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Postcolonial Resilience in Casablanca: Colonial Legacies and Climate Vulnerability

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Abstract

Casablanca, Morocco's largest Atlantic port city, faces increasing exposure to floods, drought, and other risks that align with legacies of urban transformations carried out during the colonial period. This study examines how early-20th-century interventions—including the canalization and burial of the Oued Bouskoura, extensive coastal reclamation, and the implementation of rigid zoning—were associated with a reconfiguration of the city's hydrology and coincide with persistent socio-spatial inequalities. Using historical cartography, archival sources, and GIS-based overlays of colonial-era plans with contemporary hazard maps, the analysis reveals an indicative spatial correlation between today's high-risk zones and areas transformed under the Protectorate, with the medina emerging as one of the most vulnerable districts. While previous studies have examined either colonial planning in architectural or contemporary climate risks through technical and governance lenses, this article illuminates historically conditioned relationships and long-term associations for urban resilience. In doing so, it empirically maps spatial associations and conceptually argues for reframing heritage not only as cultural memory but as a climate resource, illustrating how suppressed vernacular systems may inform adaptation strategies. This interdisciplinary approach provides a novel contribution to postcolonial city research, climate adaptation and heritage studies by proposing a historically conscious framework for resilience planning.

Keywords: Casablanca; colonial urban planning; postcolonial resilience; urban heritage; climate vulnerability

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1. Introduction

Climate change is undeniably intensifying natural disasters globally, particularly extreme weather events such as floods [1]. Morocco, being in an arid to semi-arid climate zone, is particularly vulnerable to these challenges, experiencing issues such as aridity, water scarcity, recurrent droughts, and desertification [2,3]. On the one hand, drought has become a structural component of the Moroccan climate, posing a significant threat to its agricultural sector, which accounts for nearly 20% of the economy [4]. This dependency on rainfall makes the country highly susceptible to climate-related risks. On the other hand, flash floods, characterized by their sudden onset and high peaks, have become more frequent and devastating in arid and semi-arid regions, including the Middle East and North Africa (MENA) zone [5]. This trend is exacerbated by rapid urbanization and population growth and is also consistent with longer historical development trajectories, including colonial-era planning legacies.

Casablanca, Morocco's largest city and a critical economic hub along the Atlantic coast, faces significant environmental challenges driven by the intensification of climate change and rapid, sometimes unplanned urban expansion. Among these, flood risk has become a particularly urgent concern, especially in the city's low-lying and historically marginalized coastal zones. The city has experienced recurrent flood events, notably in November 2010 and January 2013, 2016, and 2021, affecting various parts of the city. The 2010 event, for instance, saw 195 mm of rainfall in 24 h, causing substantial damage to industrial areas and transport infrastructure, largely due to the overflowing of Wadi Bouskoura [6]. Furthermore, the recent coastal flooding events such as those experienced in January 2021 (Figure 1), when torrential rains submerged major roads, paralyzed public transport, and caused extensive property damage, highlight the city's growing vulnerability. These acute disruptions are exacerbated by outdated drainage infrastructure, the proliferation of impermeable surfaces, and ongoing demographic pressures.

Figure 1. Men by the water reservoir in Marrakesh, Morocco, illustrating the cultural and ecological significance of traditional water systems in semi-arid regions [7].

Moreover, the drought situation in Casablanca and across Morocco has dramatically worsened in recent years, with 2024 marking one of the most critical episodes on record. Satellite imagery from NASA's MODIS sensors (Figure 2) in February 2024 revealed stark transformations in the landscape surrounding Casablanca [8]. The comparison reveals a dramatic shift from green, vegetated land to dry and barren terrain, particularly inland from

Casablanca toward Berrechid. This change highlights the intensifying effects of prolonged drought, worsened by below-average rainfall and rising temperatures. The brown and reddish hues in 2024 indicate widespread vegetation stress, soil desiccation, and depleted agricultural productivity across the region. In other words, areas that typically appear green and vegetated during the rainy season were instead dry and brown, indicating severe hydrological stress. Compared to the already arid conditions of 2023, the 2024 images highlighted a further decline, reflecting the cumulative impact of prolonged rainfall deficits and abnormally high temperatures [8]. Moroccan authorities have described the situation as "disastrous," citing a 70% drop in precipitation compared to average levels in the preceding months [9]. For instance, the Al Massira Dam, which plays a vital role in supplying water to agricultural zones near Casablanca, reached critically low levels—reportedly just 1–2% of its capacity in February 2024. Overall, the country's reservoirs stood at only 25% capacity, down from 32% the previous year, with significant consequences for agricultural productivity [10].

