the city reveals what facilitates surface water runoff (BENSON, 1964); however, under the influence of the semi-arid climate, heavy rains cause water to easily drain from Wadi basins, resulting in natural disasters in the regions exposed to it or those crossed by Wadis.

The flood risk analysis framework for Tebessa City generally considers four factors according to the previous study of (HADJLA, 2016):

- Topographic factors: are reflected in the city's steep south slopes, which are less steep than its north slopes. Generally speaking, the city's flat terrain is its defining characteristic.
- Hydrographic factors: are portrayed in the intricate network of water that runs through the city and is made up of the seven Wadis listed above.
- Climatic factors: are represented in the semi-arid climate and semi-cold winters, which are frequently marked by heavy and erratic rainfall. These elements, along with the type of climate and soil type reflected in the vegetation cover, all work together to cause and worsen the city's flooding problem.
- Human factors: are elements connected to the process of legal urbanization, overcrowding, and human intervention—whether beneficial or detrimental—on the field: rapid urbanization Inadequate city configuration concerning networks or watercourse correction setup...

In this study, the relationship between flood risk and its contributing factors is depicted in (Figure 16), which helps in flood risk analysis where flood hazard is a behavior or a situation of water that can cause potential harm, human losses, or material damages (Hirabayashi et al., 2013).

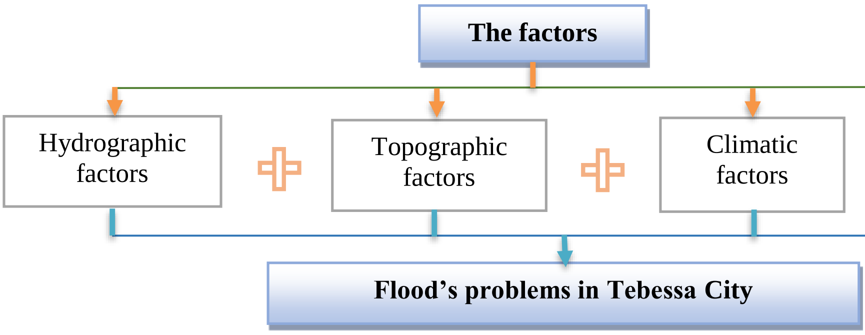


Figure 16 Factors of the occurrence of floods in the city of Tebessa (HADJLA, 2016).

Eight flood conditioning factors total—including hydrographic network, distance from Wadis, elevation, slope, profile curvature, precipitation, land use/cover, urban footprint, and built-up index—have been chosen for this study based on the findings of the previous study (HADJLA, 2016) (Table 7).

Table 7 flood factors (Tebessa city).

Flood factors	
1- Hydrographic factors	Hydrographic network
	Distance from Wadis
2- Topographic factors	Elevation
	Slope
	Profile curvature
3- Climatic factors	Precipitation
4- Human factors	Land use/ Land cover
	Urban footprint
	Built-up Index

III.3.4. Previous attempts to reduce the risk of flooding

Addressing the issue of urban resilience in the city of Tebessa is an interesting task we find that there are efforts to protect this city against the threat of flooding through several attempts such as:

III.3.4.1. The General Flood Prevention Plan

Flood risk prevention and management within the framework of sustainable development is a global system initiated and managed by the State, implemented by public institutions and local authorities within their respective areas of competence, in consultation with economic, social and scientific operators, and involving citizens under the conditions defined by law 04-20 and its implementing regulations.

According to the Law N° 04-20 of 13 Dhou El Kaada 1425 corresponding December 25, 2004 (Official Journal of the Algerian Republic, 2004), relating to the prevention of prevention and disaster management within the framework of sustainable development:

"This plan establishes all of the policies and practices intended to reduce the risk of the identified hazard and stop its consequences from happening". Article N°16 of (Official Journal of the Algerian Republic, 2004).This plan should include the following:

- A national flood map that shows every region that could flood, including Wadi beds and the perimeters of areas downstream of dams that could flood in the event of a dam failure,
- The reference height below which the affected perimeters are subject to the non-structural easement for each zone designated as floodable.
- The methods for the suspension of alerts, as well as the thresholds, conditions, modalities, and procedures for alerts and alerts for each of these threats.

According to Article N°27 in Section 2 which include "Special flood prevention requirements"; The general plan for the prevention of climatic hazards determines:

- The zones exposed to each hazard.
- The monitoring procedures for observing the evolution of each of these hazards,
- Thresholds, conditions, terms and procedures for triggering pre-alerts and alerts for each of these hazards, as well as procedures for suspending alerts,
- Preventive measures to be taken when pre-alert or alert warnings are announced.

Based on the Disaster Management in title III; The national disaster management system consists of two part: Relief and Response Planning, and Structural Measures for Disaster Management.

According to the third section of "Infrastructure and buildings of strategic value", Specifically in Article N° 46, Buildings with strategic or heritage value are subject to vulnerability study plans designed to protect them from the effects of major hazards, due to their location, the way they have been built or the age of their construction. The procedures for drawing up these plans, and in particular the buildings concerned, are laid down by regulation. On the basis of the vulnerability study plans provided for in article 46 above, prioritized reinforcement plans are instituted to preserve buildings of strategic or heritage value. The procedures for drawing up and implementing prioritized reinforcement plans are laid down by regulation- Article N°47 of (Official Journal of the Algerian Republic, 2004).

III.3.4.2. The Emergency Organization Plan

The emergency organization plan according to the Executive Decree N° 19-59 of 26 Joumada El Oula 1440 corresponding to February 2, 2019 (Official Journal of the Algerian Republic, 2019), fixes the modalities of elaboration and management of the plans of organization plans:

Emergency preparedness is essential to make sure that confusion or disarray does not obstruct a catastrophe response. It is much simpler to stay composed and navigate the chaos of a crisis with confidence when you have a map. An Emergency Operation Plan (EOP) is just that—a blueprint outlining the best course of action in the event of an emergency. Among the preventative measures for life safety are:

- Evacuation.
- Sheltering.
- Shelter-In-Place.
- Lockdown.

Depending on the scale of the disaster and/or the resources to be deployed; Emergency organization plans can be combined, especially in the event of a national disaster. these plans are subdivided into : National; Inter-wilaya; Wilaya; Communal plans; and plans for sensitive sites- Article N° 4 of (Official Journal of the Algerian Republic, 2019); Emergency organization plans are organized and planned according to the following three phases: The emergency or "red" phase, the assessment and control phase, and the rehabilitation and/or reconstruction phase. And the structural measures for disaster management include:

- Setting up strategic reserves
- Setting up a damage management system,
- Setting up specialized institutions.

All general plans for the prevention of major risks, Emergency Organization Plans and special intervention plans, whether for monitoring, warning and/or early-warning systems, or for disaster prevention or management mechanisms, must specify the roles and responsibilities of each player (Official Journal of the Algerian Republic, 2019). Also the Emergency organization plans are drawn up on the basis of: knowledge of the risks threatening the Wilaya or commune, based on the relevant history and mapping; and a summary of the risk analysis- Article N°7.

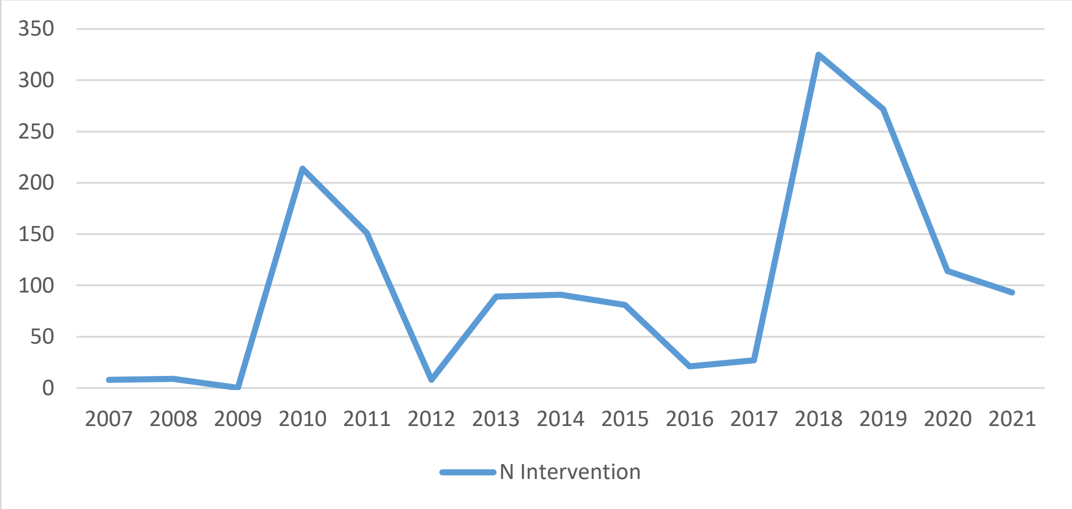


Figure 17 Census of the number of civil protection interventions against flood risks in the city of Tebessa.

Source: The author, and The direction of civil protection of the Wilaya of Tebessa, 2022.

However, all these exploited attempts by the Algerian government to achieve the resistance for our cities against the flood problems, the direction of civil protection of the Wilaya of Tebessa still registering year after year an important number of economic damages and human losses due to monsoon rainfall that causes frequent floods according to the figure that shows the census of the number of civil protection interventions against flood risks in this city (Figure 17).

III.4. Conclusion

The city of Tebessa, like other Algerian cities, has recently received special attention from decision-makers regarding urban policies due to the significant increase in its population, which necessitated the review of the Urban development Master Plan that increased the urban perimeter of the city, in order to create five new urban poles in the Wilaya of Tebessa following Executive Decrees N° 11-237 and N° 11-239 of July 9, 2011 declaring the operation relating to the construction of public housing and accompanying facilities in certain Wilayas to be in the public interest (Official Journal of the Algerian Republic, 2011). For this reason, several initiatives have been launched, including large-scale housing and infrastructure projects inside these new urban centers; for example: 5700 LPL housing units + public facilities, at pole N°28 DOKKANE…etc. And 3240 AADEL housing units, 440+100+250 LPA housing units and 1000+200 LPL housing units + university campus at pole N°03 BOULHAFDYR...etc.

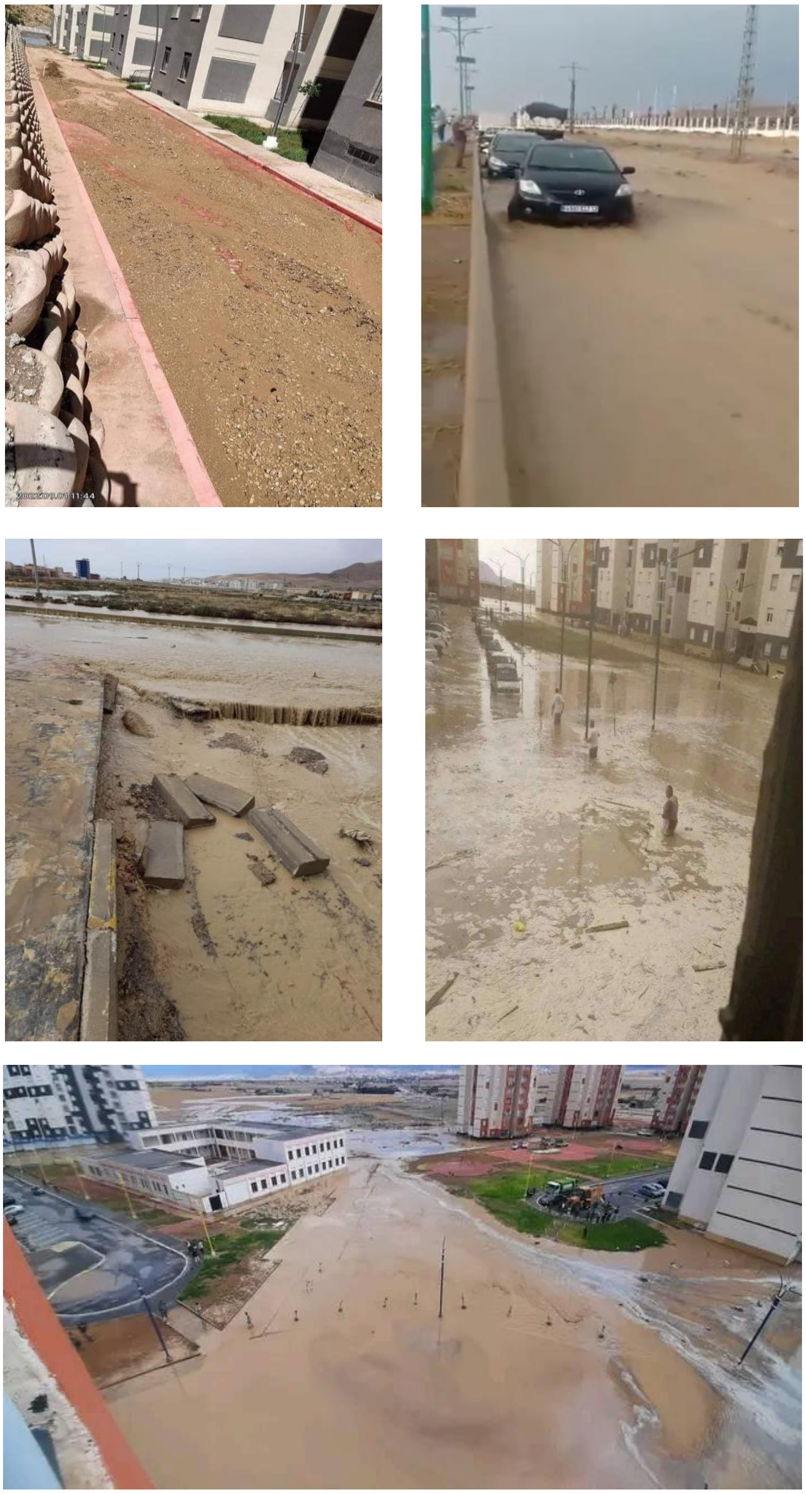
Although these urban poles have benefited from well-researched urban design and initiatives like the General Flood Prevention Plan (Law N°04-20 of 12/25/2004 (Official

Journal of the Algerian Republic, 2004) and the Emergency Organization Plan (Executive decree N°19-59 of 02/02/2019 (Official Journal of the Algerian Republic, 2019). However, these poles are still suffering from the threat of floods, which result in heavy losses, as evidenced by the documentation of notable losses caused by monsoon rainfall, such as the incident that occurred on October 25, 2021, at Pole N° 03 in Boulhaf-Dyr, specifically at the level of the 3240 AADEL housing program, which was turned over to its beneficiaries on July 8, 2021; (Photos 12, 13, 14, 15, and 16); Where the population found it difficult to adapt to these circumstances.

In order to protect its cities, the Algerian government examined this flaw in all of its legislation, which led to the establishment of the resilience concept. Reviewing the laws about urbanism is one example. This Act's goals are to establish a new urban planning system and a unique urban regime. One of the goals of this law is to "Affirm the resilience of urban spaces to the risks of natural and technological disasters." The general principles of land use and management help to apply and protect the fundamental rights provided by the Constitution. These goals encompass preserving the environment; managing waste in an ecological manner; enhancing urban resilience; diminishing social inequalities and bolstering social unity; managing green spaces in an ecological manner; managing storm water and wastewater in an ecological manner; mitigating the risk of flooding; and bringing back nature to the city (Caisse Nationale du Logement, 2020).

The results of the study indicate that urban development, whether intentional or not, has the potential to significantly change the hydrology of watersheds. As for Tebessa City, according to The National Economic and Social Council, 22nd edition (National Economic and Social Council, 2003), this city topped the national list of Algerian cities with the greatest number of buildings situated on land vulnerable to flooding. In addition, some of the city's Wadis have become sewers clogged with solid waste; even during brief periods of precipitation, this city is susceptible to flooding. Also: hydrographic, topographic, climatic, and human factors that directly affect flood events, and are closely linked to other influencing factors.

Some urban areas of the city are also at risk of flooding because of sewage system blockages and the covering of some Wadis that cross the city's urban perimeter, like Wadi *ZAAROUR* and Wadi *NAGUES*, among other things. These issues are among the most significant ones the city faces, even with the government's best efforts.



Photos 12, 13, 14, 15, 16: Flood risk in Tebessa city.

Source: Directorate of Reconstruction, Architecture and Building of Tebessa, 25/10/2021,

Chapter IV

Case study & flooding analysis

IV.1. Introduction

Climate change during the 20th century has led to a rise in the frequency of large-scale floods (Solomon et al., 2007); As a result, roads, train lines, and urban areas are frequently particularly exposed to flash floods, which can seriously endanger human life. In addition to causing massive economic damage, floods can transfer viruses into urban areas, which can lead to the development of diseases and the spread of microorganisms (J. Taylor et al., 2011; Dawod et al., 2012). Changes in rainfall patterns brought on by global warming are considerably exacerbating urban floods and their socioeconomic implications (Kulkarni et al., 2014; Rahmati & Pourghasemi, 2017a); Urban flooding has grown to be a significant problem that will influence how these communities develop going forward (Guhathakurta et al., 2011); Additionally, the Wadis channel's topology has been altered by human intervention due to growing urbanization, and flood-prone places have been intentionally designed into metropolitan centers (Yousefi et al., 2018; Choubin et al., 2019). Usually, floods begin suddenly and spread out over several hours (Borga et al., 2008), Because floods injure or kill people, thus averting them is better than making up for the losses (Regmi et al., 2014).

Precipitation is a crucial component of hydrological models, and stream flow modeling requires an accurate spatiotemporal description of precipitation (Wang et al., 2009). Accurate precipitation rate estimation is essential for hydrological simulations, flood forecasts, and water resource management (Liu et al., 2023). Catastrophic floods are frequently sparked by heavy precipitation, which presents difficulties because of their quick start and unexpected spatiotemporal patterns (Zhou et al., 2015; Goudenhoofdt & Delobbe, 2008). Quantitative Precipitation Estimation (QPE) based on meteorological stations may quickly give insights into the geographical distribution of regional precipitation by utilizing the benefits of high spatial and temporal resolution, extensive observation coverage, and spatial continuity (Berne & Krajewski, 2013; Peng et al., 2022).

Tebessa City has seen several flood incidents in various areas in recent years as a result of high seasonal precipitation and climatic conditions (ANGIRE, 2019); The most vulnerable locations to flooding are areas with marginal drainage, high population density, and agricultural lands, as well as hydrographic networks (Wadis) that form a complex system for the city, made up of several Wadis and Chaabas (Tertiary streams) which cross the agglomeration and crossing the urban perimeter of the city (Sanitation and Environmental Protection Department (DAPE), 2013) where runoff from rainfall events has concentrated (HADJLA, 2016). In addition, The

Chaabas that cross the city have been converted into collectors, and the city's wastewater is connected to the same system. Therefore, the sewerage network is unitary (rainwater + wastewater) (Wilaya de Tébessa Water Resources Department, 2018). Which contributed to the exacerbation of the risk of floods in the city. Therefore, the essential part of environmental and water management is decreasing flood damage by modeling flood vulnerability in watersheds (Siahkamari et al., 2018).

Areas that are vulnerable to flooding have been identified and assessed using a variety of ways. In this regard; Remote sensing and Geographic Information System (GIS) technology have recently added a fresh perspective to flood investigations. Due to the multi-temporal dataset involved in flood susceptibility mapping (Youssef et al., 2016). The GIS tool makes it easier to create, manage, and integrate the database of flood occurrences and their causative factors (Bates & De Roo, 2000; Bates et al., 2010). As geospatial databases are typically data-intensive and used by complex flood models, only research-level institutions can meet this need. Due to model complexity, inadequate comprehension of underlying assumptions, laborious model calibration, inexperience with managing geographic information, and high system maintenance costs, it may be challenging for stakeholders or local communities to adopt such models. Therefore, high-resolution data and geospatial technology advancements cannot be properly exploited by stakeholders unless they are provided in an appropriate manner (Miller et al., 2004).

Today, with the advancement of GIS methods and other sophisticated technologies, the determination of flood susceptibility zones using GIS methods combined with machine learning models (ML) and artificial intelligence (AI) has gained popularity and acceptance among the general public for reliable flood analysis (Azareh et al., 2021), Machine Learning (ML), which has become increasingly important with the advancement of contemporary information technology, has been used to gauge the danger of flash floods(Ma et al., 2021). Large volumes of data are iterated in order to identify patterns and correlations, and ML is skilled at managing extremely nonlinear and complicated impacting elements (Khosravi et al., 2018) . ML and AI models are currently being applied in numerous flood susceptibility studies all over the world; XGboost model (Ghosh et al., 2022), decision tree-based models (Costache et al., 2020) and K-Nearest neighbor model. The process for validating and assessing ML and AI models is very specific (Hu et al., 2020).

Accordingly, the goals of the current chapter were divided into three titles:

The first is the urban environment, which includes: i) exploring the capability of the

XGboost, Random Forest, and K-Nearest neighbor methods to predict flood susceptibility, ii) examining the role that flood conditioning factors have in the production of flood susceptibility maps, iii) creating a flood susceptibility map using an ensemble modeling strategy, iv) identifying the zones at flooding risk in Tebessa City;

The second is ecological climatology, which includes: forecasting future precipitation and water level data in Wadis using machine learning, facilitating the creation of urban flood vulnerability maps, and the prediction of flood risk probabilities associated with future water levels in conjunction with Geographic Information Systems (GIS).

And the last is the built environment, which includes the relationship between urbanized areas and flood risk based on the process of spatial sprawl characterizing the city of Tebessa in Algeria over the period from 1990 to 2023, by mapping and quantifying spatiotemporal change.

IV.2. Urban environment

The methodology of the present study is presented in three main steps: 1) Building the model; 2) Model validation; 3) Model application. A detailed description of these steps is as below (Figure 18):

Step1. Building the model:

The building of the model contains 03 stages as follows:

a. Machine learning model:

The model started with the data of the 4 factors: hydrographic factors, topographic factors, climatic factors, and human factors (Figure 16); these gave the values of each specific point on the map that was created in ArcGIS 10.8, plus another column added in the attribute table called ‘Flood’ shows the state of the point on the map, whether it was flooded or not according to the history of flooding and the previous remote sensing Table 8, (Figure 19 and Figure 20) To find out the location and area of the flooded and non-flooded zones (Figure 18 and Figure 19***Figure 9***). Where the point is estimated to be 0 if the pixel is not flooded and 1 if the pixel is flooded.

b. Select the appropriate algorithms:

The choice of the appropriate algorithms determined by the use of different algorithms gives the suitable and the closest to the real values; in this study, the chosen algorithms are XGboost, Random forest, and K-Nearest neighbor.

c. Model correction:

In case, the values of the result (Target = Flood) are not similar to the real fact, should search for another algorithm to give values closer to the real values.

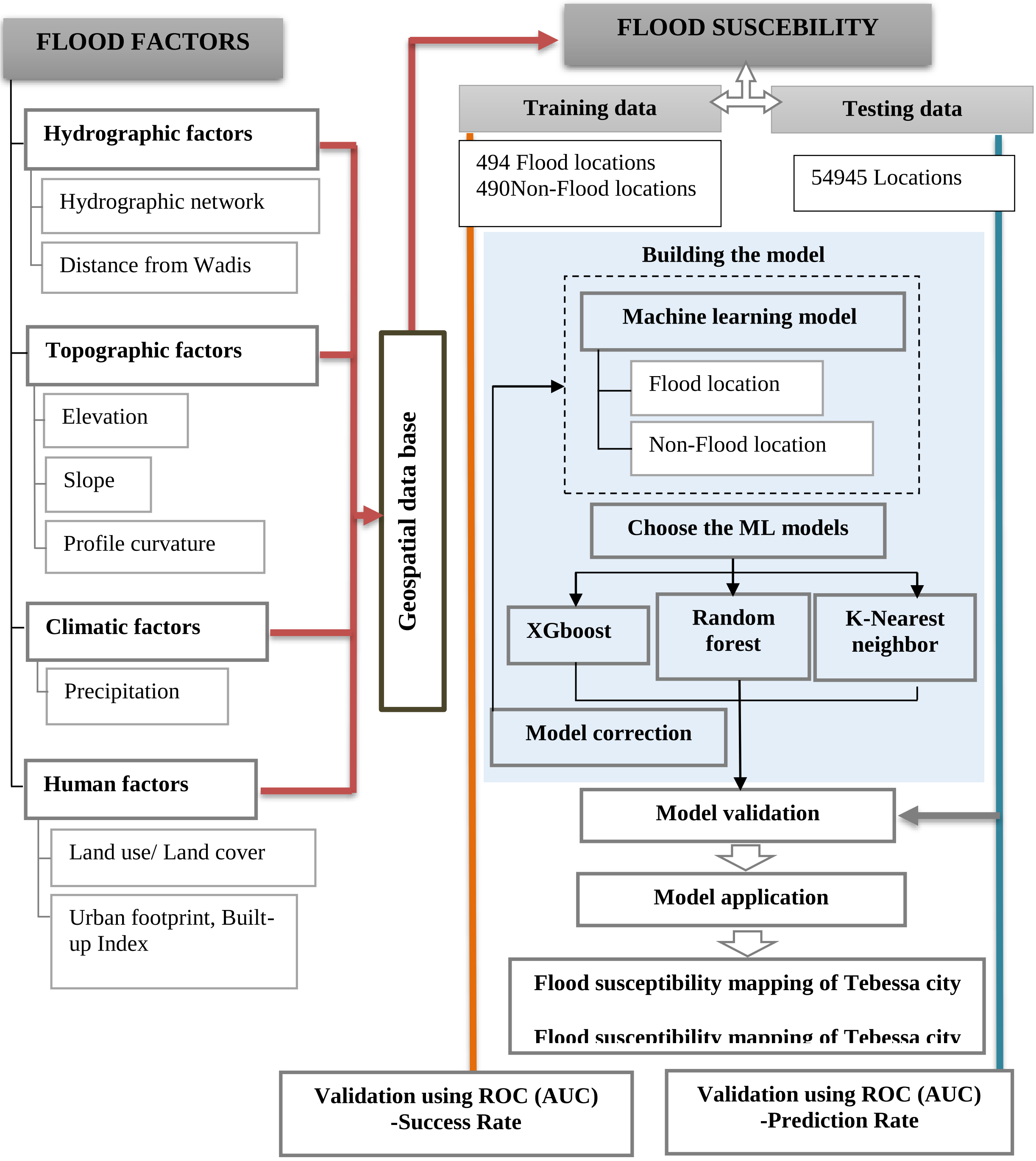


Figure 18 Illustrates the methodological flowchart of this study.

Step2. Model validation:

The validation of flood susceptibility mapping of Tebessa City using the receiver operating characteristic (ROC) method to test the model performance.

Step3. Model application:

In this step, the study area was covered by points (54,945 points) in each pixel and the distance between them is 30 m according to the grid data (one point / a pixel= at a rate of 54,945 pixels covered by 54,945 points) as a testing dataset Table 1, and every point has different values of elevation, slope, precipitation, distance Wadis, land use, profile curvature, urban footprint, Built-up index, and its coordinate. Based on the previous training dataset the selected ML models predicted our Target (which are the flood points and the non-flood points), the result has selected the value of each point by 0 or 1 in the ArcGIS platform to realize the map of Flood susceptibility zonation of Tebessa City.

IV.2.1. Past significant flood events

The majority of Algerian cities experience natural disasters, especially Tebessa, where flooding is a possibility as indicated by Table 8 and (Figure 19, Figure 21, and Figure 22) (URBA-BA, 2018). Researchers working in the urban perimeter are becoming interested in this phenomena as an issue.

In order to estimate the future possibility of such disasters, flood analysis requires knowledge of the historical record of flood occurrences (Rahmati & Pourghasemi, 2017b); and the flood inventory data may be used to confirm the final Flood susceptibility mapping (Ramesh & Iqbal, 2022).

Table 8 Past significant events (Initial Flood Risk Assessment).

Year	Months / Dates	Number of interventions	Damages	Number of victims
2013	April, September, October.	89 Operations	Cracks in housing walls and mosque.	16 Survivors
2014	May, June, September, October.	91 Operations	Housing and some public facilities +cracks in the walls (schools + mosque)	/
2015	August, September, October.	81 Operations	Housing and some public facilities	1 dead and 26 survivors.
2016	August, October.	21 Operations	Housing and some public facilities	03 dead
2017	September, October.	27 Operations	Housing and some public facilities.	/
2018	May, August, September, October.	325 Operations	Housing and some public facilities.	02 dead and 10 injured.
2019	April, Mars, August, September.	272 Operations	/	/
2020	01,08 and 11/06/2020 14/07/2020	114 Operations	/	01 survivor
2021	17,20,24 and 30/08/2021	93 Operations	/	03 survivors
2022	27/08/2022 02/09/2022	143 Operations	Housing and some public facilities	03 survivors

Source: The direction of civil protection of the Wilaya of Tebessa, 2023.

- Intensive flooding and a remarkable geographical extent.
- Remarkable flooding events.

IV.2.2. Satellite images

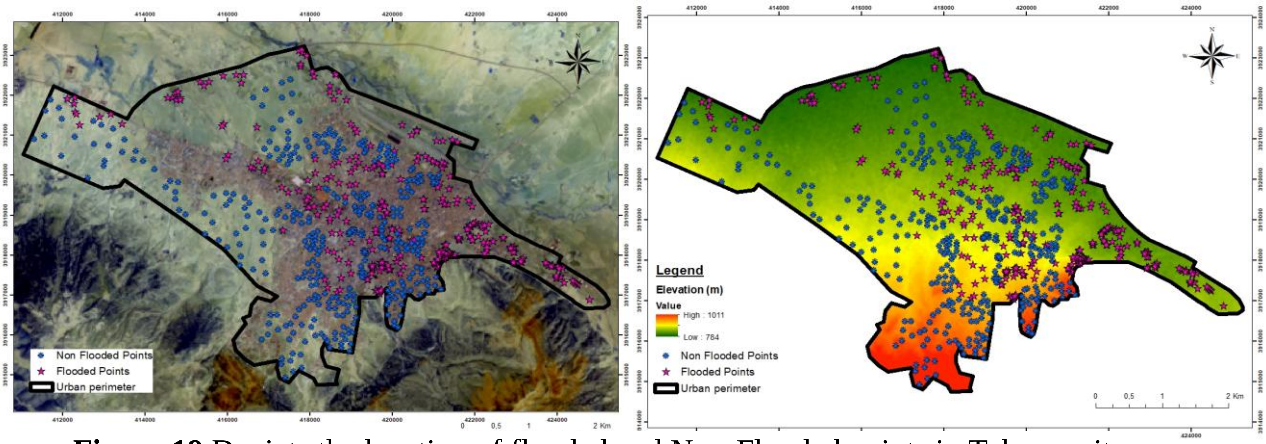


Figure 19 Depicts the location of flooded and Non-Flooded points in Tebessa city.

The Tebessa City flood inventory map was produced by compiling and obtaining information about the locations of past floods from a variety of data sources, such as the direction of civil protection, the direction of urbanization, architecture, and construction, the direction of the Tebessa Wilaya's hydraulic system, and some earlier studies.

The primary data source for this investigation was Landsat imagery, which was obtained from the US Geological Survey (USGS) (https://earthexplorer.usgs.gov). Since 2008, Free to the public, Landsat data is available worldwide and has been available since 1972 (Wulder et al., 2012).

According to the time periods noted by the Directorate of Civil Protection in the Wilaya for flood events that resulted in material and human losses, the study area's (Tebessa City) photos were investigated and downloaded without charge. These are presented in Table 8, Table 9 and Figure 19.

Table 9 Landsat Data used in the study (Tebessa City).

N°	Type of Data	Spatial resolution	Source	Acquisition date
01	Landsat 8–9	30 m (grid data)	https://earthexplorer.usgs.gov	20/10/2018
02	Landsat 8–9	30 m (grid data)	https://earthexplorer.usgs.gov	28/08/2022

One of the most crucial factors taken into account when deciding which of the many images from Landsat's extensive coverage are appropriate for this analysis is image selection. These images were taken the day after the monsoon rains to avoid clouds obstructing the view of the city's flooded areas.

Additionally, the appropriate analysis of these images obtained from Landsat in Raster format, which indicated the flooded zones in the city through the blue spots according to the (Figure 20, Figure 21, and Figure 22) and the use of Geographic Information Systems (GIS) provided the spatial indices to accelerate spatial queries. And which makes it possible to identify the areas and surfaces that were vulnerable to flooding danger on October 20, 2018, and August 28, 2022.

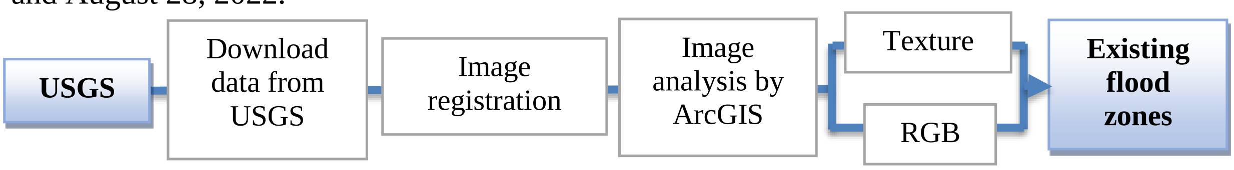


Figure 20 Workflow of existing flood zones.

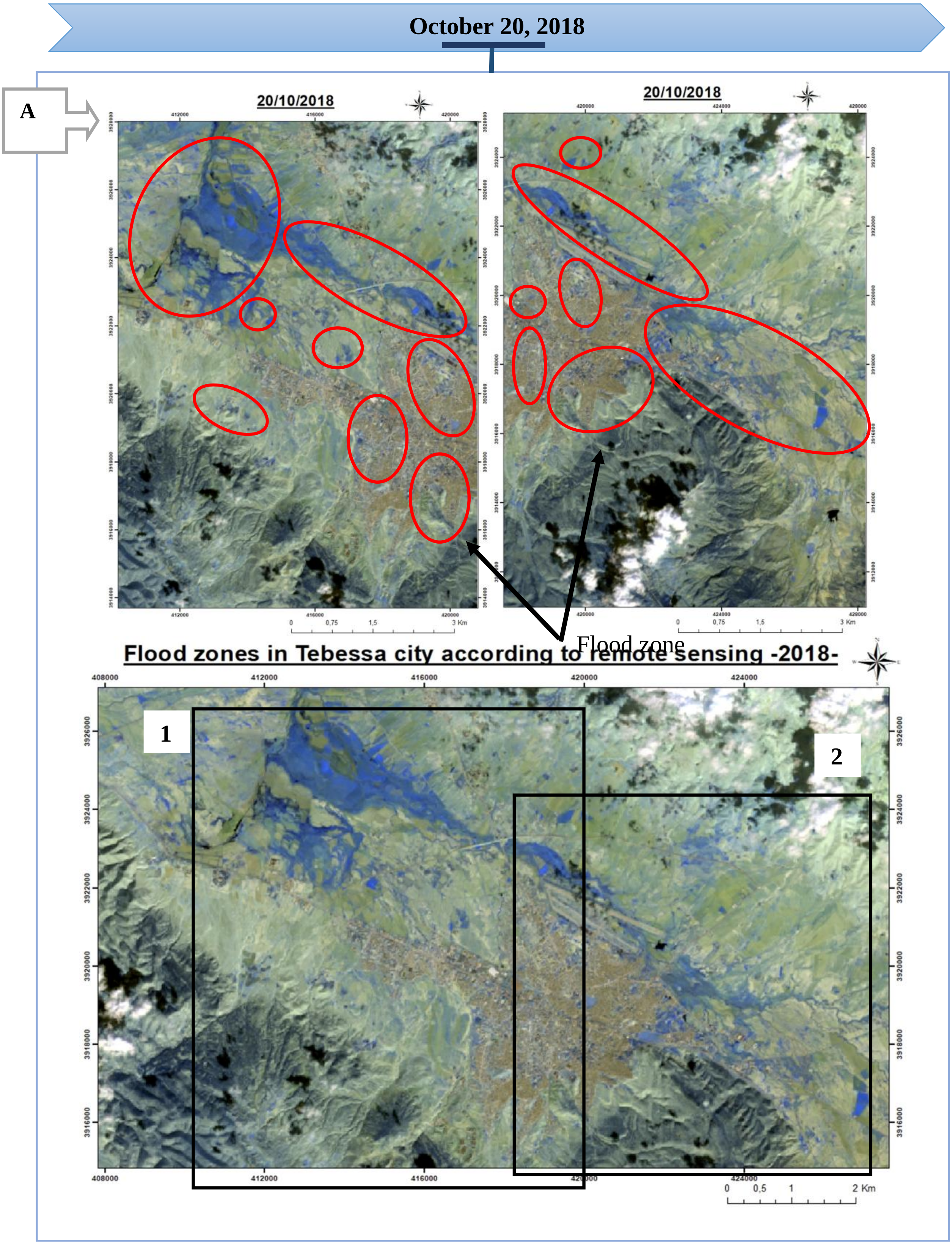


Figure 21 Landsat scenes used in the study: A (20/10/2018).

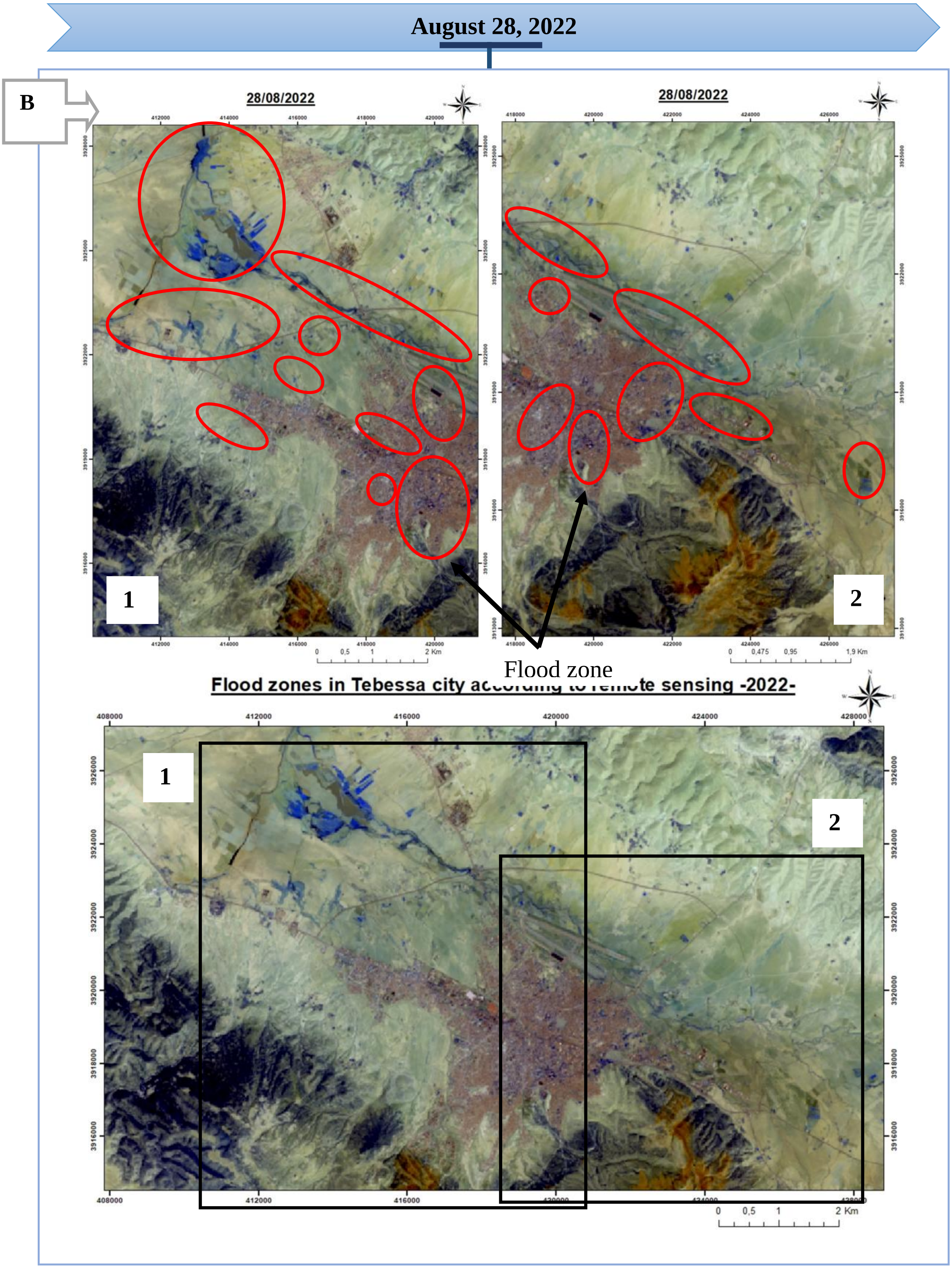


Figure 22 Landsat scenes used in the study: B (28/08/2022).

IV.2.3. Flood factors

Eight total flood adaptation factors were identified based on previous studies mentioned in Chapter III of (HADJLA, 2016), and included the following: hydrographic network, distance from valleys, elevation, slope, profile curvature, rainfall, land use/cover, urban footprint, and building index. Based on remote sensing technology, maps representing the previously mentioned factors were extracted according to the table (Table 10).

Table 10 Database of the flood factors (Tebessa city).

