Larhyss Journal, ISSN 1112-3680, n°50, June 2022, pp. 173-197

LONG TERM CITY DEVELOPMENT VERSUS WATER STRATEGY IN AL-MAGHREB

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Research Article – Available at http://larhyss.net/ojs/index.php/larhyss/index
Received February 25, 2022, Received in revised form June 2, 2022, Accepted June 5, 2022

ABSTRACT

It is commonly agreed that water availability critically influences the selection of sites for settlements and urban growth patterns. Nonetheless, this paper argues that it would be weakly involved in its later destiny. Its main objective is to discuss the issue in cities founded *ex nihilo* between the VIIth and XIth centuries over al-Maghreb based on an assessment of the water strategy efficiency, relevance, and consistency according to the hydrogeological context and the urban growth process. Qayrawan (VIIth century) from Tunisia, Fas (VIIIth century) from Morocco and Qalat Bani-Hamad (XIthc) from Algeria are formulated as demonstrative cases for this study. The results show that although those cities regularly faced extreme hydrometeorological hazards, their later development was constrained by acute political causes and economic changes over the Mediterranean region.

Keywords: al-Maghreb, city longevity, urban water strategy

INTRODUCTION

Worldwide, it used to be of critical importance for cities to select the foundation place in the vicinity of rivers, lakes or groundwater resources. Regarding the regional hydroclimatic features, most continental and coastal cities have generally proceeded from that paradigm in al-Maghreb. However, although drought, aridity and the resulting water shortage are natural constitutive parameters, the region has been regularly populated since the prehistoric era. Archaeological excavations and satellite images provide clear evidence of precocious urbanization preferably close to watering places (Côte, 2014; Ibn Khaldoun, 1959). Autochthonous people used to assume such hydroclimatic extremes by

practising transhumance, acclimatized farming praxis, and wise water management in addition to valuable bioclimatic housing and city layout patterns (Davis, 2007; Despois, 1964; Julien, 1956)). However, the main water relics in the region generally date from the Roman era and consist of surface aqueducts, storage basins, underground cisterns and sewage piping and are still visible in the Carthage site in eastern Tunis and the Tipaza site western Algiers as examples. Carthage and Tipaza were included in the UNESCO World Heritage list as protected archaeological parks in 1979 and 1982, respectively.

Actually, in similar bioclimatic regions, successive communities and/or governments had to deal with the endemic drought and subsequent water shortage by systemic rainwater harvesting along with surface and groundwater draining even from great distances and depths when necessary. For example, Shershel, the antic coastal city in Algeria, drained water from nearby mountains via a 40 km long surface aqueduct, the second-longest work ever built by Romans in North Africa after that of Carthage 132 km long (Leveau, 1976). In addition, inland cities located in semiarid to arid climates had to shape suitable water management systems endorsed by ingenious technology to meet domestic and agricultural needs. For example, starting from the XIth century, Ghardaya, located in southern Algeria put into practice an original water knowledge governing both technical and legal water-related aspects to favor local arid climate specificities (Aroua and Dahmen, 2017; Benyoucef, 2010; Remini, 2008).

Therefore, many medieval cities in the region do still enclose a specific water heritage designating how they adapted to the natural context while investing in the local hydro system over time. Some of them have continued to grow in the Modern period (> XVth century), enlarging and improving that heritage, such as Rabat in Morocco and Algiers in Algeria and Tunis in Tunisia, which became modern national capitals of the respective countries. For instance, Algiers continued to call upon the ottoman water network, which had been notably improved in the XVIth century, up to 1880, namely, fifty years after the French colonization and the consecutive population tripling (Raymond, 1985; Pasquali, 1953).

However, since the low middle age, some cities declined or disappeared shortly after their foundation - or regeneration - by Muslims starting from the VIIth century, such as the roman Tubunae or Bagai in Algeria and Carthage or Bashu in Tunisia (Tawil, 2011; Cambuzat, 1986; Najar and Misbah, 1967; Abdelwahab, 1950). Similarly, some newly founded cities experienced an ephemeral existence, such as al-Abbassiya, Ashir and Tihert in Algeria (Tawil, 2011; Abdelwahab, 1950).