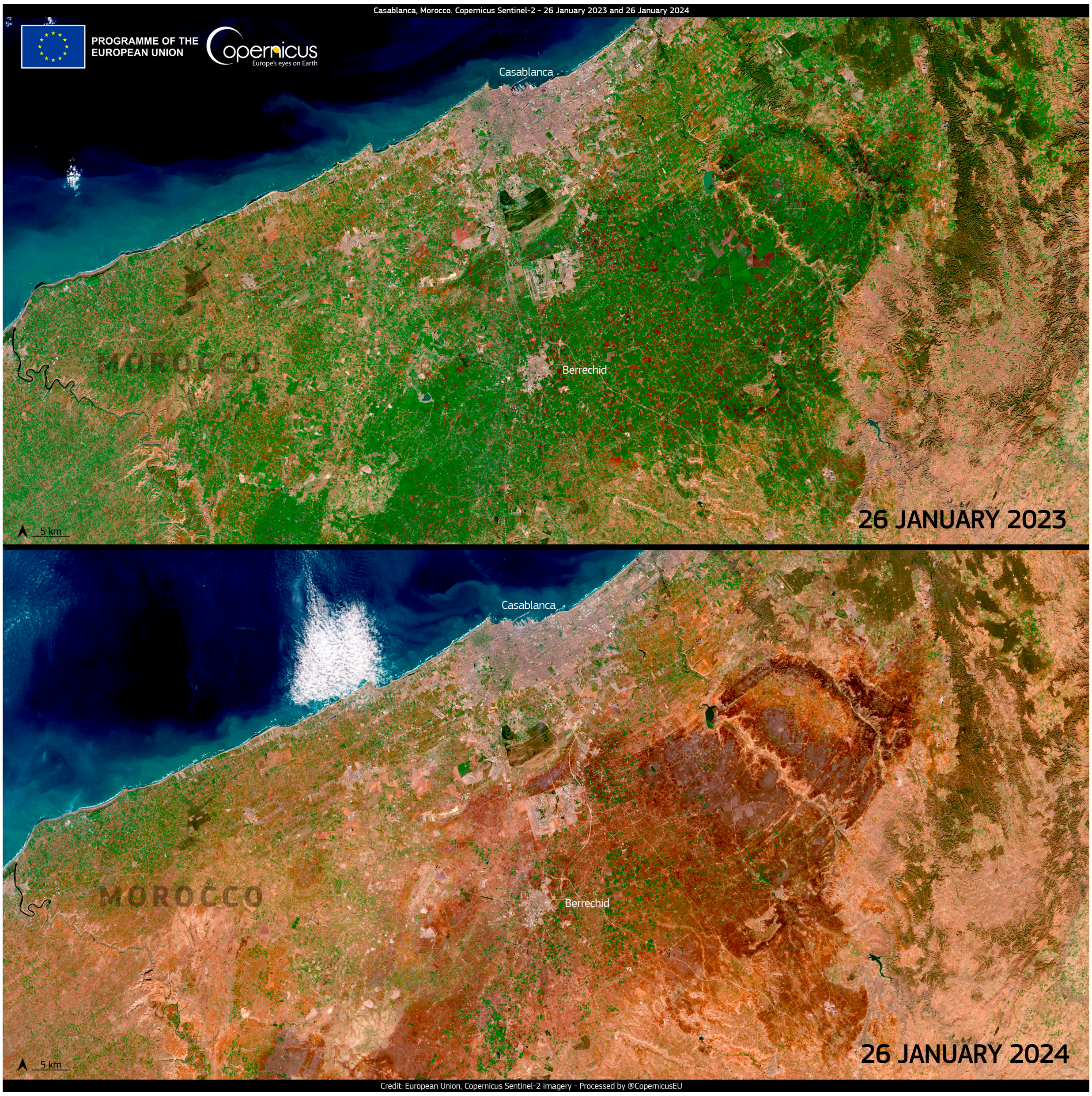

Figure 2. Satellite images from the Copernicus Sentinel-2 mission show the area surrounding Casablanca, Morocco, on 26 January 2023 (above) and 26 January 2024 (below) [8].

The conditions framed above highlight not only the intensifying vulnerability of the region to climate-induced drought, but also the urgent need for sustainable water management strategies in both rural and urban contexts. However, these vulnerabilities cannot be fully understood without tracing their roots to early 20th-century colonial interventions. Situated at the crossroads of imperial ambition and environmental disruption, Casablanca was transformed into one of the most emblematic laboratories of French colonial urbanism in Africa. Colonial planners imposed rigid spatial hierarchies, introduced canalized hydrological systems, and prioritized infrastructure that catered to European districts, thereby marginalizing indigenous settlements and informal peripheries [11,12]. In other words, the city's natural watercourse, the seasonal Oued Bouskoura, was historically integral to the landscape, flowing along the old medina's walls and into the Atlantic [13]. Furthermore, French colonial development significantly altered natural drainage system. The legacy of this period has likely influenced the city's spatial organization, ecological fragmentation, and socio-environmental inequities.

Following the French occupation in 1907 and the establishment of the Protectorate, Casablanca underwent a radical transformation driven by colonial visions of modernization. The most influential intervention in this process was the 1917 urban plan developed by Henri Prost [14], which imposed a radio-concentric grid over the organic structure of the medina and introduced zoning principles aligned with European planning ideologies. While celebrated for its rationality and esthetic coherence, archival and planning sources indicate that the plan likely altered and re-routed natural drainage paths, with wadis progressively buried, and de-emphasized traditional ecological knowledge and the spatial needs of local communities.

The intersection between colonialism, climate change, and heritage has emerged as a critical axis of climate injustice. Scholars increasingly argue that the roots of the current environmental crisis lie in colonial regimes of extraction, environmental control, and spatial domination [15–17]. In the French colonial context, architecture and urban planning became key instruments of imperial power, altering ecologies and land-use patterns under the guise of modernization. In coastal cities including Casablanca, the expansion of ports, the reclamation of wetlands, and the erasure of vernacular hydrological systems introduced changes that are associated with long-term spatial and ecological patterns. In the 1930s, French authorities implemented a significant campaign of urban reconfiguration. Natural drainage networks were often redirected or sealed off beneath new infrastructures, diminishing local adaptive capacity [18]. Peripheral bidonvilles were cleared and replaced with nouvelle medinas, often constructed with concrete and steel as materials that exacerbated heat retention and disrupted climatic adaptation [19]. These new quarters, while marketed as hygienic and modern, replaced context-sensitive vernacular typologies and gave limited consideration to local environmental knowledge, which is consistent with later socio-environmental inequities [14,20]. The legacy of these interventions is now manifest in growing climate vulnerabilities. The areas most strongly affected by natural hazards are often those built over wadis or informal settlements removed during colonial redesigns.

These spatial and ecological changes were justified ideologically through narratives of climatic determinism and the mission civilisatrice. At venues such as the 1931 Paris Colonial Exposition, French planners portrayed colonized territories as ecologically degraded and incapable of rational self-management, thereby legitimizing interventions that privileged Western epistemologies while excluding indigenous expertise [21]. The environmental consequences—altered microclimates, impermeable urban surfaces, the erasure of adaptive infrastructures—are now magnified by global climate pressures, revealing the long-term implications of treating colonized landscapes as experimental laboratories.

Despite growing recognition of the colonial roots of contemporary environmental vulnerability, much of the current discourse on climate adaptation remains predominantly technical in focus. Engineering-based approaches often dominate policy frameworks, sidelining sociohistorical drivers of vulnerability and resilience [22]. Moreover, a growing body of scholarship has argued for the need to historicize climate adaptation, particularly in postcolonial urban contexts, where colonial planning logics continue to shape spatial hierarchies and environmental risk [23,24]. In the case of North Africa, researchers have demonstrated how colonial interventions often replaced climate-adaptive vernacular systems such as seasonal mobility, traditional water harvesting, and wadis-based land use with rigid European-style zoning, fixed infrastructure, and impermeable surfaces [25].

While the IPCC's Sixth Assessment Report underscores the importance of inclusive and context-specific adaptation strategies [26], and frameworks such as Future of Our Pasts by ICOMOS advocate for the integration of cultural heritage into climate action [27,28], these recommendations have yet to be fully operationalized in many urban adaptation plans. Intangible heritage such as traditional ecological knowledge, ritual landscapes, and oral histories, offers not only a record of past adaptation but also a foundation for future resilience [29]. Recent studies stress that local knowledge systems are not merely remnants of the past but dynamic and evolving resources for confronting contemporary climate challenges [30].

Moreover, the UN Sustainable Development Goals (SDGs) [31]—particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action)—call for inclusive, participatory, and culturally grounded strategies for urban resilience. UNESCO's Global Report on Culture for Sustainable Urban Development highlights the transformative role of heritage in building sustainable and climate-responsive cities [32]. These international frameworks align with academic calls for "just resilience," which combines infrastructural adaptation with social equity, historical recognition, and cultural empowerment [33].

Research on climate adaptation in Moroccan cities often focuses on governance or infrastructure deficits, with little attention to historical urbanism. Casablanca exemplifies how foreign planning disrupted ecosystems and displaced community-based environmental practices, yet the long-term effects remain underexplored. Scholarship on colonial planning in the city has largely emphasized architecture or political symbolism rather than ecological legacies. This gap leaves unexplored how colonial infrastructures created enduring vulnerabilities. Present-day multiple risks in Casablanca reflect these historical dynamics, underscoring the urgency of integrative approaches that link engineering, heritage, and justice-based adaptation.

By framing Casablanca as a site where colonial legacies and climate risks converge and focusing on the medina and its surroundings (Figure 3), this study addresses that gap. While postcolonial research has highlighted the symbolic dimensions of colonial planning, it has rarely examined its ecological consequences.