Flood factors	Source	Spatial resolution and data (m)	Classification methods
Hydrographic network	Digital elevation model (DEM) https://earthexplorer.usgs.gov	30 m (grid data)	Natural breaks
Distance from Wadis	Digital elevation model (DEM) https://earthexplorer.usgs.gov	30 m (grid data)	Natural breaks
Elevation	Digital elevation model (DEM) https://earthexplorer.usgs.gov	30 m (grid data)	Natural breaks
Slope	Digital elevation model (DEM) https://earthexplorer.usgs.gov	30 m (grid data)	Natural breaks
Profile curvature	Digital elevation model (DEM) https://earthexplorer.usgs.gov	30 m (grid data)	Natural breaks
Precipitation	NASA power access https://power.larc.nasa.gov/data-access-viewer/	Point data	Manual
Land use/ Land cover	Sentinel-2A (S-2A) https://www.arcgis.com	30 m (grid data)	Supervised classification
Urban footprint, Built-up Index	Sentinel-2A (S-2A) https://www.arcgis.com	30 m (grid data)	Supervised classification

IV.2.3.1. Hydrographic factors

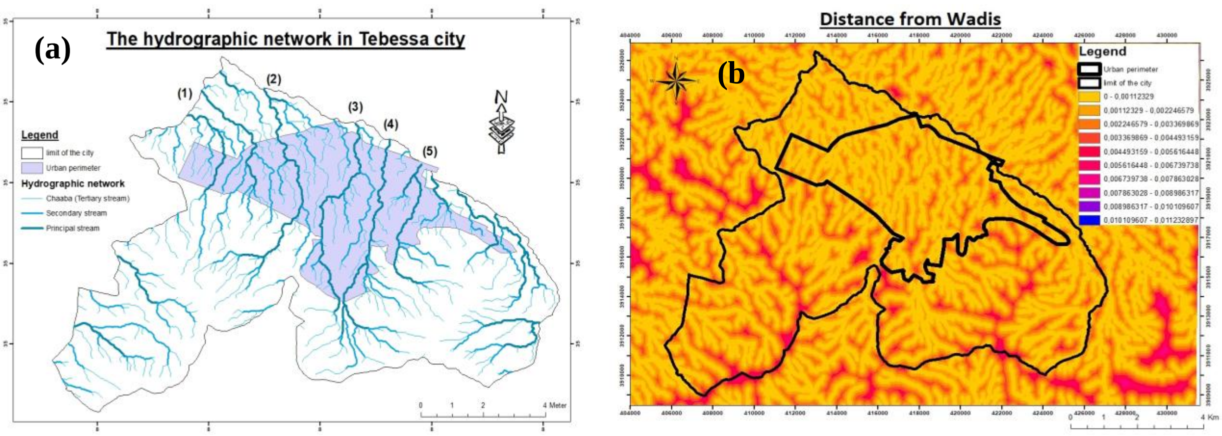


Figure 23 Hydrographic factors: (a) Hydrographic network, (b) Distance from Wadis.

Seven large Wadis traverse the Tebessa city's urban boundary, posing a risk of flooding, as seen in (Fig. 21a and Table 11). Using the hydrology (Fill, Flow direction, flow accumulation, Stream order, and Stream to feature) along with Conditional (Con) under the ArcGIS spatial analysis tool from ASTER GDEM, the hydrographic network was created, classifying the streams into three categories: The three steams in Figure 23a are: 1) Principal steam (Wadis), 2) Secondary stream, and 3) Tertiary steam (Chaabas).

Many streams flow down from the nearby watersheds into the Wadi El KEBIR, which drains the MERDJA plain; these watercourses are transient and are nothing more than torrents; Their government is combative; Table 11 and Figure 23a list the following Wadis: Wadi RAFFANA, Wadi NAGUES, Wadi ZAAROUR, Wadi SEGUI, Wadi EL ANBA, Wadi EL GNATER SOUD, and Wadi CHABRO. All of these Wadis have an outlet at the CHABRO Wadi, which is where the name "watershed" originates (URBA-BA, 2018).

Table 11 The existing Wadis in Tebessa city.

N°	Wadis	Length (km)
01	EL ANBA	19
02	SEGUI	12.5
03	RAFANA	9
04	NAGUES	9
05	ZAAROUR	7
06	EL GNATER SOUD	/
07	CHABROU	/

Source: The direction of civil protection of the Wilaya of Tebessa,2023.

Tebessa is a city at the base of the OSMOR mountain, some of whose peaks rise as high as 1500 meters. Raised to a height of 850 meters and situated atop a scree plateau that was split off from the limestone massif, it rules the vast MERDJA plain and spans a few mainly alluvial stretches, corresponding to a sizable sedimentary basin.

- <u>Distance from Wadis:</u>

Since the Wadis have an impact on the amount of flooding, the distance from and proximity to them was considered a conditioning or influencing element (Department of Environmental Protection - State of New Jersey, 2009), For instance, a location near a Wadis is particularly vulnerable to flooding. The distance from the Wadis and all other streams within the research region was determined using the Euclidean distance tool from the spatial analyst tools (Figure 23b).

IV.2.3.2. Topographic factors

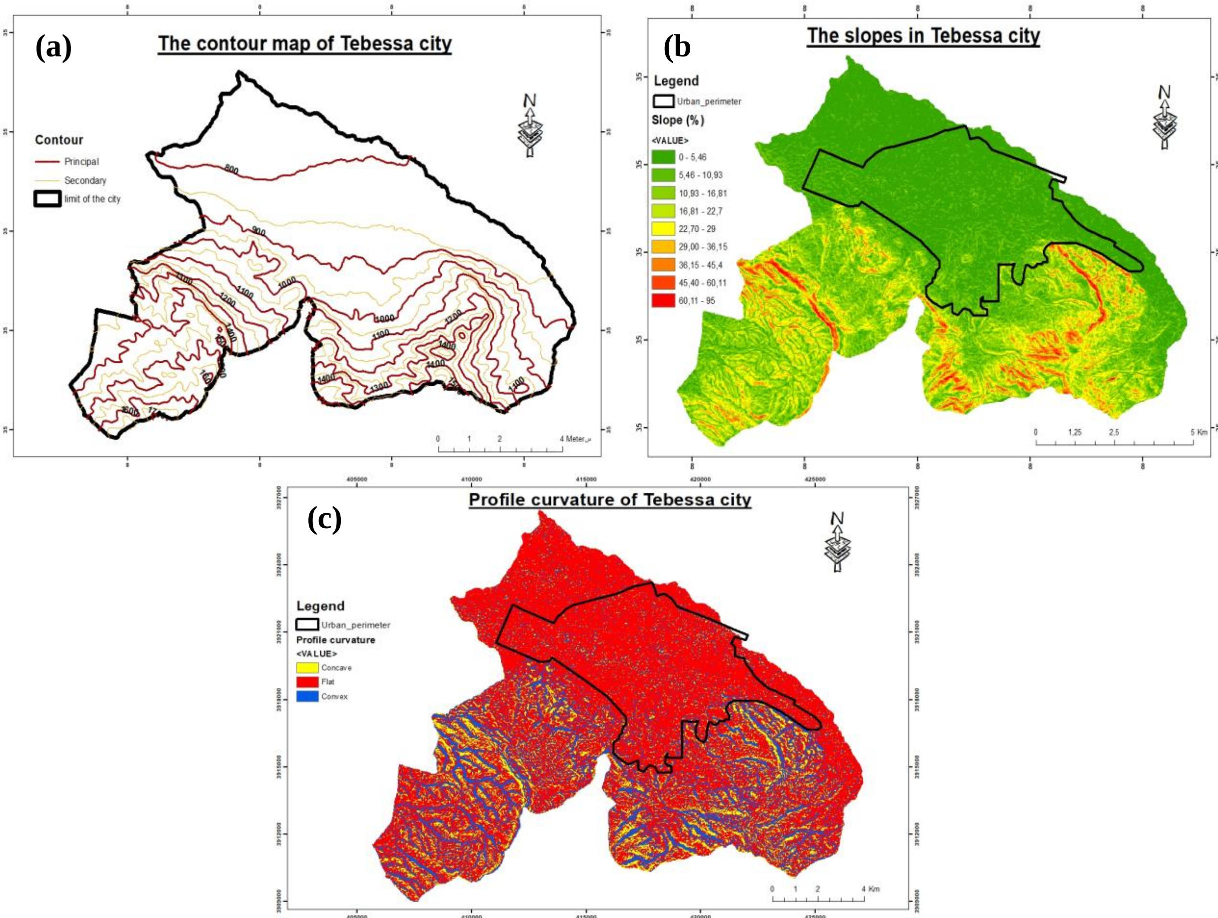


Figure 24 Topographic factors: (a) The contour, (b) The slopes, (c) Profile curvature.

- <u>Elevation and slope:</u>

The commune is primarily made up of a plain and a mountain, with the mountainous aspect predominating due to its size and strength. In fact, the mountain alone occupies over 50% of the commune's surface. The massifs reach an elevation of over 1500 meters (Figure 24a, b) and encircle the plain of MERDJA in its southern and southeast (URBA-BA, 2018). The plan is simply a basin of subsidence that stretches from the west to the east and is raised to an average height of 800 meters (Figure 24a, b); The orientation of the basin is dictated by the mountainous device, the Tebessa Mountains (URBA-BA, 2018).

Slope is the most significant hydrologic component since it directly influences surface runoff and, in turn, floods (Meraj et al., 2015). Because the slope is one of the flood conditioning elements, this aspect is significant in flooding disasters (Ramesh & Iqbal, 2022); Using the surface-slope tool under the spatial analyst tool in ArcGIS, the study area's slope in percentage was retrieved from the processed ASTER GDEM and further divided into nine classes (Figure

24b). As a result, low gradient slopes at lower reaches are far more vulnerable to flood occurrence than high gradient slopes (Figure 24b). The slope in Tebessa City's "Urban perimeter" is related to the altitude factor, which could change if the elevation of the point modified. In our case study, the slope ranges from 0% to 22.7% (Figure 24b), which represents the lowest part of the territory.

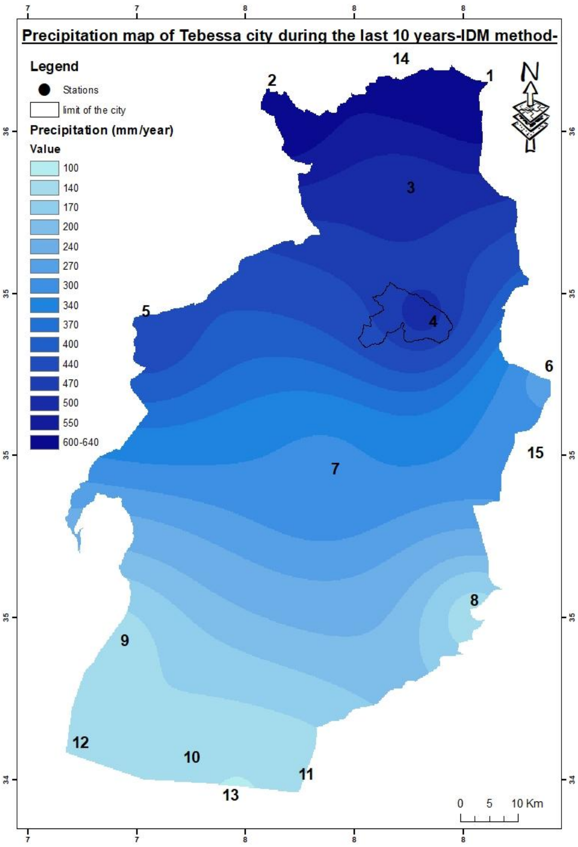
- Profile curvature:

Curvature facilitates understanding of the geomorphological properties (Rahmati & Pourghasemi, 2017b). It was separated into three classes (Figure 24c) and categorized from the curvature tool under Raster surface – 3D analyst tools in ArcGIS from ASTER GDEM. In the Concave, Flat, and Convex curvature classes, the study area makes up 38.66%, 42.83%, and 18.49% of the total area, respectively (Figure 24c).

IV.2.3.3. Climatic factors

- Precipitation:

One of the main causes of floods and soil erosion is precipitation (Essel et al., 2016), The ability of rainfall intensity to promote soil erosion is known as rainfall erosivity (Gabriels, 2006).



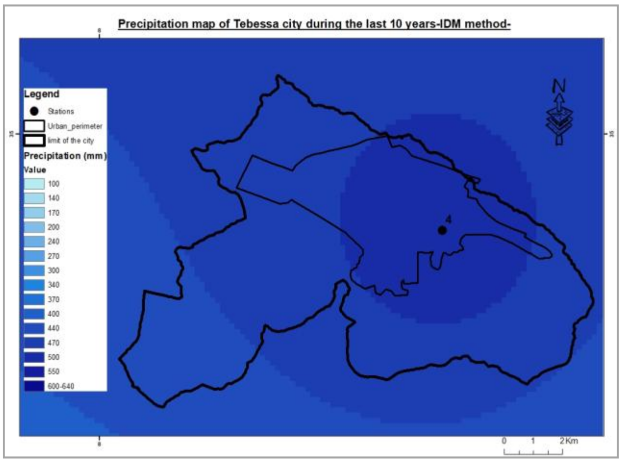


Figure 25 Climatic factors: Precipitation maps.

The pluviometry trance of the commune of Tebessa oscillates between 300 and 400 mm/year, placing it within the soft semi-arid bioclimatic region (Figure 25). There can be seasonal and inter-annual variations in this rainfall distribution. The station whose data is displayed in Table 12 can be accessed at the following website: https://power.larc.nasa.gov/data-access-viewer/ mentioned in the paper (Ly et al., 2013a), given as the range of precipitation of the last 10 years in our case of study between 2013 and 2022, in each month and also the annual precipitation that helps as to extract the global rate of the last 10 years (Table 12).

Table 12 The amount of Precipitation during the last 10 years (2013-2022) of the 4th station in the Wilaya of Tebessa.

Year	Precipitation (mm)
2013	406.05
2014	453.52
2015	585.35
2016	495.7
2017	395.51
2018	432.42
2019	601.17
2020	696.09
2021	313.46
2022	421.88

Source: https://power.larc.nasa.gov/data-access-viewer/ (Essel et al., 2016).

The location of the 15 stations (Table 13) was chosen based on a number of factors that helped to cover the Tebessa Wilaya (Figure 25). The variation in rainfall levels was also taken into consideration to give the map a variable form that would aid in visual analysis. Furthermore, the map of Tebessa City was extracted using the IDW "interpolation" approach from spatial analyst tools by adding the data and the locations of these stations to ArcGIS (Figure 25).

Table 13 Database of the flood factors (Tebessa city).

Station	X	Y	Precipitation (mm/year)
Station 1	8.2672	35.9555	603,741
Station 2	7.7618	35.92	604,931
Station 3	8.0749	35.6704	480,115
Station 4	8.1228	35.4039	480,115
Station 5	7.4314	35.3661	420,697
Station 6	8.4421	35.2316	254,879
Station 7	7.8763	35.0115	288.02
Station 8	8.2554	34.6643	124,228
Station 9	7.3435	34,592	121,829
Station 10	7.5522	34.2839	121,829
Station 11	7.8005	34.2578	121,829
Station 12	7.2281	34.3429	121,829
Station 13	7.6401	34.1931	59,211
Station 14	8.1131	36,031	603,741
Station 15	8.3932	35.0983	278.92

Source: https://power.larc.nasa.gov/data-access-viewer/ (Essel et al., 2016).

IV.2.3.4. Human factors

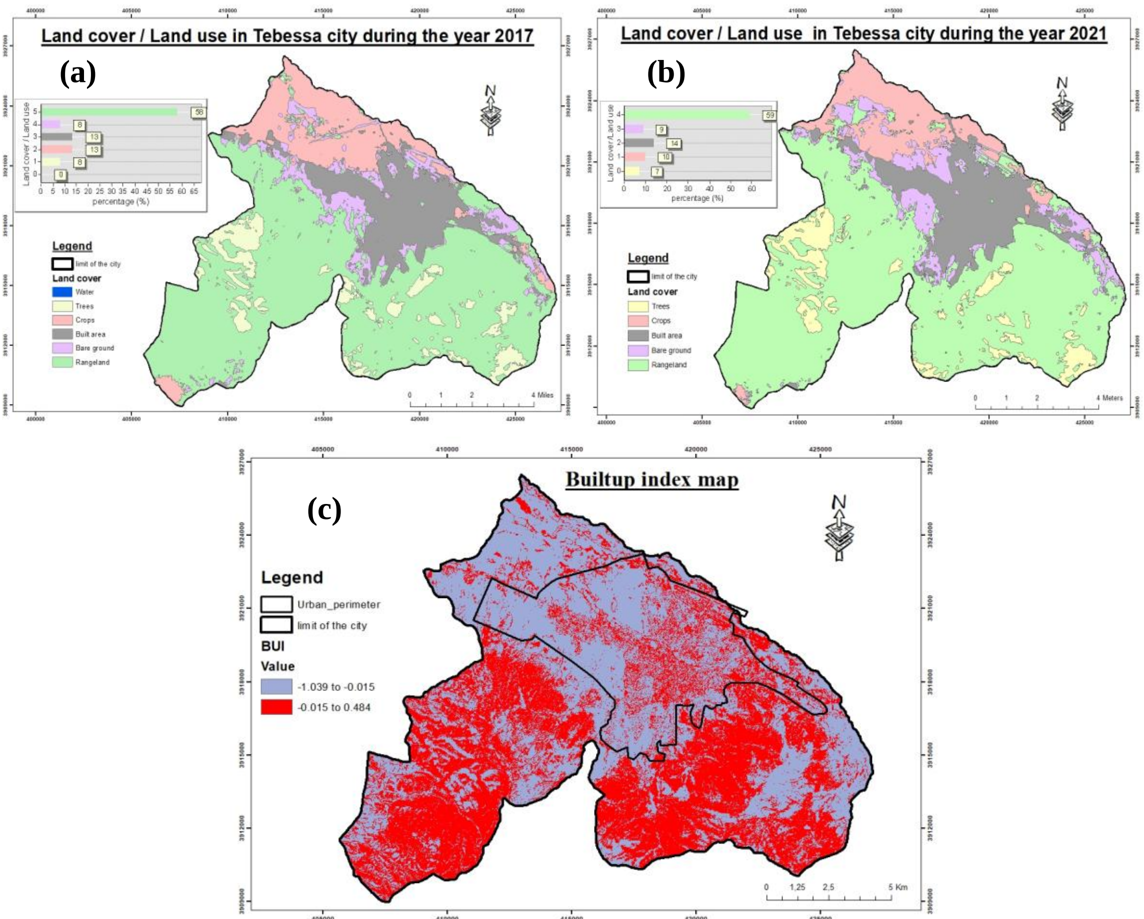


Figure 26 Human factors: (a) Land cover/land use during 2017, (b) Land cover/land use during 2021, and (c) Built-up index.

- <u>Land use / land cover:</u>

It is essential to understand the spatial distribution of land use and land cover in order to comprehend the activities occurring in a given area and the kinds of land use and land cover that are impacted by recurring floods. Because metropolitan areas have a high concentration of impermeable surfaces, storm water runoff affects them (Shafapour Tehrany et al., 2017).

The Land use /Land cover for the study area was extracted from Sentinel-2A (S-2A), using the website called: https://www.arcgis.com/apps/instant/media/index.html?appid=fc92d38533d440078f17678ebc20e8e2&fbclid=IwAR3l_KhmCRJ8hWxYpwj7pxfzNYdveWhonkc9DhAepZFf7phAg0XJ7NTnzb0

supervised categorization of multispectral data using ArcGIS 10.8. Five classes are used to categorize the study region (Figure 26a, b). Furthermore, the city's quick urbanization is a response to population expansion, especially in the 1970s, which was the period of the demographic boom. The population of the city grew from 62,639 to 200,256 between 1977 and 2018. The urban fabric has expanded, covering 4843.65 hectares in 2018 as opposed to 1637 hectares in 1988 (URBA-BA, 2018).

- <u>Urban footprint, built-up index:</u>

The urban footprint of the research region was calculated using the built-up index. This is a subclass of one of the most used methods for analyzing optical data: spectral indices. Generally speaking, its interest may be seen in the fact that urban mapping relies on the extraction of impervious regions or constructed surfaces (Lee et al., 2015).

The urban footprint of the research region was established by applying the built-up area extraction and index development methods given in Equation (4) (Bhatti & Tripathi, 2014); The required indices, such as the modified normalized difference water index (MNDWI) Equation (3), the normalized difference built-up index (NDBI) Equation (2), and the normalized difference vegetation index (NDVI) Equation (1), were extracted using a Sentinel 2A satellite image after the radiance was converted to the top of the atmosphere reflectance. ArcGIS 10.8 was used to construct each index. The method includes the four arithmetic computations below.

The MNDWI is the improved and updated version of the normalized difference water index (NDWI) (H. Xu, 2006); The recovered water zones were frequently combined with accumulated land noise in the final NDWI picture. In order to remove water signs, MNDWI lowers the noise from developed land and raises contrast with developed area, bare land, and other land use and land cover classifications. Using the green and mid-infrared spectral regions, MNDWI extracts water areas (H. Xu, 2008).

$$NDVI_{(S-2A)} = \frac{NIR-R}{NIR+2} \tag{1}$$

Where NDVI, normalized difference vegetation index; NIR, band 8 in Sentinel 2A; R, the red band (band 4 in Sentinel 2A).

$$NDBI_{(S-2A)} = \frac{SWIR-NIR}{SWIR+NIR} \tag{2}$$

NDBI, normalized difference built-up index; SWIR, bands 11 and 12 in Sentinel 2A; NIR, band 8 in Sentinel 2A.

$$MNDWI_{(S-2A)} = \frac{Green-SWIR}{Green+SWIR} \tag{3}$$

MNDWI, modified normalized difference water index; Green, pixel values from the green band; SWIR, bands 11 and 12 in Sentinel 2A.

$$BUI_{(S-2A)} = NDVI_{(S-2A)} - NDBI_{(S-2A)} - MNDWI_{(S-2A)} \tag{4}$$

Finally, the result of the three rasters viz, NDVI, NDBI, and MNDWI Equation (4) was converted into a binary image using a density slicing tool with -1,039 to -0.015 thresholds for built-up and -0.015 to 0.484 for non-built-up (Fig. 24c).

IV.2.4. Background of flood susceptibility models

IV.2.4.1. Extreme Gradient Boosting (XGBoost)

Tree boosting is a well-liked and very successful machine learning technique. which scientists frequently utilize to provide cutting-edge results on a range of machine learning problems (Chen & Guestrin, 2016) also to estimate the susceptibility to natural hazards (Pradhan & Kim, 2020) . And as of right now, the best-integrated and quickest decision tree algorithm (P. Li, 2010). And according to (Chen & Guestrin, 2016) define the XGboost as a scalable end-to-end tree boosting system. Its basis classifier, the CART, is determined by several linked decision trees working together. With this incredibly adaptable and versatile technique, the majority of regressions and classification issues can be resolved. XGBooster (Ma et al., 2021).

An advantage of XGBoost is that it can reduce processing time by acquiring the optimal number of boosting repetitions in a single run. The XGBoost model was applied in prior research projects, yielding incredibly accurate results. Furthermore, it's well known that the XGBoost can improve modeling accuracy by reducing overfitting (Samat et al., 2020). This was an additional factor that affected the model selected for this research endeavor.

To run the XGBoost model and determine the flash-flood susceptibility, a special R programming language code was used. The functioning of the XGBoost model is described by the following Equation (5):

$$g(\,bt) = \sum_{i=1}^{n} R\,\left(\rho i, \hat{\rho} i^{(m-1)} + bt(yi)\right) + \Omega(bt) + C \qquad (5)$$

Where *i* represents *i th* number of sample, $\hat{\boldsymbol{\rho}}\boldsymbol{i}^{(m-1)}$ is the projected value of the *(m-1) th* model for *i th* sample, *bt(yi)* represents newly added model *t*, ***Ω*** *(bt)* is the regular value, and *C* is the constant value and *R()* represents model error.

IV.2.4.2.Random Forest (RF)

Random Forest has proven to be an amazing technique for regression and classification (BREIMAN, 2001), also possesses the capacity to handle continuous, high-dimension, and categorical data. Since Random Forest does not require an assumption about the statistical distribution of the data, it can be considered resilient to changes in the composition of the dataset (Catani et al., 2013). These properties may be quite useful for applications involving variables with reciprocal nonlinear interactions.

In this study, we used the "Model Map" software (Freeman et al., 2023). within the R statistical environment. To automate and build the maps, the "Model Map" package allows an interface with other R-packages that are currently available.

Inside the statistical context of R. The "Model Map" package enables an interface with other available R-packages to automate and construct the maps (Pradhan & Kim, 2020). The training set includes a quick and easy method of learning a function that converts the independent IFs data (X1, X2,....., Xn) and the dependent variable (goal) X0 to the output Yi, where (X1, X2,....., Xn) can be a combination of categorical and numerical variables. X0 may be numeric for regression or binary for classification. Equations (6) and (7) demonstrate that each tree independently predicts the Yi average following training on query point x.

$$f_n^j(x) = \frac{1}{N^e\big(A_n(x)\big)} \sum_{\substack{Y_i \in A_n(x) \\ I_i = e}} Y_i \qquad (6)$$

And the forest averages each tree's projections

$$f_n^{(M)}(x) = \frac{1}{M} \sum_{j=1}^{M} f_n^j(x) \qquad (7)$$

Where $A_n(x)$ is the leaf containing *x*, and $N^e(A_n(x))$ is the number of estimation points it contains.

IV.2.4.3. K-Nearest Neighbor (K-NN)

In data mining applications, K-Nearest Neighbor is a frequently used categorization method (Q. P. He & Wang, 2007); This method stores all the data initially, then classifies fresh data points according to their distances from previously recorded data (Madhuri et al., 2021). The distance between each training point and the testing site is calculated using Equation (8) as follows:

$$Distance = (x_{train} - x_{test})^p \quad (8)$$

Where p is the Minkowski metric (pϵ[1,2,3,4]), x_{train} is a training data point and x_{test} is the data point whose class to predict.

The most frequent class is then allocated to the training point among the 'K' neighbors closest to the testing site.

IV.2.5. Flood susceptibility mapping

Figures 27A–C presents the results of the Jenks natural breaks classification approach, which was used to classify three flood susceptibility maps that were derived using XGBoost, Random Forest, and K-Nearest Neighbor into five classes: very high, high, moderate, low, and very low.

The findings display a general pattern in Figure 27, guaranteeing that the chance of vulnerability rises in tandem with the index value; that is, a higher index denotes a higher sensitivity to flooding. The extremely vulnerable region is mainly limited to flat, moderate slopes in the vicinity of Wadis.

Using the 494 training flood locations superimposed on the Flood Susceptibility maps produced by XGBoost, Random Forest, and K-Nearest Neighbor models, the proportion of flood locations falling into various susceptibility classes was calculated (Table 14) and shown as a bar diagram in Figure 27.

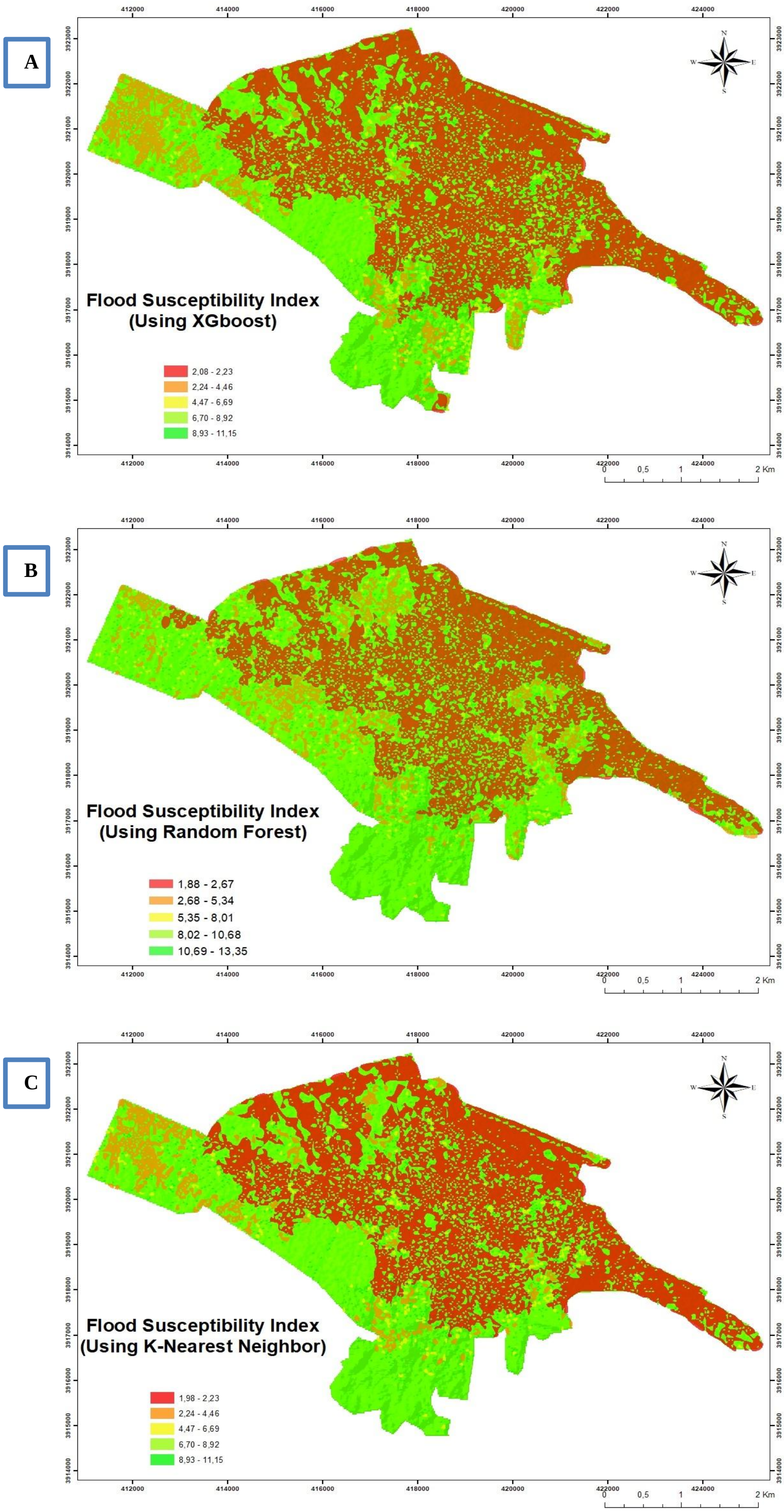


Figure 27 Flood susceptibility mapping of Tebessa City by ArcGIS 10.8: (A) XGboost, (B) Random Forest, and (C)K-Nearest Neighbor models.

Table 14 Percentage of flood locations (training) in each flood susceptibility class by XGboost, Random Forest, and K-Nearest Neighbor models.

Flood susceptibility class	N° of pixels in class	% of class pixels	N° of flood pixels in class	% of flood pixels in class
Frequency Ratio XGboost Model	21115	38.43	240	48.63
Very high	5813	10.58	177	35.74
High	3000	5.46	70	14.11
Moderate	6187	11.26	7	1.52
Low	18830	34.27	0	0
Very low				
Frequency Ratio Random-F Model	20918	38.07	286	57.79
Very high	5973	10.87	130	26.25
High	2983	5.43	73	14.87
Moderate	6280	11.40	5	1.1
Low	18791	34.23	0	0
Very low				
Frequency Ratio K-Nearest-N Model	19582	35.64	262	52.96
Very high	5929	10.79	147	29.81
High	3071	5.59	64	12.91
Moderate	6594	12	21	4.32
Low	19769	35.98	0	0
Very low				

XGBoost, Random Forest, and K-Nearest Neighbor models have 84.37%, 84.04%, and 82.77% of flood locations in their high and extremely high flood susceptibility classifications, respectively (Figure 28).

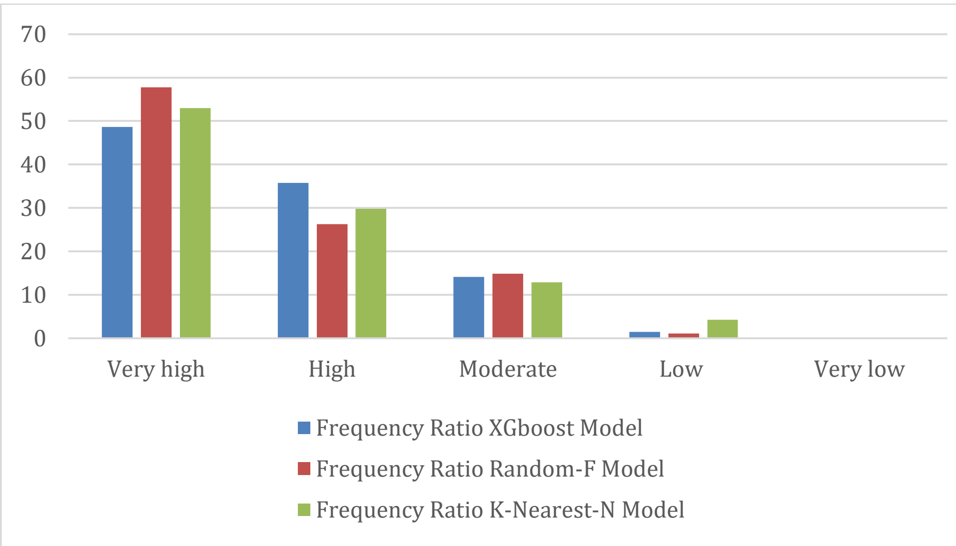


Figure 28 Percentage of flood frequency in each flood susceptibility class.

IV.2.6. Accuracy assessment of the Models

The receiver operating characteristic (ROC) is a tool used in many domains to evaluate the performance of models (Swets, 1988). The most often used technique for determining a forecast system's accuracy is the Receiver Operating Characteristic (ROC) (Tehrany et al., 2019). The ROC approach was used to evaluate the model employees' success and prediction rate. It was computed by taking the fraction of correctly identified positive outcomes (TNs) and comparing it to the fraction of incorrectly identified positive outcomes (FNs). The area under the ROC curve (AUC) is one metric to assess the overall performance of a model (Hanley & McNeil, 1982), This suggests improved model performance is indicated by a bigger AUC.

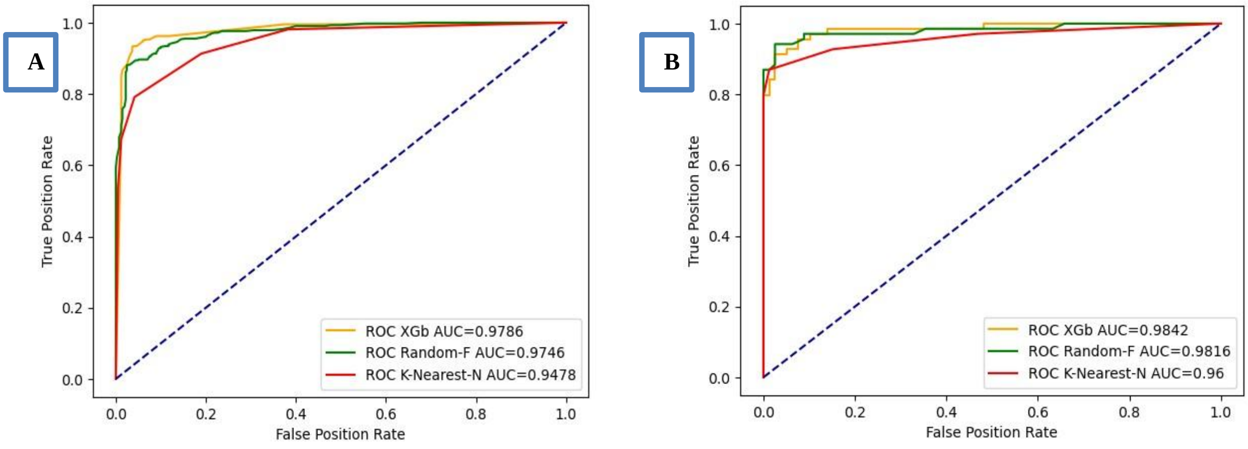


Figure 29 Accuracy assessment using ROC (AUC) :(A) training and (B) testing.

According to Ananta MS Pradhan (Pradhan & Kim, 2017), the accuracy results were categorized into five groups: fail (0.50-0.60), fair (0.70-0.80), poor (0.60-0.70), excellent (0.90-1), and good (0.80-0.90). Thus, for the Random Forest categorized, K-Nearest neighbor, and XGboost models, the predicted accuracy values of prediction rates using the Accuracy score approach were 96.00%, 98.42%, and 98.39%, respectively. However, Figure 29 displayed the ROC (AUC) method's accuracy values.

As can be seen from the receiver operating characteristic (ROC) graph in Figure 26, all of the adopted models had a fair level of prediction accuracy. However, the XGboost model outperformed the Random Forest and K-Nearest neighbor models in terms of prediction accuracy, with success rates of 97.86%, 97.46%, and 94.78%, and prediction rates of 98.42%, 98.16%, and 96.00%, respectively.

IV.2.7. Relative importance analysis of flood factors

Selecting the right conditioning factors is crucial for modeling flood susceptibility (Kourgialas & Karatzas, 2011); Using the factor analyzer method, the significance of the 07 factors was examined in this study; This technique is regarded as one unsupervised machine learning approach for dimensionality reduction; it builds factors from the observed variables to reflect the common variance, or variation arising from correlation among the observed variables (Shrestha, 2021; Biggs, 2023).

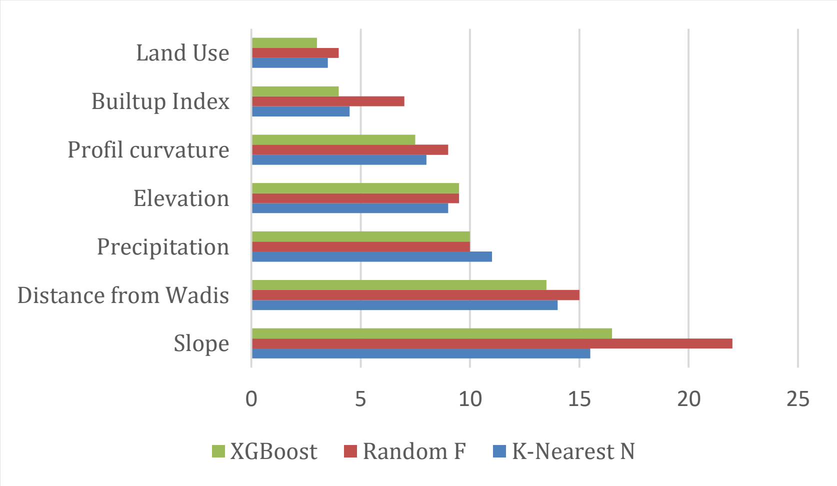


Figure 30 Factor importance analysis using Factor-Analyzer method.

The relative significance of the discovered flood susceptibility factors in the research area is displayed in Figure 30. Slope% was shown to be the most important factor for flooded areas, followed by land use, elevation, precipitation, profile curvature, built-up index, and distance from Wadis. Figure 30 illustrates that the slope percent had the highest value across all models, with values of 16.5, 22, and 15.5 for the Random forest, XGBoost, and K-Nearest neighbor models, respectively.

Distance from the Wadis, precipitation, elevation, profile curvature, built-up index, and land use values in the XGBoost model were approximately 13.5, 10, 9.5, 7.5, 4, and 3, respectively. In comparison, the same factors' Random forest values in the other models were equal to 15, 10, 9.5, 9, 7, and 4, and their K-Nearest Neighbor model values were approximately 14, 11, 9, 8, 4.5, and 3.5, respectively.

IV.3. Ecological climatology

The goal of this study is to forecast water levels in Tebessa City's Wadis, which cross the city, using an estimate of precipitation over the ensuing twelve years. The main goal is to use machine learning to predict future water levels and precipitation in Wadis. This will enable the development of maps showing urban flood vulnerability and the estimation of the probability of flooding related to future water levels, which can be done in conjunction with Geographic Information Systems (GIS).

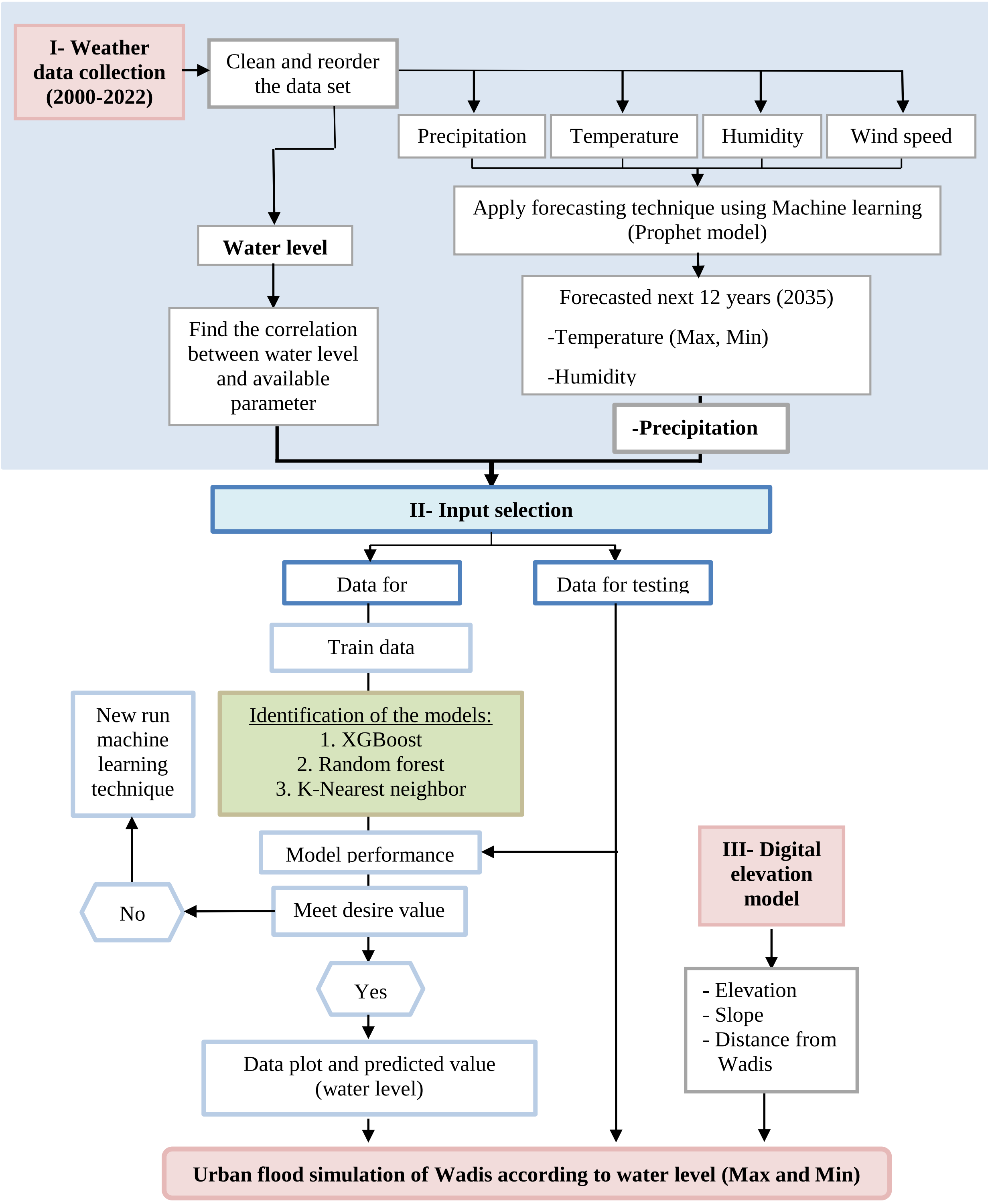


Figure 31 Methodological flowchart of spatial analysis.