The question then is to know what role water governance strategies have ever played in tuning the development and even the longevity of Maghreb cities during and beyond that time interval (VIIth-XIth centuries). In fact, while it is widely agreed that water availability is of major interest in selecting the founding place and urban growth direction, it may be weakly involved in its later city development. From a historical time scale perspective, most of the time; rather, they are a sum of complex combined effects generated by wars, political conflicts and variable economic conditions that may thwart their growth ambition much more than water scarcity and/or hydroclimatic hazards regardless of their

intensity and effects. With respect, this paper argues that the water strategy did certainly facilitate and stimulate the urban growth process and socialeconomic development, but the later city destiny would have been governed by political and economic changing interests and subsequent strategies observed starting from the XIth century. This paper's aim is to discuss the issue and appreciate short and long-term influences associated with water strategy on the development process of some Maghreb cities founded *ex nihilo* between the VIIth and XIth centuries. Qayrawan (VIIthc) from Tunisia, Fas (VIIIth century) from Morocco and Qalat Bani-Hamad (XIth century) from Algeria are formulated as demonstrative cases for this study.

MATERIALS AND METHODS

This paper aims to examine the influence of both the water context and the related governance strategy including technical, regulation and funding features on the city growth pattern and longevity in some Maghreb cities founded *ex nihilo* between the VIIth and XIth centuries. Ultimately, it is to better understand how cities become primarily adapted over space and time by combining common technical with organizational measures (i.e., structural with nonstructural measures) to address specific urban water issues. The al-Maghreb geographic area and the low middle age time interval are considered for this study given the potential contribution of past regional water heritage to addressing present critical water issues associated with anthropogenic, environmental and climate changes.

That time interval and geographic area are considered at least for two reasons: first, regarding the study time interval, recent studies on the reconstruction of the preindustrial regional climate showed that it would have stabilized from the first millennium (Lionello, 2012; Davis, 2007), and second, from the VIIth to the XIth century, al-Maghreb crossed a hectic development era incorporating various influences from the Mediterranean world and beyond (intercontinental exchanges) before unifying into a singular political-cultural entity under the Fatimids, the Almoravids and the Almohads successively (Najar and Misbah, 1967). Three cities founded *ex nihilo* in three Maghreb countries, Qayrawan (VIIth century) from Tunisia, Fas (VIIIth century) from Morocco and Qalat Bani-Hamad (XIth century) from Algeria, are formulated as demonstrative case studies. They were selected in view of i) their representativeness of the historical context during the study time interval, ii) their relevance to the issue discussed as founded *ex nihilo*, and iii) the availability of related detailed documents. For instance, they all have been stating capitals with varying later development trends while now suffering different common water issues (scarcity, contamination, flooding).

The first specific objective is to appreciate the water strategy efficiency by listing technical means employed locally, i.e., waterworks carried out to i) mobilize, drain and store available resources (surface and groundwater resources) and ii) mitigate hydrometeorological hazards' impacts (drought and flood) and water-related risks (contamination, scarcity). They are compared against major waterworks that used to be

used at that time interval in the region (e.g., aqueducts, basins, cisterns, dams). The question to be answered is as follows: According to the local water geography and dynamics, how were technical knowledge and skills mobilized to meet the local population's water needs and ensure security conditions in the face of hydrometeorological hazards and water-related risks?

The second specific objective is to appreciate the relevance of water management to the local socialeconomic-cultural context, i.e., the water sector's organization, regulation and funding appreciated against contemporary praxis in the region (e.g., water jurisprudence, public-private partnership). The question to be answered is as follows: According to contemporary water management practices, how were legal, material and financial resources combined to enhance city development?

The third specific objective is to appreciate the water strategy consistency vis-a-vis the city growth path based on a brief urban profile method. It is to examine the general land use pattern (i.e., zoning process) and water-specific space servitudes observed. The question to be answered is as follows: According to contemporary urban growth patterns, how did the city interact concretely with both the natural and the urban water cycle requirements including supply and sanitation?

This paper is structured into three sections: the first is to set the issue and give an overview of the regional natural and socioeconomic context during the study time interval (VIIth-XIth centuries), the second is to document the city water governance strategy and urban history with a brief overview of the current state, and the third is to discuss the respective water strategies in the long run, as noted above.

Relevant information is captured from various sources related to the regional physical and human geography-history in addition to the city's urban history including the water strategy structural and nonstructural measures at that time interval. Therefore, references cited consist of or are based on i) Arabic manuscripts attributed to geographers (e.g., Ibn Hawqal, Xth century, Al-Idrissi XI-XIIth cenuries) or historians (e.g., Ibn Abd al-Hakam IXthc, Ibn Idhari XII-XIVth centuries, Al-Djaznaï XIVth century); ii) archaeological excavation reports and geo-historical studies mainly led by early XXth century Orientalists (e.g., De Beylié, Le Tourneau, Despois, Bel); iii) recent studies and reports on current water issues (see the references list).