The analysis suggests that today's hydroclimatic vulnerabilities are consistent with policy path dependence: French planning embedded infrastructures into the city's terrain, displacing alternative practices and creating arrangements difficult to reverse. This mechanism reveals how past choices continue to shape risks and underscores the need to revive ecological knowledge and context-sensitive adaptation. Framing Casablanca through path dependence highlights vulnerabilities as long-term interactions between policy and geography, linking historical risk production to present challenges. In today's climate context, especially in coastal cities, revisiting Casablanca's colonial past offers a vital lens to trace layered risks and envision strategies rooted in community resilience, local knowledge, and inclusive planning. Furthermore, heritage scholarship has begun to underline the value of vernacular knowledge for sustainability, yet its integration into urban climate policy remains limited.

Figure 3. Map showing Casablanca and medina boundaries (red) in Morocco.

This article makes three contributions to bridge these gaps. Firstly, it provides present-day hydroclimatic risk in Casablanca through historical cartography, archival research and GIS overlays. Secondly, it proposes a reframing of heritage as a climate resource, demonstrating the adaptive potential of suppressed vernacular water and land-use systems. Lastly, it situates postcolonial urban studies, climate adaptation research, and heritage debates within a novel interdisciplinary framework. In addition, the relationship between colonial policies and today's vulnerabilities reflects long-term structural processes that will be unpacked in the discussion. Together, these contributions propose a decolonial perspective on resilience planning, one that foregrounds historical justice and community knowledge alongside technical adaptation measures.

2. Materials and Methods

2.1. Historical Materials and GIS Framework

This study adopts a historically informed, spatially grounded Geographic Information System (GIS) methodology to explore how early-20th-century French planning shaped present-day risks in Casablanca. The analysis focused on coastal zones and historic quarters that underwent major interventions during the period. High-resolution raster scans of historical cartography, most importantly Henri Prost's Plan d'aménagement et d'extension de Casablanca (Maroc). 1917 and Plan d'aménagement et d'extension de Casablanca (Maroc): plan de Casablanca (éch. 1/10.000e), 1929, were imported and georeferenced with the QGIS 3.28 Georeferencer tool (QGIS Development Team, Open Source Geospatial Foundation, Beaverton, OR, USA). These materials were extracted and consulted in his personal archive where multiple materials are located related to interventions from 1913 to 1929 [34]. The 1917 plan was selected because it represents the first comprehensive vision for the colonial restructuring of Casablanca and served as the foundation upon which later interventions were developed. It documents the intended layout of new boulevards, public spaces, and residential quarters at the very moment when colonial planning began to redefine the city's relationship with its natural environment. This analysis was advanced by including the 1929 plan to understand the implementations between the first plan. Furthermore, the complementary materials of cartography as detailed urban programs, speeches, historical photography indicating the implemented areas were consulted. All materials consulted in the relevant archives were digitized, meticulously translated by native speakers, and subjected to systematic analysis in order to reconstruct infrastructural specifications, planned interventions articulated through urban programs, and implemented measures disseminated via speeches and public proclamations by the urbanists involved.

A set of control points such as the Port of Casablanca, the Parc de la Ligue Arabe, major road intersections, and the walls of the old Medina was used to align the historic map to modern coordinates. All data layers were projected to WGS 84/Pseudo-Mercator EPSG:3857 to establish a common spatial reference frame. This careful georeferencing enabled consistent placement of historical features including the now-buried Oued Bouskoura riverbed, colonial-era bidonvilles, the nouvelle medina, and reclaimed port areas in relation to the city's current layout. The georeferenced colonial maps then served as base layers onto which contemporary hazard zones were superimposed for spatial comparison.

This spatial analysis was complemented by a critical review of archival documents, urban planning programs, and design reports from the colonial era, with particular attention to materials presented at the 1931 Paris Colonial Exposition and to the personal archive of Henri Prost, the chief urbanist of the Casablanca Plan. Primary sources were consulted across multiple repositories, including the Archives nationales de France, the Bibliothèque nationale de France, and the Centre d'archives d'architecture contemporaine, with a focus on original documents produced by urban planners. These archival materials were examined to reveal the ideological underpinnings of spatial segregation, resource control, and climatic determinism that informed Casablanca's urban transformation. Secondary references were used to contextualize these archival findings within broader debates.

By cross-referencing archival narratives with the mapped hydroclimatic risk data, the methodological approach integrates historical urbanism, geospatial hazard analysis, and critical heritage studies, producing a multi-temporal assessment of how past planning decisions continue to shape Casablanca's exposure to climate-related disasters.

2.2. Datasets Used in This Study and Collection

To assess present-day climate-related hazards in Casablanca, this study employed a clearly defined set of global and national datasets. Table 1 provides the complete list of data sources used, including their structural characteristics, temporal resolution, and geographic coverage. Only datasets effectively applied in the GIS analysis are included here; any preliminary sources not used were excluded.

Table 1. Details of used datasets.

Dataset Name	Type of Data	Temporal Resolution	Geographic Coverage
Copernicus Emergency Management Service (CEMS; European Commission, Brussels, Belgium)—Global Flood Awareness System (GloFAS; Joint Research Centre, European Commission, Ispra, Italy)	Flood hazard layers (model-derived rasters) drought severity indices	Near-real-time monitoring (frequently updated)	Near-global coverage, satellite- and model-based

Table 1. *Cont.*

Dataset Name	Type of Data	Temporal Resolution	Geographic Coverage
Copernicus Emergency Management Service (CEMS)—Global Drought Observatory (GDO)	Drought severity indices (model/satellite-derived)	Near-real-time (frequently updated)	Near-global coverage
UNDRR Global Risk Data Platform (United Nations Office for Disaster Risk Reduction, Geneva, Switzerland)	Multi-hazard risk datasets (floods, droughts, tsunami risk)	Baseline circa 2010–2020; updates on decadal/multi-year basis	Global extent; derived from probabilistic models and historical data
NASA EarthData (EOSDIS portal; NASA, Greenbelt, MD, USA: MODIS NDVI, rainfall anomalies)	Remote sensing imagery (vegetation indices; rainfall anomalies)	2000–2024 (daily to monthly data)	Global coverage
Google Earth Engine (GEE; Google LLC, Mountain View, CA, USA)	Cloud-based geospatial processing platform (derived data layers)	Long-term historical and near-real-time data	Global coverage
Atlas des Risques Naturels au Maroc (Ministère de l'Intérieur, Rabat, Morocco)	National hazard indices (floods, drought, seismic, coastal threats)	Static (single compilation; published atlas)	Morocco (regional detail for Casablanca); authoritative national scale
Copernicus Sentinel-2 (European Space Agency, Paris, France)	Optical satellite imagery (raster)	6 January 2023 and 26 January 2024 (snapshot images)	Casablanca region (Morocco)
Google Earth—Satellite Imagery Basemap (Google LLC, Mountain View, CA, USA)	High-resolution satellite imagery (composite basemap)	Composite of various years (updated to ~2023)	Global (used for Casablanca area)
Plan d'aménagement et d'extension de Casablanca (Maroc): vue du plan d'aménagement (éch. 1/5000e), 1917	Scanned historical map (colonial city plan; raster image)	1913–1923 (Protectorate-era plan; published 1917)	Casablanca city (urban extent)
Plan d'aménagement et d'extension de Casablanca (Maroc): plan de Casablanca (éch. 1/10.000e), 1929.	Scanned historical map (colonial city plan; raster image)	1929 (Protectorate-era plan; published 1929)	Casablanca city (urban extent)

The CEMS [35] provided near-real-time global hazard layers. Specifically, the GloFAS supplies raster-based discharge and inundation extent data at ~0.1° resolution, updated daily and validated against national hydrological stations. The GDO delivers drought severity indices derived from meteorological data and satellite observations, updated weekly [36]. The UNDRR Global Risk Data Platform aggregates multi-hazard datasets, including data for analyzed risks. These are derived from long-term disaster records and global circulation models, available at global scale, with baseline coverage around 2010–2020.