- Data Preparation

Tebessa City's urban flood modeling technique is implemented in phases. Weather data first goes through a careful cleaning and rearranging procedure. Then, to forecast conditions for the next 12 years (2035), machine learning techniques—specifically, the Prophet model—are used to precipitation, temperature, humidity, and wind speed data. Each individual outcome is thoroughly examined and adjusted.

- Correlation Analysis

The second stage evaluates the connection between Wadis water levels and weather factors such temperature, humidity, wind speed, and precipitation. All five characteristics are found to be significantly significant in the study, with precipitation being given special attention. Input parameters include historical data on precipitation, temperature, humidity, wind speed, and water level for the last 22 years (2000 to 2022).

- Data Fusion

The trained and tested dataset is integrated with the forecasts from the five parameters as input selections during the fusion phase. Several prediction techniques are used, such as Neural Network models, Seasonal Naive Method, and Random Forest. The output of the model that fits the data the best is taken into account. The ROC-AUC approach is used to assess each model's unique accuracy.

- Urban Flood Simulation

This study's main goal is to forecast water levels on days when there is a chance of precipitation. The basis for simulating urban floods in Tebessa City's Wadis is this prediction. The Digital Elevation Model (DEM) is used for the simulation, and it includes important features of the research area such as height, slope, and distance from the Wadis (Figure 31).

IV.3.1. Weather forecasting (Precipitation)

IV.3.1.1. Data collection

IV.3.1.1.1. Historic data

An essential step in research, decision-making, and strategy planning is data collection. Two main sources were used in this study to gather historical weather data for Tebessa City for the last 23 years, from 2000 to 2022:

- Local Administrative Institutions:

Local government agencies in the Tebessa Wilaya, such as the National Hydraulic Resources Agency, the Water Resources Administration, the Civil Protection Administration, and the Urbanism Architecture and Construction Administration, among others, were the ones to start gathering data.

- Online Data Source:

Additionally, data was sourced from an online platform, specifically the station available at https://power.larc.nasa.gov/data-access-viewer/ (Ly et al., 2013b).

Table 15 The weather data in Tebessa city (2000-2022).

N°	Wadis	Range
01	Precipitation	400 - 500 mm
02	Temperature (Max)	0.34 – 41.98 C
	Temperature (Min)	-6.29 – 26.35 C
03	Humidity	2.38 – 14.65 g/kg
04	Wind speed	0.94 – 14.88 m/s
05	Water level	101 -280 mm

Source: Author,2023.

The Tebessa City daily weather dataset includes a number of variables, all of which are essential for assessing natural disasters. As shown in Table 15 and Figure 32, these variables include precipitation, temperature (Max, Min), humidity, wind speed, and water level. One major element affecting Wadi streams and groundwater levels is precipitation.

In 2022, Tebessa City experienced its most ever recorded precipitation, reaching 12.24 mm. Notably, the administration of water resources The city's landscape has been severely impacted by recorded instances of floods in the past few years, notably 2007, 2009, 2013, 2015, and 2018 (National Agency For Integrated Water Resources Management, 2019).

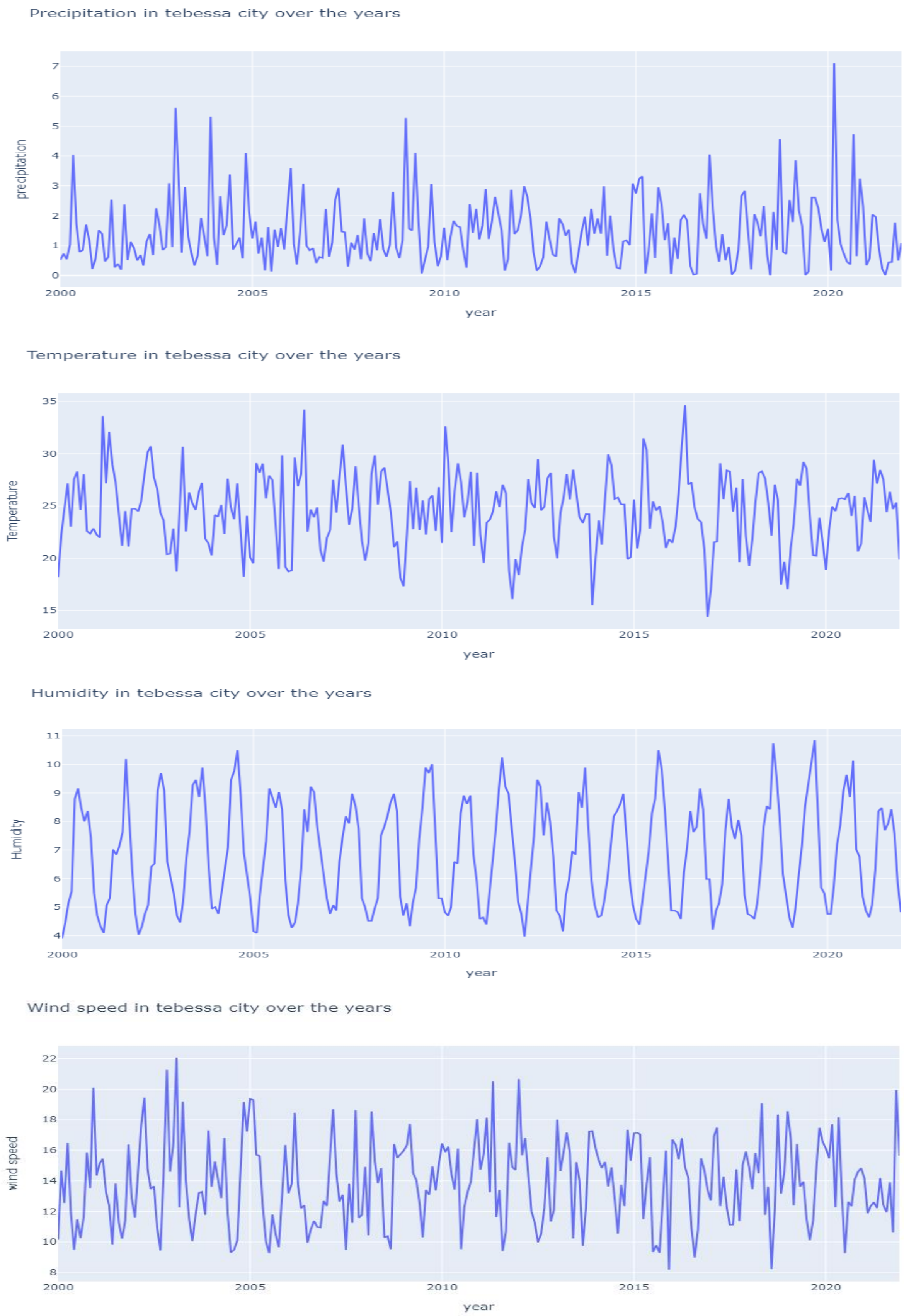


Figure 32 Weather data in Tebessa City (2000 to 2022)

IV.3.1.1.2. Future data generation

Predicted meteorological values, in particular precipitation, are essential for Wadis water level forecasting for scenarios up to 2035. The hydrographic network, slope, height, and other topographical parameters are taken for granted in this study and will not change in the future. Machine learning approaches were utilized to anticipate future meteorological parameters, such as temperature (Max, Min), humidity, wind speed (m/s), and precipitation (mm) in Tebessa City in order to obtain precipitation estimates for extreme occurrences in 2035 (Figure 33).

The Prophet model is an effective method for time series data prediction that can manage seasonality patterns and non-linear trends that happen at various intervals, from yearly and monthly to daily, including weekends and holidays. Strongly seasonal time series data with several seasons of historical information are especially well-suited for it (Menculini et al., 2021).

According to Taylor and Letham (S. J. Taylor & Letham, 2017), the Prophet model was developed with the intention of producing a versatile forecasting instrument that is easy to use and adaptable. Time series data are broken down by the model into three main components:

Growth (or Trend) $g(t)$: This component captures the underlying trend in the data, accounting for changes that occur over time.

Seasonality $s(t)$: Seasonality refers to recurring patterns that occur at regular intervals, such as daily, monthly, or annually. The model incorporates these seasonality patterns, which can be complex and overlapping.

Variance v(t): Variance represents the inherent noise or fluctuations in the data.

The decomposition of time series data is expressed as:

$$y(t) = g(t) + s(t) + \epsilon_t \qquad (9)$$

In this equation (9), ε_t represents variables that are assumed to follow a normal distribution but are not explicitly considered by the model (S. J. Taylor & Letham, 2017). The Prophet model operates within the framework of a Generative Additive Model (GAM), a concept originally introduced by Trevor Hastie and Robert Tibshirani in 1986 (Trevor Hastie and Robert Tibshirani, 1986). As time is the only regressor, the model is univariate and its forecasting process can be thought of as a curve-fitting approach.

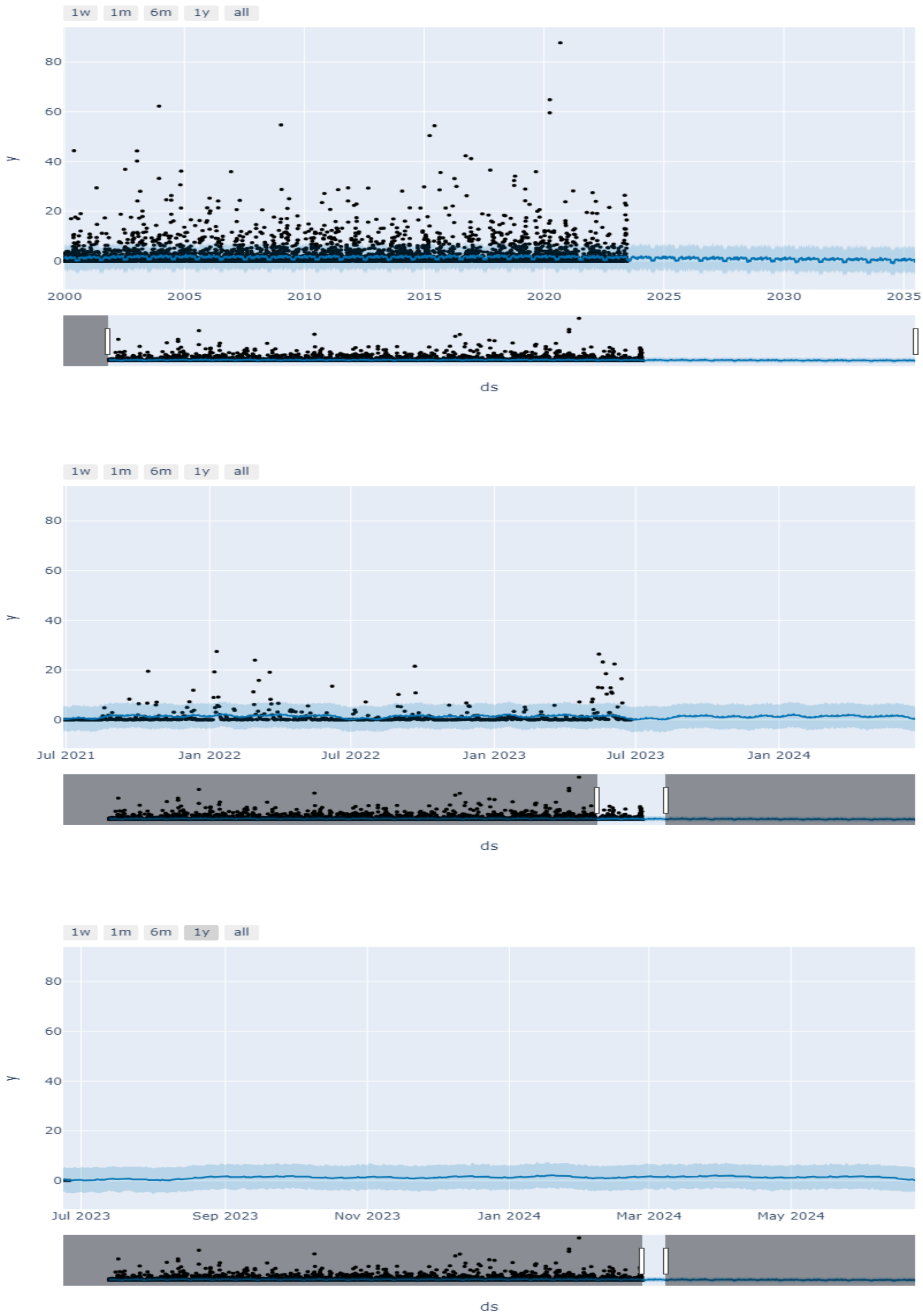


Figure 33 Plot of forecasting weather in Tebessa City to 2035 by Machine learning.

IV.3.1.1.3. Machine learning algorithms

- Extreme Gradient Boosting (XGBoost):

The XGBoost model is a strong option for this study because it has a history of producing incredibly precise outcomes in earlier research initiatives. Among its noteworthy advantages is its capacity to drastically cut down on processing time by figuring out how many boosting rounds to do in a single run (Friedman et al., 2000). Furthermore, XGBoost is renowned for its ability to improve modeling accuracy by reducing overfitting, a typical machine learning problem (Samat et al., 2020). This element had a significant impact on the choice to use the XGBoost model in this investigation (Burges, 2010).

Gradient boosting, a reliable method for building machine learning models, is the foundation of XGBoost. Its use of a more regularized model formalization, which successfully controls overfitting, enables it to perform exceptionally well. Created by Guestrin and Chen (Chen & Guestrin, 2016), XGBoost uses an additive method in its training (Chen et al., 2020).

In XGBoost, the goal is to estimate the outputs Y from input samples i with independent feature sets ($X1$, $X2$, ..., Xn). To achieve this, the model employs a tree ensemble approach, where the prediction $\phi(x_i)$ is computed as a sum of K additive functions $f_k(x_i)$, where f_k belongs to the set of all possible trees (F). The function f_k represents the relationship between the descriptor values in x_i and a specific output at each step of the ensemble (Equation 10):

$$Y_i = \phi(x_i) = \sum_{K=1}^{K} f_k(x_i), f_k \in F \tag{10}$$

- Random Forest:

The meta classifier is based on a group of unpruned trees called a random forest (BREIMAN, 2001). The process of creating the trees involves randomly choosing n attributes. The value of n is obtained by taking the square root of the number of features. The training sample data is bagged in order to create the random forest. Initially, m elements (including duplicates) are randomly selected from the training set, and then replaced to form an initial "bagged" training sample. On average, each tree is trained using two thirds of the dataset. The out-of-bag (OOB) samples are then used to evaluate the trees' efficacy. Additionally, each attribute is given a relative level of importance. To ascertain each feature's relevance, it is permuted across the observations made while the bag was empty. This treatment is applied to each tree, and changes in the prediction error are estimated. If there is a significant change in the new model's accuracy, it would be an indication that the feature is critical to the original model's accuracy. To obtain a normalized measure of the variable relevance, divide the ensemble average of this measure by the ensemble's overall standard deviation value (Das et al., 2017).

Using the consensus of every tree that has been constructed in the ensemble, categorization is finally finished. Overfitting of training data sets is a significant drawback of a single decision tree that can be mitigated with an ensemble approach. It performs better than the single tree approach and is less affected by noise in the data set (BREIMAN, 2001).

- K-Nearest Neighbor (KNN):

One of the machine learning models called K-Nearest Neighbor uses the most significant data mining techniques to handle classification problems and forecast the weather. The KNN approach assumes that comparable objects are present in close proximity. Stated differently, related things are next to each other, hence the suggested system was built and implemented using this principle. Visual Studio Workspace (Yousif, 2022).

Data mining is one of the most efficient methods for gathering and analyzing data, identifying relationships that boost predictability, and providing the most goals for knowledge development (Olaiya & Adeyemo, 2012). This method identifies new data points based on their distances from previously stored data after first storing all of the data (Madhuri et al., 2021).

According to (Gupta & Ghose, 2015) and (Olaiya & Adeyemo, 2012) The operating of K-NN classifier is as follows (Figure 34):

1. Value of K is initialized.

2. Compute the distance between input sample and coaching samples by the following equation (11):

$$dist\ ((x, y), (a, b)) = \sqrt{}\ (x\text{-}a)2 + (y\text{-}b)^2 \quad (11)$$

3. Sort the distances.

4. Take high K-nearest neighbors.

5. Apply easy majority.

6. Predict category labels with more neighbors for the provided data. (Gupta & Ghose, 2015). When new data is received, the KNN algorithm automatically assigns it to a category that is comparable to the previously saved information during the training phase.

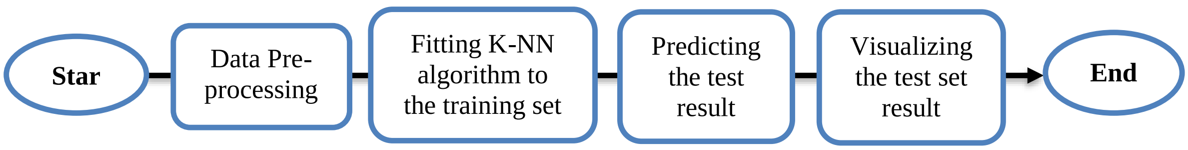


Figure 34 Plot of forecasting weather in Tebessa City to 2035 by Machine learning.

IV.3.2. Urban flood mapping (Min & Max water level in Wadis)

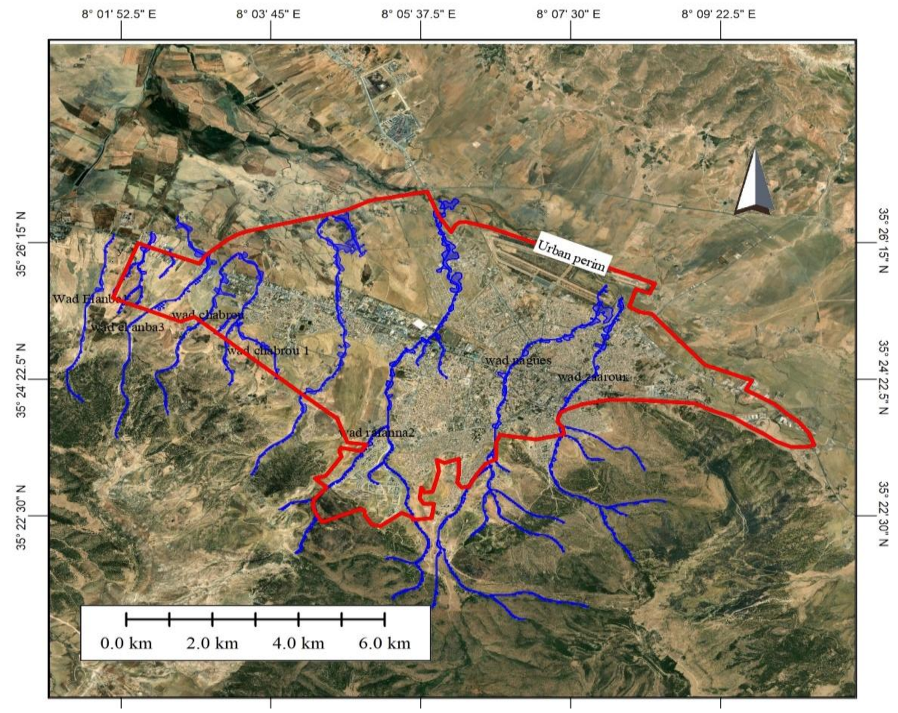


Figure 35 Urban flood mapping according to the minimum water level in Wadis of Tebessa City.

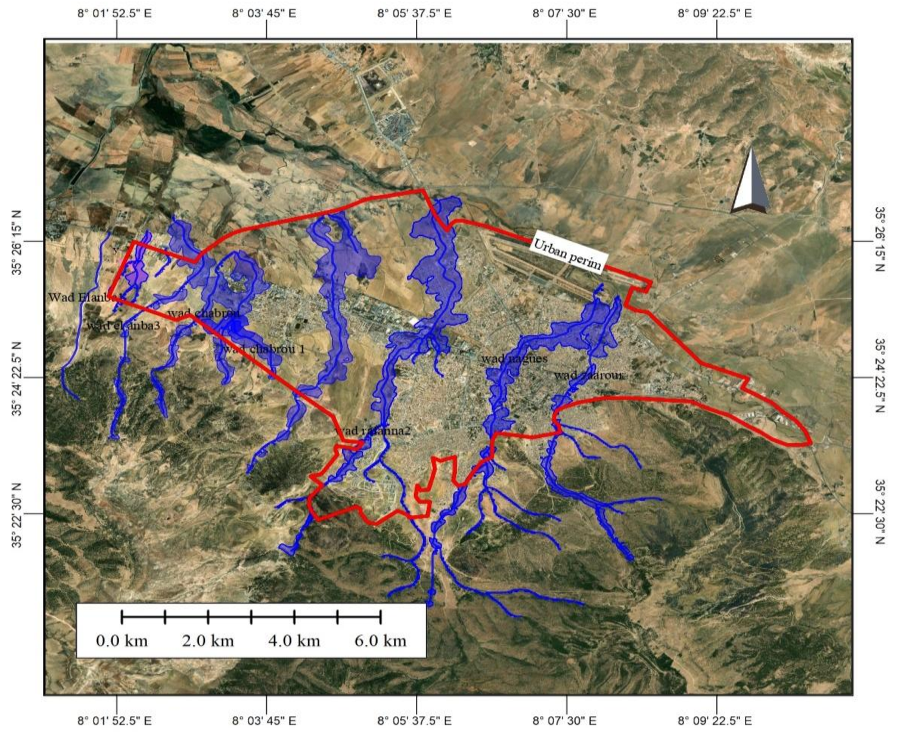


Figure 36 Urban flood mapping according to the maximum water level in Wadis of Tebessa City.

Our study has produced insightful information about how to forecast water levels using machine learning algorithms for the next twelve years. We provide two thorough maps that illustrate the projected maximum and minimum water levels. These maps, which were carefully created by using machine learning algorithms, provide Tebessa City with an idea of the issues it may face in the future with regard to urban floods. A visual depiction of these projections is given in Figure 35 and Figure 36, which makes it evident which regions are most susceptible to flooding.

These findings are important because they identify places that could flood because the city's Wadis, which crosses its boundaries, has higher water levels than other regions. The likelihood of vulnerability increases near these Wadis, highlighting the necessity of thoughtful urban development and flood risk reduction strategies. Tebessa's distinct geomorphological features and history of frequent flooding make these maps—which were created using Global Mapper—extremely useful for pinpointing susceptible areas and helping decision-makers with regard to urban planning and flood control (Figure 35 and Figure 36).

IV.3.3. Hydrographic network (Water level in Wadis)

- Accuracy assessment of the Models:

In order to anticipate water levels, different techniques for precipitation forecasting have been thoroughly reviewed in our paper. We have found clear disparities between the accuracy scores of three well-known machine learning models through comparison analysis. With a training AUC of 0.8632 and a testing AUC of 0.9875, the XGBoost model performed significantly better than the k-Nearest Neighbors model (training AUC=0.8126, testing AUC=0.8939) and Random Forest model (training AUC=0.8098, testing AUC=0.9292), as shown in Figure 37.

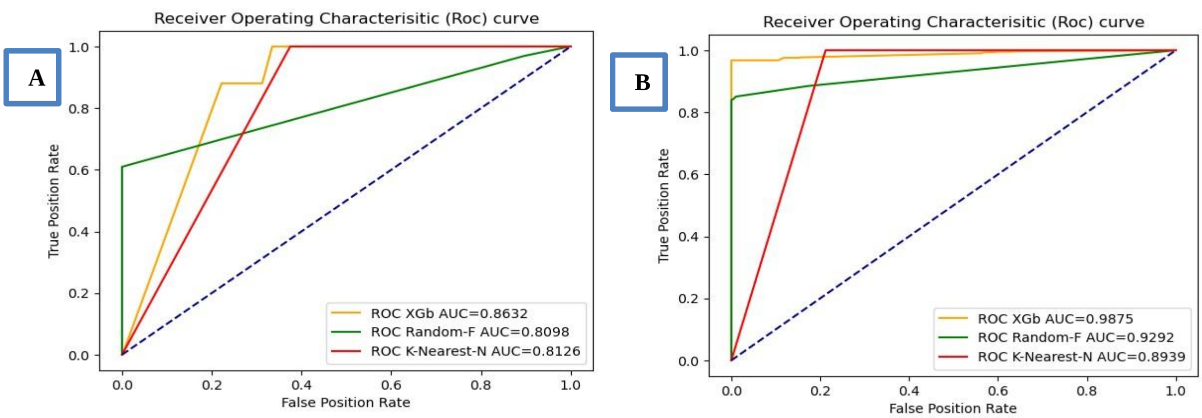


Figure 37 Accuracy assessment using ROC (AUC): (A) training and (B) testing.

The XGBoost model's effectiveness can be ascribed to its aptitude for learning from past patterns and its ability to identify nonlinear correlations within precipitation data. As a result, the final model has a great deal of potential for use in the study area's spatial planning. Its application can significantly reduce the risk of flooding, help with educated urban planning decision-making, and support efficient environmental management.

- <u>Urban Flood Modeling and Precipitation-Water Level Relationship:</u>

The results highlight the need of urban flood modeling, especially in areas such as Tebessa City where the interaction between water level forecast and precipitation estimation is critical. Urban areas have complex underlying characteristics. Variations in precipitation can cause surface overcharging because of increased water levels in the Wadis when the hydraulic network's (Wadis) capacity is insufficient. The accuracy and usefulness of our model in predicting urban floods is demonstrated by the tight alignment between its forecasts and real data (Figure 38).

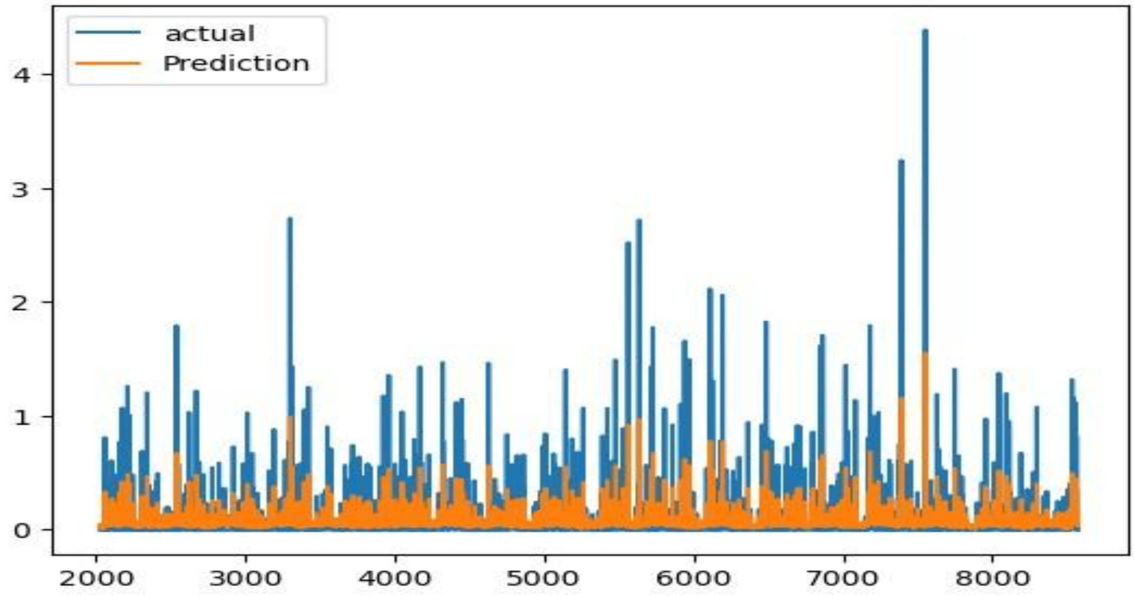


Figure 38 Prediction and actual precipitation in Tebessa City (2000- 2022).

- <u>Challenges in Large-Scale Urban Flood Modeling:</u>

The current reliance on local-scale models to depict the intricate interplay between surface water and stream flows is a major issue in modeling urban floods. The geographical variety and shallow surface water depths typical of urban catchments may not be sufficiently addressed by this technique. Faster and more accurate model algorithms that can handle large-scale modeling at high resolution are desperately needed to get around this restriction. Such developments are essential for improving preparedness and response plans and enabling real-time city-scale urban flood predictions.

- <u>Climate Patterns in Tebessa City</u>:

Interesting Tebessa City climate patterns have been revealed by our investigation. It is noteworthy that temperature and humidity have a negative association, indicating that higher temperatures are associated with lower humidity levels and vice versa (Figure 39). In addition, drought conditions result from a discernible decline in precipitation at the airport, particularly between 2010 and 2014, despite the high temperatures in the area (Figure 40). Understanding the city's susceptibility to floods and droughts, informing urban design, and improving water resource management techniques are all significantly impacted by these climate dynamics.

Furthermore, in the context of Tebessa City's urban flood modeling, our study clarifies the intricate interaction between climate parameters, precipitation estimation, and water level forecast. The findings and understandings gained from this study have important ramifications for the area's urban growth, mitigation of flood risk, and climate resilience.

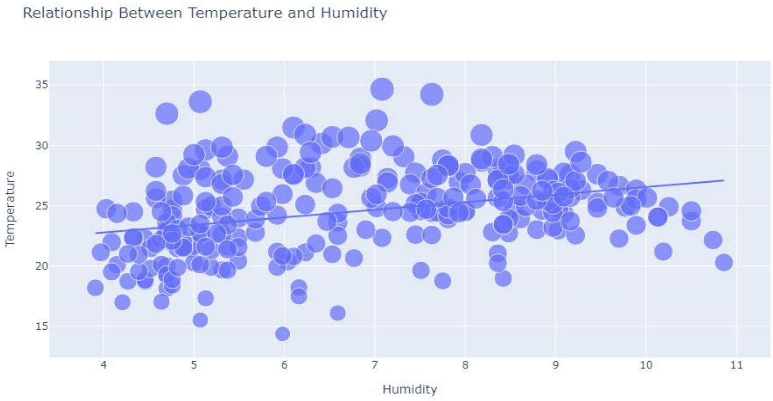


Figure 39 Relationship between temperature and humidity in Tebessa City (2000- 2022).

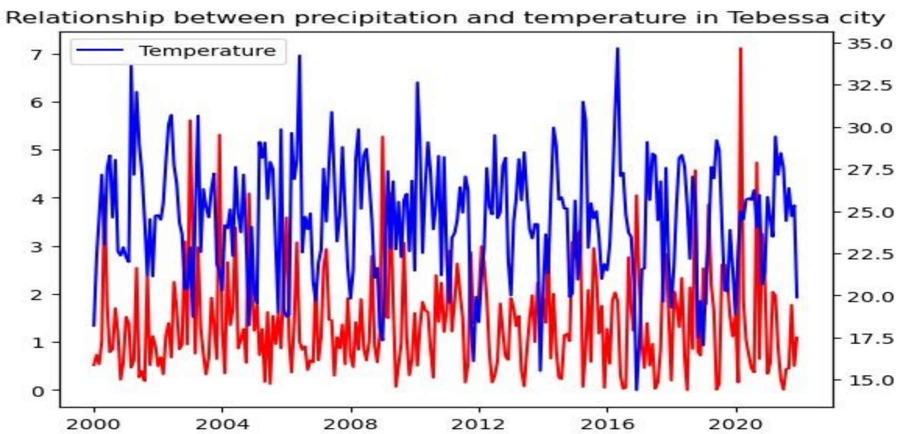


Figure 40 Relationship between precipitation and temperature in Tebessa City (2000- 2022).

- Analysis of flood maps:

According to the three prediction models, fluctuations in precipitation are a direct result of climate change, and these fluctuations in precipitation lead to variations in the water levels in Tebessa's Wadis. This result validates the claim made by the Water Resources Directorate that precipitation plays a major role in controlling urban floods and has a strong correlation with Wadis water level; Pradhan and Kim also mentioned that the slope has an adverse effect on the force of water flow both inside and outside the Wadis. (Pradhan & Kim, 2020), Locations close to the Wadis are consequently more susceptible than other places to the possibility of floods that bring them significant losses because it depends on the rise in the water level.

Interest in the topic of machine learning has increased recently; According to (Ahmed et al., 2022), The three models that were employed are trustworthy models for predicting changes in Wadis water levels, which is essential for improved planning to reduce any risk of flooding. The anticipated outcomes show the relationship between precipitation and water level but do not pinpoint the causes of floods. Nonetheless, these results may shed light on the frequency of floods.

Previous studies have shown that the Random Forest approach may properly depict the likely occurrence of forecasting geographical data and water level (Q. Feng et al., 2015b; Das et al., 2017; BREIMAN, 2001). Numerous research investigations on urban flooding have been carried out with the aid of the XGBoost algorithm (Pradhan & Kim, 2020; Chen & Guestrin, 2016; P. Li, 2010). It was found that the Boosted model performs better than the Random Forest model. Recently, K-Nearest Neighbor has become more and more popular among academics (Yousif, 2022; Olaiya & Adeyemo, 2012). Gupta and Ghose (Gupta & Ghose, 2015) state that the K-Nearest neighbor framework supposedly has higher or comparable prediction accuracy (Gupta & Ghose, 2015), and this study confirms earlier finding (Madhuri et al., 2021). Thus, K-Nearest Neighbor can offer more precise forecasts and assist us in comprehending how to handle urban flooding.

IV.4. Built environment

The methodology adopted involves digital image pre-processing and processing (Figure). It consists in comparing the maps of land use units from 1990, 2001, 2012 and 2023. The aim is to better distinguish and extract land use classes from Landsat images, using the Supervised Classification method. The process was carried out in five (05) stages:

i) Pre-processing of satellite images;

ii) Identification of land use units,

iii)Digital processing of Landsat images from 1990, 2001, 2012 and 2023;

iv) Execution and validation of supervised classification results using the maximum likelihood method; then

v) Quantification of change.

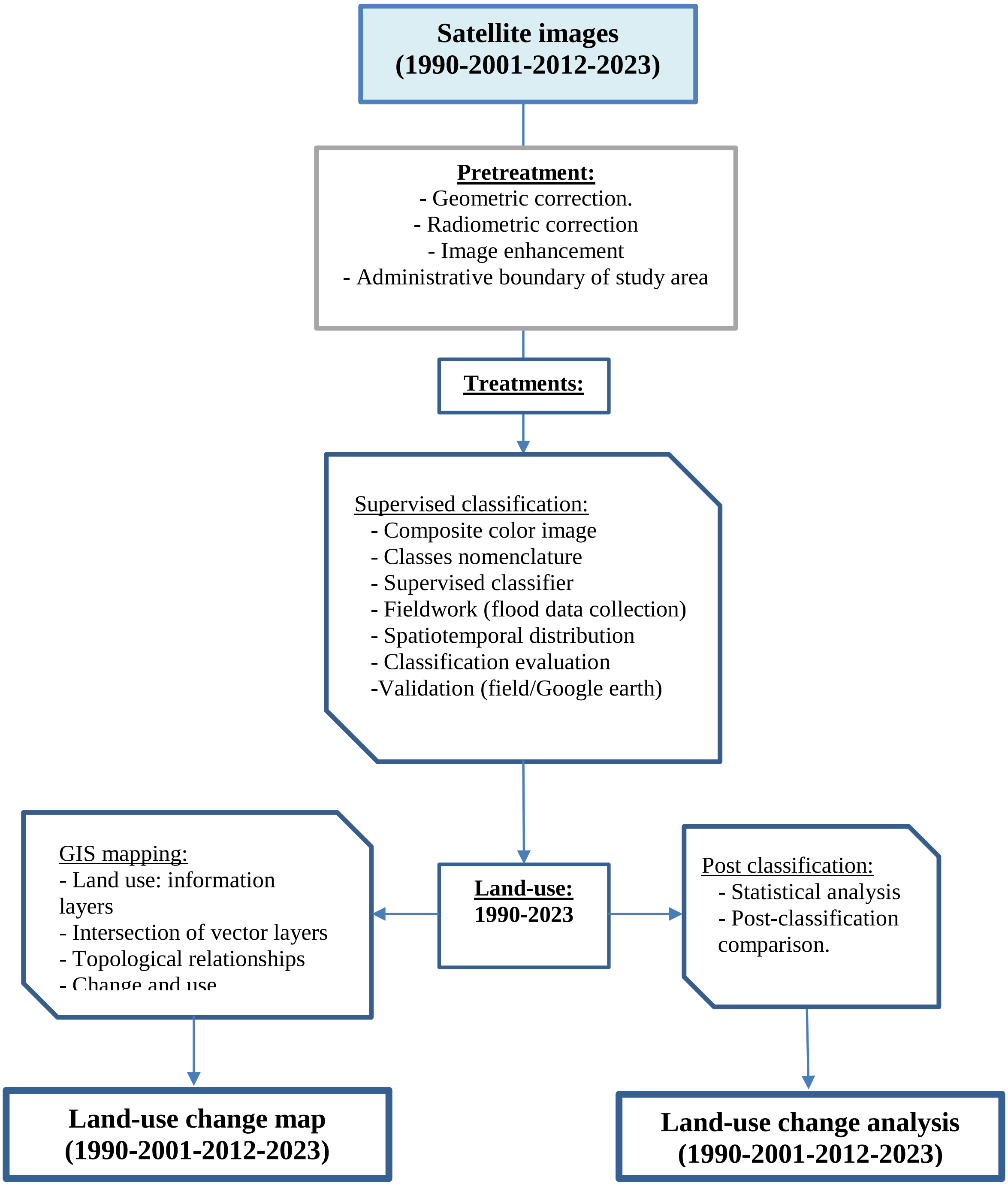


Figure 41 Methodological flowchart of spatial analysis.

IV.4.1. Satellite images

This study aims to highlight the spatial growth process in the city of Tebessa and its impact on the flood risks over the period 1990 to 2023. In this context; a sequential series of four Landsat multispectral images have been obtained by the United States Geological Survey (USGS). These images were taken in 1990, 2001, 2012, and 2023. According to similar phenological and atmospheric conditions (Lu & Weng, 2007); The technical characteristics of the images obtained are shown in Table 16.

Table 16 Characteristics of the Landsat images used.

Image	**Sensor**	**Date**	**Bands**	**Spatial resolution(m)**
Image 01	Landsat 4-5 TM C2 L1	29-03-1990	1-2-3-4-5-6-7	30
Image 02	Landsat 7 ETM + C2 L1	19-03-2001	1-2-3-4-5-6-7	30
Image 03	Landsat 7 ETM + C2 L1	13-01-2012	1-2-3-4-5-6-7-8-9-10-11	30
Image 04	Landsat 8-9 OLI/TIRS C2 L1	25-04-2023	1-2-3-4-5-6-7-8-9-10-11	30

Additional reference documents are also used. These include two urban development master plans from 1998 and 2012, as well as four satellite images (1990 - 2001 - 2012 - 2023) supplied by the USGS in natural color. The use of these historical images makes it possible to verify the areas located outside urban perimeters and not covered by urban development master plans. The satellite image processing chain (classification and post-classification) is carried out using ArcMap 10.8 software (Luca, 2021).

IV.4.1.1. Satellite images pretreatment

This pre-processing stage consists of homogenizing the differences due to atmospheric conditions and sensor positioning, which exist when images are taken or raw images recorded. Initially, the images acquired required geometric correction to facilitate their superposition. Georeferencing was applied image by image, using as reference the Landsat OLI/TIRS image, chosen for its quality.

The atmospheric correction performed in ENVI 5.3 software was carried out using the "Apply FLAACH Setting" tool. The "Radiometric Calibration" option in the same software was used to perform the radiometric correction. These operations (radiometric and atmospheric corrections) resulted in images with uniform, noise-free radiometric information.

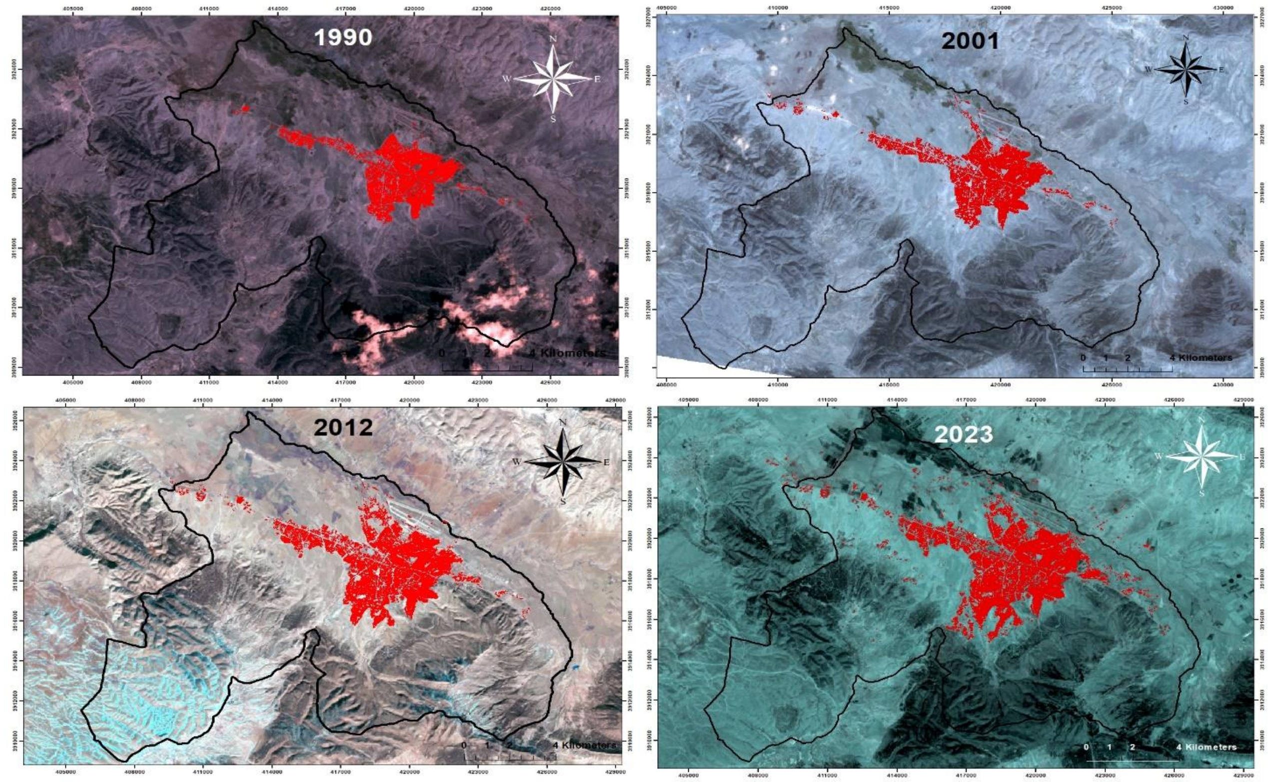


Figure 42 False color compositions of the images used (1990-2001-2012-2023).