PHYSICAL AND HUMAN GEOGRAPHY IN THE STUDY AREA

Physical geography

Since 1989, the al-Maghreb subregion has formally regrouped Morocco, Algeria, Tunisia, Libya and Mauritania inside the Arab Maghreb Union as a regional economic community acknowledged by the United Nations-Economic Commission for Africa. However, it is used literally to designate the western/occidental part of the Islamic world located in northwestern Africa vs al-Mashreq, which designates its eastern/oriental part, including

Egypt (Tawil, 2011; Despois and Ranal, 1975; Despois, 1964). Historically, it delineates the area including Morocco, Algeria and Tunisia, closely linked to each other concerning their common geologic structure, geography, history and social-cultural-economic relationship over time. For this purpose, this paper adopts that space delineation.

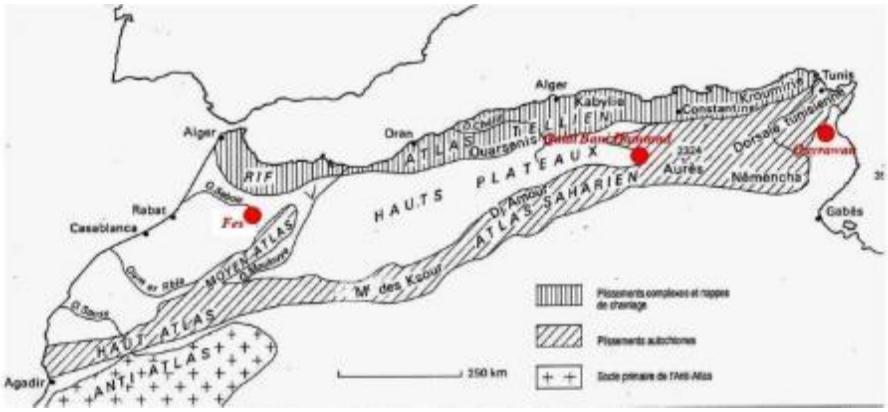

Figure 1: Al-Maghreb general morphology (After J. Desanges and J. Riser, 1989)

The region has a Mediterranean climate that is generally temperate with a wet winter and a dry hot summer while registering seasonal variability and extremes resulting from complex interactions between endogenous and exogenous influences. Endogenous criteria come to the regional physiography and biosphere features, while exogenous criteria mainly come to the atmospheric movements over the surrounding continents, sea and ocean. Withal, beyond an apparent homogeneity, the regional climate is rather hybrid, roughly designating two main types: first being wet in winter, dry and hot in summer along the coast (Csa, Köppen classification system), and second being arid to semiarid with fewer precipitations and more long summer-dry seasons over inland regions, as shown in Fig. 2 (BSh, Köppen classification system) (Allam et al., 2019; Lionello, 2012; Blumler, 2005). With respect, the regional water availability closely depends on mountains engendering rivers and temporary wads flowing into the sea or infiltrating the groundwater recharge (Despois, 1964; Margat and Vallée, 2000).

Case study cities are located by the northern limit of the steppe in the high plains, as shown in Fig.1. The subregion has an intermediate climate registering extreme temperatures during winter and summer. Even though impacted by sea and/or ocean proximity, the rainfall rate is generally irregular, varying between 300 and 600 mm/year. Groundwater resources are subsequently of vital interest to the county. The high plain's average altitude is approximately 1000m (900 to 1200m), while the land cover is characteristic of the steppe, which is traditionally the country of pastoralism and nomadism more than a sedentary lifestyle. However, with regard to the local precipitation

regime, any farming activity over the steppe strongly depends on irrigation infrastructures (Davis, 2007; Despois and Raynal, 1975; Julien, 1956).

From the low middle age, the natural environment may have changed to natural and human-made causes (Davis, 2007; Planhol (de), 1968). However, historians and geographers generally agree on the high lands' potentialities in terms of fertility, water resources and easy mobility as well as the steppe pastoral and cereal vocation since ancient eras (Despois, 1964; Julien, 1953). Indeed, a number of cities have been founded preferably below the Roman lime and the arid steppe according to water and living resources and favorable building lands being denser in coastal plains and inland high plains. Coastal and high plains have long been invested by autochthonous people who have been notably opened onto the sea, encouraged by trade with Phoenicians and later on by Roman colonization. The urbanization process over inland regions started to emerge and progress more or less vigorously and sustainably by the VIIth century (Zaydan, 1958).