The NASA EarthData [37] portal provided remote sensing products such as MODIS NDVI and EVI vegetation indices (250 m resolution) and rainfall anomaly rasters (500 m to 1 km, daily to monthly). These products were used both for hazard analysis and to monitor drought-induced vegetation stress in the Casablanca context. Data integration and processing were carried out via GEE, which enabled harmonization of datasets, precipitation climatology calculations, downscaling of coarse global layers, and export of GIS-ready hazard maps.

At the national level, the Atlas des Risques Naturels au Maroc [38] provided authoritative hazard indices for floods, droughts, and coastal threats in the form of cartographic information and static maps rather than ready-to-use shapefiles. These materials were manually digitized and converted into GIS-compatible shapefiles by cross-checking municipal planning documents to ensure spatial accuracy and consistency. In addition to this, for visual validation and manual correction, the study employed Copernicus Sentinel-2 imagery (10 m multispectral data, snapshots of January 2023 and 2024) and high-resolution Google Earth basemaps. These were used to confirm land cover, settlement morphology, and hydrological features.

Finally, historical maps were scanned, georeferenced, and aligned to contemporary coordinates to provide the colonial-era spatial framework. At the same time, the analysis remains constrained by the scale and resolution of available datasets and by the partial nature of historical archives. The pathways identified should therefore be understood as indicative rather than exhaustive. The overall aim of this approach is to maintain coherence across different scales, minimize inconsistencies between sources, and enhance causal interpretation by explicitly linking geospatial patterns with colonial-era interventions.

2.3. Data Integration and Hazard Overlay Analysis

With both historical maps and hazard layers aligned in the same coordinate system, a series of spatial overlay analyses was carried out to explore correlations between colonial-era urban transformations and contemporary risk zones. Hazard layers were first clipped to the Casablanca metropolitan extent. Each dataset was then reclassified into a standardized ordinal scale of High, Medium, and Low risk to facilitate comparison.

All layers were subsequently superimposed onto the georeferenced historical cartography using QGIS. Polygon intersection tools served to identify areas where colonial intervention footprints overlap with present-day high-risk zones. Polygon intersection tools were used to identify areas where colonial intervention footprints overlapped with present-day high-risk zones. Notable intersections included reclaimed coastal land now corresponding to flood-prone coastal strips, the canalized Oued Bouskoura coinciding with current flood hotspots, and the location of 1930s bidonvilles and old medina intersecting with multi-hazard exposure zones. These intersections were systematically recorded in a GIS attribute table (Table 2), with each polygon annotated by historical zone name and colonial function, current land use, flood/drought/tsunami risk levels, area of overlap, and data sources. This structured database provided a basis for both qualitative mapping and basic quantitative assessments.

Table 2. Detailed of constructed attribute table in GIS platform.

Field Name	Data Type	Description
ID	Numeric entry	Unique identifier for each feature
Zone Name (Zone_Name)	Textual entry	Name of the mapped historical or contemporary area
Colonial Use (Col_Use)	Textual entry	Intended function of the area during colonial planning
Current Use (Cur_Use)	Textual entry	Current land use
Flood Risk Level (Flood_Risk)	Numeric entry	Present-day flood vulnerability classification
Tsunami Vulnerability Level (Tsun_Risk)	Numeric entry	Present-day tsunami vulnerability classification
Drought Vulnerability Level (Tsun_Risk)	Numeric entry	Present-day drought vulnerability classification
Data Source (Source)	Text	Origin of hazard data
Temporal Range (Temp_Range)	Text	Years or period covered by dataset

Table 2. *Cont.*

Field Name	Data Type	Description
Historical Type (Hist_Type)	Textual entry	Type of feature
Year Plan Introduced (Intr_Year)	Textual entry	Year when the feature or intervention first appeared in planning documents
Year Plan Implemeted (Impl_Year)	Textual entry	Year when the feature or intervention first appeared in implemented planning documents or public proclamations
References (Ref)	Textual entry	Origin of the indicated data
Audio/Video URL (A/V_URL)	Media or archive link	URL link to relevant indicated data
Photo URL (P_URL)	Visual entry and relevant links	URL Link to an image of the place
Photo Copyright (P_Copy)	Textual entry	Copyright information related to the image
Notes (Notes)	Textual entry	Additional remarks or contextual notes

2.4. Data Processing and Analysis Workflow

The integration of historical urban data with contemporary hazard datasets required a structured workflow designed to ensure both spatial consistency and interpretive reliability (Figure 4). After georeferencing the colonial plans and digitizing features of interest, hazard layers from global and national sources were standardized into comparable formats. This entailed resampling raster datasets to a uniform resolution, converting static cartographic information into vector shapefiles, and harmonizing all data layers under the EPSG:3857 projection system. The resulting dataset provided a coherent spatial framework in which historical interventions and current hazard zones could be systematically compared.

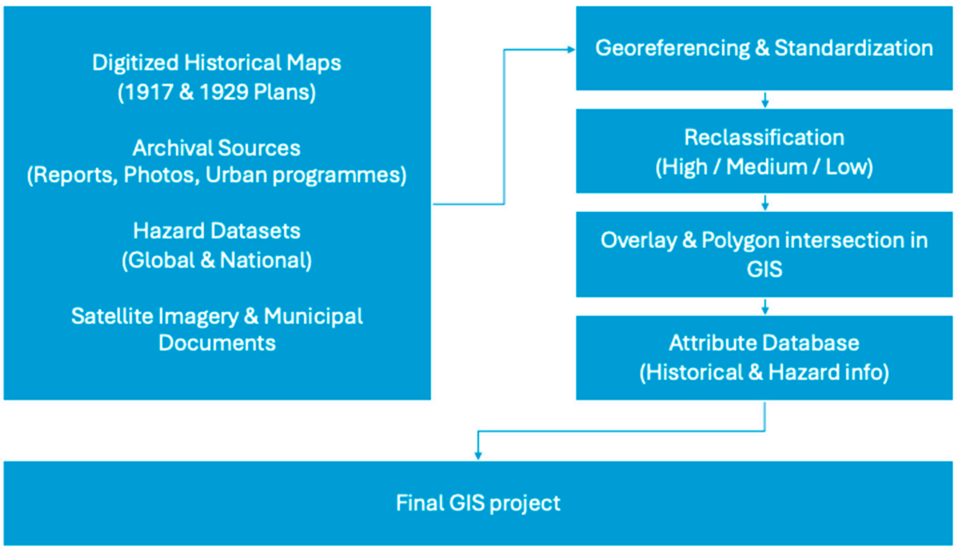

Figure 4. Overall framework of data processing and analysis workflow.