IV.4.1.2. Identification of Land-use unit classes

An image's group of surfaces with similar spectral, morphological, and textural properties is called the landscape unit or image faces. The spectral signature of the surface is defined as the amount of reflected radiation as a function of wavelength. Different channels reflect water, bare soil, and habitats in different ways. The satellite images of Landsat TM, ETM, and OLI are identified by 6, 7, and 11 bands, in that order. Because of the variations in wavelengths, each band is able to record unique information. This information is inferred by a study based on the mixing of primary colors and the spectral signatures of the different features in the picture, and it is highlighted by the color composition. It generates a summary of data that can be utilized to distinguish between various land use kinds. Following testing of several color combinations, the near-infrared (PIR) red and blue bands (4-5-3) from the photos from 1990, 2001, 2012, and 2023 were selected because they exhibit the highest degree of land-use feature discrimination.

IV.4.1.3.Supervised pre-classification and selection of training sites

The choice of training sites is an operation that consists in delimiting parcels or portions representing all the land cover types obtained after the 4-5-3 and 5-7-4 color composition of

LANDSAT images. Indeed, according to studies (Usselmann, 1999) (Kouassi, 2014) Carine et al., 2021) the color composition of bands 4-5-3 and 5-7-4 offer the best discrimination of land cover types. Sites were chosen on the basis of their accessibility, and spectrally representative pixels were selected for each training site. Based on the polygons thus defined, automatic extraction of the pixel values contained within the polygons and calculation of their mean and standard deviation will produce the spectral signature of each class from the selected bands of the Landsat TM, ETM and OLI images.

IV.4.1.4. Supervised classification using the maximum likelihood method

Our good knowledge of the study area enabled us to opt for supervised classification. This involves applying the same treatment to each pixel, independently of neighboring pixels. The Maximum Likelihood algorithm was chosen for the classification of bands 4-5-3 TM and ETM+ bands 5-7-4 OLI of the color composition. According to (Thierry, 2010), this technique automatically generates classification rules based on learning. It is a supervised classification technique which, like any supervised method, requires reference samples (training plots) for each class, as well as a discriminant attribute space.

This method calculates the probability of a pixel belonging to a given class. The pixel is assigned to the class with the highest probability. However, if this probability does not reach the expected threshold, the pixel is classified as "unknown". Next, the quality of the classification obtained was assessed using the parameters calculated by the confusion matrix, namely overall accuracy and the Kappa coefficient (Usselmann, 1999). Also known as a contingency table, the confusion matrix is a table displaying the statistics of an image's classification accuracy, in particular the degree of misclassification among the various classes. It is calculated with values expressed in pixels and percentages. In addition, other synthetic measures of classification reliability can be calculated: accuracy for the user, accuracy for the producer, errors of omission and errors of commission (Congalton, 1991).

Post-processing:

After image classification, the confusion matrix was run to detect errors, separability between classes and accuracy.

Vectorization and mapping:

In order to facilitate management in the GIS analysis program, the raster land-use map is transformed into vector data. The methodological synthesis used in our case study to map land use units using remote sensing data produced in a GIS is shown in Figure .

Confusion matrix:

It can be used to highlight the various forms of conversion undergone by land-use units between two dates *t1* and *t2*, and to describe the changes that have taken place. It describes, in condensed form, the changes in state of the elements of a system during a given period (Bamba et al., 2008), whose cells contain the value of a variable having passed from an initial class x to a final class *y* during the period from *t1* to *t2*. In the present work, this matrix is obtained from the values derived from the overlay of land-use maps, in ArcGIS GIS software (thanks to the "Intersect polygons" algorithm of the Geoprocessing extension), and processed in Excel.

IV.4.2. Land use change maps

The maps below (Figure) show the results of supervised classification using the maximum likelihood method, of Landsat generation sensor images for 1990, 2001, 2012 and 2023.

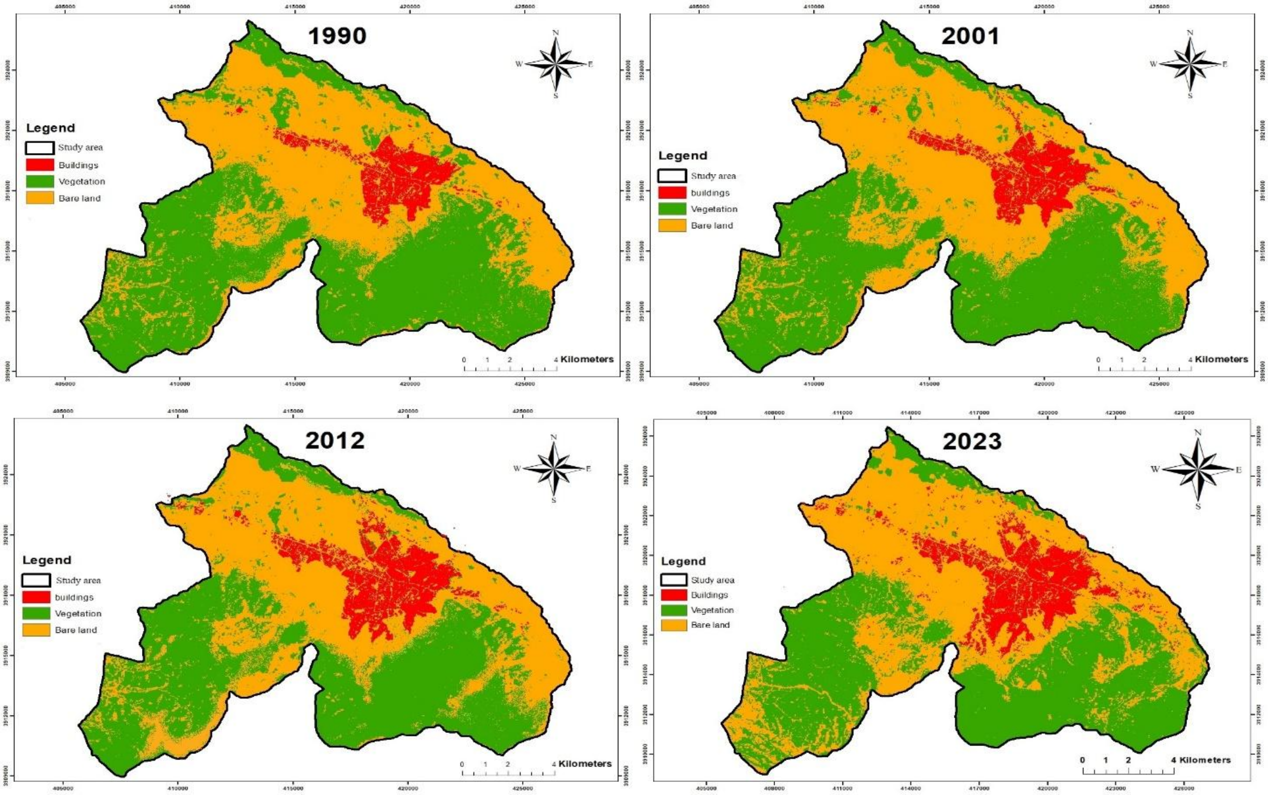


Figure 43 Land use change maps (1990 -2001-2012- 2023).

A first cartographic reading of the results illustrated in Figure reveals a clear growth in the building class against a significant regression in the bare land class. The growth of urbanized surfaces has followed practically all directions; this occurred during the period from 1990 to 2023. As a result, natural vegetation is declining considerably in favor of man-made formations.

This can generally be explained by the various pressures these formations constantly undergo.

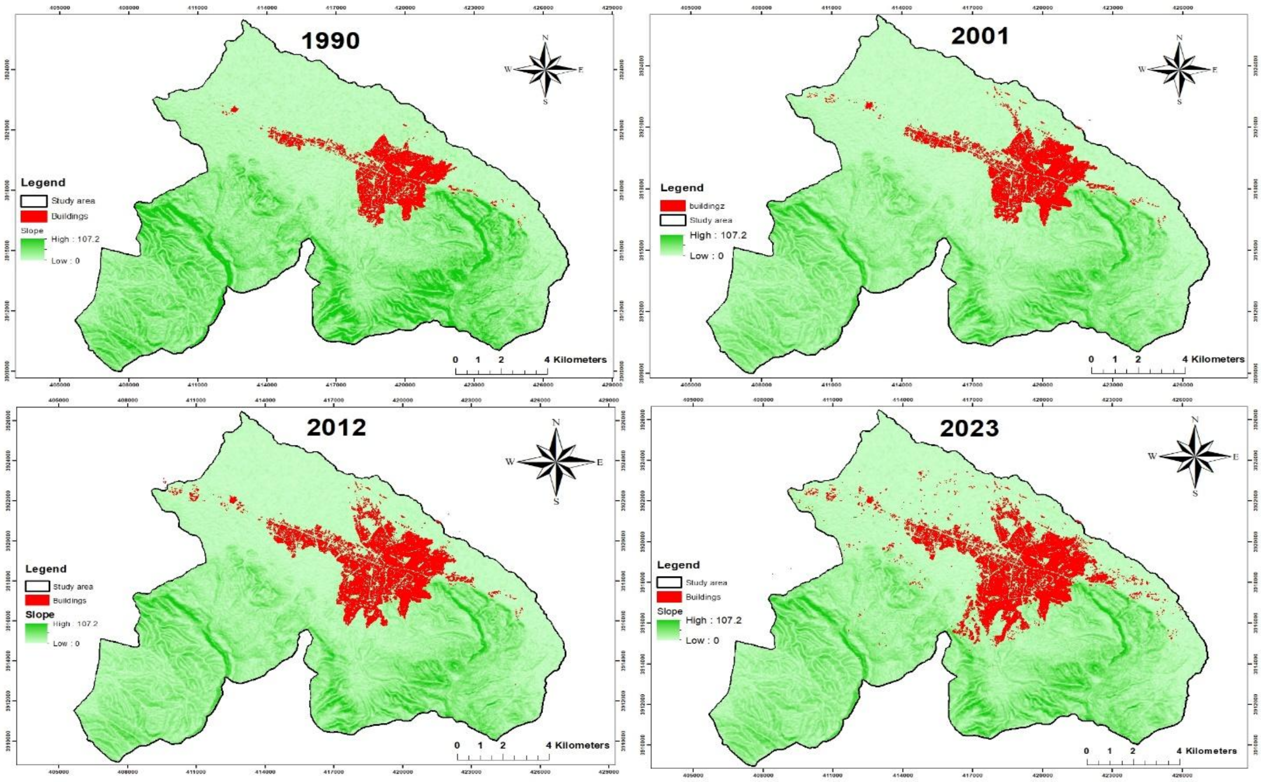


Figure 44 Spatiotemporal evolution of building class over the period (1990 - 2023).

Between 1990 and 2001; The urban fabric's spatial expansion followed a consistent trend. This geographical evolution was guided by two main directions (Figure and Figure): radio concentric around Tebessa's old down town (historic center), and linear westwards along the RN 10 and northwards along the RN 16.

Over the period 2001- 2012, the spatial growth of the urban area underwent several extensions, with a continuous pattern of development, particularly towards the south-west (hence the extension of the Skanska district and the 600 and Djbal-Anoual districts); towards the north-west (with the extension of the Fatma-Zohra district), and towards the north (the extension of the El-Djorf and El-Mizeb districts).

During the last period (2012 - 2023), urban expansion is mainly taking place away from the historic center, in the creation of new urban hubs (Land use plan N° 9A and Land use plan N°28) following the revision of the Tebessa-Hammamet-Elkouif-Bekkaria-Boulhafdyr Intercommunal Urban Development Master Plan (URBA-BA, 2018).

IV.4.3. The effect of urbanization on flooding

IV.4.3.1. Relationship between land use and flooding

To extract the class of areas exposed to floods or flooded area, urban planning instruments were used, especially the master plan for urban development of Tebessa city, as well as its land occupation plans (LUPs), along with the important past flood events recorded by the city's civil protection, and with the help of geographic information systems GIS. The following Figure shows a spatial distribution of floods and its number of events according to the urban perimeter of the study area.

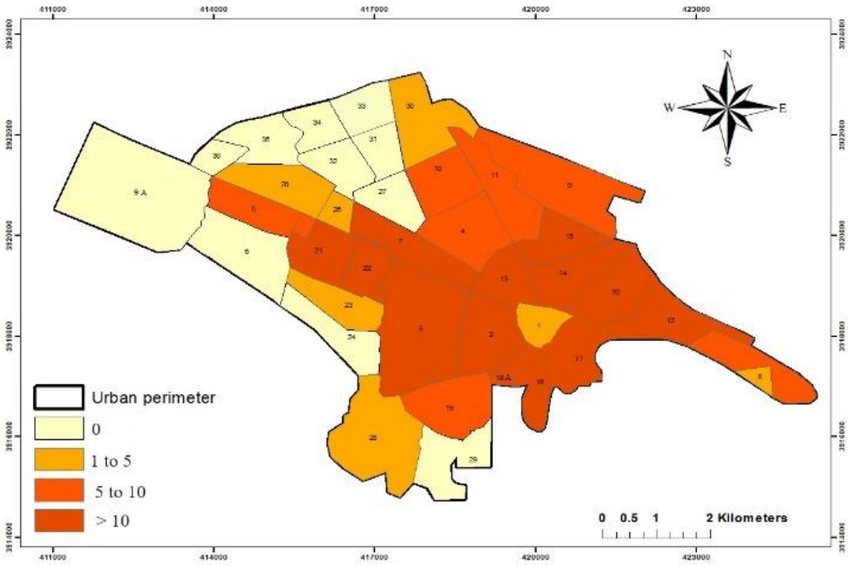


Figure 45 Spatial distribution of flooding in land use plans (LUPs) of the city of Tebessa over the period (1990-2023).

From 1990 to 2023, 29 of 39 Tebessa's LUPs were exposed to flooding, according to reports from the Civil Protection and Hydraulic Direction. 07 land-use plans experienced 1 to 5 floods, and 08 land-use plans were affected by more than 5 floods, 14 of which experienced 10 or more floods.

One of the main causes of the issue of frequent flooding in this area is the dense hydrographic network that the city's urban fabric is situated on, as seen in figure 06 (Talbi et al., 2023); Some events, such as those in August, September and October 2015, and May, August, September and October 2018 (Department of Sanitation and Environmental Protection, 2014), exhibited significant regional dispersal and severe flooding.

IV.4.3.2. Relationship between urban density and flooding

The maps below (Figure) illustrate the spatiotemporal distribution of floods from 1990 to 2023 based on the Tebessa urban development master plan's urban perimeter Land Use Plans.

The number of flooded LUPs rose from 10 over the period 1990-2001 (11 years) to 17 over the period 2001-2012 (11 years) and then to 20 after 2015 (03 years), while the total number of LUPs only almost tripled between 1990 (10) and 2023 (29).

Flooding in the 1990-2001 period was mainly concentrated in the historic city center and outlying districts (LUPs N° 01, 02, 03,12,13,14,15,16,18, and 17). The main flooded areas are largely made up of densely populated districts. Indeed, the central districts of the city, where flooding is long-standing but still frequent, such as LUPs N° 14, 15, 16 and 17, suffer from excessive urban densification, leading people to settle on Wads easements (water drainage).

Over the 2001-2012 period, With the emergence of new urban expansion in the city of Tebessa, the circle of areas exposed to flooding began to expand only gradually, and their number rose to 17 LUPs, such as LUPs N°04, 05,07,9, 11, 22, and 26.

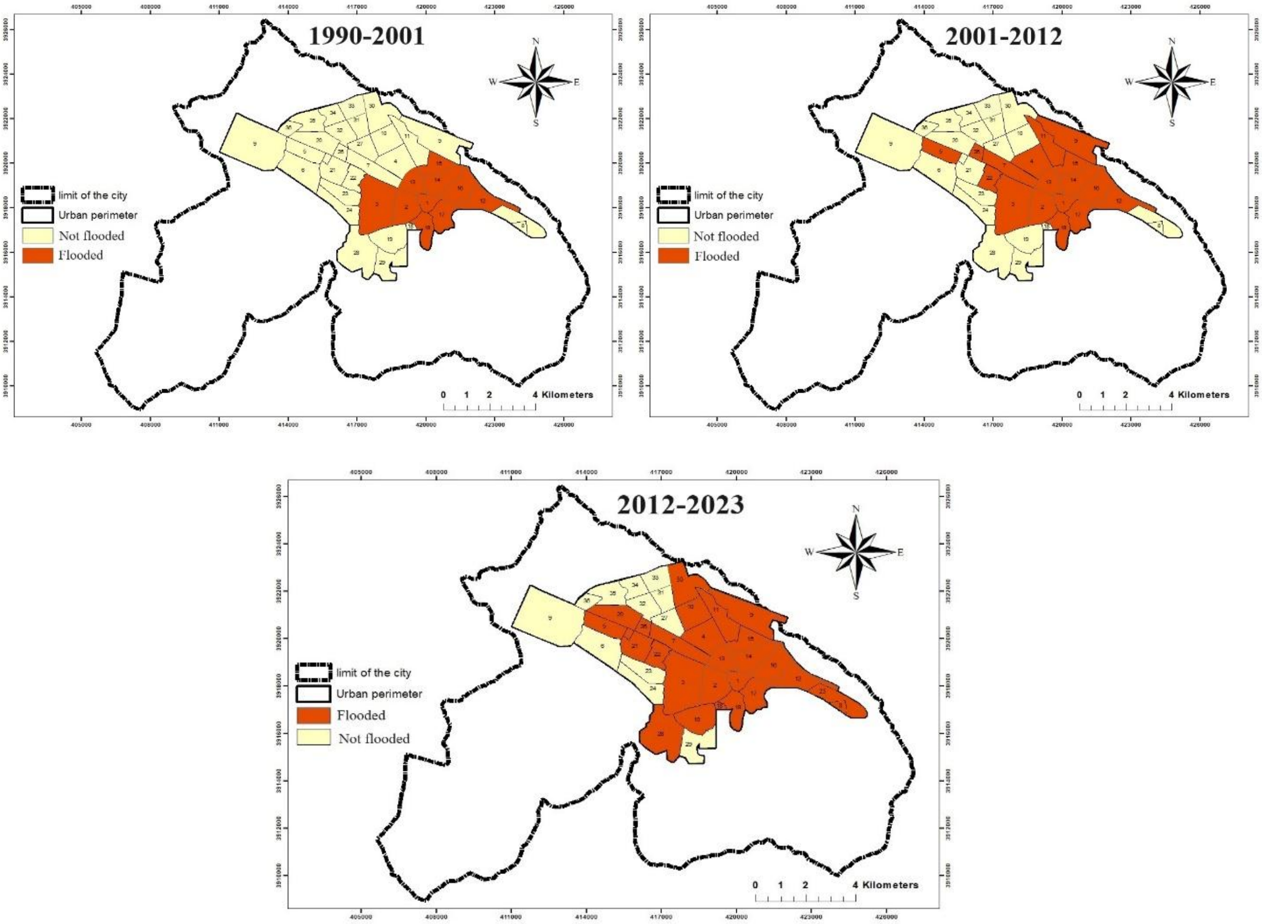


Figure 46 Spatiotemporal distribution of flooded LUPs in the city of Tebessa over different periods.

During the period 2012-2023, and according to the table 17; The urban perimeter of the city witnessed a noticeable expansion as its area increased to 4843.65 hectares (according to the revised Urban Development Master Plan (Table 17)). New ministerial housing programs such as AADL, LPL and LPA have been built on the new poles (LUP N°28 and LUP N° 9A). This further exacerbated the flood risk situation (Photos 17, 18, 19, 20), which expanded to include all of LUPs N° 08, 10, 18A, 19, 20, 21, 23, 28, and 30.

Table 17 Distribution of the urban perimeter of Tebessa city by sector (URBA-BA, 2018).

<table>
<tr><th>Designation</th><th>Zone</th><th colspan="2">Total area (ha)</th><th colspan="2">Easement area (ha)</th><th colspan="2">Net area (ha)</th></tr>
<tr><td>Urbanized area</td><td>U.A</td><td colspan="2">2629.41</td><td colspan="2">928.14</td><td colspan="2">/</td></tr>
<tr><td rowspan="5">Development area</td><td>D.A.1</td><td>578.16</td><td rowspan="5">1680.42</td><td>116.03</td><td rowspan="5">145.19</td><td>462.13</td><td rowspan="5">1086.56</td></tr>
<tr><td>D.A.2</td><td>148.51</td><td>0</td><td>148.51</td></tr>
<tr><td>D.A.3</td><td>390.24</td><td>0</td><td>390.24</td></tr>
<tr><td>D.A.4</td><td>297.39</td><td>40.18</td><td>257.21</td></tr>
<tr><td>D.A.5</td><td>266.12</td><td>13.94</td><td>252.18</td></tr>
<tr><td rowspan="2">Future urbanization area</td><td>F.U.A.1</td><td colspan="2">434.91</td><td colspan="2">38</td><td colspan="2">396.91</td></tr>
<tr><td>F.U.A.2</td><td colspan="2">98.89</td><td colspan="2">33</td><td colspan="2">65.89</td></tr>
<tr><td>Non-developable area</td><td>N.D.A</td><td colspan="6">1973.07</td></tr>
<tr><td>Urban perimeter area</td><td colspan="7">4843.65</td></tr>
</table>

Photos 17, 18, 19, 20: Examples of some of the areas affected by flooding in Tebessa city (Water Ressources Departement, 2018).

IV.4.3.3. Statistical analysis of land use change: Quantifying change

Following classification, multiple buffer rings are made for every 1 km stretch outward from Tebessa city's core, ranging from 1 to 16 km. The multi-buffer ring method's primary goal is to identify temporal and spatial correlations.

To give a better idea of the changes that have occurred over the period 1990 to 2023, the rates of change for the various land-use units calculated are summarized in Table 18 and figure 46.

- From 1990 to 2001: There was an increase in the classes Urbanized area, and Flooded area respectively in the order of 0.85%; and 20.10%, and a regression in the Bare land -22.27%.
- From 2001 to 2012: There was an increase in the classes Urbanized area, and Flooded area respectively in the order of 4.83%; and 13.36%, and a regression in the Bare land -9.28%.
- From 2012 to 2023: There was an increase in the classes Urbanized area, and Flooded area respectively in the order of 1.80%; and 5.92%, and a regression in the Bare land -10.50%.

Table 18 Surface evolution of land use classes (1990- 2023).

Classes	**Area (ha)**				**Annual change (%)**			
	1990	**2001**	**2012**	**2023**	**1990-2001**	**2001-2012**	**2012-2023**	**1990-2023**
Urbanized area	321.14	362.51	596.84	684.32	0.85	4.83	1.80	7.49
Flooded area	1383.81	2357.61	3004.96	3292	20.10	13.36	5.92	39.39
Bare land	2657.24	1578.36	1128.51	619.82	-22.27	-9.28	-10.50	-42.06

Figure shows that bare land took the lead with a surface area of 2657.24 hectares in 1990, while flood-prone areas followed with a surface area of 1383.81 hectares. As for urbanized areas only, their surface area was small, estimated at 321.14 hectares. On the other hand; in 2001, the flooded area and urbanized area reached 2357.61 hectares, and 362.51 hectares respectively, but the bare land decreased to 1578.36 hectares, the same thing in 2012, the flooded area and urbanized area reached 3004.96 hectares and 596.84 hectares respectively, however, the bare land reduced to 1128.51 hectares; Finally, in 2023 the flooded area reached the highest level during the study period, as its area reached 3292 hectares, as for the urbanized area and bare land are almost close, at 684.32 hectares and 619.82 hectares respectively.

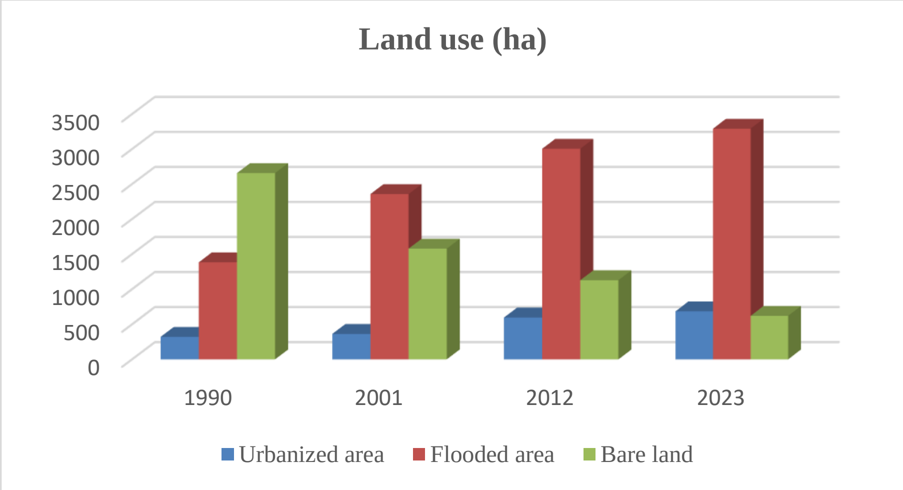


Figure 47 Evolution of urbanized areas, flooded areas and bare land (1990 - 2023).

Figure shows the relationship between urban area and flood area in 1990, 2001, 2012 and 2023. It appeared that the greater the urban expansion in the study area, the greater the area of areas exposed to the risk of flooding. This is confirmed by the reality and statistics recorded by both the Directorate of Civil Protection and the Directorate of Reconstruction, Architecture and Construction. Whenever the urban fabric of the city expands through urban planning tools, there is a noticeable increase in the number of civil protection interventions as well as the number of human and material losses when floods occur.

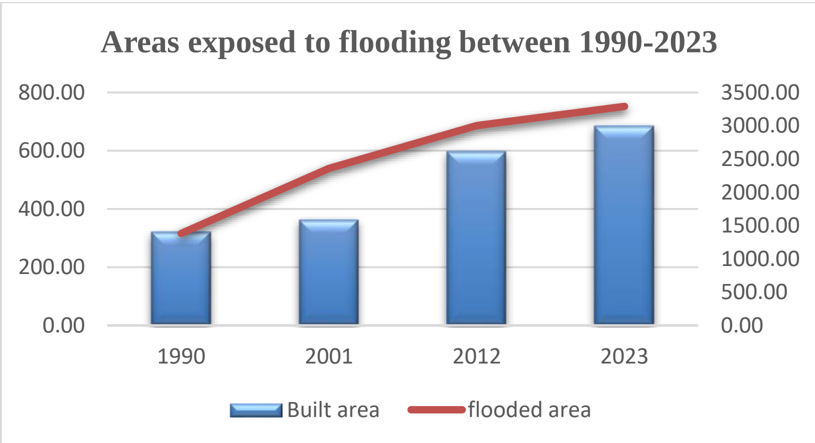


Figure 48 Surface areas exposed to flooding at each study period.

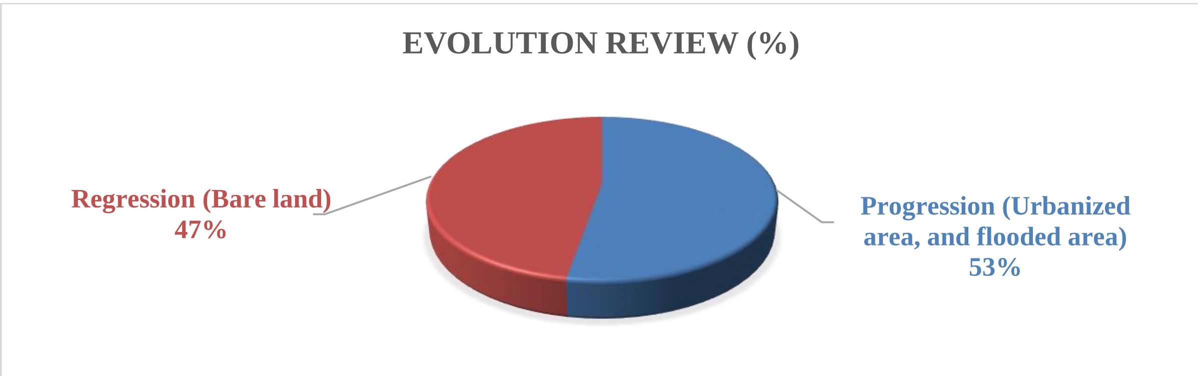


Figure 49 Evolution of land use units (1990 - 2023).

Analysis of Figure reveals that the orders of progression and regression are very pronounced, bare land has declined by 47% over its surface area, while buildings and flooded areas have increased by 53%. Generally speaking, the surface area of buildings is constantly increasing, which reveals the importance of paying attention to the seriousness of the situation to be controlled by the decision-makers.

IV.4.4. Land use change analysis

The processing and analysis of multispectral images, combined with field observation data, have shown that the decline in bare land between 1990 and 2023 is essentially linked to anthropogenic pressures, following increasingly pressing demands for land for building construction. The present study identifies two main groups of factors that can be considered as the causes of the increase in areas exposed to flooding: demographic factors and the expansion of urban space to the detriment of bare land, as well as the total absence of vegetation within the city's urban perimeter and other factors (hydrographic factors, environmental predispositions).

The overall accuracy obtained in the supervised classification of the present study is 94.59% for the classification of 1990 images, 91.89% for 2001, 97.29% for 2012 and 89.18% for 2023. The Kappa coefficient obtained for 1990 images is 0.92; 0.88 for 2001 images; 0.95 for 2012 images and 0.84 for 2023 images. Furthermore, (COPPIN, P et al., 2004) confirms that the results of an image analysis with a Kappa value greater than 0.50 are good and usable. The present classification, with three (3) classes, is acceptable and enables us to assess the trend in land cover changes over a 33-year period.

With regard to the results of land use dynamics from 1990 to 2023, the progressive evolution of the Urbanized area and flooded area classes respectively of the order of 7.49% and 39.39% of the surface area of the study area, and the regressive evolution of the bare land surface area of -42.06%. In fact, demographic growth, the expansion of urbanized area (buildings) and the uncontrolled use of land reserves such as empty pockets, which are often transformed and channeled into investments, have all contributed to this trend.

The significant transformation of bare land into urbanized land, or land earmarked for future urbanization, highlights a significant increase in the amount of land exposed to flooding between 1990 and 2023, and also demonstrates that these developments are contributing to an increase in the risk of flooding within the city. In fact, housing has been built randomly in correlation with the demographic growth of the area. As a result, some buildings have been built above the watercourses (hydrographic network), leading to flooding during the rainy season. As shown in photos 21, 22, 23, and 24, it presents the random buildings that were built on Wads easements, and the photos 25, 26, and 27 shows the implementation of demolition instructions by the Directorate of Reconstruction, Architecture and Building of Tebessa

Photos 21, 22, 23, 24: Unlicensed buildings built along Wads in Tebessa city.

Source: Directorate of Reconstruction, Architecture and Building of Tebessa, 2023.

Photos 25, 26, 27: After implementing the demolition decision.

Source: Directorate of Reconstruction, Architecture and Building of Tebessa, 2023.

IV.4.5. Spatiotemporal distribution of flooding LUPs

The present study of land use dynamics in the city of Tebessa, using supervised classification with the maximum likelihood method, has shown the evolution of the various land use units in the study area from 1990 to 2023. The use of Landsat TM, ETM and OLI images and GIS enabled us to draw up land-use maps, analyze the evolution of land-use units and quantify the change between 1990-2001, 2001-2012 and 2012-2023.

The use of the supervised classification method enabled us to extract the most important land-use units in this study with excellent agreement, i.e. an overall accuracy equal to 94.59%, 91.89%, 97.29% and 89.18% respectively in 1990; 2002; 2012 and 2023, and a Kappa coefficient equal to 0.92; 0.88; 0.95 and 0.84 respectively in 1990, 2002, 2012 and 2023; Statistical analysis of land-use maps obtained from 1990 to 2023 shows an increase in the surface areas of urbanized area classes and areas exposed to flooding of 7.49% and 39.39% respectively, and a decrease in the surface areas of bare land classes of -42.06%.

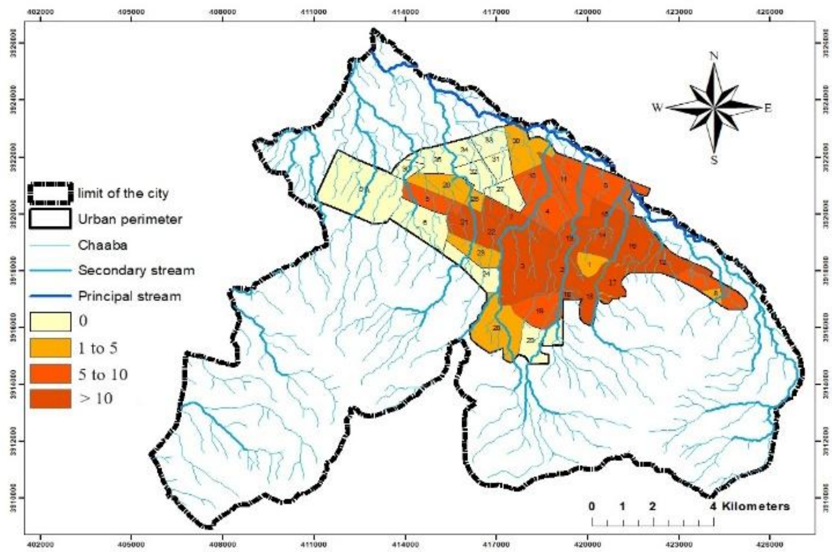


Figure 50 Spatiotemporal distribution of flooding LUPs of the city of Tebessa over the period (1990-2023).

The outcome clearly demonstrates how developed areas are gradually replacing bare countryside (Figure) As a result, over the complete urban perimeter of Tebessa, the areas vulnerable to floods have significantly increased. Lack of vegetation, particularly around the city's urban periphery, makes this region more vulnerable to floods since vegetation (trees, green areas) slows the flow of water. In actuality, vegetation increases water infiltration, which reduces runoff. The more porous soils may therefore hold more water in their pores, functioning as a kind of sponge to varying degrees depending on the soil's saturation level. Additionally, it lowers the amount, concentration, and rate of water drainage. Moreover, vegetation strengthens the mechanical qualities of the soil by binding the soil together through its root systems. Soil erosion results from high rainfall-induced runoff. This erosion can be subtle or dramatic, forming deep ravines.

In light of the changing urban fabric due to population growth and the need to consider the morphology and configuration of the site (the dense hydrographic network that currently exists) as well as the passage of time, policies pertaining to the construction of drainage infrastructures, urbanization, and the placement of buildings in accordance with their level must be developed immediately.

IV.5. Conclusion

Natural disasters occur all over the world and have a catastrophic influence on everyone since they have such a big impact on people's lives and the environments they live in. Although we cannot stop natural disasters from occurring because they are generated by nature, we can prepare for them by understanding their effects and analyzing their influencing factors to develop disaster recovery recommendations in advance. By linking all the factors influencing the flooding phenomenon that the current study concluded on the city of Tebessa, the built-up land use and proximity to the Wadis located within the urban area 'urban perimeter' of the city are the main conditioning factors for flood sensitivity and are also closely related to natural factors such as precipitation, elevation, slope, distance from Wadis, curvature…Etc.

Decision-makers and hazard managers can reduce damage and increase resistance to flood threats by using flood susceptibility maps. Unchecked urbanization and human activity, however, have the potential to change the hydrology of watersheds and increase the danger of flooding. Tebessa City has problems including clogged sewage systems and Wadi blockage owing to urban growth. Tebessa City faces flood threats even with moderate rainfall.

The results of the study indicate that:

- Planned or unplanned, urban land growth has the potential to significantly change the hydrology of watersheds. Some of the Wadis in Tebessa City have become solid waste-filled sewers. As a result, even during brief periods of precipitation, this city is susceptible to flooding. However, it is also important to note that human intervention and the urban footprint are two of the most important factors influencing flood research, and they are inextricably linked to other influencing factors.

- Emphasizes how crucial precise precipitation estimation is for managing water supplies, ensuring public safety, and protecting the environment. Even though precipitation estimation is essential, it is prone to errors because of regional and geographic differences, which makes it an important field for research and development.
- In the case of Tebessa, the right to the easement of Wadis within the city was determined to be between five (05) and eleven (11) meters in accordance with Article 13 of Law N° 05-12 mentioned above, the local authority represented by the Water Resources Directorate, based on the statements of experts working there. And this essentially validates our findings, which we arrived at in the map that includes Figures 7 and 8. According to Article N° 31 of Law 17-83 and Article N° 12 From Law N° 12-05, which also expressly forbids any new construction, cultivation, the erection of any fixed fence, or any work that would impair the upkeep of Wadis within the areas subject to the right of buoyancy easement, no new building may be constructed or elevated within the easement-affected areas.
- The results highlight how open space is gradually being replaced by urbanized regions, and how flood-prone areas have been spreading within Tebessa's metropolitan boundaries. This pattern is a reflection of the growing contact between hydrological processes and urban growth, which is made worse by the lack of vegetation inside city limits. Vegetation loss reduces the effectiveness of natural flood mitigation systems to reduce flood hazards and increases the susceptibility of urban populations to inundation events.
- In order to reduce the danger of flooding and improve urban resilience, the study emphasizes the critical necessity for proactive land management techniques and focused interventions. Creating a thorough drainage system, incorporating green areas and vegetated corridors into urban designing frameworks, and implementing sustainable land use practices to reduce impermeable surfaces and encourage natural infiltration processes are some of the main recommendations.
- Furthermore, in order to direct future urban growth in a way that emphasizes sustainability and resilience while preserving natural ecosystems and hydrological functions, effective rules and regulations are needed. In order to promote communal ownership of flood risk management efforts and adaptive governance frameworks

that adapt to changing circumstances, community participation and stakeholder collaboration are essential.

In summary, the study's findings offer important new understandings of the intricate interactions that exist between Tebessa's urbanization, land use patterns, climate change, and flood risk. In order to ensure the safety and well-being of current and future generations in Tebessa and beyond, policymakers should address these interconnected concerns through comprehensive and inclusive approaches that promote more resilient and sustainable urban development pathways.

Chapter V

Flooding assessment through urban design

V.1. Introduction

During recent years in Algerian cities; One of the primary causes of the damage is the existence of urban networks in flood zones; during the 1990s, people were moving away from mountainous areas for safety reasons, which resulted in a significant urbanization of the cities' periphery without necessarily considering the areas susceptible to flooding. These were not the best years to apply the rules and laws correctly. In addition, the State is compelled to construct social housing near large cities for a population that will actually be more susceptible to floods due to population expansion, security concerns, and employment opportunities (Puchol-Salort, O'Keeffe, van Reeuwijk, et al., 2021).

Urban sprawl has led to deforestation of the land, limiting the potential attenuating power of forests on floods and sediment transport while increasing the level of soil sealing, one of the main sources of the urban storm-water runoff problem (United Nations, 2021). As a result, flooding is a common problem in our cities, having caused significant losses in terms of both human lives and material goods. And among the issues that made the flood scenario worse are: The absence of crisis management and preventive tools; The implementation of development without first conducting high-quality research; Inadequate hydraulic work design, inadequate or nonexistent sewage networks, the issue of maintaining watercourses, insufficient financial resources, issues pertaining to basin conservation, Insufficient cooperation among concerned parties; and lenient implementation of rules (Puchol-Salort, O'Keeffe, van Reeuwijk, et al., 2021).

TEBESSA, one of the Algerian cities, is particularly affected by this issue during periods of significant rainfall. While certain safeguards have been put in place, we believe they are insufficient (Department of Sanitation and Environmental Protection, 2014).

The following measures have been implemented to safeguard the institution from the floods that are threatening the city on its western side: ditch accomplished the diversion dike and canal, The construction of the *El Djorf* Canal, the 300 ml Trapezoidal Canal, the *Wad Zaarour* Canal, the *Wad Rafana* Canal, etc (Water Ressources Departement, 2018).

Unfortunately, despite all of these efforts, the Civil Protection Directorate's record of flood damage was not lessened. This is because, over the past few decades, there has been a notable increase in the frequency of intense rainfall, which has led to flood damage. As a result, this city has risen to the top among Algerian cities in terms of the amount of material and human losses caused by floods at the national level.

In the many urban resilience literatures, resilience is commonly described as a system's ability to withstand a significant shock and continue or quickly return to regular operation (Leichenko, 2011b).

Urban resilience is becoming a popular notion among academics and urban planners as a way to address the many complicated issues that cities face (Wardekker et al., 2020). Because resilience may be applied to a wide range of urban risks and concerns, it has garnered interest in urban studies, including urban planning and emergency management (O'Hare & White, 2013); Moreover, "vulnerability reduction" is a significantly less desirable policy framework than "strengthening resilience." (McEvoy et al., 2013).

It is difficult to translate resilience from a theoretical scientific notion into a workable solution. Research on resilience is scattered across several academic subjects, and its meaning shifts over time and across disciplines (Leichenko, 2011b). Nevertheless, resilience is often employed as a catch-all term for future-proofing, without a clear explanation of what resilience actually entails or how specific interventions or system elements may boost it (Leichenko, 2011a).

However, having just been conceived about 20 years ago, the concept of resilience is relatively new to the field of urban architecture and planning (Sharifi, 2016). Since the year 2000, resilience has gained increasing attention in the field of urban planning and architecture. This is because cities all throughout the world are seeing a growing amount of negative impacts from a wide variety of risks (Sharifi & Yamagata, 2018).

The lessons learned from this example may be applied to help Tebessa City's ad hoc measures against flood catastrophes remain intentional, implicit, and explicit, or they can be utilized to translate local resilience. On the other hand, determining robust indicators is a contentious issue as there isn't currently agreement on a definition, which contributes to the difficulty of evaluating flood resistance. Resilience in the flood domain is constantly influenced by the interaction of people (e.g., economic status, health, and past experiences) and the physical environment (e.g., buildings, flood protection level, material selection of flood barriers). This is partially because of this. These signals may be indicated by a number of criteria, including flood characteristics. Others, such as the consequences of floods, are difficult to assess and carry a large degree of uncertainty. The majority of frameworks used to quantify flood resilience focus on the relationship between floods' likelihood and (direct) consequences. Flooding (damage) models are used to assess the possibility, impact, and effectiveness of management strategies (Jongman et al., 2012).