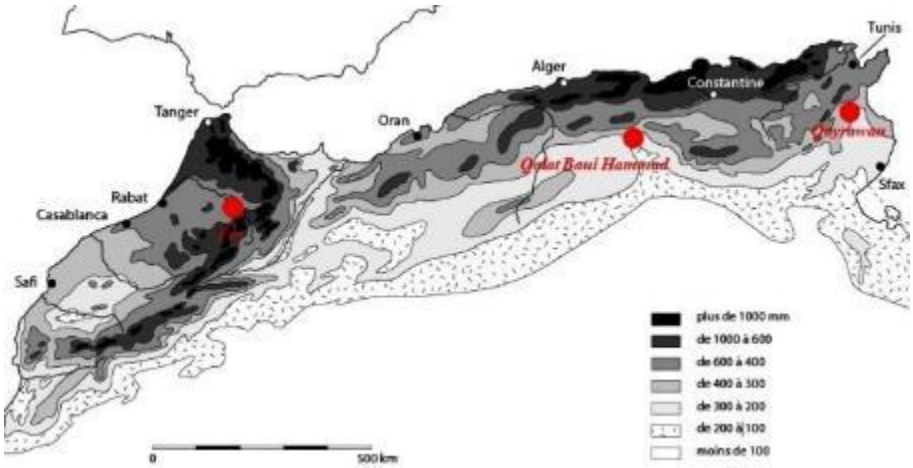

Figure 2: Al-Maghreb rainfall regime (After Despois and Raynal, 1975)

However, contrary to Phoenicians and Romans who arrived by sea from the north, Muslims approached al-Maghreb by land from the east and should have relied on local auxiliaries' skills to select itineraries and new setting places preferably along with or near watering places (Wood and Sir Mortimer, 1966; Planhol (de),1968; Najar and Misbah, 1967; Cambuzat, 1986). Nevertheless, successive raids have been necessary to explore the unknown Maghreb and appreciate the regional physic and human geography Najar and Misbah, 1967; Cambuzat, 1986). Most populated and urbanized areas were then located in the north, being sea-oriented in parallel with several inner defensive fortified cities (Cambuzat, 1986; Despois, 1964).

Since then and for almost four centuries (VIIth -XIth centuries), the region has crossed four main political periods, dedicated first to achieving the conquest of North Africa up to the end of the VIIth century, second to consolidating the social cohesion up to mid-VIIIth century, third to building up various autonomous states (Idrissid, Rostemid, Hammadid, Zirid and Aghlabid) and fourth to reunification under the Fatimids banner starting from the beginning of the Xth century (Najar and Misbah, 1967). Thereby, the Idrissids founded Fas (end of VIIIth century) while the Rostemids founded Tihart (mid-VIIIth c) as respective capitals. Later, the Hammadids and the Zirids founded a number of cities, some of which have been capitals such as Ashir (end of Xth century) and Qalat Bani Hammad (beginning of XIth century). However, at least up to the XIth century, Qayrawan, founded by the end of the VIIth century, remained the most important city in the region, successively being the Capital of the Aghlabids, the Fatimids and the Zirids.

Actually, the XIth century would have been fatal or opportune to those cities' later development depending on their strategic significance for the Almoravids (by mid-XIth century) and the Almohads (by mid-XIIth century) and, more generally, for the navigation a new boom. Thus, despite the general political confusion over the region due to the long distance to the Central Government in Baghdad (Capital of the Abbasid) *inter alia*, at the end of the VIIth century, al-Maghreb engaged in an unprecedented urbanization process incorporating, mixing and enhancing multiethnic cultural and technical heritage (Miquel, 1995; Zaydan, 1958). With regard to the population increase at that time, although local water resources would have seemed to be sufficient, they very likely required facilities to be transferred and distributed (Tawil, 2011; Saoud, 2004). Thereby, from the urban history perspective, that time interval (VIIth-XIth centuries) has been paradoxical, a prosperous as much as an inconstant era for al-Maghreb. Indeed, the Islamic period would have started here by the end of the VIIth century after a long period of political instability and economic weakening inherited from the Roman Empire decline and regular conflicts between Vandals and Byzantine (Najar and Misbah, 1967; Cambuzat, 1986). As a result, several cities and provincial capitals were ravaged, similar to the famous Carthage in Tunisia, Volubilis in Morocco and Timgad in Algeria, advancing serious damage to smaller depending towns (Cambuzat, 1986; Julien, 1953). For that new historical era requirements, some of them have been rebuilt and repopulated by Muslims, such as Cirta becoming Quasantina in Algeria, Tangis becoming Tanger in Morocco, Hadrumetum becoming Susse and Taparura becoming Sfax in Tunisia. On the other hand, some other cities had been founded *ex nihilo* over strategic military sites or trade crossroads. Except for Qayrawan, which was the first extrapolated Muslim base for the western Islamic conquest, many inland towns have been founded to be the capital of newly emerging autonomous states in the region, such as Fas, the capital of the Idrissid in Morocco, and Qalat Bani Hammad, the capital of the Hammadid in Algeria.