To operationalize the overlay analysis, the study employed a two-step procedure. First, each hazard dataset was normalized into three ordinal categories of High, Medium, and Low vulnerability. This classification was applied consistently across global models and national indices, enabling cross-comparison without privileging one dataset's raw scale over another. Second, the reclassified hazard layers were intersected with the digitized colonial footprints through polygon feature. This process produced discrete units of analysis in which each polygon carried dual attributes: its historical designation and its present-day hazard level.

These polygons were assembled into the attribute table designed to capture both spatial coincidence and the temporal and functional significance of each area. Where discrepancies arose between information, especially when global models diverged from Moroccan national sources, a decision protocol was followed: national sources were prioritized as locally validated baselines, while global layers were recalibrated or annotated as annotated for contextual reference. Manual verification supported this localization process, involving high-resolution satellite imagery (Google basemaps, Copernicus Sentinel-2) and municipal planning documents to assess terrain and land use. Additional triangulation with archival materials ensured that correlations reflected historically documented processes rather than coincidental spatial overlap.

Despite these procedures, the analysis remains constrained by the limitations of the available data. Global datasets sometimes lack the resolution to capture micro-scale features such as neighborhood drainage channels, while historical maps, though invaluable, retain positional uncertainties after georeferencing. Consequently, the spatial correlations presented here should be interpreted as indicative rather than exhaustive.

The outcome of this integrative workflow was not limited to static maps but extended to a dynamic relational framework, enabling both qualitative and quantitative insights. On the qualitative side, the overlays revealed patterns of spatial path dependency, showing how colonial interventions continue to shape the geography of vulnerability. On the quantitative side, area calculations of overlapping polygons provided measurements of the extent to which historically planned zones fall within present-day high-risk categories.

3. Results

The results reveal how French colonial planning has left a lasting imprint on Casablanca's hydrological vulnerabilities. Using GIS overlays of the 1917 master plan with current flood, drought, and tsunami risk maps, the analysis is presented in three parts: 3.1 examines the colonial reshaping of the urban waterscape; 3.2 explores drought vulnerability linked to ecological simplification; and 3.3 highlights the compounded risks and structural inequalities affecting the old medina.

3.1. Colonial Reshaping of the Urban Waterscape

The result (Figure 5) shows that the most flood-prone zones (classified in three risk levels) coincide with colonial-era interventions, particularly along the coast, the historical course of Oued Bouskoura, and the reclaimed port districts.

The areas identified as high-risk largely correspond to zones where the natural drainage network was either interrupted or concealed, most notably along the course of the Oued Bouskoura. Once a visible element of the city's landscape, the Oued was progressively canalized and buried during the Protectorate period. These planning ideas treated the area not as a free-flowing river but as a design element to be controlled and built over. Its path became an organizing axis for boulevards and parks, channeled through underground conduits and landscaped areas. In other words, key urban interventions promoted by French authorities—such as the construction of Boulevard Houphouët-Boigny and Parc de la Ligue Arabe—were implemented directly over or alongside its original path, replacing the natural terrain with impermeable surfaces and engineered stormwater systems [39,40].

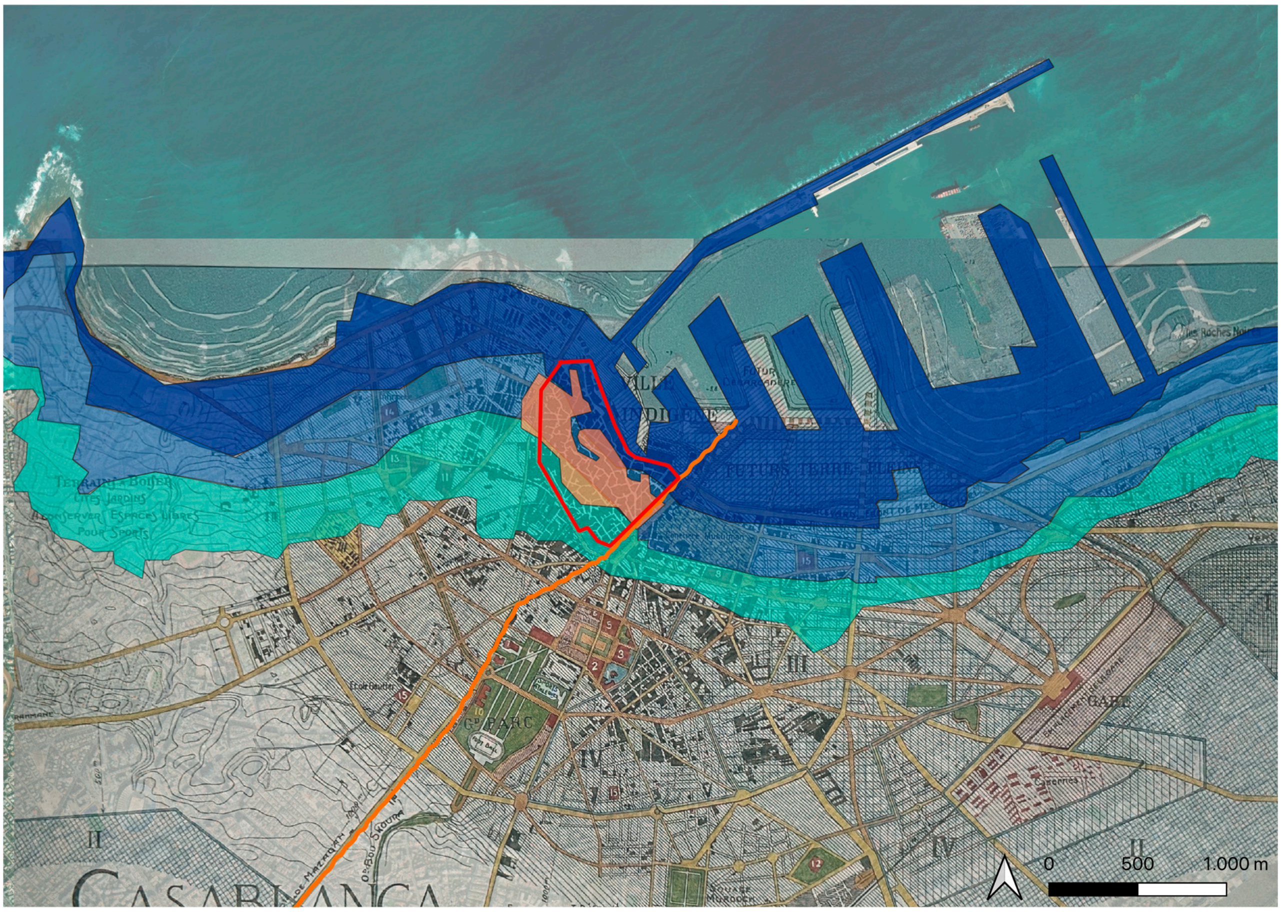

Figure 5. Flood hazard map showing high (dark blue), medium (blue), and low (light blue) risk levels, overlaid on historical maps of Casablanca; the red polygon indicates the medina boundaries, and the orange line traces the historical Oued Bouskoura course. Basemaps: Google Satellite overlapped with Development and extension plan of 1917 for Casablanca in France-Maroc 1917.