Resilience is becoming a central concept in scientific and political debates on cities. The importance of this has been emphasized in UN publications pertaining to cities. Under the newly adopted New Urban Agenda (UN-HABITAT, 2020), a wide range of stakeholders at different scales commit to creating policies, programs, strategies, and actions for increasing urban resilience. In line with the Sendai Framework for Disaster Risk Reduction 2015–2030, cities must develop strategies to strengthen their resilience. SDG 9 of the UN Sustainable Development Goals (SDGs) focuses on building resilient infrastructure to support sustainable development (United Nations, 2015b) in the Sendai Framework for Disaster Risk Reduction 2015–2030.

Based on the results of the flood analysis in Tebessa city, especially the flood susceptibility map, and land use change maps using remote sensing and GIS to analyze urban expansion and its impact on urban flooding, which in turn showed that new urban expansion, including new urban poles, that are the focus of the study problem, contributed to the exacerbation of flood risks and amplified the vulnerability of urban populations to flood events. This calls for the urgent need for proactive land management strategies and targeted interventions to mitigate flood risks and enhance urban resilience. Therefore, a part of the urban perimeter of Tebessa city called Land Use Plan N° 9A "New Urban Pole" was identified to improve and assess its urban resilience through urban design against flood risks, considering that it has recently been the focus of decision-makers, as more than 5 000 housing units of various types have been programmed in this area, while its urban design was prepared by experts and designers in the field of urban planning, but it still suffers from floods according to what was recently recorded by local administrations, and this was also confirmed by the results of the flood analysis in this study; which showed that this area in particular is among the areas most exposed to floods according to its morphological and geological features. The improvement and assessment of the urban resilience of the area were based on exploiting the results of previous research such as estimating the precipitation rate as an input to predict the water level using ML algorithms to simulate urban floods in Wadis within the city, and was used as data in the "Rhino+ Grasshopper" program to determine the current watershed areas. And the future directly helped in attempts to enhance the design of the chosen urban fabric to address the risk of floods and thus assess its resilience and discover the important urban features in improving its resilience through the three parameters (buildings, streets, plots). This is what will be discussed in more detail in this chapter.

V.2. The urban design framework

The method consists of 5 distinct steps (Fig. 51), any new urban design must start by determining the baseline conditions of the development, or the pre-development scenario which forms a necessary first step. And depending on the sort of redevelopment , certain information may be needed , including studies of the site's ecology, the current urban design ,hydrology , and land use…etc (Jabareen, 2006). Urban design is a compositional hierarchy, involving different spatial elements combined to form larger elements in a part-whole relationship. The buildings and associated open areas form plots, and a series of plots can be accessed by streets, and these parameters are interspersed with a set of characteristics that control their design, in a multi-level structure that is “logically infinitely extensible.” (Kropf, 2009; Feliciotti et al., 2018). The different morphological parameters are linked to the five characteristics of modularity, redundancy, diversity, efficiency, and connection (Forgaci & Timmeren, 2014).

Once these new integrated design solutions are combined and used to update the baseline, a new urban design is created by designing scenarios that will attempt to help reduce the risk of flooding in Step 2; The designs are entered into the chosen simulation tools, where these designs are modeled according to the data specified by the previously mentioned parameters, and then simulated using Rhinoceros + Grasshopper as a flexible and extensible system that allows continuous improvement during its application to actual case studies, which gives urban flood results on the design presented in step 3.

During the urban flood results analysis phase in Step 4, the impact of the proposed change to the land layout or existing structures on the flood behavior is considered. After examining the current flood behavior of the site in great detail, the computer flood model can then be updated to include the proposed actions, and determine the flood behavior under the “suggested” conditions (scenarios) (Fedczyna, 2024); The flood impact is also assessed at this step, by visualizing the urban design using Rhinoceros + Grasshopper with the help of a set of urban resilience parameters and characteristics to measure the degree of flood impact on each scenario, comparing flood behavior and impact in the existing and proposed cases, and determining the extent and location of any changes resulting from the proposed works (Fedczyna, 2024).

In case the results indicate the proposed design is suitable or reduces flood damage to the site for a particular characteristic, this may be the final stage of the flood risk design process for that characteristic, to be included in the most efficient design group and move on to another urban design that represents the next characteristic.

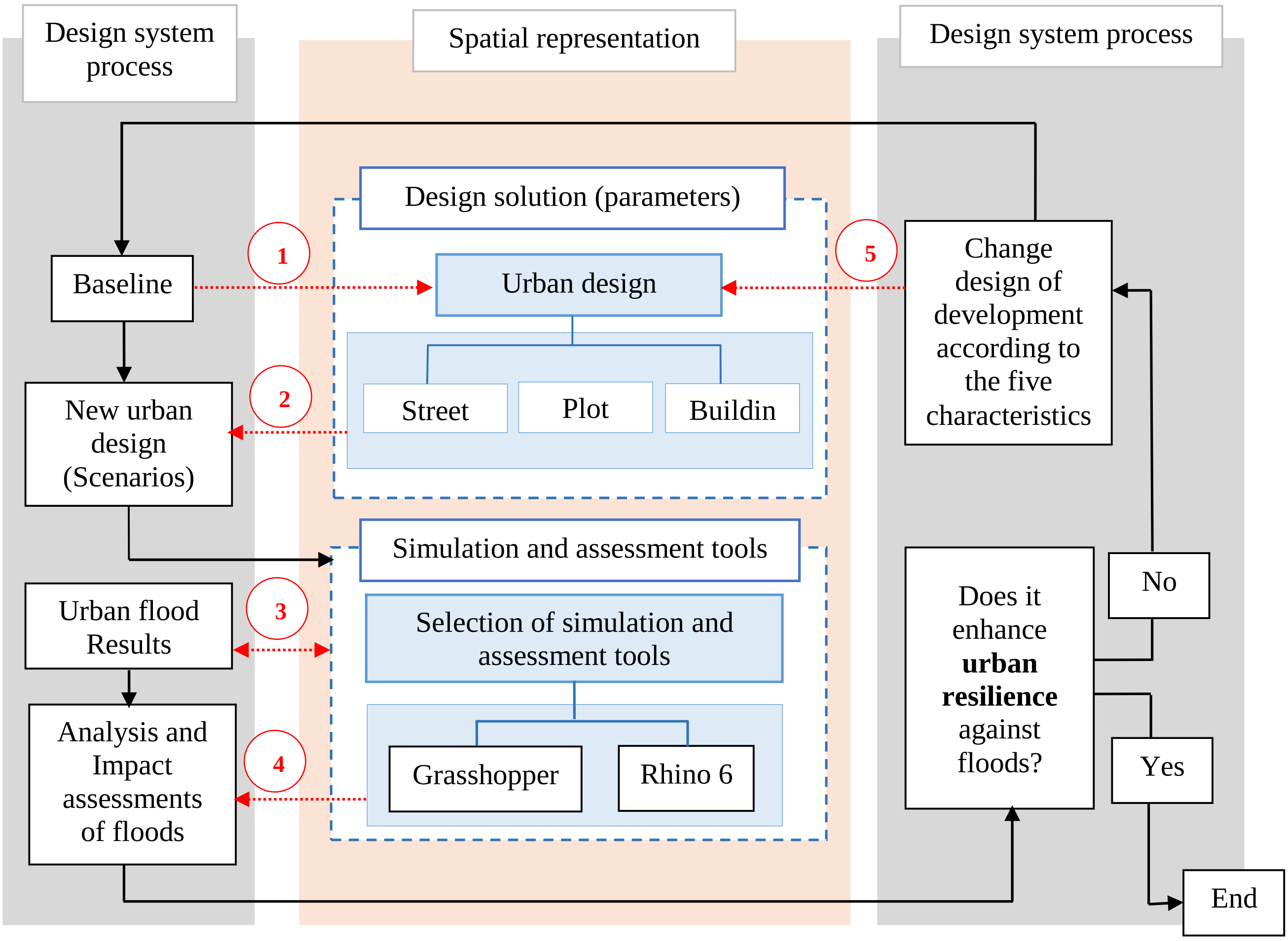


Figure 51 General diagram of the process. The author, 2024

However, if the results indicate that the proposed design is not suitable, or not suitable enough, the process continues to find a different solution using a one-variable-at-time OVAT method, by modifying the design again based on the observations of the parameters and according to the five characteristics (return to step 2) trying to avoid the negative impact of the design on the surrounding area or property in step 5 by finding a suitable design for it. The iterative process of the Rhino 6 + Grasshopper application also provides a unified sequence that takes the user from an initial baseline scenario to a resilient urban design plan, incorporating the requirements of governance and regulatory bodies, as well as the requirements of end users, especially residents. However, if a suitable urban design is found that reduces flood damage within the study area, it is selected from the top 5 scenarios to be completed for analysis and quantitative assessment and testing of different design options, which can then be compared to the baseline and resilience measures, in order to deduce general rules and guidelines that should be taken to improve urban resilience.

V.3. Study area for urban design

V.3.1. Description of study area

V.3.1.1. Situation

In this part of research, the experiment applied on a part of the city of Tebessa namely 'POS 09A or LUP N° 9A'which occupies an estimated area of 270.88 hectares; It is among the areas most prone to flooding as we mentioned above, as well as for being among the new urban poles on which the city has been expanded despite its hydrography characteristics that this area suffers from; And also in order to realize the principle of urban resilience of this part of the city through the urban design as a tool for optimizing this notion against flood disasters. (Fig. 52).

Therefore, this part of the city was chosen because it is characterized by:

- -The Wadis and ravines in their upstream part cut into the relief over considerable depths.
- -The vegetation on the site is weak due to the very difficult climatic conditions.
- -The limits of the intervention perimeter are linked to natural and artificial constraints, (The natural limits are characterized by an important wad which is *Wad Rafana* and the current alluvial grounds of *Wad Nagues* and *Kebir* (or *Wad Kebir*). The artificial are essentially the two electric transmission lines (high voltage) and the industrial zone.

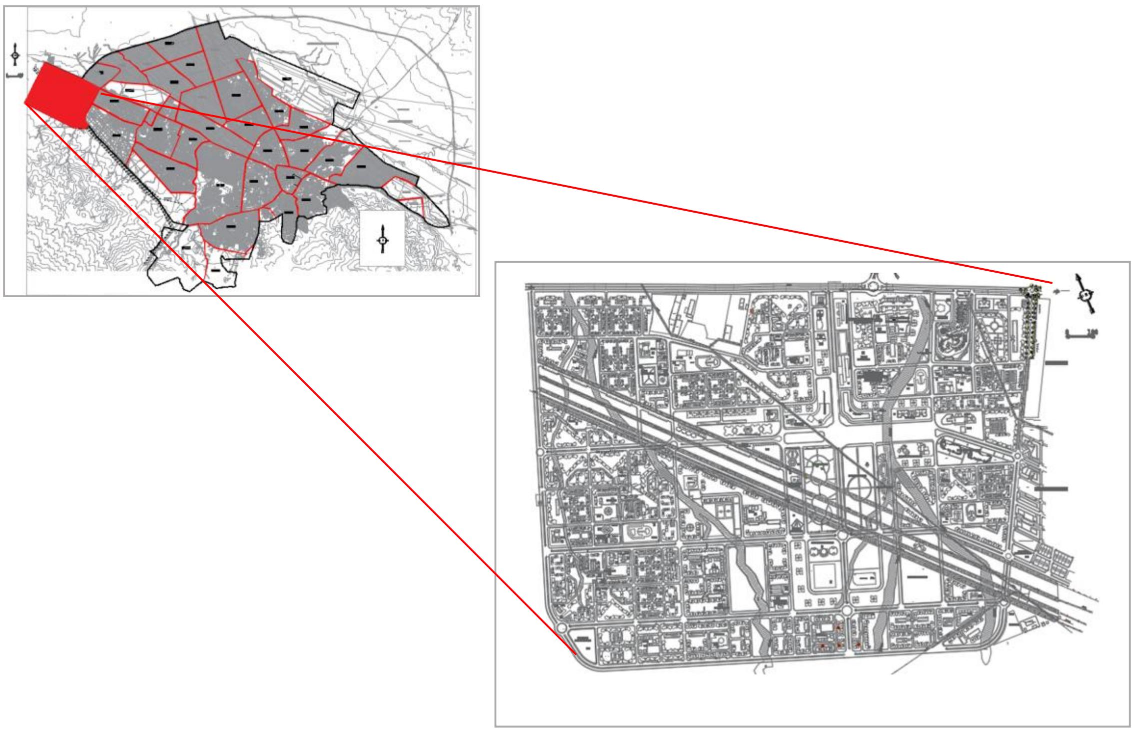


Figure 52 Situation of the Land use plan N° 9A according to the Urban development master plan of Tebessa city, (URBA-CO, 2013).

V.3.1.1. Hydrography

According to the report of Land use plan N° 9A (URBA-CO, 2013), *wad El Kebir* which drains the plain of *MERDJA*, receives numerous tributaries which flow down from the surrounding watersheds. These watercourses are temporary and are no other than torrents. Their regime is aggressive: These are the wadis: *Zaarour, Nargues, Rafana, Sergui* and *Chabro*.

Let us note that it is the wad CHABRO which is used as an outlet for all these wadis and to which we attribute the name of watershed (Fig. 53).

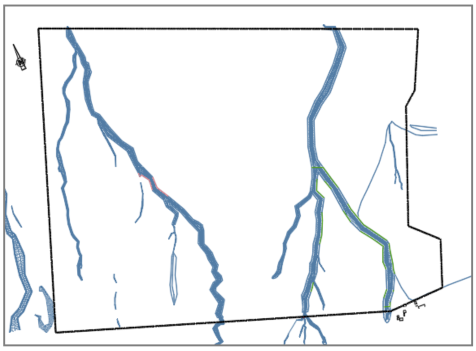


Figure 53 Hydrography of the Land use plan N° 9A (URBA-CO, 2013).

V.3.1.1. Topography

The topographic survey is the basic tool to reproduce the existing physical state, it allows to have the image of the terrain, its morphology, its slopes, its natural and / or urbanistic constraints. A first analysis of the topographic survey reveals that the study area is located on a regular terrain with a slope lower or equal to 5%.

A few plots of land appear in some places with slopes reaching 15%.

They are isolated, integrated into the surrounding terrain and developed (URBA-CO, 2013) (Fig. 54).

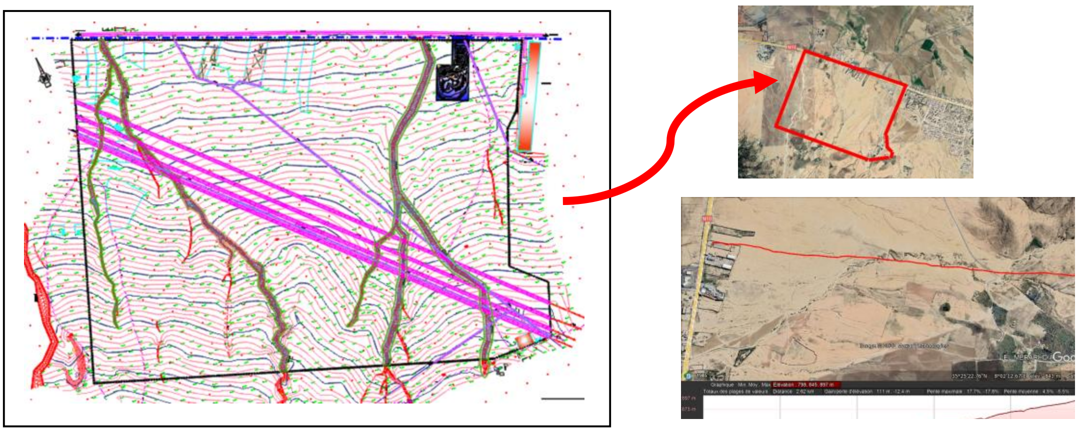


Figure 54 The contour lines of Land use plan N° 9A

Source: The Direction of urbanism, architecture, and construction of the wilaya of Tebessa, 2018 (URBA-CO, 2013) and Google earth pro,2024**.**

V.3.1.1. Relation precipitation-temperature

According to the Umbrothermal diagram the dry period is from the end of May to the end of October (4 months).

The delimitation of this period is very useful for the knowledge of the period of water deficit and the delimitation of this period is very useful for the knowledge of the water deficit period and therefore for the forecasting of the water needs for irrigation (Fig. 55).

In the link between temperature and precipitation indicates that, even in the face of high temperatures, there has been a decline in precipitation, particularly between 2010 and 2014, which has resulted in drought at that time (Talbi et al., 2023).

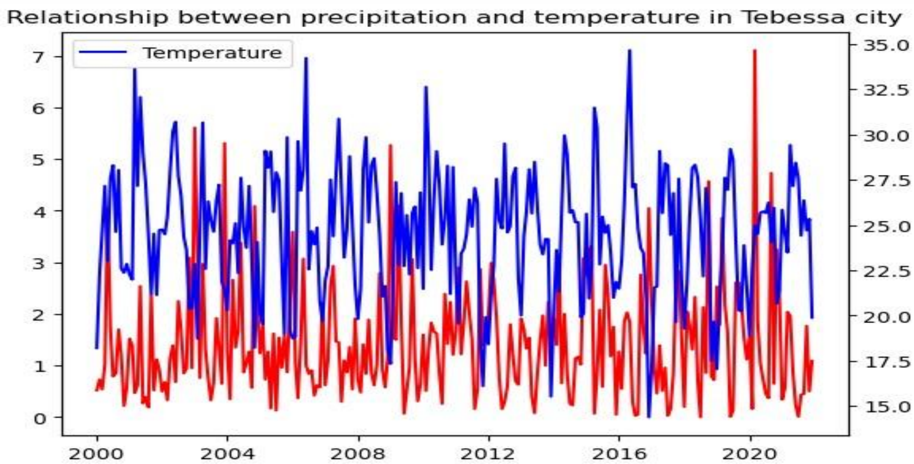


Figure 55 Relation precipitation-temperature (Talbi et al., 2023).

V.3.1.1. Relation Precipitation-Water level

The map below shows areas at risk of flooding due to Wadis' high water level, which spans the city's urban border. These zones are more sensitive since the chance of susceptibility increases with the proximity to the Wadis. Because of Tebessa's unique geomorphology, frequent flooding, and the extent of damage documented over the last several decades, maps derived from Global Mapper Fig. 65 can be utilized to identify the city's susceptible zones (Talbi et al., 2023).

According to previous research (Talbi et al., 2023), the catchment areas were extracted from “Urban flood maps according to the maximum water level in the Wadis of the city of Tebessa” (Fig. 56) in which the water level rise in the Wadis was modeled based on the rainfall rate over the coming years, as these areas were included in the Grasshopper program as data for the locations of the catchment areas, which in turn helped in simulating the study area for the next stage.

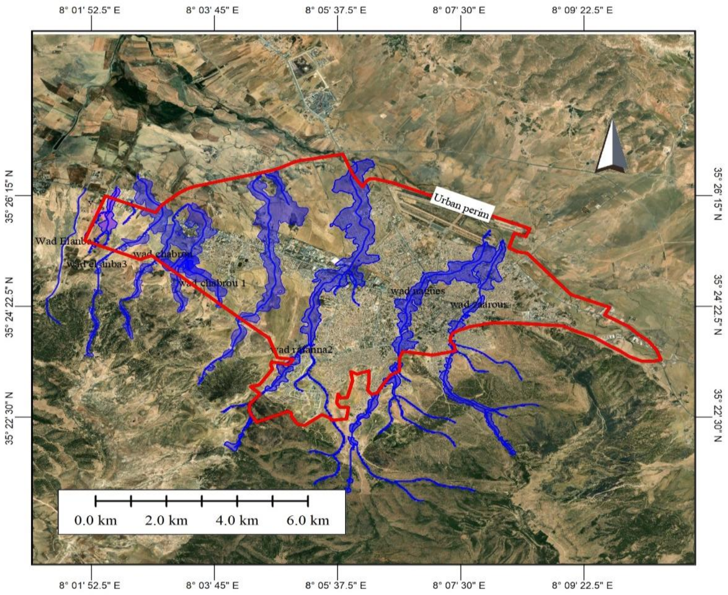


Figure 56 Urban flood mapping according to the maximum water level in Wadis of Tebessa City (Talbi et al., 2023).

V.4. Urban design parameters

Achieving urban resilience is a major challenge to flood risk that determines the ability to adapt to change and innovate at various scale parameters.

Many urban design parameters, such as building form, street layout, open space configuration, land use distribution, and transit infrastructure …etc, may be required to accomplish this. Thus, urban form in urban morphology has historically been regarded as a collection of morphological components, dating back to the early literature of the German and Italian schools (Kropf, 2009). Particularly, the tripartite subdivision of townscape elements proposed by Conzen (Conzen, 1960) in town plans (with streets, plots, and building-plans), building form, and land utilization, as well as the Caniggia and Maffei (Caniggia , Maffer, 1979) classification of streets, plots, and buildings, became widely accepted and applied in urban morphology (Alessandra, 2018) (Fig. 57).

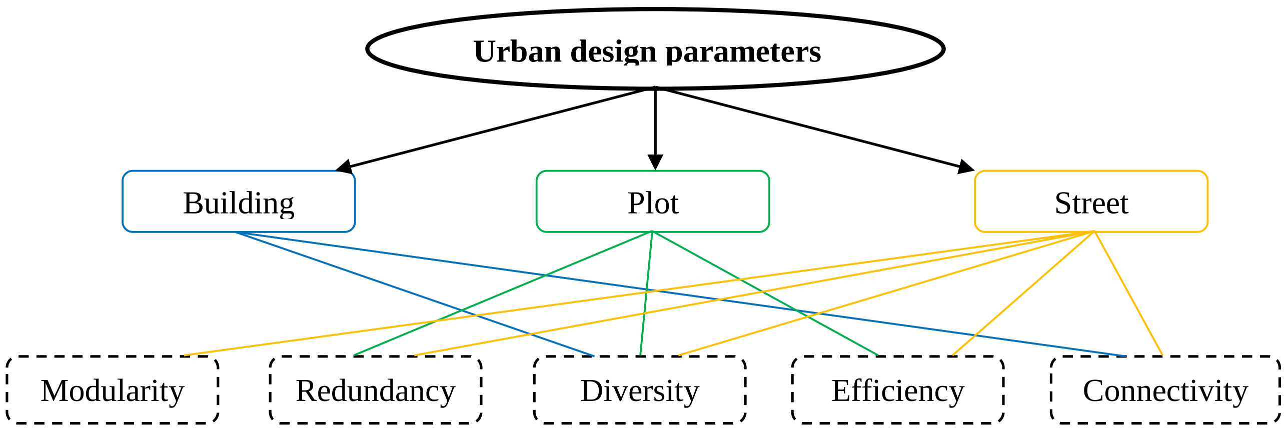


Figure 57 Correlation of urban design characteristics with urban resilience parameters (Mangalkar & Sonar, 2021a).

In urban design analysis, these classification schemes are frequently taken for granted (Dibble et al., 2019). To address the five distinct elements offered in connection to urban form, however, it should be taken into consideration that precisely identifying certain morphological components is part of the duty of the current study (Alessandra, 2018).

The different morphological parameters are linked to the five characteristics of modularity, redundancy, variety, efficiency, and connection (Forgaci & Timmeren, 2014). These assets directly affect each of the four resilience functions, recovery, adaptability and transformability of urban design; Therefore, based on the corpus of knowledge in the domains of urban morphology, sustainability science, network science, and urban geography, as well as previously published literature, it was determined to focus emphasis on a small number of metrics for each feature (Alessandra, 2018) (Table 19).

Table 19 Parameters for resilience and their respective characteristics of urban design (Alessandra, 2018; Mangalkar & Sonar, 2021).

Characteristics/ Parameters		Building	Plot	Street
Modularity	Urban Design	/	/	- Street - Granularity
	Design guidance			- Street should be divided into several tiny plots that are each under the separate administration of various agents.
Redundancy	Urban Design	/	- Redundancy index	- Local meshedness
	Design guidance		- Expand the range of destinations and travel options that city residents can choose from to reach their desired locations.	- The majority of redundant street networks have a form more akin to a linked grid than a rigidly hierarchical tree-like structure.
Diversity	Urban Design	- Building size	- Accessible plot - Density, Plot-size heterogeneity	- Street-edge - Interface matrix;
	Design guidance	- Building sizes should be maintained modest from the beginning of the design process, but a few	- Plot sizes have to be maintained modest, and there ought to be a multitude of entry points from open areas. A certain	- In places where a greater number of public uses—rather than only residential ones—are anticipated, direct

		bigger blocks should also be taken into consideration to add more spatial variation.	amount of variance in plot size should be permitted to ensure that applications with unique space requirements may also be accommodated or throughout time.	and active street margins should be given preference. Although the connection between the two impermeable boundaries should be minimized and regularly interrupted, areas where privacy is more important should be further shielded from the public realm—ideally situated in back alleys or service lanes.
Efficiency	Urban Design	/	- Plot-size - Distribution	- Street – length distribution
	Design guidance		- Plot-wise, an effective urban form is defined by a fine-grained pattern of plots in a wide range of sizes, with a long tail of tiny plots offset by a limited number of large ones.	- An efficient network at the street level is defined by a large number of regular, direct links and fewer longer-range connections.
Connectivity	Urban Design	- Building section; building size - Building face Length; - Compactness;	/	- Topological connectivity - Metric connectivity - Street connectivity
	Design guidance	- Buildings that are compact, dispersed, and non-obstructive should be used to improve permeability between various areas of a site. - When obstructive blocks are present, they should be minimized and, if existent, their fronts should be broken apart.		- There should be many four-way stops and few, if any, cul-de-sacs in places where there is a greater need for seclusion. - Intersections should be spaced apart as little as possible.

These criteria were taken into account when formulating scenarios to evaluate their responses accordingly. The scenarios have been formulated in a way that helps in understanding the users' perception of the built environment in relation to these parameters.

The assessment will help in understanding the conditions of the built environment in terms of- diversity, redundancy, modularity, efficiency, and connectivity.

The study area was evaluated using a number of parameters that were specified in previous studies. The information was collected through the study of the land use plan completed by the Center for Studies and Applications in Urban Planning URBA-CO and approved by the Directorate of Development, Architecture and Construction of the Wilaya of Tebessa. Through a review of the literature, each indicator type was further linked to the pertinent urban design and urban resilience parameter, which are listed beneath each completed scenario (Table 20).

Table 20 The different scenarios of urban design and their requirement (Alessandra, 2018; Mangalkar & Sonar, 2021).

Scenarios	**Parameters**		
	Building	**Plot**	**Street**
Modularity Scenario			- Limit the occurrence of massive street composed of a single plot to extremely rare cases, especially if the margins are lengthy and continuous. - Establish guidelines for the most consecutive plots that a developer may combine or build on a given street. - Establish guidelines for plot division and aggregation following development.
Redundancy Scenario		- Require that there be several ways to go from one location to another for the majority of plots, especially those that correspond to significant urban services of public importance.	- Demand that the street network's design avoids having mobility concentrated in a small number of routes, as in a rigidly hierarchical

		- Establish guidelines that encourage the redundant supply of public interest services by various users.	network, or that, in the case of networks that already exist, more routes be provided.
Diversity Scenario	- Determine suitable block-size ranges and establish guidelines for the proportional proportions of each range within the development as a whole, taking into account the nearby regions as well.	- Determine the permitted ranges for plot sizes with respect to the roadway they front. - Determine a limited number of unique or exceptional plots that can break the norm in order to satisfy certain use cases.	- Assign allowed building alignment ranges that are suitable with the overall character of the region and reflect the kind of roadway for each plot. - Control the position and/or maximum continuous length of unbuilt or impervious street.
Efficiency Scenario		- Make sure your design has an effective distribution of plot sizes, with many small ones set aside for common buildings and a small number of huge, pepper-potted plots allocated to more notable structures and specialized uses.	- Make sure the site's and the area's street network is designed with a few big thoroughfares connecting to the larger metropolitan and regional environment, a number of urban main streets connecting neighborhoods and districts, and an abundance of narrow local streets.
Connectivity Scenario	- Establish guidelines for the proportionate proportions of each range in the overall development, taking into account average values observed in the nearby areas. Define acceptable ranges for block-compactness, section, and face-length ranges.		- Demand that any alteration to the roadway system result in a quantifiable improvement in the amount of time or distance traveled to get to current destinations. - Restrict the number of cul-de-sacs to designated locations and, even in this situation, make it possible for one-ways to become three-ways or more.

V.5. Baseline scenarios

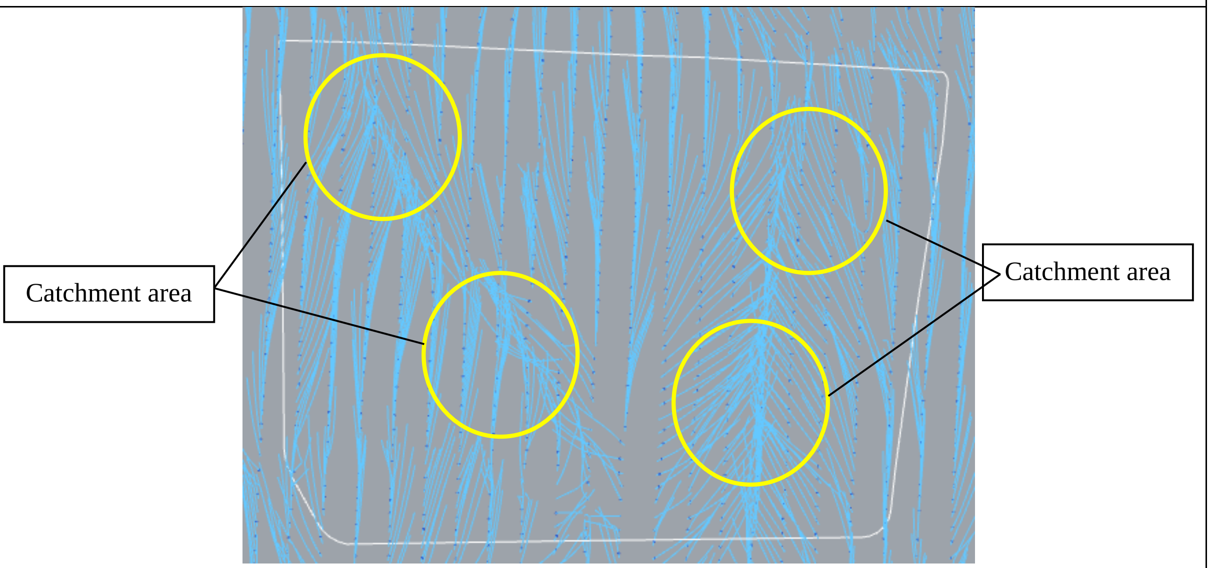
In this step, the land use plan N° 9A, was presented according to the design prepared by URBA-CO, and it was simulated as a current situation without interfering with it as an integral part of the future expansion of the city of Tebessa, where floods were simulated in the study area in two stages:

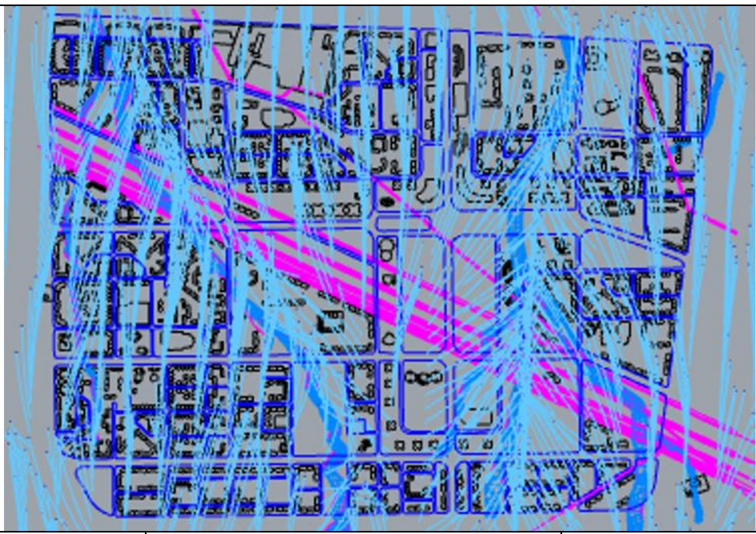
* The first stage was to simulate floods on barre land that did not contain any urban development.

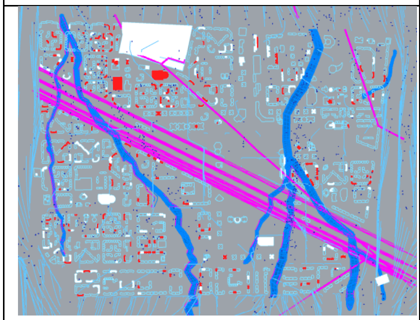
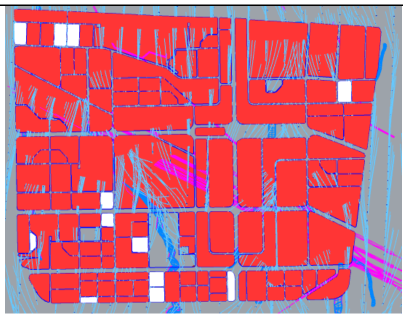
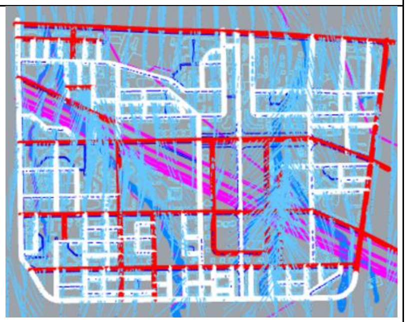
* The second stage was prepared as previously mentioned ‘floods in development land’, which was divided into: Buildings, plots, streets (Table 21).

At this stage, a previous study (Talbi et al., 2023), was also used that dealt with the relationship between the rise in water levels in the Wadis and precipitation (the information was taken from mapping urban floods according to the maximum water level in the Wadis of the city of Tebessa), as this study enabled us to know the catchment areas. This is what was included in the Rhino program, in order to accurately estimate the degree of vulnerability of the study area to the risk of floods (Table 21).

Table 21 Simulation of floods in barre land and in development land, The author, 2024.

Floods on bare land

Floods on developed land



Buildings	Plots	Streets
		

V.6. Urban design scenarios

Simulating the existing situation on bare natural land was the first step toward understanding the consequences of floods on the ecosystem and how they interact with the hydrographic network. Subsequently, the Land Use Plan N° 9A study area's urban design was simulated using the design circumstances of the present urban rules established by the municipal government (URBA-CO) as a baseline (scenario 0), as indicated in the preceding table (Table 21).

The study area's urban design was altered in an effort to increase the urban fabric's resilience to flooding risk. This was accomplished by developing a number of urban designs that, when applied to the study area's buildings, plots, and streets, utilized the one variable at a time OVAT method to activate the resilience urban design characteristics of modularity, redundancy, diversity, efficiency, and connectivity. This resulted in a total of 78 different scenarios. To extract the final optimal urban design in the research region, the best 5 scenarios was chosen for each parameter for each feature (Table 22).

Table .22 The different scenarios of urban design variables.

Scenarios	Parameters		
	Building	**Plot**	**Street**
Modularity Scenarios			**Variable: (street division):** S 1= 1 division (560 m). S 2= 2 division (490 m). S 3= 3 division (420 m). S 4= 4 division (350 m). S 5= 5 division (280 m). S 6= 6 division (210 m). S 7= 7 division (140 m). **S 8= 8 division (70 m) > Optimal scenario.**
Redundancy Scenarios		**Variable: (redundancy plot according to regular square grid):** S 1= Length of grid (140 m). S 2= Length of grid (120 m). S 3= Length of grid (100 m). S 4= Length of grid (80 m). **S 5= Length of grid (60 m) > Optimal scenario.** S 6= Length of grid (40 m).	**Variable: (Local meshedness):** S 1= Distance (140 m). S 2= Distance (120 m). S 3= Distance (100 m). S 4= Distance (80 m). S 5= Distance **(60 m) > Optimal scenario.** S 6= Distance (40 m).
Diversity Scenarios	**Variable: (building size according to BFR):** S 1= BFR: 1. S 2= BFR: 0.9. S 3= BFR: 0.8. S 4= BFR: 0.7. S 5= BFR: 0.6. **S 6= BFR: 0.5. > Optimal scenario.** S 7= BFR: 0.4. S 8= BFR: 0.3. S 9= BFR: 0.2. S 10= BFR: 0.1.	**Variable: (Plot shape and size):** S 1= Width: 300 m. S 2= Width: 260 m. S 3= Width: 220 m. S 4= Width: 180 m. S 5= Width: 140 m. **S 6= Width: 100 m.> Optimal scenario.** S 7= Width: 60 m.	**Variable: (Street-edge, and interface matrix):** S 1= Distance: 300 m. S 2= Distance: 260 m. S 3= Distance: 220 m. S 4= Distance: 180 m. S 5= Distance: 140 m. **S 6= Distance: 100 m.> Optimal scenario.** S 7= Distance: 60 m.
Efficiency Scenarios		**Variable: (Plot size and distribution):** S 1= Size: 0.96%. S 2= Size: 0.79%. S 3= Size: 0.62%. S 4= Size: 0.45%. S 5= Size: 0.28% **S 6= Size: 0.11% > Optimal scenario.**	**Variable: (Street-length distribution):** S 1= Link: 2000 m. S 2= Link: 1660 m. S 3= Link: 1320 m. S 4= Link: 980 m. S 5= Link: 640 m. **S 6= Link: 300 m.> Optimal scenario.**
Connectivity Scenarios	**Variable: (building compactness, sectional ranges and façade length):** S 1= Density: 1.5%.		**Variable: (Street connectivity and metric connectivity):** S 1= Intersection: 300 m.

	S 2= Density: 2%. S 3= Density: 2.5%. S 4= Density: 3%. S 5= Density: 3.5%. S 6= Density:4%. S 7= Density: 4.5%. S 8= Density: 5%. **S 9= Density: 5.5%.> Optimal scenario.** S 10= Density: 6%.		S 2= Intersection: 280 m. S 3= Intersection: 260 m. S 4= Intersection: 240 m. S 5= Intersection: 220 m. S 6= Intersection: 200 m. S 7= Intersection: 180 m. S 8= Intersection: 160 m. **S 9= Intersection: 140 m. > Optimal scenario.** S 10= Intersection: 120 m. S 11= Intersection: 100 m. S 12= Intersection: 80 m.

The urban design created by the research office "URBA-CO" was adopted exactly as it is in Scenario 0 in order to assess the degree to which the flood risk would influence the potential urban fabric for growth. In the meanwhile, a more grounded scenario was created and called the Modularity Scenario. The modular unit feature, which is defined by the arrangement of the various morphological parts in strongly linked groupings that function as cohesive units' despite being comparatively autonomous, served as the basis for this scenario. This perspective states that the street network was divided into several small plots that allowed for the development of a modular urban fabric. The large plots were split into smaller sections by streets, but in an ascending order, beginning with one section, then two, and so on, until there were 08 sections per 70 meters (Table 22). These sections had internal configurations that could be changed to meet specific needs that improved urban resilience against flood risks, resulting in 08 scenarios that typified modular units. Furthermore, by connecting the cut structures in more geographically dispersed ways, regional management was made possible as well as quicker, more economical, and context-responsive adjustments. Accordingly, after calculating the extent to which each design would be impacted by flooding using Figure 58, scenario N° 8 was found to be the most optimal scenario for this fabric.

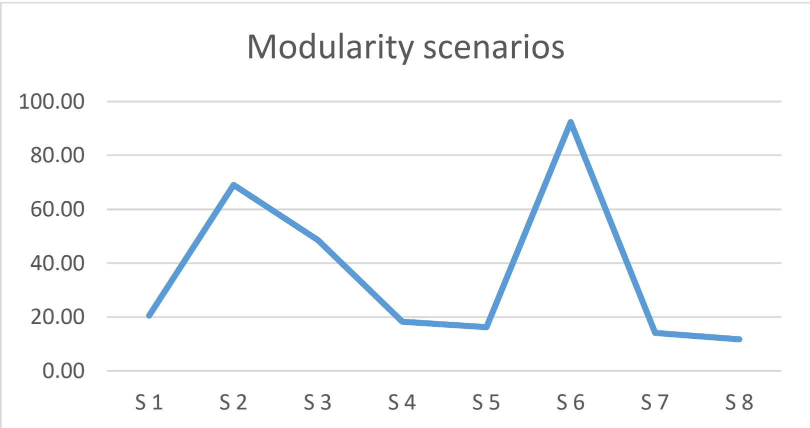


Fig. 58 Modularity street scenarios.

The redundancy scenario shows how street networks may incorporate more durable, non-degradable secondary streets and tree-like patterns based on the redundancy characteristic, which is defined by repeated connections in streets. Instead of focusing traffic on a small number of streets, as is the case in a rigid hierarchical network, the street network design creates a number of regular, linked streets that provide quick connectivity in the event that flooding affects important streets. With the help of a regular framework, multi-access streets are made to be usable even in the event that some of them flood. The division was started gradually at the intersection of five main streets that were already in place and derived from Scenario 0, which was not significantly affected by flooding. From there, new streets were added every 20 meters to provide access to the areas most at risk of flooding while also integrating with the city's overall design. This resulted in six scenarios at the street factor level (Table 22), of which scenario 5 was determined to be the most effective scenario based on Figure 59.

In order to create several connected streets that allow easy movement between sites based on the variable size of the plot, the design of the plots required the implementation of a regular division with small parts compatible with the street network, always relying on the regular square grid. This in turn led to the division of these plots by increasing the number of streets, especially in areas that provide important urban services of general importance. Out of these six scenarios, which were also compatible with their previous counterpart (street factor), scenario 5 (S 5) demonstrated efficiency in terms of reducing the degree of flood impact on the plots when compared to the other scenarios (Figure 9).

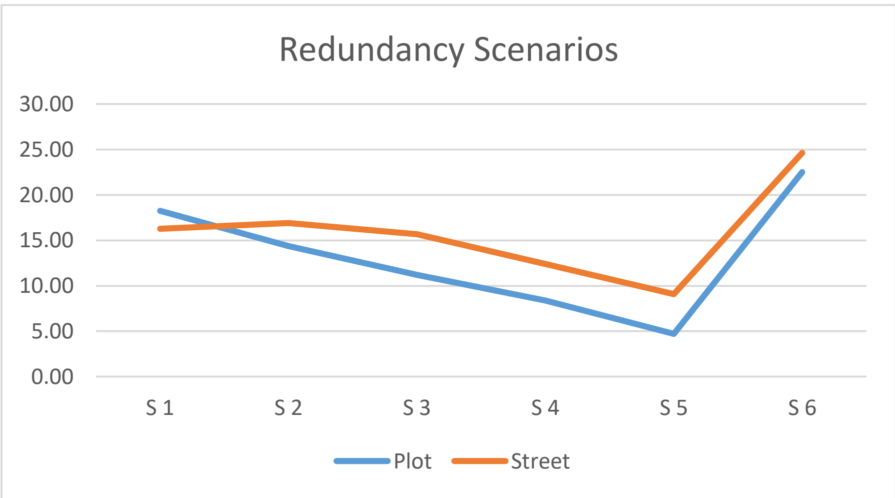


Fig. 59 Redundancy plot and street scenarios.