Water geography

As shown in Fig. 2, the case study cities are located in the semiarid bioclimatic region, registering between 200 and 600 mm/year.

Qayrawan is located in southern Tunis approximately 50 km from the Mediterranean coast within a wide semiarid plain 60 meters high, 100 km long and 40 km large crossed by the Merguellil, Zeroud and Nabhana Rivers, as shown in Fig.3. The general latitude and longitude are 35° 40′N and 10° 05′E, respectively.

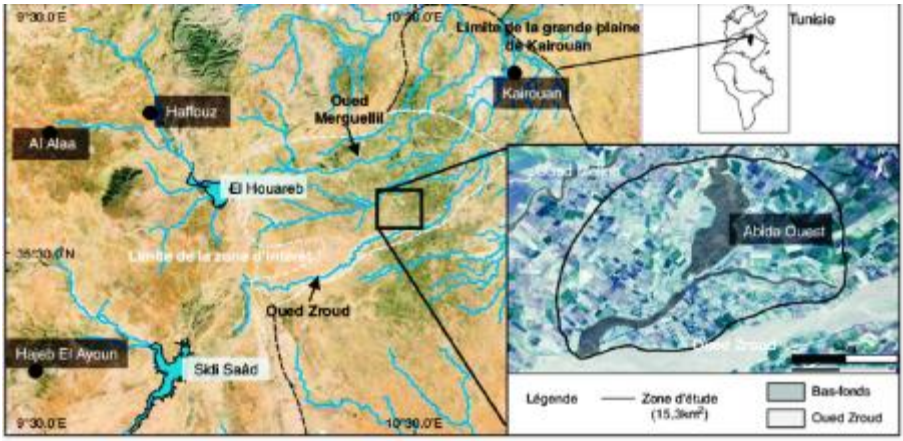

Figure 3: Main rivers supplying Qayrawan (Kchouk et al., 2015)

The plain is integrated into the west-central hydrographic region delineated northwestern by mountains (700 m average altitude, 1300 m max peak) and eastern by temporary salted lakes sebkha Kalbia and sebkha Sidi el-Hani (Cambuzat, 1986; Julien, 1953). While the average rainfall is 200 to 400 mm/year, it seems to be irregular, with a maximum of 42mm in October and minimum 4 mm in July, designating a semiarid bioregion. Temperatures may vary significantly between summer and winter, Max 37,1°C in July, Min 15,9°C in January. Local water resources consist of groundwater in addition to the Merguellil, Zerroud and Nebhana temporary rivers that overflow from time to time and are at the origin of a large swampy area east of the city (Mrabet, 2016; Leduc and al., 2004). Western Fas is located at Wadi Fas tributaries' confluence with the Sebou River, north of the Saïs wide fertile plain crossed by a number of watercourses, as shown in Fig. 4. The general latitude and longitude are 34° 03′ 00″N and 4° 58′ 59″W, respectively.