Archival planning documents further reveal the motivations behind these interventions. By 1920, initial canalization works constrained the wadi into covered conduits through the urban core. Reports by French actors and contemporaneous municipal records framed the canalization of Oued Bouskoura as a hygienic necessity and an emblem of modernization, portraying open watercourses as sources of disease and urban disorder. In the publicly communicated urban program presented during the Congrès International de l'Urbanisme aux Colonies et dans les Pays de Latitude Intertropicale in 1931, the economic rationales were also emphasized. These included the need to reclaim land for new boulevards and industrial zones [39]. These justifications as sanitary, esthetic, and functional, help to contextualize why colonial authorities prioritized burying the Oued, with archival records describing ecological trade-offs discussed at the time. By 1956, Oued Bouskoura was largely a buried storm drain, with the cityscape built over its former course. This "burial of the city's seasonal watercourses" effectively severed and paved over natural drainage [41].

Reclaimed coastal areas, developed for port and industrial purposes in the early 20th century, have become some of the most flood-prone zones in Casablanca today. The construction of the industrial harbor, completed in 1912, marked a decisive stage in the city's urban transformation [39]. In 1950s, the massive collecteur ouest (western trunk storm sewer) was built to intercept the floodwaters of Oued Bouskoura before they reached the city center, diverting them directly to the Atlantic [41]. While this infrastructure reduced surface flooding in central districts, it substantially modified the city's hydrological configuration.

By prioritizing economic functionality over ecological integrity, French colonial planners facilitated developments that have left a lasting imprint as evident today in the spatial overlap between former industrial zones and the highest flood-risk areas.

The GIS attribute table indicates that over 65% of high flood risk areas intersect with zones significantly altered during the colonial period, including areas built over Oued Bouskoura and the port's artificial expansion. Urban elements associated with colonial planning, such as axial boulevards and public parks with concrete infrastructures, were often constructed over former natural drainage corridors, reengineering the city's hydrology without long-term environmental foresight.

3.2. Drought Vulnerability and the Ecological Legacy of Colonial Urbanism

The overlay analysis of drought risk zones (Figure 6) with historical urban layers and contemporary drought data gathered from global datasets reveals a critical spatial convergence between colonial urban planning and present-day water scarcity in Casablanca. The old medina, delineated in red, lies almost entirely within the high-drought-risk zone (orange), with a small northern fringe in the low drought risk category (yellow). Historically reliant on the Oued Bouskoura as a seasonal water source, the medina now faces heightened water stress, which aligns with patterns of infrastructural marginalization and limited access to green–blue infrastructure. This dual exposure, which is high drought vulnerability combined with the flood and tsunami risks identified in previous overlays, underscores the paradox of being simultaneously overexposed to both water scarcity and water excess. This condition reflects a broader pattern of ecological marginalization embedded in the urban fabric during the colonial era.

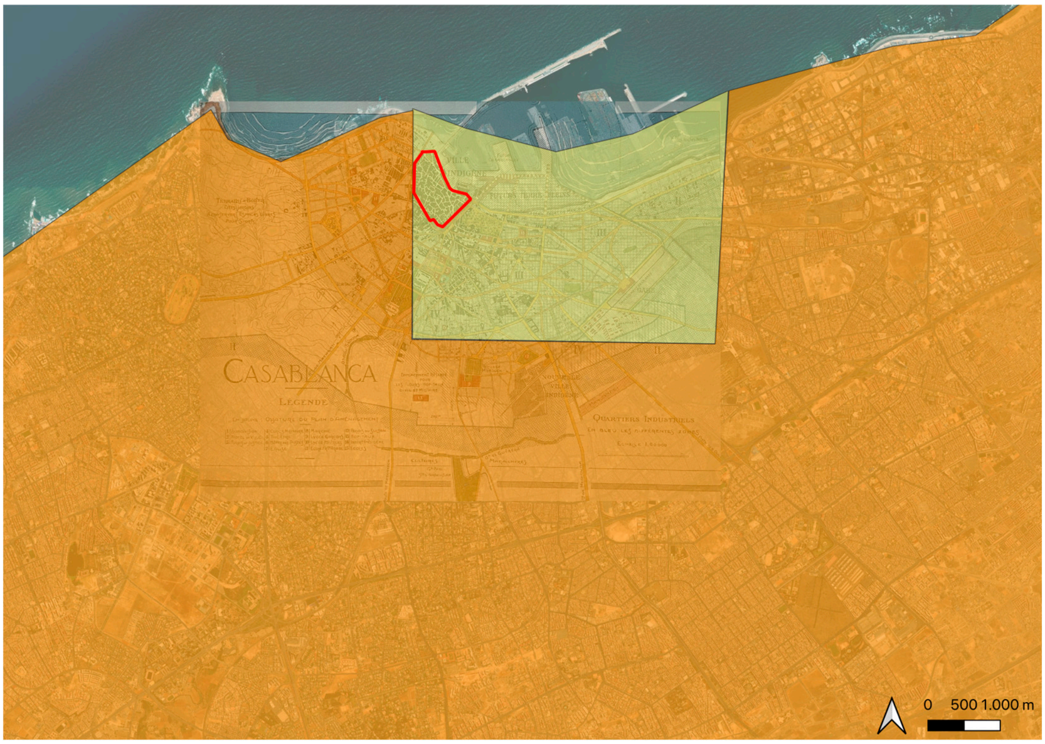

Figure 6. Drought hazard map showing high- (orange) and low- (yellow) risk zones based on the information gathered from COPERNICUS. Basemaps: Google Satellite overlapped with development and extension plan of 1917 for Casablanca in France-Maroc 1917.

More strikingly, the area designated as under active drought warning (dark yellow) overlaps with the central sector of Prost's planned urban grid. This includes the main residential axes, institutional zones, and formal green spaces of the colonial core—areas once artificially irrigated through diverted water flows from the now-buried Oued Bouskoura [14,39]. The rigid geometric order and mono-functional zoning are associated with reduced adaptive capacity to seasonal water variability. By replacing vernacular water management practices such as decentralized rainwater harvesting, the preservation of soil permeability, and multifunctional land uses [42–44] with a centralized, Eurocentric infrastructure model, colonial urbanism embedded structural hydrological fragility into Casablanca's spatial fabric.

The overlay shows that the districts most exposed to drought are also those most changed during the colonial period, through coastal land reclamation or the urbanization of former farmland and wetlands [14,45]. These interventions prioritized mono-functional uses, introducing impermeable surfaces that disrupt hydrological cycles. The loss of vegetation and natural infiltration zones removed key ecological buffers, while the lack of infrastructural redundancy left these districts poorly equipped to face long-term climatic stress [46–48].

3.3. Structural Vulnerabilities and Unequal Exposure

In stark contrast to the planned European quarters, the old medina has emerged as one of Casablanca's most structurally exposed and hydrologically precarious zones. The spatial analysis reveals a critical convergence of hazards: the medina lies at the intersection of medium-to-high flood risk, high tsunami vulnerability, and, according to the most recent datasets, heightened susceptibility to drought. This compound hazard profile positions it among the most fragile segments of the urban fabric in the face of accelerating climate pressures.

Historically, the medina was characterized by high-density construction, a fine-grained network of alleys, clusters of informal housing, and shared amenities such as fountains, hammams, and internal courtyards. In colonial urban plans, it was acknowledged and mapped, yet it received comparatively limited infrastructural investment such as drainage canals, stormwater networks, or planned open spaces, relative to the new districts developed under French administration.