Diversity scenario began with nearly the same number of buildings as Scenario 0, but it stood out for its diversity because it was designed using the building size variable (changes in the floor area ratio FAR and the building footprint ratio BFR), which was characterized by a small building footprint ratio because the design began with the first ratio for the buildings as a starting point in Scenario 0 (in accordance with the URBA-CO design), After that, the ratio was lowered, and it started to gradually decrease from 1 to 0.1 at a rate of 0.1. This resulted in ten distinct scenarios (Table 22), of which Scenario 6 was determined to be the best scenario (Figure 60), given that the buildings' continued reduction in the building footprint ratio after reaching 0.5 (Scenarios 6, 7, 8, 9, and 10) did not alter their level of flood vulnerability, but rather remained constant (Figure 60). As a result, Scenario 6 maintained the building footprint ratio of 0.5 as it makes the most sense in this situation. While the floor area ratio (building height) had no direct bearing on the degree of flood impact on the presented urban design, the FAR was raised from 4 to 10 in order to restore parts of the cancelled buildings by increasing the number of floors in the buildings, but with high foundations built on columns or high structures that maintain their basic structure located in areas exposed to potential flood waters. Also, the plots were designed with an emphasis on the variable of diversity in size and shape by consistently referring to the zero point. This was done through redesigning the plots, which involved altering their size and shape in accordance with the direction of rainwater flow and runoff within the study area. This included decreasing the width of some plots that were exposed to greater risk than others (from 300 to 60 meters), in accordance with the scenario 0, and increasing the slope of the plots with high elevations and slopes by 0.1% each time to improve natural drainage and divert rainwater from areas of concern. In the end, resulted in 07 scenarios (Table 22), the best of which was scenario 6 (S 6) in terms of lessening the degree of damage from flood risk. In terms of street design, the interface matrix's street edge variable was given precedence. The public and private domains' intermingling with the existing buildings and plots, as well as the area's facilities, dictated the design's varied grid. By minimizing the contact between the two impermeable barriers and intermittently breaking them, the design to safeguards areas where privacy is more valuable than the public domain. This was directly related to the plot parameter, which called for the integration of the two designs with the previously mentioned parameters. As a result, 07 different scenarios were created (Table 22), the most effective of which was scenario 6 (S 6) (Figure 60), which was eventually chosen to carry out additional research.

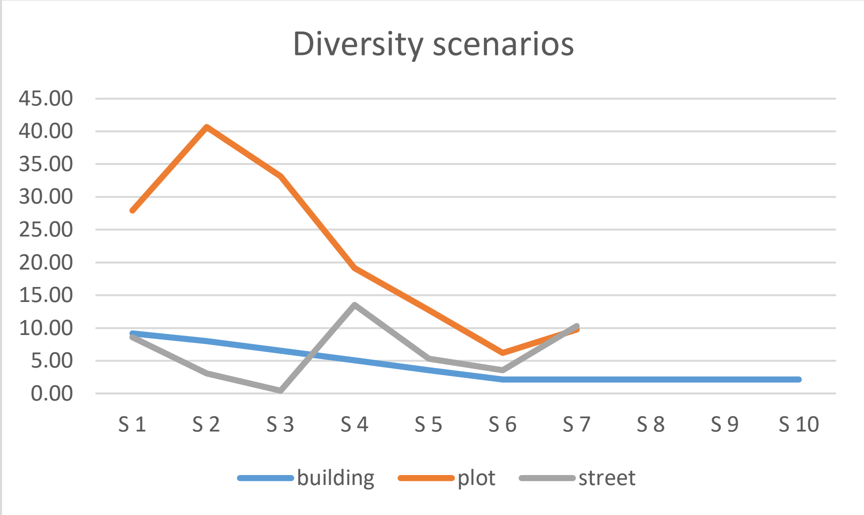


Fig. 60 Diversity building, plot, and street scenarios.

The efficiency feature served as the foundation for the Efficiency Scenario, which based its urban design at the land parcel level on two primary variables: the size and distribution of plots. The main urban form was designed using the triangular network as a starting point, drawing from the literature on the efficiency feature previously mentioned in the streets and plots, which included a wide range of plot sizes, characterized by a long tail of small plots corresponding to a limited number of large plots. Since the Wadis that cross the study area and the main axes of each high-voltage power line intersect, the design started with right-angled triangles. This made the triangles more efficient and compatible than square networks, particularly in regions with curved or uneven borders. In an effort to lessen the impact of floods on the urban fabric, this design also decreased space waste and improved the efficiency of distributing plots in the area. It achieved this by increasing the frequency of major intersections to secondary intersections, where the plot sizes start at a rate of 0.96% of the total area according to the initial design shown in scenario 0 and end at 0.11%, see Table 22. In order to connect neighborhoods and areas in accordance with the triangle network that was initially adopted at the beginning of the design, the street level design relied solely on the distribution of street length. This was achieved by increasing the number of regular direct links and distributing them among fewer long-distance connections. Starting with a link every 2000 meters, the design expanded a second link every 1660 meters, and so on until six primary linkages were increased at 300 meter intervals (Table 22). This resulted in the creation of six distinct situations (Figure 61), of which scenario 6 (S 6) was chosen as the most effective one after comparison. Additionally, this design made it simpler for the urban fabric to be distributed and united, facilitating the reintegration of various land parcels while preserving a higher level of resilience against climate change (Figure 61).

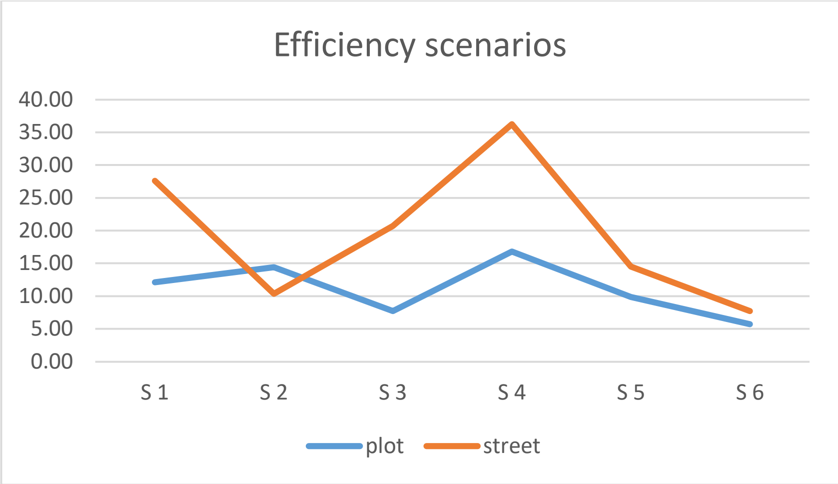


Fig. 61 Efficiency plot and street scenarios.

Finally, connectivity scenario has a similar spirit to diversity scenario, however with a more integrated design that conserves a greater portion of the current environment. This is particularly evident in the specification of building compactness, sectional ranges, and façade length. Because of this, the building design in this feature makes use of compact, dispersed, and unobstructed buildings to enhance permeability between various site areas and minimize the presence of obstacles within flood-prone areas, thereby improving access during an emergency. As a result, the long facades were balanced, harmoniously divided, and somewhat connected to one another. Permeability was also characterized in accordance with the study area's characteristics and the BFR, which was previously determined in the diversity scenario and estimated at BFR=0.5. However, the building density was the main factor that was prioritized in this design more than in the previous one, with the lowest density found in the areas most vulnerable to flooding. The design started by reducing density at an ascending rate estimated at 1.5%, 2%, 2.5%, 3%, 3.5%, and so on until the percentage of decrease reached 6% of the building density (Table 22), which ultimately resulted in the formation of 10 different scenarios as seen in Figure 62. However, the results demonstrated that the impact of floods on the design remained relatively constant when it reached 5%, 5.5%, and 6%, as represented in scenarios S 8, S 9, and S 10. It demonstrates that there is a maximum limit that keeps the impact of floods constant as building density drops. In terms of the streets, they were planned with a lot of four- and three-way stops to cut down on dead ends. Additionally, the street network was strengthened to minimize the distances between intersections by turning one-way streets into three-way streets or more, ensuring that people could move easily within and between locations for quick emergency response to prevent material and human losses from flooding brought on by climate change. In order to improve the metric connection feature between places, a street intersection was placed every 300 meters (Table 22). This intersection may be extended as needed, resulting in 12 possibilities, of which scenario 9 was determined to be the optimum option based on Figure N° 62.

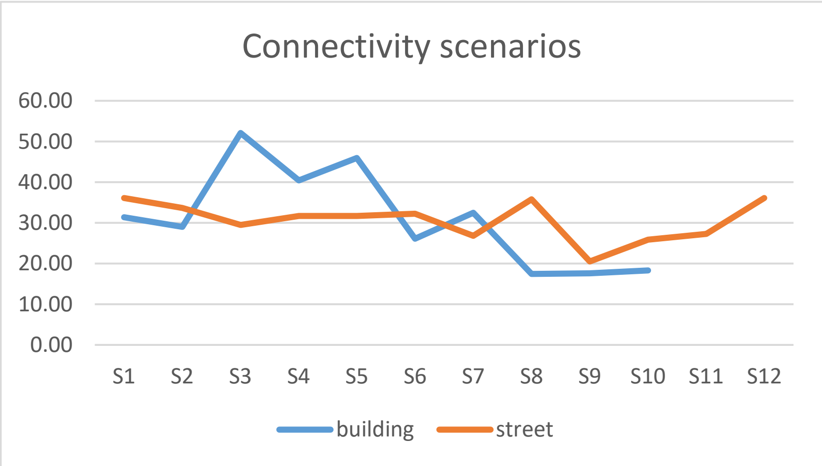


Fig. 62 Connectivity building and street scenarios.

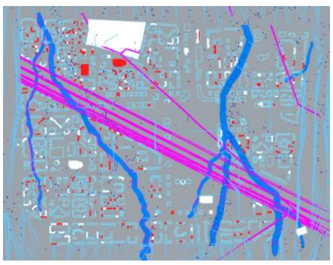
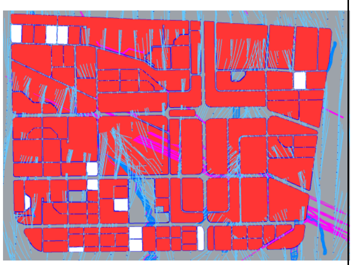
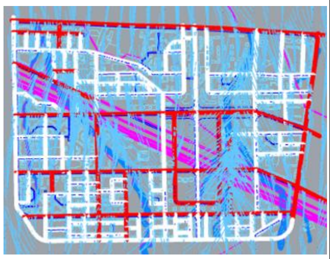
V.7. Urban design application

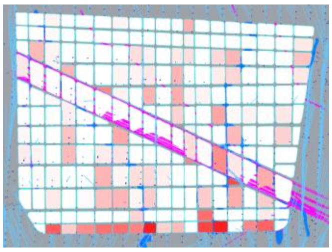
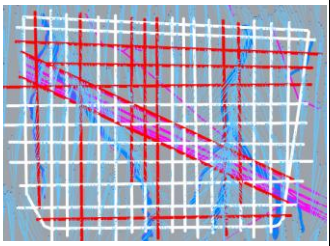
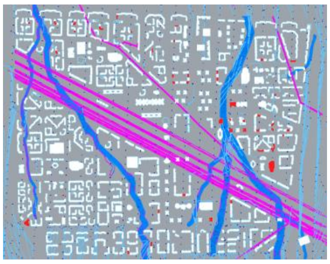
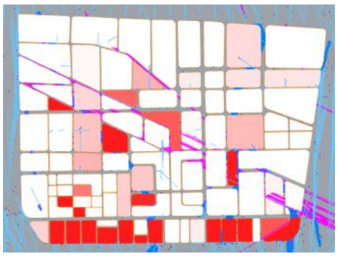
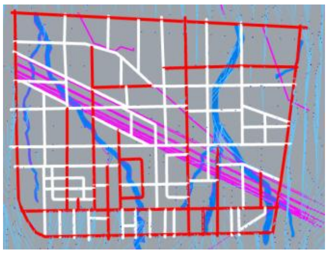
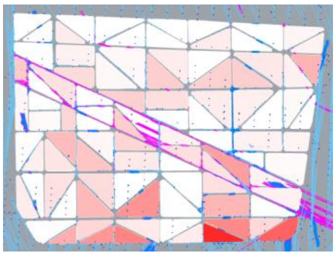
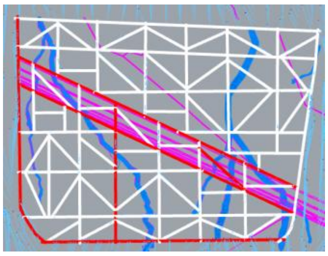
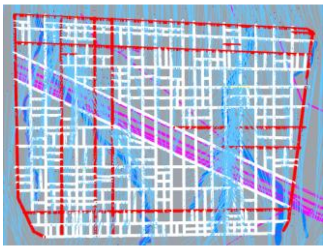
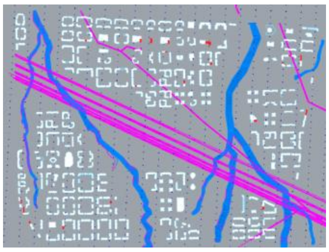
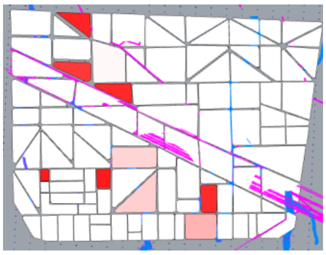
V.7.1. Scenarios creation

The results shown in Table 23 showed the different scenarios that include simulating land use plan N° 9A, as well as the changes made to the plan based on urban design settings to combat floods.

The scenarios study was based on frameworks and directives drawn from previous studies, where simulation of the current design situation during floods was taken into account, and then a set of designs were built following the directives of the characteristics of resilient urban design, which are modularity, diversity, connectivity, redundancy, and efficiency, Through the three parameters: buildings, plots, and streets, in order to assess the resilience of the urban fabric in the face of flood risk; and giving a final result about the final optimal urban design for Land Use Plan N° 9A.

Table 23 Scenario maps of Tebessa city according to urban design framework, the author,2024.

Scenarios	Building	Plot	Street
Baseline **‘Scenario 0’**			

Modularity Scenario			
Redundancy Scenario			
Diversity Scenario			
Efficiency Scenario			
Connectivity Scenario			
Final optimal scenario			

V.7.2. Urban flood analysis

- Buildings:

Building positions and building typologies within the delineated area were studied to help in understanding the diversity of the structures of the urban fabric in terms of position, uses and density. It is noted that there is a higher diversity in public equipment, unlike the buildings designated for housing, which were of a unified type, due to the collective nature of the housing prevailing over the individual character within the study area. However, the latter did not constitute a significant difference in the resilience of the urban fabric, as well as its response to flood risks, as the residential buildings that were most affected by the floods were those buildings that were located somewhat close to the Wadis that pass through the study area.

The small divisions of the buildings, as well as their density within the urban fabric, helped them confront the threat of floods. The results showed that the density should not exceed 5.5% in areas close to Wadis and that the building footprint ratio should be within the range of 0.5 to 0.3.

The small divisions of residential buildings formed blocks that were less damaged because of their ability to permeate and allow water currents to pass through them without damaging them like other components of the urban fabric. Their positioning also played an important role in confronting the threat of floods, as the blocks that were vertical were less damaged than Those that were horizontal due to their flow and compatibility with the morphological nature of the field of study, as well as in terms of their integration with the site.

As is known, density negatively affects urban flooding, as different surface runoff characteristics are related to urban density, as they effectively mitigate urban flooding resulting from urban development.

- Plot:

Plot structure has a significant impact on the physical, social, and economic development of a certain city or local area. It also has an indirect impact on the comfort and livability of a certain city or neighborhood. The use of these lands, such as open spaces, mixed use, etc., can make them resilient by integrating it into the planning and policy of various sectors across the city.

Within the study area, there is a large number of vacant plots, as it is an area with many Wadis (Natural constraints), which forces the designer to take into account the easements that sometimes reach fifty meters on both sides, and the high-voltage electrical network (Physical constraints) that passes through it also necessitated a specific design for the land plots and This is out of caution. However, despite the restrictions in this area, it was not an obstacle to diversity in urban design, as the small division of land made it more flexible and resistant to large divisions that somewhat exposed it to the risk of flooding. Also, the design that was characterized by redundancy was the most resilient of the others. Based on the results of the final optimal scenario, if the regular square grid is adopted in the urban design, the grid dimensions should not exceed 60 to 100 meters, while when adopting the triangular grid with right angles, the sizes of the plots should not exceed 0.11% of the total area.

Plot characteristics shall further help in understanding its impact on resilience indicators of connectivity, diversity and efficiency. It also helps in understanding the gap between plot distribution and size as per guidelines and existing land-use distribution for further provisions or recommendations to improvise to make the study area more resilient.

- Street:

Adding to our understanding of how the street systems affect the built environment and the surrounding environment. This helps in understanding the degree of accessibility that the street plan provides in this location. Street systems greatly affect the resilience of the urban fabric against the risk of flooding through their connectivity, diversity, modularity, and redundancy. Poor urban design leads to a decrease in the efficiency of the provided system. Hence, to make the street system resilient, these factors must be taken into consideration while designing or modifying it. This also helps in understanding the degree of accessibility provided by the surrounding street characteristic at this location.

Furthermore, it has been noted that there is a very weak connection to this area in terms of its previously designed character, and that the continuity of the streets extending along the study area made it more vulnerable to floods compared to others. Therefore, a connection should be created every 300m according to the final optimal scenario (Table 23).

On the other side, the multiple street connections and their efficiency contribute to reducing the risk of floods, as they should not exceed 140 m, which in turn allows different surface runoff to flow without obstacles. The integrated urban design with the morphology of the site allows it to follow the natural flow of water, which reduces the material losses caused by floods.

V.8. Impact assessment of floods

Based on the results of the proposed design scenarios presented previously, the impact of the flood was different from one to another, as the table 23 below present the degree of flood impact of each scenario, in this case the comparison will be divide in three part: Building, plot, and street.

Building:

The design of the ‘Scenario 0’ is the weaknest of this group. The maximum degree of impact on buildings reached 32 degrees, while the ‘Diversity scenario’ and ‘Connectivity scenario’ were better in terms of the degree of impact, as the highest degree in them reached 25.5 degree; But in general, the best design went to the ‘Connectivity scenario’ due to the low degree of vulnerability of the rest of the buildings to the risk of flooding. Thus, the final optimal scenario had the lowest impact degree of 10.

Plot:

According to the table 24, the worst design was ‘Scenario 0’, because it came first in terms of the highest degree of vulnerability of plot to the risk of floods, as the highest value reached 34 degrees, while the impact value in ‘Diversity scenario’ reached 10 degrees, which was considered a better degree than the first one. As for the second and fourth scenarios, they were classified as the best scenarios for resilient urban design against the risk of floods, as the highest value in them reached 4 degrees.

As for the final optimal scenario had a maximum vulnerability degree of 2.61 degree at the plot level.

Street:

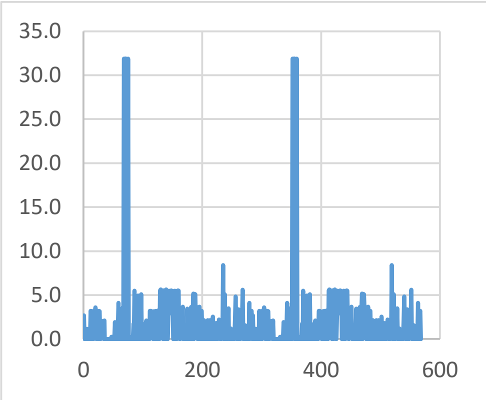
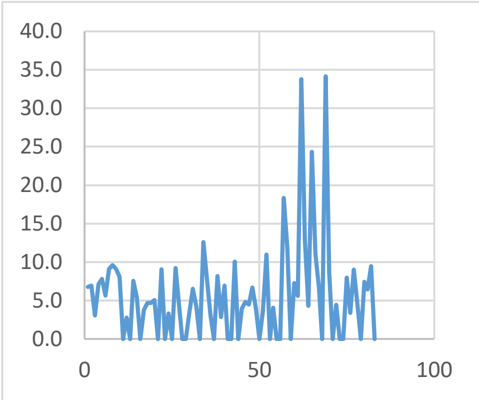
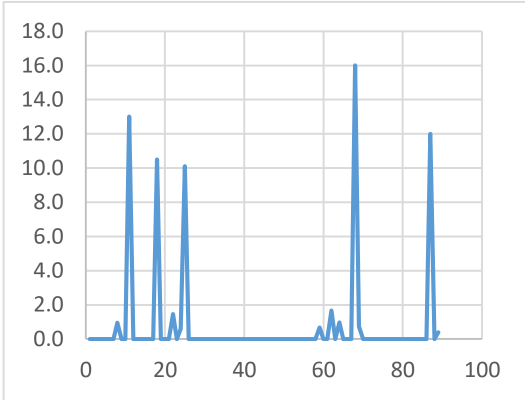
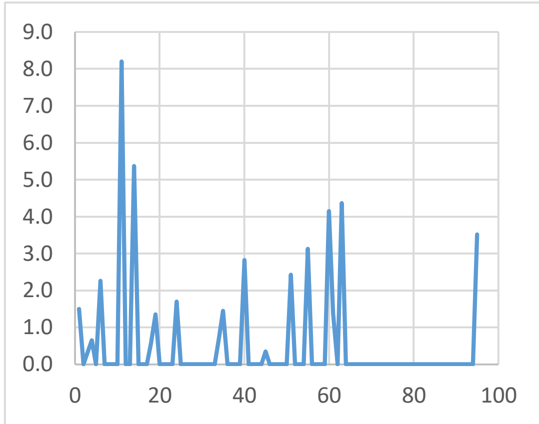
In ‘Efficiency scenario’, urban design presented a comprehensive situation for the study area. There is great harmony between the design of the streets and the morphology of the ground. Although the design was designed using parametric techniques, the model was the most efficient among the other models. The highest value affected was 1.5 degrees, which is considered the lowest degree among the other scenarios.

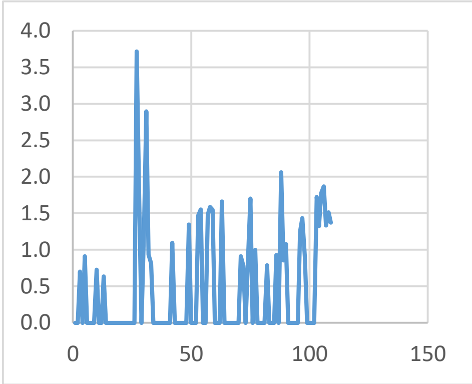
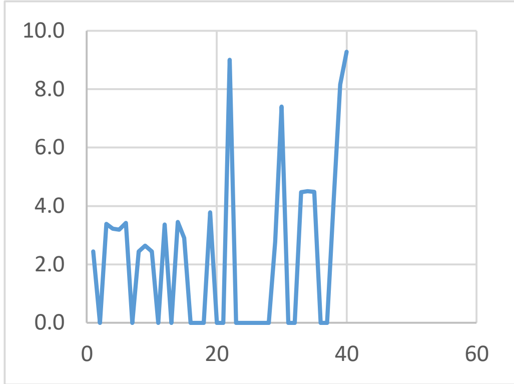
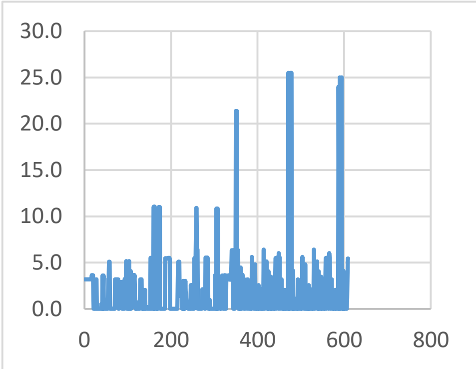
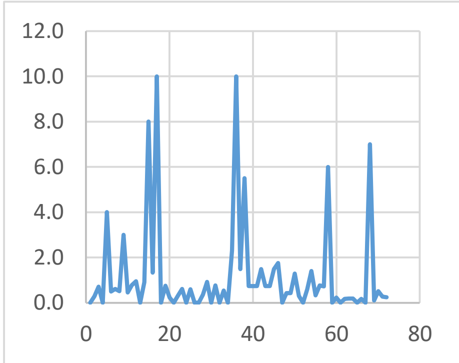
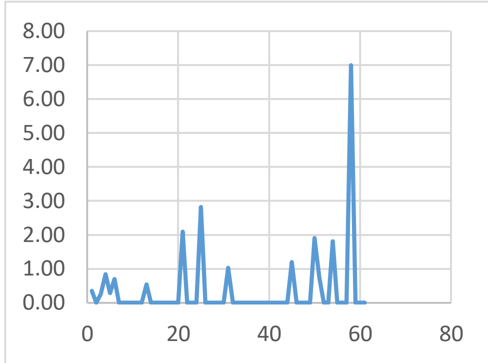
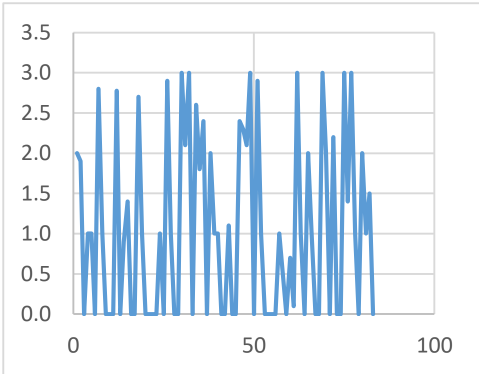
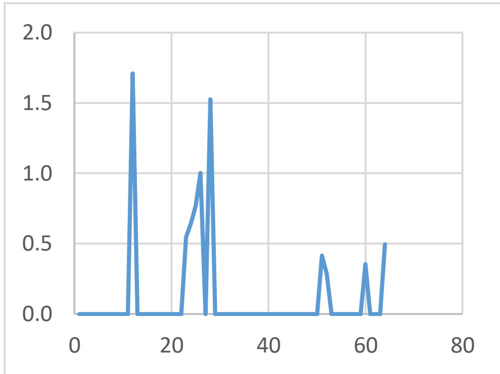
Below, ‘Scenario 0’ was also less affected in terms of the number of streets affected by the floods, but in contrast, the degree of impact was very high, reaching 16 degrees.

As for ‘Modularity and diversity scenario’, the number of damaged streets was greater compared to other scenarios, but on the other hand, the degree of impact was low compared to the ‘Scenario 0’. The impact value reached 8.2 and 7 degrees, respectively.

As for the rest of the ‘Redundancy and connectivity scenarios’, they were somewhat acceptable in terms of the number of damaged streets and the impact values, which were estimated at 9.1, and 5.1, respectively; and according to the final optimal scenario, the highest degree of impact reached 6.21 degrees (Table 24).

Table 24 Degree of flood impact in each scenario; The author, 2024.

Scenarios	Building	Plot	Street
Baseline **'Scenario 0'**			
Modularity Scenario			

Redundancy Scenario			
Diversity Scenario			
Efficiency Scenario			

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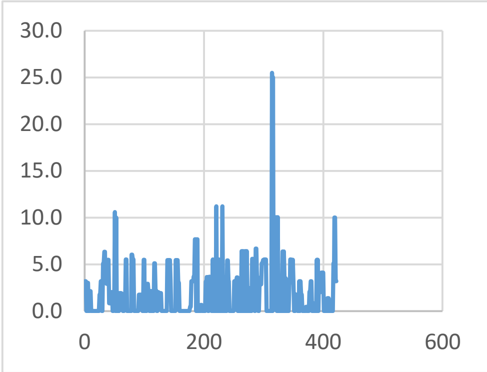
Scenario</td>
<td>
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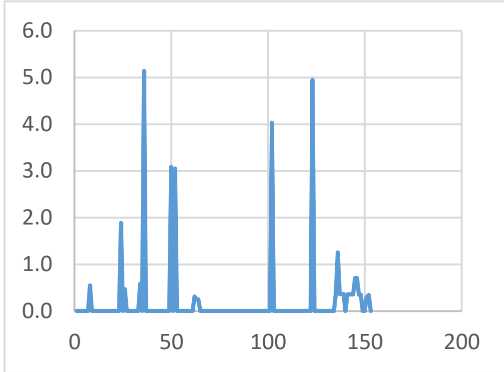
<td>
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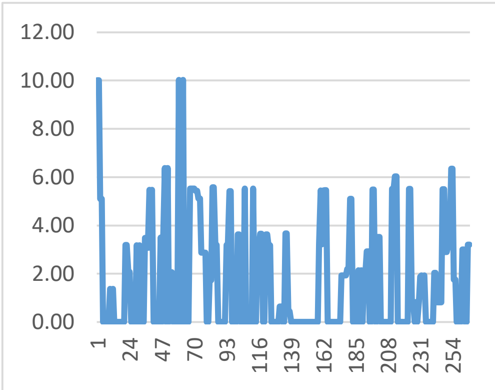
<tr>
<td>Final optimal
scenario</td>
<td>
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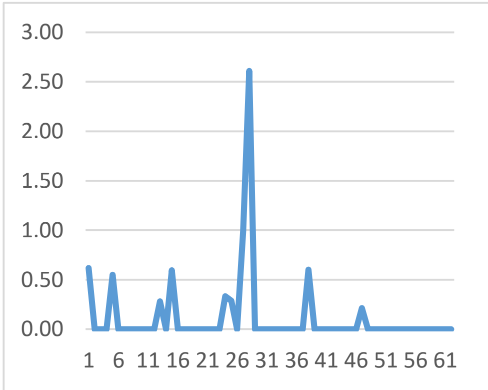
<td>
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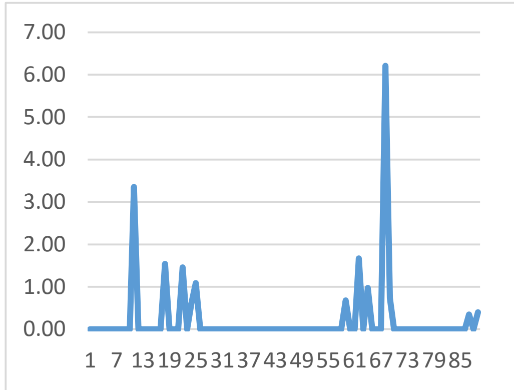
<td>
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V.9. Conclusion

Resilience is a widely recognized term in research, policy and decision-making regarding sustainability and the challenges of natural hazards such as floods. In order to address the integrated social, economic and environmental concerns of reducing these disasters, resilience is related to adaptation and reducing vulnerabilities, as well as the ability of any system to deal with external changes while maintaining its structure, functions and identity. On the other hand, the concept of urban design is to design cities, buildings, spaces, landscapes and streets, and to establish frameworks and procedures that will achieve successful development to address developments, to create a feeling of comfort, and to make the city a place of balanced diversity.

Using a case study of land use plan N° 9A of the master plan for the development and reconstruction of the city of Tebessa, the research focused on the current situation of flood risks, as well as after predicting a rise in water levels in the Wadis linked to the rate of precipitation, and in accordance with the previous study (Talbi et al., 2023) provided knowledge of the catchment area, which had an effective role in the simulation process in the Rhinoceros program, despite the different scenarios presented in this study.

Therefore, the floods in this urban area were analyzed by comparing the three parameters: buildings, plots and streets for different scenarios, while their resilience was assessed by comparing the results of the urban fabric impact degree obtained from the Grasshopper program. According to the research's findings, creating design suggestions necessitates a thorough comprehension of design, as well as its applications and policies. This is followed by the integration of frameworks, toolkits, and guidelines that have been proposed in various cities or nations. Because of this, a large portion of this literature might be cited and filtered down for this particular research field based on the particular characteristics of urban resilience and design. Moreover, these characteristics may be used to complete design recommendations for the chosen location, enhancing the neighborhood's urban resilience.

Thus, according to the results of the study, we can conclude:

First, through parametric simulation, the distinction between urban design parameters and their influence on the urban fabric is demonstrated to evaluate urban resilience against flood risk.

Secondly, the obtained simulation results can be used as justification to determine the extent of damage that floods may cause in order to reduce it through appropriate urban design for the studied area.

Thirdly, the five system-level properties of modularity, redundancy, diversity, efficiency, and connectivity, are useful in determining the resilience of an urban system. Control designs and strategies can enhance the efficiency of urban areas, optimizing the urban resilience of the urban fabric against flood risks, and although these characteristics have an impact on the resilience of these urban fabric systems, their impact was presented separately in this study.

By highlighting the interplay between urban design and urban resilience against flood risk, this research provides valuable insights into incorporating resilience considerations into design performance evaluation and management strategies. It also emphasizes how certain designs can impact efficiency and recovery, which are key considerations when evaluating whether a retrofit project is resilient.

Furthermore, the study calls for the inclusion of the resilient perspective in assessments of adaptation performance over time. Recognizing the demand for adaptable, automated and resilient urban fabric systems; This study provides a scientific contribution by guiding the selection of design types to ensure stability amidst disturbances, whether natural or man-made. From a societal perspective, the research also emphasizes the need for methods that facilitate information exchange between citizens and decision-makers, with the aim of promoting coordinated actions within more advanced command systems.

General conclusion and perspectives

GENERAL CONCLUSION

The main objective of this thesis was to enhance urban resilience against flood risks that threaten our cities, and to find a common ground between resilience theory and urban design parameters, by concentrating on a study area that suffers every time from the threat of flood risk, which causes material and human losses. The study focuses on the urban perimeter of Tebessa city – Algeria, known for its historical events of floods that occupies the first position in terms of the number of buildings built in vulnerable zones, which reached 17 236 buildings according to the National Economic and Social Council, 22 editions. Besides, the city has witnessed in the last decades a large expansion of its urban perimeter, this prompted the directorate of urban planning, architecture and construction to review the Urban Development Master Plan (PDAU) in 2018 due to the city's rapid urban expansion, which was evident through the population increase, especially during the necessary demographic phase, where the city's population increased from 62,639 to 249,583 inhabitants between 1977 and 2023. As for the urban fabric, its area was requested to be 4,843.65 hectares in 2018 after it was 1,637 hectares in 1988. The Land Use Plan N° 9A was selected as a study area in this research as the focus of attention in the last time by decision makers, not to mention the natural and physical constraint that characterize the area, so this sample was chosen after studying the urban perimeter of Tebessa city to determine the areas exposed to risk based on the factors causing floods according to the previous studies, in addition to analyzing the relationship between the precipitation and water level in the Wadis, by estimating rainfall as an input to predict the water level to simulate urban floods in the Wadis, in addition to analyzing land use and its impact on urban floods in the city.

Overall, the thesis begins with a general introduction, which contains: a context study presenting the thesis issue from both a global and local perspective, and a problem statement that demonstrates the relevance of the research concerns within the scope of the selected case study and draws logical connections between the terms of the study object. The thesis's points are defined in the objectives section, which targets the conceptual parameters that affect the vulnerable urban fabric to reduce flood risk and improve urban resilience at the environmental, urban, and architectural levels. As for the concepts that guide scientific research, open doors to new discoveries, that were confirmed in the final portion of this section, they were outlined in the assumptions section, which were summarized into two basic assumptions: either through environmental conditions only such as Wadis, rainfall…etc, and according to the flood susceptibility mapping of the city, or through the spatial morphology of the urban fabric that requires adaptation and anticipation of flood-related disasters through the spatial form of the urban fabric only. The main body consists of two parts, the first one contains two chapters, dealing with a literature review of flood risk and urban resilience, and presenting key studies related to urban resilience through urban design. The second part contains three chapters, presenting practical work on the study of urban resilience at the urban case study level starting with the case study research approach, then flood analysis, and flood assessment through urban design.

Following an overview of the thesis's primary goal and organizational framework, the next sections provide a review of the primary axes and significant turning points associated with the study's sub-objectives as well as an excerpted response to the opening questions. The following parts validate the theories, provide a scientific viewpoint on the research that was examined, outline potential directions for further study, and discuss the limitations of this study.

On the issues of flood risks and urban resilience in the theoretical support; Chapter one shows that flood risk, as the most common natural hazard that causes material losses and serious environmental damage, has a long-term impact on the development of countries, especially in urban areas where there is a high risk of flooding. Therefore, the concept of urban resilience is a response to this situation, as it enables us to understand the behavior of the city, and to improve its response to extreme climate-related events. To delve deeper into this concept, was addressed through urban design in the second chapter of this part, which considers urban design as a complex adaptive system built on five features represented by modularity, redundancy, diversity, efficiency and connectivity and linked to different morphological components such as buildings, streets and plots, to discover the impact of the dynamics of change in urban design, which is one of the most prominent evidence-based approaches: it applies the lessons learned from studying cities from history to the present to develop resilient cities in the future. Practically: it promotes the process of building revised places and provides the means to implement them, making it a very important resource for designers, legislators or policy makers. As well as its morphological components and its relationship to resilience. It also addressed in its content the theoretical framework of urban design resilience through previous literature to set the framework for analyzing and assessing urban design resilience in terms of methods and tools used during the next part.

In terms of the context, mainly the second part of the thesis, which concerns Algeria, the government tried through some of its policies and strategies to reduce the impact of floods on its cities, such as the city of Tebessa, with a large number of buildings located in vulnerable areas, due to the presence of the hydrographic network that crosses its urban perimeter, in addition to its morphological characteristics, this made it a city exposed to the risk of recurring floods. At this stage, the framework of the fourth chapter was divided into three elements based on what was extracted from the previous second chapter, as follows:

1/ The urban environment:

Using remote sensing data from Landsat, predictive mapping of the regional occurrence of flooding zones was carried out for the urban perimeter of Tebessa City, Algeria, to identify the historical impact of flood events during the last 10 years and project the possible future potential flood disaster. Three models—XGboost, Random Forest, and Nearest Neighbor—were used in machine learning (ML) to forecast Tebessa City's flood zones. According to the data set recorded by Tebessa Wilaya's direction of civil protection, about 495 flood locations and 490 non-flood locations were chosen as training data to create the flood susceptibility mapping of the city, with approximately 15% of them being used as a validation set. To forecast the 54,945 locations used as a test dataset, the XGboost, Random Forest categorized, and K-Nearest neighbor models' estimated accuracy values of prediction rates using the Accuracy scores technique were 98.42%, 98.16%, and 96.00%, respectively. In a geographic information system environment (GIS), databases related to flood zone occurrence (topography, climate, human factors, and hydrological variables) were examined. The results of the analysis of the susceptibility of Tebessa city to floods showed that urban land use, proximity to Wadis, and natural factors such as rainfall, elevation, slope, and curvature are major factors affecting flood sensitivity. Also, Uncontrolled urban expansion and human interventions can also change the hydrology of watersheds, even with low rainfall, and poor drainage systems, blocked Wadis due to urban development, can exacerbate flood risks.

2/ The ecological climatology:

This section seeks to provide insights into climate to better understand the impacts of changes in climate and meteorological parameters including temperature, humidity, wind speed, and precipitation. Estimating precipitation is essential for reducing the danger of flooding, especially in cities. A Geographic Information System (GIS) and machine learning (ML) approaches were used to model urban flooding in the Wadis of Tebessa city during the next 12 years (2035). Using a 22-year weather dataset, the Prophet model was used to forecast future values of atmospheric parameters (2000 to 2022). In particular, to understand the relationship between different parameters - especially rainfall - and water levels. For the same 12-year period, water levels in the Wadis crossing the urban area of Tebessa were estimated using XGBoost, Random Forest and K-Nearest Neighbor models. The outputs of the forecast models were compared to training set's ground truth data to assess their accuracy. The ROC-AUC approach was used to assess the prediction accuracy of the test data. The results showed that the Random Forest (92.92%), K-nearest Neighbor (89.93%), and XGBoost (98.75%) models had good prediction rates. As the results showed after conducting an administrative investigation, along the banks of Wadis, lakes, ponds, salt marshes and riverbeds whose floating area cannot be determined and used for reasons related to topography and/or water flow, a floating easement is created. Its width ranges from three (3) to five (5) meters, depending on the case and its boundaries. In the case of the city of Tebessa, and based on Law N° 05-12 of August 4, 2005 relating to water, in particular Article N°13 thereof, the local authority represented by the Directorate of Water Resources has set the easement of Wadis within the city from five (05) meters to eleven (11) meters, according to the statements of the experts working there. This actually confirms our findings in the maps bearing 'Urban flood mapping according to the minimum and maximum water level in Wadis of Tebessa City' , and this prevents the construction of any new building or the erection of a fixed fence within the areas subject to the easement right according to Article N° 31 of Law N° 17-83 and Article N° 12 of Law N° 12-05, which also explicitly stipulates the prohibition of any new building or any planting or the erection of any fixed fence or any work that would affect the maintenance of Wadis within the areas subject to the floating easement right.

3/ The ecological climatology:

In conjunction with the fieldwork to collect flood data, this part attempted to map the land use units in the city of Tebessa using the supervisory classification through the maximum likelihood approach on multispectral Landsat images for the years 1990, 2001, 2012 and 2023. By mapping and measuring spatial and temporal changes, it also sheds light on the relationship between urban areas and flood risks while analyzing the spatial expansion process experienced by Tebessa, Algeria, between 1990 and 2023. The method involved pre-processing the images, classifying the land use units, constructing and implementing the supervisory classification using the maximum likelihood technique and measuring the change. The creation of land use maps for the years 1990, 2001, 2012 and 2023 was made possible by these procedures, each of which distinguished three land use categories: bare land, flooded areas and urban areas. The study of the dynamics of land use units and their changes between 1990 and 2023 also indicated a downward trend in the bare land category (-42.06%) and a positive trend in the urban (47%) and flooded (39.39%) categories. This development is the result of significant environmental pressures from humans, which led to the growth of flooded and urban areas. The results confirm the gradual disappearance of bare land in favor of urban areas, accompanied by a significant expansion of flood-prone areas across the urban perimeter of Tebessa city. This trend reflects the increasing interaction between urban development and hydrological processes, exacerbated by the absence of vegetation cover within the city limits. The depletion of vegetation cover has reduced natural flood mitigation capacities, which has resulted in an exacerbation of flood risks and amplification of the vulnerability of urban populations to flood events. The study emphasizes the urgent need for proactive land management strategies and targeted interventions to mitigate flood risks and enhance urban resilience. Key recommendations include developing comprehensive sanitation infrastructure, integrating green spaces and vegetated corridors into urban planning frameworks, and implementing sustainable land use practices to reduce impervious surfaces and enhance natural infiltration processes.