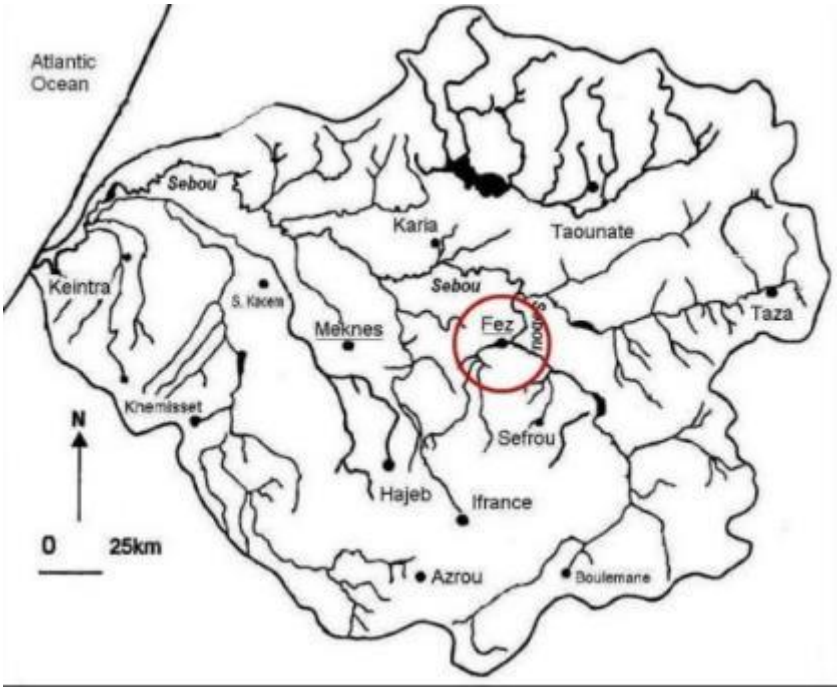

Figure 4: Main rivers supplying Fas (Saddiki et al., 2011)

The plain is integrated into the Sebou hydrographic region between the northern Rif Mountains and the southern Middle Atlas Mountains. At approximately 300 meters altitude, the climate would be continentally influenced by oceanic atmospheric flows. Temperatures may vary significantly between summer and winter, with a maximum of 34°C in July and minimum of 4°C in January. The rainfall average is approximately 500 mm/year, albeit irregular over time, and the maximum is 74 mm in October and the minimum is 3 mm in July, designating a semiarid bioregion (El-Ibrahimi, 2015; Despois and Raynal, 1975). The local water resources mainly consist of rivers and several resurgences emerging from 0.5 to 5.0 m in depth southwestern over the left bank of Wadi Fas.

Qalat Bani Hammad is located in central-eastern Algeria, at almost 1000 m altitudes on the south side of the Maadid Mountain from the Sahara Atlas, north of the Hodna Plain and the steppe. The general latitude and longitude are 35° 49′ 15″N and 4° 47′ 21″E, respectively. The site is integrated into the Hodna hydrographic subregion composed of the Hodna Mountains (1200 to 2000 m) and the Hodna Plain (500 to 900 m) crossed by many permanent and temporary rivers (e.g., Wad Q'sob, Wad Barika) flowing into the salted lake Chott Hodna at 400 m altitudes. Temperatures may vary significantly between summer and winter, with a maximum of 40°C in July and minimum of 2°C in January.

Referring to the average rainfall of 200-300 mm/year, the local climate is arid with stormy rain between September and October being the origin of disastrous floods. Local water resources mainly consist of underground aquifers in addition to surface waters (Kebiche, 1994; Despois, 1953).