Unlike the ville nouvelle, which was equipped with paved boulevards, landscaped parks, and centralized stormwater infrastructure, the medina retained much of its pre-colonial morphology and was left with inadequate water management systems. Archival sources often framed interventions in ideological terms, which helps explain the emergence of a spatial disparity as not incidental but ideological: colonial planning documents frequently depicted the medina as unsanitary and socially "backward," thereby justifying its exclusion from the "modern" city's infrastructural and administrative systems [39].

The GIS attribute analysis is consistent with the enduring effects of this neglect. Nearly 70% of areas classified as highly vulnerable to tsunamis correspond to historically underserved neighborhoods, with the medina as a principal example. Its location along the former course of Oued Bouskoura—a seasonal waterway that once bordered its outer wall—has further amplified its exposure. While adjacent European districts were restructured into geometric grids and integrated into engineered drainage systems, the medina was left physically intact yet functionally isolated from these protections.

The resulting vulnerabilities appear to be multi-layered. High population density, aging and often informal building stock, and limited modern water infrastructure heighten its exposure to flooding. Narrow streets and impermeable surfaces inhibit drainage and complicate emergency response. Simultaneously, drought vulnerability mapping shows the medina lies entirely within a high drought risk zone, indicating that its restricted access to water resources also places it at risk during prolonged dry periods. The medina is thus caught between the extremes of hydrological scarcity and excess, with neither adaptive infrastructure nor decentralized water systems to buffer these hazards.

4. Discussion

The discussion section is structured in three interconnected parts that collectively frame the implications of the findings. The first part examines the results through the lens of postcolonial urban injustice and spatial inequity, highlighting how colonial planning choices in Casablanca created enduring patterns of uneven exposure to climate hazards. The second part reinterprets heritage not simply as a cultural asset, but as a dynamic climate resource, emphasizing the relevance of vernacular water systems and local environmental knowledge for contemporary adaptation. The third part explicitly connects these insights to the broader sustainability discourse, underscoring the need for long-term ecological thinking, historical justice, and social inclusion to serve as core principles of urban sustainability, particularly in formerly colonized cities such as Casablanca.

4.1. Postcolonial Urban Injustice and Spatial Inequity

The spatial analysis conducted in this study suggests a persistent pattern of environmental injustice rooted in the spatial logics of the colonial era. One of the most significant findings is the structural disparity between the planned European quarters and the old medina, a division that embedded during the French Protectorate and still visible in contemporary vulnerability patterns. The colonial urban fabric, as laid out in Prost's 1917 master plan, privileged centrality, visibility, and monumentality for European districts, while marginalizing indigenous settlements both spatially and infrastructurally [14,45]. In other words, the planning decisions prioritized monumental vistas, hygienic public spaces, and climate-moderating designs in European quarters, while the medina was segregated both spatially and institutionally. These divisions were not merely esthetic or administrative, but they are consistent with enduring hierarchies of exposure and protection that likely influence the city's climate risk profile.

The medina, highlighted in red on the GIS overlays, emerges as a critical site of compounded hydrological vulnerability, exposed at once to flooding, tsunami risk, and increasing drought stress. This multi-hazard profile reflects both its exclusion from the large-scale infrastructural investments that characterized the French urban project and its own inherent constraints, such as high density and limited infrastructure, which shaped its adaptive capacity. Colonial interventions were not entirely ideological, as economic and sanitary concerns were also invoked, often to legitimize territorial control. While the ville nouvelle was equipped with paved boulevards, engineered stormwater canals, and landscaped public spaces designed for hygiene and climate moderation, the medina retained its precolonial morphology of narrow alleys, clustered informal housing, and decentralized water systems. Features that were originally adapted to local environmental conditions were reframed in colonial discourse as dysfunctional, thus providing the rationale for their neglect in modernization initiatives.

This systematic underinvestment persists today in the form of degraded infrastructure, overcrowded housing, and limited access to water management systems in the medina and similar historically marginalized districts. Nearly 70% of the areas with highest tsunami risk fall within neighborhoods that have historically been underserved. Despite their central location and cultural significance, these areas remain peripheral to contemporary risk mitigation and resilience strategies. This spatial marginalization can be understood as postcolonial infrastructural injustice which is a condition where historical patterns of exclusion continue to shape who is protected from climate risk and who remains exposed.

The interventions that once appeared to modernize urban space also altered hydrological balances and displaced vernacular systems of water management. Over time, these decisions are consistent with patterns of ecological fragility visible today. The spatial overlap between present-day flood and drought exposure and areas most affected by colonial interventions suggests that climate risks cannot be addressed solely through technical infrastructures. More durable strategies must re-engage ecological functions, recover marginalized forms of spatial knowledge, and guarantee equitable access to water resources. From this perspective, spatial justice becomes not an abstract ideal but a necessary foundation for resilience, requiring planning frameworks that address historical exclusion while directing investment toward the needs of vulnerable communities.

In this context, structural vulnerability in Casablanca emerges both as a legacy of colonial intervention and as an ongoing driver of climate risk. The canalization of the Oued Bouskoura, the spread of impermeable surfaces, and the systematic neglect of the medina not only changed ecological balances at the time but also embedded fragilities into the city's spatial and institutional fabric. Resilience theory describes such dynamics as path dependence, where past planning choices constrain future adaptive possibilities. In Casablanca, vulnerabilities once produced by colonial interventions have solidified into structural conditions that magnify subsequent hazards, limit adaptive capacity, and perpetuate socio-spatial inequalities. This recursive mechanism helps explain how colonial legacies continue to shape environmental development: disruptions of the past created fragile infrastructures and unequal systems, which now actively undermine resilience under accelerating climate pressures.

Colonial legacies have also influenced how climate risk is conceptualized and addressed. Technocratic adaptation approaches often prioritize the reinforcement of infrastructure in economically strategic or high-value districts which are the choices that replicate colonial-era investment logics. As a result, informal settlements, vernacular neighborhoods, and historic cores such as the medina are not comprehensively integrated in adaptation projects or targeted for redevelopment under the pretext of "resilience" [43]. This dynamic aligns with the concept of "climate gentrification" in which sustainability agendas advance elite interests while displacing or disempowering vulnerable communities [44,45].

4.2. Reframing Heritage: From Cultural Asset to Climate Resource

The findings of this study challenge prevailing assumptions in both heritage and climate adaptation by arguing that heritage is not a static cultural asset to be safeguarded, but a dynamic repository of ecological knowledge and adaptive strategies. In Casablanca, the colonial reconfiguration of space not only transformed the city's physical form but also systematically erased or sidelined vernacular systems of environmental management that had evolved over centuries. Prior to the Protectorate, the city's hydrological landscape was managed through a combination of seasonal wadi regulation, rainwater harvesting, and decentralized water storage. These included shallow wells connected to domestic courtyards, sāqiya channels for garden irrigation, and community cisterns strategically located near mosques and public squares. Shaded arcades, inward-facing houses, and narrow street grids mitigated heat and enhanced passive ventilation, while open spaces at wadi crossings acted as temporary flood buffers [49–51].