In the same context, the main objective aims to enhance urban resilience through urban design against flood risks, based on a set of various spatial parameters as streets, buildings, and plots designed with the five typical characteristics of modularity, redundancy, diversity, efficiency, and connectivity; furthermore, to introduce a parametric design tool – Rhinoceros6 + Grasshopper- that is utilized to assess direct flood damages under various scenarios for Tebessa’s new urban expansion area (Land Use Plan N° 9A), This tool enables the analysis and evaluation of these damages across multiple levels and categories under flood simulation scenarios. Therefore, the findings demonstrate the value of the five system-level characteristics—modularity, redundancy, diversity, efficiency, and connectivity—in assessing an urban system's resilience. Although these features have an influence on the resilience of these urban fabric systems, their impact was given independently in this study. Control designs and tactics have the potential to improve urban areas' efficiency while enhancing the resilience of the urban fabric against flood threats.

After all the findings in this work; It is interesting to open a window for the hypothesis in this part by combining the earlier accomplishments with the declarative notions.

Assumption one:

Through the environmental conditions:

Participation promotes not only the production of sustainable development factors, but also the improve urban design through environmental parameters only (Wadis, precipitation ... etc.) according to the flood susceptibility mapping of the city, to make the city of Tebessa more resilient permanently and to assimilate the disturbances and risks of recurrent flooding or future.

Chapter four, especially in environmental climatology, in its analysis and results, gives an answer and a return to this assumption. It shows that environmental conditions cannot make our cities permanently resilient and that controlling or predicting them does not prevent floods, but they can be exploited to complete the research in assessing urban resilience through urban design. Through this study, the simulation of the relationship between precipitation and water level in Wadis was used to know to what extent water can reach the maximum level in the Wadis, which contributed directly in Chapter five during the simulation process to verify the effectiveness of the completed urban designs by determining the water catchment area based on the map of the maximum water level in the Wadis. At the same time, the study showed that the relationship between precipitation and the rise in the water level in the Wadis is not a permanent relationship of compatibility, and that sometimes floods occur not only because of the high rate of precipitation, but other factors play an important role in exacerbating this risk in the city, including the blockage of some Wadis and waterways due to waste that obstructs their paths, as well as some interventions carried out by humans, such as covering some Wadis or changing their course, which often led to dangerous floods, and this was confirmed by experts from both the Civil Protection Directorate and the Water Resources Directorate during the study.

Assumption two:

Through the spatial morphology of the urban fabric:

The conservation and protection of cities require the emergence of urban design that allows the adaptation and anticipation of disasters related to floods through the spatial morphology of the urban fabric only (Urban structure: roads, the shape of open spaces, infrastructure, buildings, and plot layout ...etc) that can control these risks and reduce losses.

This assumption was also assessed in the context of the thesis. The results show that there is a great importance for urban design in reducing the risk of flooding based on the five characteristics that were previously discussed, which had a great impact on the response of the urban fabric and confronting the risk of flooding through the three variables: buildings, streets, and plots. However, urban design alone cannot have a direct impact on enhancing urban resilience, but there is an integrated relationship between the environmental conditions and the spatial morphology of the urban fabric.

This study was conducted on a real land use plan in Tebessa which may provide a future vision for decision makers in the field of natural hazard management, especially floods in the context of climate change. Moreover, encouraging the use of simulation programs such as: GIS, Rhinoceros, and Grasshopper, at the level of local administrations and decision makers to evaluate the best urban design and its response to the objective set for it, and may lead to the transition of the built environment, especially vulnerable cities, to cities that are resilient against the risk of floods. Furthermore, intervention to reduce flood risk in existing urban fabrics may require the previous strategy, but with prior assessment of the intervention possibilities; Moreover, in building new urban design, the use of climate change prediction methods and their impact on a specific urban scale such as machine learning ML approach will be more useful.

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Research limitations

Regarding the assessment of urban resilience through urban design parameters, it is worth noting that the five urban design patterns were addressed separately in this study and their impact was not assessed in a connected manner with each other in facing the risk of floods, which could give other dimensions through its results in facing the risk of floods and thus a resilient city.

Development perspectives

The scope of this study can be extended to other types of urban fabrics in other sectors and/or cities, which would help provide guidance on resilient urban design against flood risk depending on climate change and the built environment and its characteristics.

In the same perspective, the application of urban form design optimization in terms of addressing other natural hazards such as fires, earthquakes, soil erosion, etc. with future climate forecasts could be an interesting line of research. First, it would lead to high efficiency in urban land use and effective strategies for climate change adaptation and mitigation. Second, it could be achieved through artificial intelligence such as deep learning for prediction.

Bibliographic references

BIBLIOGRAPHY

A. Balasubramanian. (2005). *Floods as Natural Hazards*. https://doi.org/10.13140/RG.2.2.18898.96962

Adams, D., Tiesdell, S., & White, J. T. (2013). Smart Parcelization and Place Diversity: Reconciling Real Estate and Urban Design Priorities. *Journal of Urban Design*, *18*(4), 459–477. https://doi.org/10.1080/13574809.2013.824367

Adger, W. N. (2000). Social and ecological resilience: Are they related? *Progress in Human Geography*, *24*(3), 347–364. https://doi.org/10.1191/030913200701540465

African Union. (2015, 2018). *Bi-ennial Report on the Programme of Action for the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 in Africa*.

Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning*, *100*(4), 341–343. https://doi.org/10.1016/j.landurbplan.2011.02.021

Ahmed, A. N., Yafouz, A., Birima, A. H., Kisi, O., Huang, Y. F., Sherif, M., Sefelnasr, A., & El-Shafie, A. (2022). Water level prediction using various machine learning algorithms: A case study of Durian Tunggal river, Malaysia. *Engineering Applications of Computational Fluid Mechanics*, *16*(1), 422–440. https://doi.org/10.1080/19942060.2021.2019128

Akkelies van Nes. (2007). *MICRO SCALE SPATIAL RELATIONSHIPS IN URBAN STUDIES: the relationship between private and public space and its impact on street life*.

Albert, L. (1999). *Urban morphology and the problem of the modern urban fabric: Some questions for research*.

Alberti, M., Marzluff, J. M., Shulenberger, E., Bradley, G., Ryan, C., & Zumbrunnen, C. (2003). Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. *BioScience*, *53*(12), 1169. https://doi.org/10.1641/0006-3568(2003)053[1169:IHIEOA]2.0.CO;2

Aldardasawi, A. F. M., & Eren, B. (2021). Floods and Their Impact on the Environment. *Academic Perspective Procedia*, *4*(2), 42–49. https://doi.org/10.33793/acperpro.04.02.24

Alessandra, F. (2018). *RESILIENCE AND URBAN DESIGN: A SYSTEMS APPROACH TO THE STUDY OF RESILIENCE IN URBAN FORM*.

Al-Ghamdi, K. A., Elzahrany, R. A., Mirza, M. N., & Dawod, G. M. (2012). *Impacts of urban growth on flood hazards in Makkah City, Saudi Arabia*.

Almeida, M. D. C., Telhado, M. J., Morais, M., Barreiro, J., & Lopes, R. (2020). Urban Resilience to Flooding: Triangulation of Methods for Hazard Identification in Urban Areas. *Sustainability*, *12*(6), 2227. https://doi.org/10.3390/su12062227

Anderson, D. (1978). *Effects of urban development on the flood-flow characteristics of the Walnut Creek Basin, Des Moines Metropolitan area, Iowa*. https://doi.org/10.3133/wri7811

ANGIRE, N. agency for integrated water resources management. (2019). *Collecte et analyse de données sur les inondations -Site de Tébessa-*.

Apreda, C. (2016). Climate change, urban vulnerability and adaptation strategies to pluvial flooding. *UPLanD - Journal of Urban Planning, Landscape&environmental Design*, 233 Pages. https://doi.org/10.6092/2531-9906/5040

Armitage, D., & Johnson, D. (2006). Can Resilience be Reconciled with Globalization and the

Increasingly Complex Conditions of Resource Degradation in Asian Coastal Regions? *Ecology and Society*, *11*(1), art2. https://doi.org/10.5751/ES-01485-110102

Arnaud-Fassetta, G., & FORT, M. (2011). *Risques naturels en Méditerranée Occidentale*.

ARUP. (2015). *City Resilience Framework*.

Asadzadeh, A., Khavarian-Garmsir, A. R., Sharifi, A., Salehi, P., & Kötter, T. (2022). Transformative Resilience: An Overview of Its Structure, Evolution, and Trends. *Sustainability*, *14*(22), 15267. https://doi.org/10.3390/su142215267

Asadzadeh, A., Kötter, T., & Zebardast, E. (2015). An augmented approach for measurement of disaster resilience using connective factor analysis and analytic network process (F'ANP) model. *International Journal of Disaster Risk Reduction*, *14*, 504–518. https://doi.org/10.1016/j.ijdrr.2015.10.002

Ausubel, J., & Biswas, A. K. (Eds.). (1980). *Climatic constraints and human activities* (1st ed). Pergamon Press.

Azareh, A., Rafiei Sardooi, E., Choubin, B., Barkhori, S., Shahdadi, A., Adamowski, J., & Shamshirband, S. (2021). Incorporating multi-criteria decision-making and fuzzy-value functions for flood susceptibility assessment. *Geocarto International*, *36*(20), 2345–2365. https://doi.org/10.1080/10106049.2019.1695958

Balawejder, M., Matkowska, K., & Rymarczyk, E. (2021). Effects of land consolidation in Southern Poland. *Acta Scientiarum Polonorum Administratio Locorum*, *20*(4), 269–282. https://doi.org/10.31648/aspal.6573

Bamba, I., Mama, A., Neuba, D., Koffi, K., Traore, D., Visser, M., Sinsin, B., Lejoly, J., & Bogaert, J. (2008). Influence des actions anthropiques sur la dynamique spatio-temporelle de l\'occupation du sol dans la province du Bas-Congo (R.D. Congo). *Sciences & Nature*, *5*(1), 49–60. https://doi.org/10.4314/scinat.v5i1.42151

Banasik, K., & Pham, N. (2010). Modelling of the effects of land use changes on flood hydrograph in a small catchment of the Płaskowicka, southern part of Warsaw, Poland. *Annals of Warsaw University of Life Sciences - SGGW. Land Reclamation*, *42*(2), 229–240. https://doi.org/10.2478/v10060-008-0081-7

Bates, P. D., & De Roo, A. P. J. (2000). A simple raster-based model for flood inundation simulation. *Journal of Hydrology*, *236*(1–2), 54–77. https://doi.org/10.1016/S0022-1694(00)00278-X

Bates, P. D., Horritt, M. S., & Fewtrell, T. J. (2010). A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling. *Journal of Hydrology*, *387*(1–2), 33–45. https://doi.org/10.1016/j.jhydrol.2010.03.027

Batty, M. (2008a). The Size, Scale, and Shape of Cities. *Science*, *319*(5864), 769–771. https://doi.org/10.1126/science.1151419

Batty, M. (2008b). The Size, Scale, and Shape of Cities. *Science*, *319*(5864), 769–771. https://doi.org/10.1126/science.1151419

Beceiro, P., Brito, R. S., & Galvão, A. (2022). Assessment of the contribution of Nature-Based Solutions (NBS) to urban resilience: Application to the case study of Porto. *Ecological Engineering*, *175*, 106489. https://doi.org/10.1016/j.ecoleng.2021.106489

Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. (2017). Weights and importance in composite indicators: Closing the gap. *Ecological Indicators*, *80*, 12–22.

https://doi.org/10.1016/j.ecolind.2017.03.056

Ben, W., Piers, B., Terry, C., & Lan, D. (2003). *At risk: Natural hazards, people's vulnerability and disasters*.

BENSON, M. A. (1964). *Factors affecting the occurrence of floods in the Southwest*. https://doi.org/10.3133/wsp1580D

Berne, A., & Krajewski, W. F. (2013). Radar for hydrology: Unfulfilled promise or unrecognized potential? *Advances in Water Resources*, *51*, 357–366. https://doi.org/10.1016/j.advwatres.2012.05.005

Bhatti, S. S., & Tripathi, N. K. (2014). Built-up area extraction using Landsat 8 OLI imagery. *GIScience & Remote Sensing*, *51*(4), 445–467. https://doi.org/10.1080/15481603.2014.939539

Biggs, J. (2023). *Factor_analyzer Documentation*.

Bonan, G. B. (2002). *Ecological climatology: Concepts and applications* (1. publ). Cambridge University Press.

Booth, Derek. B. (1991). *Urbanization and the natural drainage system—Impacts, Solutions, and Prognoses-*.

Borga, M., Gaume, E., Creutin, J. D., & Marchi, L. (2008). Surveying flash floods: Gauging the ungauged extremes. *Hydrological Processes*, *22*(18), 3883–3885. https://doi.org/10.1002/hyp.7111

Borkowska, M., & Laurence, J. (2021). Coming together or coming apart? Changes in social cohesion during the Covid-19 pandemic in England. *European Societies*, *23*(sup1), S618–S636. https://doi.org/10.1080/14616696.2020.1833067

Bourdic, L., & Salat, S. (2012). Building energy models and assessment systems at the district and city scales: A review. *Building Research & Information*, *40*(4), 518–526. https://doi.org/10.1080/09613218.2012.690951

Brand, F. S., & Jax, K. (2007a). Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object. *Ecology and Society*, *12*(1), art23. https://doi.org/10.5751/ES-02029-120123

Brand, F. S., & Jax, K. (2007b). Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object. *Ecology and Society*, *12*(1), art23. https://doi.org/10.5751/ES-02029-120123

BREIMAN, L. (2001). *Random Forests*.

Bristow, G., & Healy, A. (2018). Innovation and regional economic resilience: An exploratory analysis. *The Annals of Regional Science*, *60*(2), 265–284. https://doi.org/10.1007/s00168-017-0841-6

Bronstert, A., Bárdossy, A., Bismuth, C., Buiteveld, H., Disse, M., Engel, H., Fritsch, U., Hundecha, Y., Lammersen, R., Niehoff, D., & Ritter, N. (2007). Multi-scale modelling of land-use change and river training effects on floods in the Rhine basin. *River Research and Applications*, *23*(10), 1102–1125. https://doi.org/10.1002/rra.1036

Brown, A., Dayal, A., & Rumbaitis Del Rio, C. (2012). From practice to theory: Emerging lessons from Asia for building urban climate change resilience. *Environment and Urbanization*, *24*(2), 531–556. https://doi.org/10.1177/0956247812456490

Brunetta, G., & Salata, S. (2019). Mapping Urban Resilience for Spatial Planning—A First

Attempt to Measure the Vulnerability of the System. *Sustainability*, *11*(8), 2331. https://doi.org/10.3390/su11082331

Buckley, R. M., Clarke Annez, P., & Spence, M. (Eds.). (2008). *Urbanization and Growth*. The World Bank. https://doi.org/10.1596/978-0-8213-7573-0

Burges, C. J. C. (2010). *From RankNet to LambdaRank to LambdaMART: An Overview*.

Büyüközkan, G., Ilıcak, Ö., & Feyzioğlu, O. (2022). A review of urban resilience literature. *Sustainable Cities and Society*, *77*, 103579. https://doi.org/10.1016/j.scs.2021.103579

Cabinet Office. (2011). *Natural-hazards-infrastructure*.

Caisse Nationale du Logement. (2020). *Loi relative à l'urbanisme Avant-projet V1*.

Campanella, T. J. (2006a). Urban Resilience and the Recovery of New Orleans. *Journal of the American Planning Association*, *72*(2), 141–146. https://doi.org/10.1080/01944360608976734

Campanella, T. J. (2006b). Urban Resilience and the Recovery of New Orleans. *Journal of the American Planning Association*, *72*(2), 141–146. https://doi.org/10.1080/01944360608976734

Campbell, J. L. (1998). [No title found]. *Theory and Society*, *27*(3), 377–409. https://doi.org/10.1023/A:1006871114987

Caniggia , Maffer. (1979). *Architecture, Design and cities*.

Carine, N. M. A., Marc, Y. T., Mathunaise, S. V., Vincent, A. T., & Germain, M. (2021). *Dynamique d'occupation du sol du bassin versant de la volta, par la méthode de l'arbre de décision, à partir des images multispectrales de la génération Landsat de 1990 à 2020*.

Cariolet, J.-M., Vuillet, M., & Diab, Y. (2019). Mapping urban resilience to disasters – A review. *Sustainable Cities and Society*, *51*, 101746. https://doi.org/10.1016/j.scs.2019.101746

Carmona, M. (Ed.). (2003). *Public places, urban spaces: The dimensions of urban design*. Architectural Press.

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From Metaphor to Measurement: Resilience of What to What? *Ecosystems*, *4*(8), 765–781. https://doi.org/10.1007/s10021-001-0045-9

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, *100*(14), 8086–8091. https://doi.org/10.1073/pnas.1231332100

Castel, P. (1914). *Tébessa: Histoire et Description d'un Territoire Algèrien*.

Catani, F., Lagomarsino, D., Segoni, S., & Tofani, V. (2013). Landslide susceptibility estimation by random forests technique: Sensitivity and scaling issues. *Natural Hazards and Earth System Sciences*, *13*(11), 2815–2831. https://doi.org/10.5194/nhess-13-2815-2013

Chandra, A. (Ed.). (2011). *Building community resilience to disasters: A way forward to enhance national health security*. RAND.

Chelleri, L. (2012). *Multidisciplinary perspectives on urban resilience.* Basque Centre For Climate.

Chen, T., & Guestrin, C. (2016). XGBoost: A Scalable Tree Boosting System. *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 785–794. https://doi.org/10.1145/2939672.2939785

Chen, T., Singh, S., Taskar, B., & Guestrin, C. (2020). *Efficient Second-Order Gradient Boosting for Conditional Random Fields*.

Choubin, B., Moradi, E., Golshan, M., Adamowski, J., Sajedi-Hosseini, F., & Mosavi, A. (2019). An ensemble prediction of flood susceptibility using multivariate discriminant analysis, classification and regression trees, and support vector machines. *Science of The Total Environment*, *651*, 2087–2096. https://doi.org/10.1016/j.scitotenv.2018.10.064

Clauset, A., Shalizi, C. R., & Newman, M. E. J. (2009). Power-Law Distributions in Empirical Data. *SIAM Review*, *51*(4), 661–703. https://doi.org/10.1137/070710111

Cloete, C. E. (2012). *Assessing urban resilience*. 341–351. https://doi.org/10.2495/RISK120291

Coaffee, J., & O'Hare, P. (2008). Urban resilience and national security: The role for planning. *Proceedings of the Institution of Civil Engineers - Urban Design and Planning*, *161*(4), 173–182. https://doi.org/10.1680/udap.2008.161.4.173

Collier, M. J., Nedović-Budić, Z., Aerts, J., Connop, S., Foley, D., Foley, K., Newport, D., McQuaid, S., Slaev, A., & Verburg, P. (2013). Transitioning to resilience and sustainability in urban communities. *Cities*, *32*, S21–S28. https://doi.org/10.1016/j.cities.2013.03.010

Community Resilience Group. (2015). *Community resilience planning guide for buildings and infrastructure systems: Volume II* (NIST SP 1190v2; p. NIST SP 1190v2). National Institute of Standards and Technology. https://doi.org/10.6028/NIST.SP.1190v2

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, *37*(1), 35–46. https://doi.org/10.1016/0034-4257(91)90048-B

Conzen, M. R. G. (1960). Alnwick, Northumberland: A Study in Town-Plan Analysis. *Transactions and Papers (Institute of British Geographers)*, *27*, iii. https://doi.org/10.2307/621094

COPPIN, P, JONCKHEERE, I, & NACKAERTS, K. (2004). *Digital change detection methods in ecosystem monitoring: A review*.

Costache, R., Ngo, P. T. T., & Bui, D. T. (2020). Novel Ensembles of Deep Learning Neural Network and Statistical Learning for Flash-Flood Susceptibility Mapping. *Water*, *12*(6), 1549. https://doi.org/10.3390/w12061549

Cote, M., & Nightingale, A. J. (2012). Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. *Progress in Human Geography*, *36*(4), 475–489. https://doi.org/10.1177/0309132511425708

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*, *20*(4), 529–539. https://doi.org/10.1177/030913259602000407

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008a). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), 598–606. https://doi.org/10.1016/j.gloenvcha.2008.07.013

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008b). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), 598–606. https://doi.org/10.1016/j.gloenvcha.2008.07.013

Da Silva, J., Kernaghan, S., & Luque, A. (2012). A systems approach to meeting the challenges of urban climate change. *International Journal of Urban Sustainable Development*, *4*(2), 125–145. https://doi.org/10.1080/19463138.2012.718279

Da Silva, L., Marques Prietto, P. D., & Pavan Korf, E. (2019). Sustainability indicators for urban solid waste management in large and medium-sized worldwide cities. *Journal of Cleaner Production*, *237*, 117802. https://doi.org/10.1016/j.jclepro.2019.117802

Das, S., Chakraborty, R., & Maitra, A. (2017). A random forest algorithm for nowcasting of intense precipitation events. *Advances in Space Research*, *60*(6), 1271–1282. https://doi.org/10.1016/j.asr.2017.03.026

Davoudi, S., Shaw, K., Haider, L. J., Quinlan, A. E., Peterson, G. D., Wilkinson, C., Fünfgeld, H., McEvoy, D., Porter, L., & Davoudi, S. (2012). Resilience: A Bridging Concept or a Dead End? “Reframing” Resilience: Challenges for Planning Theory and Practice Interacting Traps: Resilience Assessment of a Pasture Management System in Northern Afghanistan Urban Resilience: What Does it Mean in Planning Practice? Resilience as a Useful Concept for Climate Change Adaptation? The Politics of Resilience for Planning: A Cautionary Note: Edited by Simin Davoudi and Libby Porter. *Planning Theory & Practice*, *13*(2), 299–333. https://doi.org/10.1080/14649357.2012.677124

Dawod, G. M., Mirza, M. N., & Al-Ghamdi, K. A. (2012). GIS-based estimation of flood hazard impacts on road network in Makkah city, Saudi Arabia. *Environmental Earth Sciences*, *67*(8), 2205–2215. https://doi.org/10.1007/s12665-012-1660-9

De Bellefon, M.-P., Combes, P.-P., Duranton, G., Gobillon, L., & Gorin, C. (2021). Delineating urban areas using building density. *Journal of Urban Economics*, *125*, 103226. https://doi.org/10.1016/j.jue.2019.103226

de Moel, H., van Alphen, J., & Aerts, J. C. J. H. (2009). Flood maps in Europe – methods, availability and use. *Natural Hazards and Earth System Sciences*, *9*(2), 289–301. https://doi.org/10.5194/nhess-9-289-2009

Dennis, S. M. (1999). *DISASTERS BY DESIGN*.

Department of Environmental Protection - State of New Jersey. (2009). *What is flood risk?*

Department of Sanitation and Environmental Protection. (2014). *Flood risk diagnosis Tébessa(Wilaya de Tébessa)*.

Desouza, K. C., & Flanery, T. H. (2013). Designing, planning, and managing resilient cities: A conceptual framework. *Cities*, *35*, 89–99. https://doi.org/10.1016/j.cities.2013.06.003

Dhar, T. K., & Khirfan, L. (2017). A multi-scale and multi-dimensional framework for enhancing the resilience of urban form to climate change. *Urban Climate*, *19*, 72–91. https://doi.org/10.1016/j.uclim.2016.12.004

Dibble, J., Prelorendjos, A., Romice, O., Zanella, M., Strano, E., Pagel, M., & Porta, S. (2019). On the origin of spaces: Morphometric foundations of urban form evolution. *Environment and Planning B: Urban Analytics and City Science*, *46*(4), 707–730. https://doi.org/10.1177/2399808317725075

Dingman, S. L., & Dingman, S. L. (2015). *Physical hydrology* (Third edition). Waveland Press, Inc.

Directorate of Civil Protection. (2021). *Flood Accident Statistics*.

Dovey, K., & Pafka, E. (2017). What is functional mix? An assemblage approach. *Planning Theory & Practice*, *18*(2), 249–267. https://doi.org/10.1080/14649357.2017.1281996

Dumont, G.-F. (2010). Le système migratoire méditerranéen: *Outre-Terre*, *n° 23*(3), 257–272. https://doi.org/10.3917/oute.023.0257

El-Masri, S., & Tipple, G. (2002). Natural Disaster, Mitigation and Sustainability: The Case of Developing Countries. *International Planning Studies*, *7*(2), 157–175. https://doi.org/10.1080/13563470220132236

Elsner, A., Mai, S., Meyer, V., & Zimmermann, C. (2003). Integration of Flood Risk in Coastal Hinterland Management. *Integrated Coastal Zone Management*.

Enrique Peña Nieto. (2016). *Guide de résilience urbaine 2016*.

Ernstson, H., van der Leeuw, S. E., Redman, C. L., Meffert, D. J., Davis, G., Alfsen, C., & Elmqvist, T. (2010). Urban Transitions: On Urban Resilience and Human-Dominated Ecosystems. *AMBIO*, *39*(8), 531–545. https://doi.org/10.1007/s13280-010-0081-9

Essel, P., Glover, E. T., Yeboah, S., Adjei-Kyereme, Y., Yawo, I. N. D., Nyarku, M., Asumadu-Sakyi, G. S., Gbeddy, G. K., Agyiri, Y. A., Ameho, E. M., & Aberikae, E. A. (2016). Rainfall erosivity index for the Ghana Atomic Energy Commission site. *SpringerPlus*, *5*(1), 465. https://doi.org/10.1186/s40064-016-2100-1

Evans, B., & Reid, J. (2013). Dangerously exposed: The life and death of the resilient subject. *Resilience*, *1*(2), 83–98. https://doi.org/10.1080/21693293.2013.770703

Ewing, R., Handy, S., Brownson, R. C., Clemente, O., & Winston, E. (2006). Identifying and Measuring Urban Design Qualities Related to Walkability. *Journal of Physical Activity and Health*, *3*(s1), S223–S240. https://doi.org/10.1123/jpah.3.s1.s223

FAO, United Nations. (2016). *Resilience Index Measurement and Analysis II*.

Fedczyna, D. (2024). *Flood Risk Assessment—Catchment Simulation Solutions*. https://csse.com.au/index.php/services/flood-impact-assessments

Feliciotti, A. (2016). *Socio-ecological resilience and urban design: Defining the common ground and a way forward for practice*.

Feliciotti, A., Romice, O., & Porta, S. (2016). Design for Change: Five Proxies for Resilience in the Urban Form. *Open House International*, *41*(4), 23–30. https://doi.org/10.1108/OHI-04-2016-B0004

Feliciotti, A., Romice, O., & Porta, S. (2018). From system ecology to urban morphology: Towards a theory of urban form resilience. *Proceedings of IFoU 2018: Reframing Urban Resilience Implementation: Aligning Sustainability and Resilience*, 5993. https://doi.org/10.3390/IFOU2018-05993

FEMA pub 1. (2010). *The Federal Emergency Management Agency*.

Feng, B., Zhang, Y., & Bourke, R. (2021). Urbanization impacts on flood risks based on urban growth data and coupled flood models. *Natural Hazards*, *106*(1), 613–627. https://doi.org/10.1007/s11069-020-04480-0

Feng, Q., Liu, J., & Gong, J. (2015a). Urban Flood Mapping Based on Unmanned Aerial Vehicle Remote Sensing and Random Forest Classifier—A Case of Yuyao, China. *Water*, *7*(12), 1437–1455. https://doi.org/10.3390/w7041437

Feng, Q., Liu, J., & Gong, J. (2015b). Urban Flood Mapping Based on Unmanned Aerial Vehicle Remote Sensing and Random Forest Classifier—A Case of Yuyao, China. *Water*, *7*(12), 1437–1455. https://doi.org/10.3390/w7041437

Feofilovs, M., & Romagnoli, F. (2020a). Assessment of Urban Resilience to Natural Disasters with a System Dynamics Tool: Case Study of Latvian Municipality. *Environmental and Climate Technologies*, *24*(3), 249–264. https://doi.org/10.2478/rtuect-2020-0101

Feofilovs, M., & Romagnoli, F. (2020b). Assessment of Urban Resilience to Natural Disasters with a System Dynamics Tool: Case Study of Latvian Municipality. *Environmental and Climate Technologies*, *24*(3), 249–264. https://doi.org/10.2478/rtuect-2020-0101

Feofilovs, M., & Romagnoli, F. (2021). Dynamic assessment of urban resilience to natural hazards. *International Journal of Disaster Risk Reduction*, *62*, 102328. https://doi.org/10.1016/j.ijdrr.2021.102328

Figueiredo, L., Honiden, T., & Schumann, A. (2018). *Indicators for Resilient Cities* (OECD Regional Development Working Papers 2018/02; OECD Regional Development Working Papers, Vol. 2018/02). https://doi.org/10.1787/6f1f6065-en

Fonseka, H. P. U., Zhang, H., Sun, Y., Su, H., Lin, H., & Lin, Y. (2019). Urbanization and Its Impacts on Land Surface Temperature in Colombo Metropolitan Area, Sri Lanka, from 1988 to 2016. *Remote Sensing*, *11*(8), 957. https://doi.org/10.3390/rs11080957

Forgaci, C., & Timmeren, A. V. (2014). *ISDRC2014/Please paste your Paper No here URBAN FORM AND FITNESS: TOWARDS A SPACE- MORPHOLOGICAL APPROACH TO GENERAL URBAN RESILIENCE*. https://doi.org/10.13140/2.1.4017.3444

Foudi, S., & Osés, N. (2014a). *Assessment for prevention with hydro-e- conomic approaches*. 19.

Foudi, S., & Osés, N. (2014b). *Assessment for prevention with hydro-e- conomic approaches*. 19.

Frankenberger, T. R. (2020). *Nongovernmental organizations' approaches to resilience programming*.

Freeman, E. A., Frescino, T. S., & Moisen, G. G. (2023). *ModelMap: An R Package for Model Creation and Map Production*.

Friedman, J., Hastie, T., & Tibshirani, R. (2000). Additive logistic regression: A statistical view of boosting (With discussion and a rejoinder by the authors). *The Annals of Statistics*, *28*(2). https://doi.org/10.1214/aos/1016218223

Füssel, H.-M., & Klein, R. J. T. (2006). Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. *Climatic Change*, *75*(3), 301–329. https://doi.org/10.1007/s10584-006-0329-3

Gabriels, D. (2006). Assessing the Modified Fournier Index and the Precipitation Concentration Index for Some European Countries. In J. Boardman & J. Poesen (Eds.), *Soil Erosion in Europe* (pp. 675–684). John Wiley & Sons, Ltd. https://doi.org/10.1002/0470859202.ch48

Galderisi, A. (2014). *Urban resilience: A framework for empowering cities in face of heterogeneous risk factors*.

Ganor, D. M., & Ben-Lavy, Y. (2003). *COMMUNITY RESILIENCE: LESSONS DERIVED FROM GILO UNDER FIRE*.

Gautam, K. P., & Van der Hoek, E. E. (2003). *Literature Study on ENvironmental Impact of FLoods*.

Gauthier, P., & Gilliland, J. (2005). Mapping urban morphology: A classification scheme for interpreting contributions to the study of urban form. *Urban Morphology*, *10*(1), 41–50. https://doi.org/10.51347/jum.v10i1.3926

Gérard-François, D. (2008). *LA MEDITERRANÉE, UN ESPACE MIGRATOIRE MAJEUR DANS LE MONDE [MEDITERRANEAN, A MAJOR SPACE MIGRATION IN THE WORLD]*.

Gérard-François, D. (2012). *L'URBANISATION DANS LE MONDE : UN PROCESSUS DIVERSIFIÉ [Urbanization in the world: A diversified process]*.

GHERZOULI, L. (2014). *Les instruments d'urbanisme et le développement urbain durable de la ville algérienne. Cas d'une ville patrimoniale: Tébessa.*

Ghosh, S., Saha, S., & Bera, B. (2022). Flood susceptibility zonation using advanced ensemble machine learning models within Himalayan foreland basin. *Natural Hazards Research*, *2*(4), 363–374. https://doi.org/10.1016/j.nhres.2022.06.003

Ghouchani, M., Taji, M., Yaghoubi Roshan, A., & Seifi Chehr, M. (2021). Identification and assessment of hidden capacities of urban resilience. *Environment, Development and Sustainability*, *23*(3), 3966–3993. https://doi.org/10.1007/s10668-020-00752-8

Glade, T. (2003). *Vulnerability Assessment in Landslide Risk Analysis*.

Godschalk, D. R. (2003a). Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review*, *4*(3), 136–143. https://doi.org/10.1061/(ASCE)1527-6988(2003)4:3(136)

Godschalk, D. R. (2003b). Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review*, *4*(3), 136–143. https://doi.org/10.1061/(ASCE)1527-6988(2003)4:3(136)

Goudenhoofdt, E., & Delobbe, L. (2008). *Evaluation of radar-gauge merging methods for QPE*.

Grabher, G. (1993). *The weakness of strong ties: The lock-in of regional development in the Ruhr area. In: The embedded firm: On the socio-economics of industrial networks*.

Guhathakurta, P., Sreejith, O. P., & Menon, P. A. (2011). Impact of climate change on extreme rainfall events and flood risk in India. *Journal of Earth System Science*, *120*(3), 359–373. https://doi.org/10.1007/s12040-011-0082-5

Guo, K., Guan, M., & Yu, D. (2020). *Urban surface water flood modelling – a comprehensive review ofcurrent models and future challenges* [Preprint]. Urban Hydrology/Modelling approaches. https://doi.org/10.5194/hess-2020-655

Gupta, D., & Ghose, U. (2015). A comparative study of classification algorithms for forecasting rainfall. *2015 4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO) (Trends and Future Directions)*, 1–6. https://doi.org/10.1109/ICRITO.2015.7359273

Haase, D. (2003). Holocene floodplains and their distribution in urban areas—Functionality indicators for their retention potentials. *Landscape and Urban Planning*, *66*(1), 5–18. https://doi.org/10.1016/S0169-2046(03)00071-9

HADJLA, A. (2016). *Urbanization and sustainable development in the city of Tebessa*.

Hanley, J. A., & McNeil, B. J. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*, *143*(1), 29–36. https://doi.org/10.1148/radiology.143.1.7063747

He, P., Ng, T. S., & Su, B. (2019). Energy-economic resilience with multi-region input–output linear programming models. *Energy Economics*, *84*, 104569. https://doi.org/10.1016/j.eneco.2019.104569

He, Q., He, W., Song, Y., Wu, J., Yin, C., & Mou, Y. (2018). The impact of urban growth patterns on urban vitality in newly built-up areas based on an association rules analysis using geographical 'big data.' *Land Use Policy*, *78*, 726–738. https://doi.org/10.1016/j.landusepol.2018.07.020

He, Q. P., & Wang, J. (2007). Fault Detection Using the k-Nearest Neighbor Rule for Semiconductor Manufacturing Processes. *IEEE Transactions on Semiconductor Manufacturing*, *20*(4), 345–354. https://doi.org/10.1109/TSM.2007.907607

Henshaw, V. (2014). Socially Restorative Urbanism: The Theory, Process and Practice of Experiemics. *Urban Policy and Research*, *32*(3), 384–386. https://doi.org/10.1080/08111146.2014.929937

Henstra, D. (2012). Toward the Climate-Resilient City: Extreme Weather and Urban Climate Adaptation Policies in Two Canadian Provinces. *Journal of Comparative Policy Analysis: Research and Practice*, *14*(2), 175–194. https://doi.org/10.1080/13876988.2012.665215

Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H., & Kanae, S. (2013). Global flood risk under climate change. *Nature Climate Change*, *3*(9), 816–821. https://doi.org/10.1038/nclimate1911

Hochrainer-Stigler, S., Laurien, F., Velev, S., Keating, A., & Mechler, R. (2020). Standardized disaster and climate resilience grading: A global scale empirical analysis of community flood resilience. *Journal of Environmental Management*, *276*, 111332. https://doi.org/10.1016/j.jenvman.2020.111332

Hodgson, G. M. (2006). *What Are Institutions?*

Holling, C. S. (1973). *RESILIENCE AND STABILITY OF ECOLOGICAL SYSTEMS*.

Holling, C. S., & Goldberg, M. A. (1971). Ecology and Planning. *Journal of the American Institute of Planners*, *37*(4), 221–230. https://doi.org/10.1080/01944367108977962

Hu, J., Zheng, B., Wang, C., Zhao, C., Hou, X., Pan, Q., & Xu, Z. (2020). A survey on multi-sensor fusion based obstacle detection for intelligent ground vehicles in off-road environments. *Frontiers of Information Technology & Electronic Engineering*, *21*(5), 675–692. https://doi.org/10.1631/FITEE.1900518

Huang, Q., Wang, J., Li, M., Fei, M., & Dong, J. (2017). Modeling the influence of urbanization on urban pluvial flooding: A scenario-based case study in Shanghai, China. *Natural Hazards*, *87*(2), 1035–1055. https://doi.org/10.1007/s11069-017-2808-4

Huntjens, P., Lebel, L., Pahl-Wostl, C., Camkin, J., Schulze, R., & Kranz, N. (2012). Institutional design propositions for the governance of adaptation to climate change in the water sector. *Global Environmental Change*, *22*(1), 67–81. https://doi.org/10.1016/j.gloenvcha.2011.09.015

Iglouli, S. (2020). *«The master plan for development and reconstruction and the land occupancy plan under Law 90-29»*.

Iorhen, R. T. (2021). Vulnerability: Types, causes, and coping mechanisms. *International Journal of Science and Management Studies (IJSMS)*.

Irani, M., & Rahnamayiezekavat, P. (2021a). An overview of urban resilience: Dimensions, components, and approaches. *Acta Scientiarum Polonorum Administratio Locorum*, *20*(4), 305–322. https://doi.org/10.31648/aspal.7054

Irani, M., & Rahnamayiezekavat, P. (2021b). An overview of urban resilience: Dimensions, components, and approaches. *Acta Scientiarum Polonorum Administratio Locorum*, *20*(4), 305–322. https://doi.org/10.31648/aspal.7054

Iturriza, M., Hernantes, J., Abdelgawad, A. A., & Labaka, L. (2020). Are Cities Aware Enough? A Framework for Developing City Awareness to Climate Change. *Sustainability*, *12*(6), 2168. https://doi.org/10.3390/su12062168

Iturriza, M., Hernantes, J., & Labaka, L. (2019). Coming to Action: Operationalizing City Resilience. *Sustainability*, *11*(11), 3054. https://doi.org/10.3390/su11113054

J. Twigg. (2007). *Characteristics of a Disaster-resilient Community: A Guidance Note*.

Jabareen, Y. R. (2006). Sustainable Urban Forms: Their Typologies, Models, and Concepts. *Journal of Planning Education and Research*, *26*(1), 38–52. https://doi.org/10.1177/0739456X05285119

Jane Jacobs. (1961). *THE DEATH AND LIFE OF GREAT AMERICAN CITIES*.

Jażdżewska, I. (2022). Vítor Oliveira, Urban Morphology. An Introduction to the Study of the Physical Form of Cities, The Urban Book Series, Springer International Publishing, Cham 2016, ss. XXIII, 192. *Konwersatorium Wiedzy o Mieście*, *35*(7), 107–109. https://doi.org/10.18778/2543-9421.07.02

Jiang, B., & Claramunt, C. (2002). Integration of Space Syntax into GIS: New Perspectives for Urban Morphology. *Transactions in GIS*, *6*(3), 295–309. https://doi.org/10.1111/1467-9671.00112

Jongman, B., Kreibich, H., Apel, H., Barredo, J. I., Bates, P. D., Feyen, L., Gericke, A., Neal, J., Aerts, J. C. J. H., & Ward, P. J. (2012). Comparative flood damage model assessment: Towards a European approach. *Natural Hazards and Earth System Sciences*, *12*(12), 3733–3752. https://doi.org/10.5194/nhess-12-3733-2012

Julien, B. (1962). *SP-Tebessa_Internet.qxp*.

Justice Institure of British Columbia. (2020). *Community Resilience Index (CRI)*.

Kammouh, O., & Cimellaro, G. P. (2018). PEOPLES: A Tool to Measure Community Resilience. *Structures Conference 2018*, 161–171. https://doi.org/10.1061/9780784481349.015

Kates, R. W., Clark, W. C., Corell, R., Hall, M., Jaeger, C. C., Lowe, I., Schellnhuber, H. J., Bolin, B., Dickson, M., Faucheux, S., Gallopin, G. C., Huntley, B., Jäger, J., Jodha, N. S., Kasperson, E., Mabogunje, A., Matson, P., Iii, B. M., O'Riordan, T., & Svedin, U. (2000). *Belfer Center for Science & International Affairs*.

Keck, M., & Sakdapolrak, P. (2013). What is social resilience? Lessons learned and ways forward. *Erdkunde*, *67*(1), 5–19. https://doi.org/10.3112/erdkunde.2013.01.02

Kendall, S., & Teicher, J. (2000a). *Residential open building*. E&FNSpon.

Kendall, S., & Teicher, J. (2000b). *Residential open building*. E&FNSpon.

Khosravi, K., Pham, B. T., Chapi, K., Shirzadi, A., Shahabi, H., Revhaug, I., Prakash, I., & Tien Bui, D. (2018). A comparative assessment of decision trees algorithms for flash flood susceptibility modeling at Haraz watershed, northern Iran. *Science of The Total Environment*, *627*, 744–755. https://doi.org/10.1016/j.scitotenv.2018.01.266

Kikegawa, Y., Genchi, Y., Yoshikado, H., & Kondo, H. (2003). Development of a numerical simulation system toward comprehensive assessments of urban warming countermeasures including their impacts upon the urban buildings' energy-demands. *Applied Energy*, *76*(4), 449–466. https://doi.org/10.1016/S0306-2619(03)00009-6

Klein, B. (2016). *Managing urban resilience*.