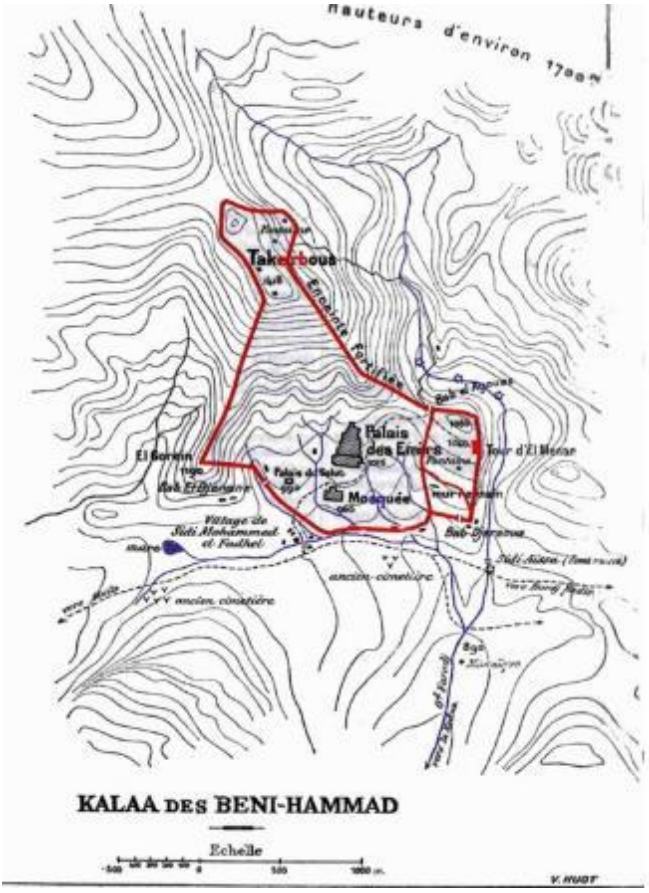

Figure 5: Main Rivers supplying Qalat Bani Hammad (Encyclopedia of Islam, Volume IV, 500p.)

URBAN HISTORY

Qayrawan in Tunisia (VIIth century)

After Ibn Abd al-Hakam, Qayrawan was founded by Uqba ibn Nafi in 670 as a karawan, literally a "military camp" in Persian being the first Muslim capital and operating base in North Africa (Najar and Misbah, 1967; Ibn Abl al-Hakam, 1964). The valley position was seen to be safe from any Byzantine attack from the sea or devastating river flood while closing near inland lakes and pastures (Ibn Idhari, 2013; Mahdoufh and al., 2004). Originally, the area looked like a wild dense forest dominated by trees and grasses. Once the forest partly thinned, the famous commandant Uqba Ibn Nafi himself outlined the city perimeter (3600 arms ± 6500 m), shaped it into parcels, and built the official residence and the great mosque while people built houses all around using bricks made from locally abundant clay (Ibn Idhari, 2013; Cambuzat, 1986; Najar and Misbah, 1967). Historical sources give no more consistent details about waterworks the local population did necessarily engage in at that time. However, as later noticed by a number of geographers, it is very likely that rainwater harvesting and river transfer were commonly practiced using nearby ancient facilities and/or setting new ones (Mahdoufh and al, 2004).

During the two next centuries, the city experienced different ephemeral governments before becoming the political and religious capital of the Aghlabids by mid-IXth century (Ibn Idhari, 2013). At that time, it became necessary to build additional water facilities, such as transferring water from neighboring rivers into several underground cisterns and two great basins built at the city gates as shown in Fig. 6 (Ibn Idhari, 2013; Ibn Abl al-Hakam, 1964).

Figure 6: Two great basins in Qayrawan (ICOMOS, 2015)

That original double infrastructure was to clear out carried water of alluvial sediments along with reducing the flow velocity progressively and thus prevents any damage resulting from flooding (Mahdoufh and al., 2004; Marçais, 1954). Thus, autochthonous people used to accommodate the local water context by regularly reshaping the roads' layout along rivers and storing every available surface resource (Hamza, 1988). Several water relics date from that era, such as wells, water pipes, storage infrastructure, and cisterns in addition to a sewage system. Later, many harvesting works, dams and canals have been regularly added by Fatmidis (Xth century) and Hafsids (XIIIth century) specifically (Mrabet, 2016).

That location seems to have never been urbanized before, as locals preferably occupied a distant heightened land named al-Qarn (Mahdoufh and al., 2004). Ultimately, Uqba would have been more concerned with military and natural advantages since planning for a capital city able to receive a large population (al-Nuweyri cited by Cambuzat, 1986). However, contradictory legends on the location of Qayrawan have been reported by historians. Some authors maintained that the steppe is not profitable to the economic development of a great capital (Ibn Abl al-Hakam, 1964). Conversely, some other authors argued that the alluvial plain had a major strategic asset being at an almost equal distance from the sea and the mountains (Cambuzat, 1986). In addition, it can be noticed that the primary forested context would attest to local water availabilities. Indeed, Uqba, being a trained chief native of an arid country, was certainly of the strategic and vital importance of water availability in such a steppe region.