As climate change intensifies hazard frequency and severity, the medina represents both a cultural asset of exceptional heritage value and a site of acute environmental precarity. Addressing these vulnerabilities likely requires more than technical retrofitting; it calls for historically informed adaptation strategies that acknowledge how legacies of exclusion perpetuate present-day risk. Integrating heritage conservation with climate adaptation—

particularly in historically marginalized districts—ensures that spatial justice becomes a foundational principle of urban resilience [52,53].

These transformations were ideologically justified under the mission civilisatrice [54,55], which framed indigenous spatial practices as irrational or unsanitary. However, many of these discarded practices are highly relevant for 21st-century adaptation. Decentralized water harvesting systems, permeable ground surfaces, and the flexibility of informal settlements can be understood as forms of vernacular resilience and context-sensitive responses developed through long-term interaction with place-based ecologies. Treating such practices as heritage means recognizing them not merely as symbolic traditions, but as living knowledge systems with potential for reuse, adaptation, and innovation under current climate pressures.

In Morocco, ancestral hydro technologies such as khéttaras (subterranean galleries for groundwater capture and transport) and matfiyas (rock-dug cisterns for rainwater harvesting and storage) exemplify these adaptive capacities. These systems, still operational in regions including Tafilalet, embody principles of gravity-fed distribution, sediment filtration, and community-led governance, ensuring equitable water sharing during droughts [56]. While marginalized during the colonial period in favor of centralized hydraulic works, their rehabilitation could diversify and decentralize climate adaptation strategies, reducing dependence on single large-scale infrastructures.

While Casablanca illustrates how colonial infrastructures created lasting hydrological and social vulnerabilities, it is important to situate these findings within the wider Moroccan context. Non-colonial cities such as Marrakesh, Fez, and Ouarzazate also experience recurrent droughts and floods, but their risks stem largely from hydrological stress, groundwater over-extraction, topography, or dam management rather than from historical urban restructuring. The absence of large-scale colonial reconfigurations—such as the canalization of rivers, coastal reclamation, or rigid zoning—distinguishes their vulnerability from that of Casablanca. This contrast highlights the specificity of colonial cities, where climate risks are compounded by planning ideologies that entrenched spatial segregation. In Casablanca, addressing these legacies requires re-engaging with suppressed water cultures, restoring communal infrastructures in the medina, and integrating local memory into hazard mapping and emergency planning. The findings emphasize heritage—tangible and intangible—as a climate resource, where reviving practices such as cisterns and irrigation networks can diversify adaptation strategies, reduce dependence on large-scale infrastructures, and position heritage as a living repository of ecological knowledge for inclusive resilience.

This reframing aligns with a growing body of interdisciplinary work calling for heritage to be repositioned as a critical resource in climate action. The IPCC's Sixth Assessment Report recognizes the role of cultural heritage, particularly intangible knowledge and traditional practices, in contextually appropriate adaptation [26]. Similarly, ICOMOS's Future of Our Pasts report [27] and UNESCO's Global Report on Culture for Sustainable Urban Development [32] emphasize the need to integrate heritage into planning frameworks—not merely as objects to protect, but as sources of adaptive capacity and community resilience.

Despite increasing recognition in academic and policy circles, heritage remains peripheral in most urban adaptation strategies. This disconnect is particularly evident in postcolonial contexts, where imperial epistemologies continue to determine which knowledges are considered legitimate in planning [53,57,58]. Addressing climate risk in such settings requires decolonizing knowledge hierarchies and validating diverse epistemologies, particularly those rooted in Indigenous and local traditions.

4.3. Toward Historically Conscious Sustainability in Postcolonial Cities

In Casablanca, as in many postcolonial cities, the foundational urban fabric was shaped by planning ideologies that prioritized control, efficiency, and imperial representation over environmental integrity and community wellbeing. Urban interventions during colonial era were not incidental byproducts of modernization; they were deliberate strategies that reorganized urban space and are associated with vulnerabilities that persist today [59].

This increase in risk over time calls into question the usual approach to sustainability, which is often too focused on technology and the future while ignoring history. As Pelling and Garschagen [60] argue, equity must be central to climate adaptation; however, adaptation plans frequently ignore the spatial and social exclusions that produced vulnerability in the first place. In Casablanca, flood mitigation projects have often concentrated on protecting commercial and administrative districts, while historically underserved neighborhoods such as the medina, remain under-protected despite their dense populations and heritage significance.

A shift toward equitable and context-sensitive sustainability requires engaging with the historical processes that shaped the urban landscape. In Casablanca, colonial interventions disrupted pre-existing ecological systems, while post-independence planning often reinforced these disruptions through modernist infrastructure priorities [61,62]. At the same time, locally rooted forms of knowledge were sidelined in favor of imported models poorly suited to the city's climatic realities.

National frameworks such as Morocco's Plan National de l'Eau and the Stratégie Nationale de Développement Durable acknowledge the urgency of integrated water governance and sustainable development. However, their effectiveness in cities like Casablanca depends on embedding historical awareness and postcolonial justice into their implementation. Casablanca illustrates why "just sustainability" must be prioritized.

The overlapping geographies of drought-prone zones, high flood-risk areas, and socioeconomically marginalized districts reflect long-standing urban patterns where vulnerable populations have borne the brunt of environmental degradation, while others benefited from planned resilience measures. These inequities directly contradict the principles of the United Nations Sustainable Development Goals—particularly SDG 11 and SDG 13, which call for inclusive, participatory, and culturally responsive approaches to managing urban risk.

Sustainability in postcolonial cities cannot be reduced to carbon metrics, hazard maps, or infrastructure upgrades. Environmental resilience is inseparable from spatial justice, epistemic inclusion, and historical reckoning. By adopting a historically conscious approach, cities including Casablanca can transform colonial legacies from enduring vulnerabilities into foundations for renewal, equity, and climate resilience.

5. Conclusions

This study indicates that Casablanca's present exposure to floods, drought, and other hydroclimatic hazards aligns with legacies of colonial past. French planning introduced spatial and infrastructural interventions that not only disrupted hydrological systems but coincides with persistent socio-spatial inequalities, suppressing vernacular water management, erasing permeable landscapes, and privileging certain districts over others. These choices created enduring vulnerabilities that continue to shape the city's climate risks. From the perspective of resilience theory, such dynamics illustrate system coupling. In this context, system coupling refers to the way decisions in one domain become locked into others, producing self-reinforcing vulnerabilities that persist over time [63,64]. Once established, these interdependencies limited adaptive options for future generations, a form of path dependence observed in other colonial and post-colonial contexts as well.

GIS analysis indicates these historical legacies: today's high-risk zones overlap with areas transformed under French rule, including the reclaimed coastal districts, the canalized and buried Oued Bouskoura, and rigidly zoned sectors of the ville nouvelle. By contrast, the medina—long excluded from major investments—remains one of the most vulnerable areas, exposed simultaneously to water scarcity, flood hazards, and tsunami risk.

Current adaptation strategies often concentrate on protecting commercial and administrative districts, leaving historically marginalized areas under-protected despite their exposure to multiple hazards. Tracing how decisions such as the burial of the Oued Bouskoura or the zoning of impermeable port areas are associated with these enduring vulnerabilities: effective adaptation in Casablanca requires historical accountability and a recognition that present hazards cannot be understood apart from their colonial urban legacy.

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