Klein, R. J. T., Nicholls, R. J., & Thomalla, F. (2003). Resilience to natural hazards: How useful is this concept? *Environmental Hazards*, *5*(1), 35–45. https://doi.org/10.1016/j.hazards.2004.02.001

Kouassi, J.-L. (2014). *SUIVI DE LA DYNAMIQUE DE L'OCCUPATION DU SOL A L'AIDE DE L'IMAGERIE SATELLITAIRE ET DES SYSTEMES D'INFORMATIONS GEOGRAPHIQUES: CAS DE LA DIRECTION REGIONALE DES EAUX ET FORETS DE*

YAMOUSSOUKRO (COTE D'IVOIRE). https://doi.org/10.13140/2.1.2359.7128

Kourgialas, N. N., & Karatzas, G. P. (2011). Flood management and a GIS modelling method to assess flood-hazard areas—A case study. *Hydrological Sciences Journal*, *56*(2), 212–225. https://doi.org/10.1080/02626667.2011.555836

Kropf, K. (1996). Urban tissue and the character of towns. *URBAN DESIGN International*, *1*(3), 247–263. https://doi.org/10.1057/udi.1996.32

Kropf, K. (2009). Aspects of urban form. *Urban Morphology*, *13*(2), 105–120. https://doi.org/10.51347/jum.v13i2.3949

Kulkarni, A. T., Mohanty, J., Eldho, T. I., Rao, E. P., & Mohan, B. K. (2014). A web GIS based integrated flood assessment modeling tool for coastal urban watersheds. *Computers & Geosciences*, *64*, 7–14. https://doi.org/10.1016/j.cageo.2013.11.002

Lak, A., Hasankhan, F., & Garakani, S. A. (2020). Principles in practice: Toward a conceptual framework for resilient urban design. *Journal of Environmental Planning and Management*, *63*(12), 2194–2226. https://doi.org/10.1080/09640568.2020.1714561

Lamond, J. E., Proverbs, D. G., & Hammond, F. N. (2009). Accessibility of flood risk insurance in the UK: Confusion, competition and complacency. *Journal of Risk Research*, *12*(6), 825–841. https://doi.org/10.1080/13669870902768614

Laura, V. (2015). *Suburban Urbanities*. UCL Press. https://doi.org/10.14324/111.9781910634134

Lee, M.-J., Kang, J. E., & Kim, G. (2015). Application of fuzzy combination operators to flood vulnerability assessments in Seoul, Korea. *Geocarto International*, 1–24. https://doi.org/10.1080/10106049.2015.1027290

Leichenko, R. (2011a). Climate change and urban resilience. *Current Opinion in Environmental Sustainability*, *3*(3), 164–168. https://doi.org/10.1016/j.cosust.2010.12.014

Leichenko, R. (2011b). Climate change and urban resilience. *Current Opinion in Environmental Sustainability*, *3*(3), 164–168. https://doi.org/10.1016/j.cosust.2010.12.014

Leitner, H., Sheppard, E., Webber, S., & Colven, E. (2018). Globalizing urban resilience. *Urban Geography*, *39*(8), 1276–1284. https://doi.org/10.1080/02723638.2018.1446870

Lerch, D. (2017). Six Foundations for Building Community Resilience. In D. Lerch (Ed.), *The Community Resilience Reader* (pp. 9–42). Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-861-9_2

Leykin, D., Lahad, M., Cohen, O., Goldberg, A., & Aharonson-Daniel, L. (2013). Conjoint Community Resiliency Assessment Measure-28/10 Items (CCRAM28 and CCRAM10): A Self-report Tool for Assessing Community Resilience. *American Journal of Community Psychology*, *52*(3–4), 313–323. https://doi.org/10.1007/s10464-013-9596-0

Lhomme, S., Serre, D., Diab, Y., & Laganier, R. (2010). Les réseaux techniques face aux inondations, ou comment définir des indicateurs de performance de ces réseaux pour évaluer la résilience urbaine (Urban networks and floods: How to define performance indicators to evaluate urban resiliency). *Bulletin de l'Association de géographes français*, *87*(4), 487–502. https://doi.org/10.3406/bagf.2010.8193

Li, L., Van Eetvelde, V., Cheng, X., & Uyttenhove, P. (2020). Assessing stormwater runoff reduction capacity of existing green infrastructure in the city of Ghent. *International Journal of Sustainable Development & World Ecology*, *27*(8), 749–761.

https://doi.org/10.1080/13504509.2020.1739166

Li, P. (2010). *Robust LogitBoost and Adaptive Base Class (ABC) LogitBoost*.

Liu, R., Zhou, H., Li, D., Zeng, L., & Xu, P. (2023). Evaluation of Artificial Precipitation Enhancement Using UNET-GRU Algorithm for Rainfall Estimation. *Water*, *15*(8), 1585. https://doi.org/10.3390/w15081585

Localize, B. (2020). *Community resilience Toolkit*.

Loerzel, J., & Dillard, M. (2021). An Analysis of an Inventory of Community Resilience Frameworks. *Journal of Research of the National Institute of Standards and Technology*, *126*, 126031. https://doi.org/10.6028/jres.126.031

Lu, D., & Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing*, *28*(5), 823–870. https://doi.org/10.1080/01431160600746456

Luca, C. (2021). *Semi-Automatic Classification Plugin: A Python tool for the download and processing of remote sensing images in QGIS*.

Ly, S., Charles, C., & Degré, A. (2013a). Different methods for spatial interpolation of rainfall data for operational hydrology and hydrological modeling at watershed scale. A review. *Biotechnol. Agron. Soc. Environ.*

Ly, S., Charles, C., & Degré, A. (2013b). *Different methods for spatial interpolation of rainfall data for operational hydrology and hydrological modeling at watershed scale. A review*.

Ma, M., Zhao, G., He, B., Li, Q., Dong, H., Wang, S., & Wang, Z. (2021). XGBoost-based method for flash flood risk assessment. *Journal of Hydrology*, *598*, 126382. https://doi.org/10.1016/j.jhydrol.2021.126382

MacKinnon, D. (2015). Resilient City. In *International Encyclopedia of the Social & Behavioral Sciences* (pp. 561–567). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.74046-3

Madhuri, R., Sistla, S., & Srinivasa Raju, K. (2021). Application of machine learning algorithms for flood susceptibility assessment and risk management. *Journal of Water and Climate Change*, *12*(6), 2608–2623. https://doi.org/10.2166/wcc.2021.051

MAE. (2019). *Algeria, Voluntary National Report 2019.*

Mandych, A. F. (2007). Flood Control For Specific Types Of Floods. *NATURAL DISASTERS*.

Mangalkar, M., & Sonar, P. (2021). *Addressing Urban Resilience through Urban Design Principles for Built Environment*.

Marcus, L. (2011). *Towards a Spatial Morphology of Urban Social-Ecological Systems*.

Marcus, M., Yali, W., & UN-Habitat. (2019). *ADDRESSING URBAN AND HUMAN SETTLEMENT ISSUES IN NATIONAL ADAPTATION PLANS*.

Marshall, S. (2005). *Streets & patterns* (1st ed). Spon.

McEvoy, D., Fünfgeld, H., & Bosomworth, K. (2013). Resilience and Climate Change Adaptation: The Importance of Framing. *Planning Practice and Research*, *28*(3), 280–293. https://doi.org/10.1080/02697459.2013.787710

Meerow, S., & Newell, J. P. (2015). Resilience and Complexity: A Bibliometric Review and Prospects for Industrial Ecology. *Journal of Industrial Ecology*, *19*(2), 236–251. https://doi.org/10.1111/jiec.12252

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Mehaffy, M., Porta, S., Rofè, Y., & Salingaros, N. (2010). Urban nuclei and the geometry of streets: The 'emergent neighborhoods' model. *URBAN DESIGN International*, *15*(1), 22–46. https://doi.org/10.1057/udi.2009.26

Meineke, E. K., Dunn, R. R., & Frank, S. D. (2014). Early pest development and loss of biological control are associated with urban warming. *Biology Letters*, *10*(11), 20140586. https://doi.org/10.1098/rsbl.2014.0586

Menculini, L., Marini, A., Proietti, M., Garinei, A., Bozza, A., Moretti, C., & Marconi, M. (2021). Comparing Prophet and Deep Learning to ARIMA in Forecasting Wholesale Food Prices. *Forecasting*, *3*(3), 644–662. https://doi.org/10.3390/forecast3030040

Meraj, G., Romshoo, S. A., Yousuf, A. R., Altaf, S., & Altaf, F. (2015). Assessing the influence of watershed characteristics on the flood vulnerability of Jhelum basin in Kashmir Himalaya: Reply to comment by Shah 2015. *Natural Hazards*, *78*(1), 1–5. https://doi.org/10.1007/s11069-015-1861-0

MERE. (2017). *Catalogue des ouvrages*.

Messner, F., & Meyer, V. (2006). FLOOD DAMAGE, VULNERABILITY AND RISK PERCEPTION – CHALLENGES FOR FLOOD DAMAGE RESEARCH. In J. Schanze, E. Zeman, & J. Marsalek (Eds.), *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures* (Vol. 67, pp. 149–167). Springer Netherlands. https://doi.org/10.1007/978-1-4020-4598-1_13

Mikael, P. (2022). *Murmuring city: Banal architecture*.

Miller, R. C., Guertin, D. P., & Heilman, P. (2004). INFORMATION TECHNOLOGY IN WATERSHED MANAGEMENT DECISION MAKING. *Journal of the American Water Resources Association*, *40*(2), 347–357. https://doi.org/10.1111/j.1752-1688.2004.tb01034.x

Ministry of Culture. (2007). *THE MASTER PLAN FOR ARCHAEOLOGICAL AND HISTORICAL ZONES*.

Ministry of Ecological Transition and Solidarity. (2020). *ANALYSE DES RISQUES DE DEFAILLANCE: Note de cadrage*.

Moghadas, M., Asadzadeh, A., Vafeidis, A., Fekete, A., & Kötter, T. (2019). A multi-criteria approach for assessing urban flood resilience in Tehran, Iran. *International Journal of Disaster Risk Reduction*, *35*, 101069. https://doi.org/10.1016/j.ijdrr.2019.101069

Montgomery, J. (1998). Making a city: Urbanity, vitality and urban design. *Journal of Urban Design*, *3*(1), 93–116. https://doi.org/10.1080/13574809808724418

Mora, H., Gilart-Iglesias, V., Pérez-del Hoyo, R., & Andújar-Montoya, M. (2017). A Comprehensive System for Monitoring Urban Accessibility in Smart Cities. *Sensors*, *17*(8), 1834. https://doi.org/10.3390/s17081834

Moriconi-Ebrard, F., & Perez, J. (2017). Shanghai et Guangzhou sont les deux agglomérations urbaines les plus peuplées du monde. *Confins*, *30*. https://doi.org/10.4000/confins.11729

Naeem, S., Iii, F. S. C., Costanza, R., Ehrlich, P. R., Golley, F. B., Hooper, D. U., & Lawton, J. H. (1999). *Biodiversity and Ecosystem Functioning: Maintaining Natural Life Support Processes*. *4*.

Nalau, J., & Verrall, B. (2021). Mapping the evolution and current trends in climate change adaptation science. *Climate Risk Management*, *32*, 100290. https://doi.org/10.1016/j.crm.2021.100290

Nanditha, P. J. (2022). *Community Resilience and Engagement: What brings communities together? 3*(5).

Narieswari, L., Sitorus, S. R. P., Hardjomidjojo, H., & Putri, E. I. K. (2021). Assessment of disaster resilience in Semarang City. *IOP Conference Series: Earth and Environmental Science*, *771*(1), 012026. https://doi.org/10.1088/1755-1315/771/1/012026

National Agency For Integrated Water Resources Management. (2019). *PLAN DE PREVENTION DES RISQUES D'INONDATION*.

National Economic and Social Council. (2003). *Rapport: L'urbanisation et les risques naturels et industriels en Algérie: Inquiétudes actuelles et futures*.

Nedjai, F. (2012). *Les intstruments d'urbanisme entre proprietaire foncier et application cas d'etude: La ville de BATNA.*

Nicola, T., J.Hamhaber, Stelios, G., Shuaib, L., & Jordi, M. (2016). *Sustainable urbanization in the Paris Agreement: Comparative review of nationally determined contributions for urban content—Pre-release 2016 Comparative review of Nationally Determined Contributions for Urban Content*.

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness. *American Journal of Community Psychology*, *41*(1–2), 127–150. https://doi.org/10.1007/s10464-007-9156-6

Official Journal of the Algerian Republic N° 84, O. J. of the A. R. (2004). *Correspondant au 29 décembre 2004*. 28.

Official Journal of the Algerian Republic, N. (1990). *The low 90-29 on urban planning and development*.

Official Journal of the Algerian Republic, N. (1991a). *Executive Decree N° 91-177 of May 28, 1991 setting out the procedures for drawing up and approving Urban Development Master Plans and the content of related documents.*

Official Journal of the Algerian Republic, N. (1991b). *Executive Decree N°91-178 of May 28,1991.*

Official Journal of the Algerian Republic, N. (2004). *The Law N° 04-20 of 13 Dhou El Kaada 1425 corresponding December 25, 2004 , relating to the prevention of prevention and disaster management within the framework of sustainable development*.

Official Journal of the Algerian Republic, N. (2005). *Executive Decree N° 05-318 of September 10,2005.*

Official Journal of the Algerian Republic, N. (2011). *Executive Decrees N° 11-237 and N° 11-239 of July 9, 2011 declaring the operation relating to the construction of public housing and accompanying facilities in certain wilayas to be in the public interest*.

Official Journal of the Algerian Republic, N. (2019). *Executive Decree N° 19-59 of 26 Joumada El Oula 1440 corresponding to February 2, 2019, fixes the modalities of elaboration and management of the plans of organization plans*.

O'Hare, P., & White, I. (2013). Deconstructing Resilience: Lessons from Planning Practice: Special Edition of Planning Practice and Research. *Planning Practice and Research*, *28*(3), 275–279. https://doi.org/10.1080/02697459.2013.787721

Olaiya, F., & Adeyemo, A. B. (2012). Application of Data Mining Techniques in Weather

Prediction and Climate Change Studies. *International Journal of Information Engineering and Electronic Business*, *4*(1), 51–59. https://doi.org/10.5815/ijieeb.2012.01.07

Oliveira, E. A., Andrade Jr., J. S., & Makse, H. A. (2014). Large cities are less green. *Scientific Reports*, *4*(1), 4235. https://doi.org/10.1038/srep04235

Overly, K. (2021). *The Factors Influencing Hazard Mitigation Governance*.

Papachristos, G. (2019). System dynamics modelling and simulation for sociotechnical transitions research. *Environmental Innovation and Societal Transitions*, *31*, 248–261. https://doi.org/10.1016/j.eist.2018.10.001

Pasteur, K. (2011). *From Vulnerability to Resilience*.

Patrick, M.-B., & J.Marty, A. (2011). *Resilience: A Literature Review*.

Pendall, R., Foster, K. A., & Cowell, M. (2010). Resilience and regions: Building understanding of the metaphor. *Cambridge Journal of Regions, Economy and Society*, *3*(1), 71–84. https://doi.org/10.1093/cjres/rsp028

Peng, W., Bao, S., Yang, K., Wei, J., Zhu, X., Qiao, Z., Wang, Y., & Li, Q. (2022). Radar Quantitative Precipitation Estimation Algorithm Based on Precipitation Classification and Dynamical Z-R Relationship. *Water*, *14*(21), 3436. https://doi.org/10.3390/w14213436

Perez, J., Fusco, G., & Moriconi-Ebrard, F. (2019). Identification and quantification of urban space in India: Defining urban macro-structures. *Urban Studies*, *56*(10), 1988–2004. https://doi.org/10.1177/0042098018783870

Pfefferbaum, R. L., Pfefferbaum, B., Van Horn, R. L., Klomp, R. W., Norris, F. H., & Reissman, D. B. (2013). The Communities Advancing Resilience Toolkit (CART): An Intervention to Build Community Resilience to Disasters. *Journal of Public Health Management and Practice*, *19*(3), 250–258. https://doi.org/10.1097/PHH.0b013e318268aed8

Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Boone, C. G., Groffman, P. M., Irwin, E., Kaushal, S. S., Marshall, V., McGrath, B. P., Nilon, C. H., Pouyat, R. V., Szlavecz, K., Troy, A., & Warren, P. (2011). Urban ecological systems: Scientific foundations and a decade of progress. *Journal of Environmental Management*, *92*(3), 331–362. https://doi.org/10.1016/j.jenvman.2010.08.022

Pimm, S. L. (1984). The complexity and stability of ecosystems. *Nature*, *307*(5949), 321–326. https://doi.org/10.1038/307321a0

Pishnamazzadeh, M., Sepehri, M. M., & Ostadi, B. (2020). An Assessment Model for Hospital Resilience according to the Simultaneous Consideration of Key Performance Indicators: A System Dynamics Approach. *Perioperative Care and Operating Room Management*, *20*, 100118. https://doi.org/10.1016/j.pcorm.2020.100118

Porta, S., Latora, V., Wang, F., Rueda, S., Strano, E., Scellato, S., Cardillo, A., Belli, E., Càrdenas, F., Cormenzana, B., & Latora, L. (2012). Street Centrality and the Location of Economic Activities in Barcelona. *Urban Studies*, *49*(7), 1471–1488. https://doi.org/10.1177/0042098011422570

Pradhan, A. M. S., & Kim, Y.-T. (2017). Spatial data analysis and application of evidential belief functions to shallow landslide susceptibility mapping at Mt. Umyeon, Seoul, Korea. *Bulletin of Engineering Geology and the Environment*, *76*(4), 1263–1279. https://doi.org/10.1007/s10064-016-0919-x

Pradhan, A. M. S., & Kim, Y.-T. (2020). Rainfall-Induced Shallow Landslide Susceptibility

Mapping at Two Adjacent Catchments Using Advanced Machine Learning Algorithms. *ISPRS International Journal of Geo-Information*, *9*(10), 569. https://doi.org/10.3390/ijgi9100569

Proag, V. (2014). The Concept of Vulnerability and Resilience. *Procedia Economics and Finance*, *18*, 369–376. https://doi.org/10.1016/S2212-5671(14)00952-6

Puchol-Salort, P., O'Keeffe, J., Van Reeuwijk, M., & Mijic, A. (2021). An urban planning sustainability framework: Systems approach to blue green urban design. *Sustainable Cities and Society*, *66*, 102677. https://doi.org/10.1016/j.scs.2020.102677

Puchol-Salort, P., O'Keeffe, J., van Reeuwijk, M., & Mijic, A. (2021). An urban planning sustainability framework: Systems approach to blue green urban design. *Sustainable Cities and Society*, *66*, 102677. https://doi.org/10.1016/j.scs.2020.102677

Quinan, J., & Alexander, C. (1981). A Pattern Language: Towns, Buildings, Construction. *Leonardo*, *14*(1), 80. https://doi.org/10.2307/1574526

Quitana, G., Molinos-Senante, M., & Chamorro, A. (2020). Resilience of critical infrastructure to natural hazards: A review focused on drinking water systems. *International Journal of Disaster Risk Reduction*, *48*, 101575. https://doi.org/10.1016/j.ijdrr.2020.101575

Rahmati, O., & Pourghasemi, H. R. (2017a). Identification of Critical Flood Prone Areas in Data-Scarce and Ungauged Regions: A Comparison of Three Data Mining Models. *Water Resources Management*, *31*(5), 1473–1487. https://doi.org/10.1007/s11269-017-1589-6

Rahmati, O., & Pourghasemi, H. R. (2017b). Identification of Critical Flood Prone Areas in Data-Scarce and Ungauged Regions: A Comparison of Three Data Mining Models. *Water Resources Management*, *31*(5), 1473–1487. https://doi.org/10.1007/s11269-017-1589-6

Ramesh, V., & Iqbal, S. S. (2022). Urban flood susceptibility zonation mapping using evidential belief function, frequency ratio and fuzzy gamma operator models in GIS: A case study of Greater Mumbai, Maharashtra, India. *Geocarto International*, *37*(2), 581–606. https://doi.org/10.1080/10106049.2020.1730448

RCEP. (2007). *The Urban Environment: Summary of the Royal Commission on ENvironmental Pollution's Report*.

Rechkemmer, A., & Von Falkenhayn, L. (2009). The human dimensions of global environmental change: Ecosystem services, resilience, and governance. *The European Physical Journal Conferences*, *1*, 3–17. https://doi.org/10.1140/epjconf/e2009-00906-y

Rega, C., & Bonifazi, A. (2020). The Rise of Resilience in Spatial Planning: A Journey through Disciplinary Boundaries and Contested Practices. *Sustainability*, *12*(18), 7277. https://doi.org/10.3390/su12187277

Regmi, A. D., Yoshida, K., Dhital, M. R., & Pradhan, B. (2014). Weathering and mineralogical variation in gneissic rocks and their effect in Sangrumba Landslide, East Nepal. *Environmental Earth Sciences*, *71*(6), 2711–2727. https://doi.org/10.1007/s12665-013-2649-8

Resilience Alliance. (2010). *Assessing Resilience in Social-Ecological systems: Workbook for Practitioners*.

Reu Junqueira, J., Serrao-Neumann, S., & White, I. (2021). Managing urban climate change risks: Prospects for using green infrastructure to increase urban resilience to floods. In *The Impacts of Climate Change* (pp. 379–396). Elsevier. https://doi.org/10.1016/B978-0-12-822373-4.00013-6

Robert, W. K. (1985). *The Interaction of Climate and Soceity*.

Rolland, A. (2020). *COVID-19, Generosity, and Gender: How Giving Changed During the First Year of a Global Pandemic*.

Romero-Lankao, P., & Gnatz, D. M. (2013). Exploring urban transformations in Latin America. *Current Opinion in Environmental Sustainability*, *5*(3–4), 358–367. https://doi.org/10.1016/j.cosust.2013.07.008

Romice, O., Porta, S., & Feliciotti, A. (2018). Urban form Resilience Urban Design Practice: Masterplanning for Change. *Proceedings of IFoU 2018: Reframing Urban Resilience Implementation: Aligning Sustainability and Resilience*, 5976. https://doi.org/10.3390/IFOU2018-05976

Romice, O., Thwaites, K., Porta, S., & Greaves, M. (2016). *Chapter 14 Urban Design and Quality of Life*.

Rose, A. (2004). Economic Principles, Issues, and Research Priorities in Hazard Loss Estimation. In Y. Okuyama & S. E. Chang (Eds.), *Modeling Spatial and Economic Impacts of Disasters* (pp. 13–36). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-24787-6_2

Rozalis, S., Morin, E., Yair, Y., & Price, C. (2010). Flash flood prediction using an uncalibrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions. *Journal of Hydrology*, *394*(1–2), 245–255. https://doi.org/10.1016/j.jhydrol.2010.03.021

Ryan, B. D. (2005). Morphological change through residential redevelopment: Detroit, 1951-2000. *Urban Morphology*, *10*(1), 5–22. https://doi.org/10.51347/jum.v10i1.3924

SACN-Cities-Network. (2022). *Urban resilience in South Affrica Cities*.

Saja, A. M. A., Goonetilleke, A., Teo, M., & Ziyath, A. M. (2019). A critical review of social resilience assessment frameworks in disaster management. *International Journal of Disaster Risk Reduction*, *35*, 101096. https://doi.org/10.1016/j.ijdrr.2019.101096

Salat, S. (2017). A systemic approach of urban resilience: Power laws and urban growth patterns. *International Journal of Urban Sustainable Development*, *9*(2), 107–135. https://doi.org/10.1080/19463138.2016.1277227

Salat, S., & Bourdic, L. (2012). Urban Complexity, Efficiency and Resilience. In Z. Morvaj (Ed.), *Energy Efficiency—A Bridge to Low Carbon Economy*. InTech. https://doi.org/10.5772/38599

Salingaros, N. A. (2000). Complexity and Urban Coherence. *Journal of Urban Design*, *5*(3), 291–316. https://doi.org/10.1080/713683969

Samat, A., Li, E., Wang, W., Liu, S., Lin, C., & Abuduwaili, J. (2020). Meta-XGBoost for Hyperspectral Image Classification Using Extended MSER-Guided Morphological Profiles. *Remote Sensing*, *12*(12), 1973. https://doi.org/10.3390/rs12121973

Sanitation and Environmental Protection Department (DAPE). (2013). *Réalisation d'une étude portant sur l'élaboration d'une stratégie nationale de lutte contre les inondations*.

Sapountzaki, K. (2007). Social resilience to environmental risks: A mechanism of vulnerability transfer? *Management of Environmental Quality: An International Journal*, *18*(3), 274–297. https://doi.org/10.1108/14777830710731743

Sapountzaki, K. (2014). "Resilience for All" and "Collective Resilience": Are These Planning Objectives Consistent with One Another? In P. Gasparini, G. Manfredi, & D. Asprone (Eds.), *Resilience and Sustainability in Relation to Natural Disasters: A Challenge for Future Cities* (pp. 39–53). Springer International Publishing. https://doi.org/10.1007/978-3-319-04316-6_4

Schanze, J. (2002). *Die gesellschaftliche riskovorsorge bedarf einer transdisziplinären Hochwasserforschung*.

Seville, E. (2009). *Compete Briefing Bite*.

Shafapour Tehrany, M., Shabani, F., Neamah Jebur, M., Hong, H., Chen, W., & Xie, X. (2017). GIS-based spatial prediction of flood prone areas using standalone frequency ratio, logistic regression, weight of evidence and their ensemble techniques. *Geomatics, Natural Hazards and Risk*, *8*(2), 1538–1561. https://doi.org/10.1080/19475705.2017.1362038

Shahabi, H., Shirzadi, A., Ghaderi, K., Omidvar, E., Al-Ansari, N., Clague, J. J., Geertsema, M., Khosravi, K., Amini, A., Bahrami, S., Rahmati, O., Habibi, K., Mohammadi, A., Nguyen, H., Melesse, A. M., Ahmad, B. B., & Ahmad, A. (2020). Flood Detection and Susceptibility Mapping Using Sentinel-1 Remote Sensing Data and a Machine Learning Approach: Hybrid Intelligence of Bagging Ensemble Based on K-Nearest Neighbor Classifier. *Remote Sensing*, *12*(2), 266. https://doi.org/10.3390/rs12020266

Sharifi, A. (2016). A critical review of selected tools for assessing community resilience. *Ecological Indicators*, *69*, 629–647. https://doi.org/10.1016/j.ecolind.2016.05.023

Sharifi, A. (2019). Urban form resilience: A meso-scale analysis. *Cities*, *93*, 238–252. https://doi.org/10.1016/j.cities.2019.05.010

Sharifi, A., & Yamagata, Y. (2018). Resilience-Oriented Urban Planning. In Y. Yamagata & A. Sharifi (Eds.), *Resilience-Oriented Urban Planning* (Vol. 65, pp. 3–27). Springer International Publishing. https://doi.org/10.1007/978-3-319-75798-8_1

Sheffi, Y., & Jr, J. B. R. (2005). *An organization's ability to recover from disruption quickly can be improved by building redundancy and flexibility into its supply chain. While investing in redundancy represents a pure cost increase, investing in flexibility yields many additional benefits for day-to- day operations.*

Sherrieb, K., Norris, F. H., & Galea, S. (2010). Measuring Capacities for Community Resilience. *Social Indicators Research*, *99*(2), 227–247. https://doi.org/10.1007/s11205-010-9576-9

Showalter, P. S., Riebsame, W. E., & Myers, M. F. (1990). *NATURAL HAZARD TRENDS IN THE UNITED STATES: A PRELIMINARY REVIEW FOR THE 1990s*.

Shrestha, N. (2021). Factor Analysis as a Tool for Survey Analysis. *American Journal of Applied Mathematics and Statistics*, *9*(1), 4–11. https://doi.org/10.12691/ajams-9-1-2

Siahkamari, S., Haghizadeh, A., Zeinivand, H., Tahmasebipour, N., & Rahmati, O. (2018). Spatial prediction of flood-susceptible areas using frequency ratio and maximum entropy models. *Geocarto International*, *33*(9), 927–941. https://doi.org/10.1080/10106049.2017.1316780

Siregar, R. I. (2018). Land cover change impact on urban flood modeling (case study: *Upper Citarum watershed*). *IOP Conference Series: Earth and Environmental Science*, *126*, 012027. https://doi.org/10.1088/1755-1315/126/1/012027

Smith, A., & Stirling, A. (2010). The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions. *Ecology and Society*, *15*(1), art11. https://doi.org/10.5751/ES-03218-150111

Soleimani-Alyar, M., Ghaffari-Hadigheh, A., & Sadeghi, F. (2016). Controlling Floods by Optimization Methods. *Water Resources Management*, *30*(12), 4053–4062. https://doi.org/10.1007/s11269-016-1272-3

Solomon, S., Intergovernmental Panel on Climate Change, & Intergovernmental Panel on Climate Change (Eds.). (2007). *Climate change 2007: The physical science basis: contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Stangl, P. (2015). Block size-based measures of street connectivity: A critical assessment and new approach. *URBAN DESIGN International*, *20*(1), 44–55. https://doi.org/10.1057/udi.2013.36

Star, S. L., & Griesemer, J. R. G. R. (1989). Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420.

Steinø, N., & Veirum, N. E. (2005). *A Parametric Approach to Urban Design*. 679–686. https://doi.org/10.52842/conf.ecaade.2005.679

Stern, P. C., & Fineberg, H. V. (1996). *Understanding risk: Informing decisions in a democratic society*. National Academy Press.

Swets, J. A. (1988). Measuring the Accuracy of Diagnostic Systems. *Science, New Series*, *240*(4857), 1285–1293.

TALBI, S., GHERZOULI, L., & FEZZAI, S. (2022). *Urban Resilience—Tools and methods for analyzing flood problems in the city of Tebessa.*

Talbi, S., Gherzouli, L., & Fezzai, S. (2023). Precipitation estimation as an input for water level prediction using machine learning algorithms to simulate urban flooding of Wadis in the city of Tebessa, Algeria. *PERIODICO Di MINERALOGIA*, *92*(5).

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). Vulnerability to flooding: Health and social dimensions. *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, *360*(1796), 1511–1525. https://doi.org/10.1098/rsta.2002.1013

Taylor, J., Lai, K. man, Davies, M., Clifton, D., Ridley, I., & Biddulph, P. (2011). Flood management: Prediction of microbial contamination in large-scale floods in urban environments. *Environment International*, *37*(5), 1019–1029. https://doi.org/10.1016/j.envint.2011.03.015

Taylor, S. J., & Letham, B. (2017). *Forecasting at scale* [Preprint]. PeerJ Preprints. https://doi.org/10.7287/peerj.preprints.3190v2

Tehrany, M. S., Jones, S., & Shabani, F. (2019). Identifying the essential flood conditioning factors for flood prone area mapping using machine learning techniques. *CATENA*, *175*, 174–192. https://doi.org/10.1016/j.catena.2018.12.011

Tehrany, M. S., Pradhan, B., & Jebur, M. N. (2013). Spatial prediction of flood susceptible areas using rule based decision tree (DT) and a novel ensemble bivariate and multivariate statistical models in GIS. *Journal of Hydrology*, *504*, 69–79. https://doi.org/10.1016/j.jhydrol.2013.09.034

Thierry, T. (2010). *«Analyse à l'échelle régionale de l'impact de l'occupation du sol dans les corridors rivulaires sur l'état écologique des cours d'eau», Thèse de Doctorat de Institut des Sciences et Industries du Vivant et de l'Environnement (Agro Paris Tech), Français*.

Thompson, P. M., Wigg, A. H., & Parker, D. J. (1991). Urban flood protection post-project appraisal in England and Wales. *Project Appraisal*, *6*(2), 84–92.

https://doi.org/10.1080/02688867.1991.9726799

Tobler, W. R. (1970). A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography*, *46*, 234. https://doi.org/10.2307/143141

Torabi, E., Dedekorkut-Howes, A., & Howes, M. (2018). Adapting or maladapting: Building resilience to climate-related disasters in coastal cities. *Cities*, *72*, 295–309. https://doi.org/10.1016/j.cities.2017.09.008

Trevor Hastie and Robert Tibshirani. (1986). *Generalized Additive Models*. 297–318.

Truitt, A. (2012). The Viet Village Urban Farm and the Politics of Neighborhood Viability in Post- K atrina N ew O rleans. *City & Society*, *24*(3), 321–338. https://doi.org/10.1111/ciso.12003

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, *100*(14), 8074–8079. https://doi.org/10.1073/pnas.1231335100

Turner, M. D. (2014). Political ecology I: An alliance with resilience? *Progress in Human Geography*, *38*(4), 616–623. https://doi.org/10.1177/0309132513502770

UN, Frankfurt School. (2016). *The Green Climate Fund: An Appetite for Risk?*

UN Office for Disaster Risk Reduction. (2017). *DISASTER RESILIENCE Scorecard for Cities.*

UN, Sendai, Japon,. (2015). *UNITED NATIONS WORLD CONFERENCE ON DISASTER RISK REDUCTION KICKS OFF AN IMPORTANT YEAR FOR SUSTAINABLE DEVELOPMENT*.

UNDESA, United Nations Department of Economic and Social Affairs. (2009). *World Urbanization Prospects*.

UNDP Drylands Development Centre. (2016). *Community Based Resilience Analysis (CoBRA) Conceptual Framework and Methodology*.

UNFPA (United Nations Population Fund. (2018). *LEAD CLHEAADPTCEHRARPETSEERARCESHEEARRSCAHNEDRSAAUNTDHOARUSTHORS*.

UN-HABITAT. (2017). *SUSTAINABLE URBANIZATION IN THE PARIS*.

UN-HABITAT. (2020). *Enhancing Nationally Determined Contributions through Urban Climate Action*.

UNISDR. (2015). *For a Resilient Algeria*.

UNISDR. (2017). *Flood Hazard and Risk Assessment*.

United Nations. (2005). *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters*.

United Nations. (2010). *UN Common Guidance on Helping Build Resilient Societies. Denmark: United Nations.*

United Nations. (2015a). *PARIS AGREEMENT*.

United Nations. (2015b). *Sendai Framework for Disaster Risk Reduction 2015—2030*. 37.

United Nations. (2021). *An Analytical Review: A Decade of Urban Resilience: Lessons and recommendations*.

United Nations Development Programme. (2021). *An Analytical Review: A Decade of Urban Resilience: Lessons and recommendations*.

United Nations, General Assembly. (2015). *Transforming our world: The 2030 Agenda for*

Sustainable Development.

United Nations (HBITAT III). (2016). *THE CONFERENCE: The united Nations Conference on HOusing and Sustainable Urban Development (HBITAT III)*.

URBA-BA, D. d'urbanisme d'architecture et de construction-W. de T. (2018). *Rapport PDAU intercommunal Tebessa-Hammamet-Elkouif-Bekkaria-Boulhaf Dyr the final phase*.

URBA-CO. (2013). *Land Use Plan N° 9A Regulations*.

Usselmann, P. (1999). *Traiter les données de télédétection: Michel-Claude Girard, Colette M. Girard, Traitement des données de télédétection, Paris: Dunod, 1999*.

Valy, J. (2010). *Approches méthodologiques du croisement entre croissance urbaine et risque inondation*.

Vasilevska, L., & Slavkovic, M. (2023). Urban resilience: Definitions, understanding and conceptualization. *Facta Universitatis - Series: Architecture and Civil Engineering*, *00*, 23–23. https://doi.org/10.2298/FUACE230630023V

Verbeiren, B., Van De Voorde, T., Canters, F., Binard, M., Cornet, Y., & Batelaan, O. (2013). Assessing urbanisation effects on rainfall-runoff using a remote sensing supported modelling strategy. *International Journal of Applied Earth Observation and Geoinformation*, *21*, 92–102. https://doi.org/10.1016/j.jag.2012.08.011

Walker, B. H., Anderies, J. M., Kinzig, A. P., & Ryan, P. (2006). Exploring Resilience in Social-Ecological Systems Through Comparative Studies and Theory Development: Introduction to the Special Issue. *Ecology and Society*, *11*(1), art12. https://doi.org/10.5751/ES-01573-110112

Wang, Y., He, B., & Takase, K. (2009). Effects of temporal resolution on hydrological model parameters and its impact on prediction of river discharge / Effets de la résolution temporelle sur les paramètres d'un modèle hydrologique et impact sur la prévision de l'écoulement en rivière. *Hydrological Sciences Journal*, *54*(5), 886–898. https://doi.org/10.1623/hysj.54.5.886

Wardekker, A., Wilk, B., Brown, V., Uittenbroek, C., Mees, H., Driessen, P., Wassen, M., Molenaar, A., Walda, J., & Runhaar, H. (2020). A diagnostic tool for supporting policymaking on urban resilience. *Cities*, *101*, 102691. https://doi.org/10.1016/j.cities.2020.102691

Water Ressources Departement. (2018). *Rapport sur l'evaluation de l'etat d'execution du plan d'action de lutte contre les inondations la Wilaya de Tébessa*.

Weichselgartner, J., & Kelman, I. (2014). *Challenges and opportunities for building urban resilience*.

Werlen, B. (2017). Action, Knowledge, and Social Relations of Space. In P. Meusburger, B. Werlen, & L. Suarsana (Eds.), *Knowledge and Action* (Vol. 9, pp. 31–56). Springer International Publishing. https://doi.org/10.1007/978-3-319-44588-5_2

Wilaya de Tébessa Water Resources Department. (2018). *Rapport sur l'evaluation de l'etat d'execution du plan d'action de lutte contre les inondations -la Wilaya de Tébessa-*.

Wilkinson, C., Porter, L., & Colding, J. (2010). *Metropolitan Planning and Resilience Thinking: A Practitioner's Perspective*.

Winograd, M. (2005). *Concepts, frameworks and methodologies for vulnerability and adaptation assessments*.

Wood, S., & Dovey, K. (2015). Creative Multiplicities: Urban Morphologies of Creative Clustering. *Journal of Urban Design*, *20*(1), 52–74. https://doi.org/10.1080/13574809.2014.972346

Wu, B. S., Wang, Z. Y., Huang, G. H., & Fang, H. W. (2002). *Flood Defence*.

Wulder, M. A., Masek, J. G., Cohen, W. B., Loveland, T. R., & Woodcock, C. E. (2012). Opening the archive: How free data has enabled the science and monitoring promise of Landsat. *Remote Sensing of Environment*, *122*, 2–10. https://doi.org/10.1016/j.rse.2012.01.010

Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International Journal of Remote Sensing*, *27*(14), 3025–3033. https://doi.org/10.1080/01431160600589179

Xu, H. (2008). A new index for delineating built-up land features in satellite imagery. *International Journal of Remote Sensing*, *29*(14), 4269–4276. https://doi.org/10.1080/01431160802039957

Xu, W., Cong, J., Proverbs, D., & Zhang, L. (2021). An Evaluation of Urban Resilience to Flooding. *Water*, *13*(15), 2022. https://doi.org/10.3390/w13152022

Xun, X., & Yuan, Y. (2020). Research on the urban resilience evaluation with hybrid multiple attribute TOPSIS method: An example in China. *Natural Hazards*, *103*(1), 557–577. https://doi.org/10.1007/s11069-020-04000-0

Yin, J., Yu, D., Yin, Z., Wang, J., & Xu, S. (2015). Modelling the anthropogenic impacts on fluvial flood risks in a coastal mega-city: A scenario-based case study in Shanghai, China. *Landscape and Urban Planning*, *136*, 144–155. https://doi.org/10.1016/j.landurbplan.2014.12.009

Yousefi, S., Mirzaee, S., Keesstra, S., Surian, N., Pourghasemi, H. R., Zakizadeh, H. R., & Tabibian, S. (2018). Effects of an extreme flood on river morphology (case study: Karoon River, Iran). *Geomorphology*, *304*, 30–39. https://doi.org/10.1016/j.geomorph.2017.12.034

Yousif, Y. E. (2022). Weather Prediction System Using KNN Classification Algorithm. *European Journal of Information Technologies and Computer Science*, *2*(1), 10–13. https://doi.org/10.24018/compute.2022.2.1.44

Youssef, A. M., Pradhan, B., & Sefry, S. A. (2016). Flash flood susceptibility assessment in Jeddah city (Kingdom of Saudi Arabia) using bivariate and multivariate statistical models. *Environmental Earth Sciences*, *75*(1), 12. https://doi.org/10.1007/s12665-015-4830-8

Yu, D., & Lane, S. N. (2006). Urban fluvial flood modelling using a two-dimensional diffusion-wave treatment, part 1: Mesh resolution effects. *Hydrological Processes*, *20*(7), 1541–1565. https://doi.org/10.1002/hyp.5935

Zhang, X., & Li, H. (2018a). Urban resilience and urban sustainability: What we know and what do not know? *Cities*, *72*, 141–148. https://doi.org/10.1016/j.cities.2017.08.009

Zhang, X., & Li, H. (2018b). Urban resilience and urban sustainability: What we know and what do not know? *Cities*, *72*, 141–148. https://doi.org/10.1016/j.cities.2017.08.009

Zhang, X., Song, J., Peng, J., & Wu, J. (2019). Landslides-oriented urban disaster resilience assessment—A case study in ShenZhen, China. *Science of The Total Environment*, *661*, 95–106. https://doi.org/10.1016/j.scitotenv.2018.12.074

Zhou, Y., Smith, S. J., Zhao, K., Imhoff, M., Thomson, A., Bond-Lamberty, B., Asrar, G. R., Zhang, X., He, C., & Elvidge, C. D. (2015). A global map of urban extent from nightlights. *Environmental Research Letters*, *10*(5), 054011. https://doi.org/10.1088/1748-9326/10/5/054011

Ziervogel, G., Cowen, A., & Ziniades, J. (2016). Moving from Adaptive to Transformative

Capacity: Building Foundations for Inclusive, Thriving, and Regenerative Urban Settlements. *Sustainability*, *8*(9), 955. https://doi.org/10.3390/su8090955

Zimmermann, E., Bracalenti, L., Piacentini, R., & Inostroza, L. (2016). Urban Flood Risk Reduction by Increasing Green Areas for Adaptation to Climate Change. *Procedia Engineering*, *161*, 2241–2246. https://doi.org/10.1016/j.proeng.2016.08.822

Zipperer, W. C., Morse, W. F., & Gaither, C. J. (2011). Linking Social and Ecological Systems. In J. H. Breuste, T. Elmqvist, G. Guntenspergen, P. James, & N. E. McIntyre (Eds.), *Urban Ecology* (pp. 298–308). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199563562.003.0035