Initially, the city perimeter was 7.5 km, while its surface was approximately 3.5 km². The population has been estimated to be 50 000 inhabitants with a comparatively high urban density (approximately 140 inhabitants/ha) (Ibn Idhari, 2013). At its apogee (IXth century), the city integrated two near fortified royal residences built southern, al-Abassiya (by 800) and Raqadada (by 870), including public buildings (e.g. mosques, *hammam*, *souqs*, hotels, gardens) and housing neighborhoods becoming approximately 16 km² wide (Mahdoufh and al., 2003). Consecutive increasing water needs automatically require further water infrastructures, such as dams, basins and cisterns (Mahdoufh and al, 2004; Mahdoufh and al., 2003; Najar and Misbah, 1967). Moreover, activities strongly depending on water used to be set along rivers close to the city's ramparts. Thus, wool washers were settled west at wad al-Qassarin, while potters and vegetable merchants were settled east at koudiat al-fakharin (Mahdoufh and al., 2004). In addition, approximately 3500 m far from Qayrawan, there was a singular construction named Qasr al-Ma', namely, the Water Palace, which seems to be an ancient water work rehabilitated by Zirids in the Xth century. Many water vestiges have been excavated in the city region (e.g., a great basin, a water tower and a number of holes) (Mrabet, 2016).

However supplanted by the coastal capital city Mahdiya founded by the Fatimids at the beginning of the Xth century, Qayrawan conserved its aura for four centuries and continued to grow south incorporating Abbasiya and Raqqada successively (Najar and Misbah, 1967). The city welcomed refugees from al-Andalus in the XVth century and experienced notable urban sprawl by the XVIIth and XVIIIth centuries during the Ottoman

period. The French colonial period significantly modified the urban growth pattern and introduced modern water infrastructure for groundwater intensive mobilization. For instance, from the end of the XIXth century, Qayrawan's local economic development pattern is mainly based on agriculture (cereals, olives, almonds) and traditional handicraft activities (carpets, tannery), which are strongly and increasingly dependent on groundwater resources (Leduc et al., 2004). As a result of that continual pressure, the local hydro system is now suffering long-and short-term effects such as drawdown and salination in parallel with water quality concerns, river drying up, erosion and disastrous floods (Chebbi and al., 2008; Leduc and al., 2004). In 1969, the city registered a historical flood event generating dozen victims and important material damages (Ballais, 1973). Despite major natural disasters, the city would never have been deserted completely or even temporarily depopulated at the beginning of the XIth century for conjectural conflicts. Currently, it is no longer a capital city but is still celebrated as a spiritual hub in al-Maghreb. Qyrawan was included in the world heritage list in 1988.

Fas in Morocco (VIIIth century)

Fas was most likely founded by the beginning of the IXth century (~ 808-809) by Idris Ibn Abdallah II on the left bank of Wad Fas over the Saïs wide fertile plain being the first new capital in the far west, namely, al-Maghreb al-Aqsa (Najar and Misbah, 1967; Al-Djaznai, 1923). According to the contemporary chronicle, Idris II would have started the construction work with a master mason. After Al-Djaznai, the site was amply watered in addition to being at an optimal distance from the sea, the mountains and the desert. It seems it was an idyllic place, a green plain crossed by Wad Fas named Nahr al-Jawaher (The Perl River) in addition to a number of small watercourses and emerging crystal clear sources. From that time, the urban structure used to be delineated by a canal network distributing surface water toward public ablution rooms, basins, fountains and houses while wastewaters were transferred *extra muros* over a sewage system. Additionally, there were a number of inner private wells for domestic use. Almost immediately, the city welcomed Andalusian migrants from Cordoba (in 818) and then from Qayrawan (in 825) being at the origin of two twin urban settlements on both sides of Wad Fas named Madinat Fas (the City of Fas) and Fas al- Alya (the High Fas), respectively (Najar and Misbah, 1967). Three centuries later, as the intermediate space filled, Madinat Fas and Fas al-Alya were joined in Fas al-Bali (the Old Fas) by Almoravids (Le Tourneau, 1949).

Figure 7: Fas city's Noria (https://ouedaggai.wordpress.com/**)**

The city has continued to densify since then and grow over time by concentrating houses, craft factories and many urban facilities some of which require a continuous water supply, such as mills, hammams, mathara (ablution room), public basins and fountains. The urban sprawl called upon reshaping or building new walls to supply new suburbs connected through a number of additional crossing bridges over canals and rivers. Socioeconomic development used to be based on agriculture (cereal, fruits and vegetables) and many various processing or transformative activities, such as textile, leather, iron, copper and glassworks, necessitating further water infrastructure (Le Tourneau, 1949).

In the XIIIth century, the Merinid extended the city in the plain setting Fas al-Jadid (the New Fas) supplied by another river running a few kilometers west (El-Hajjam, 1988; Le Tourneau, 1949). Some activities strongly dependent on water resources were set on the river's banks, such as water-mills, tanneries, dyeing, and abattoirs (El-Hajjam, 1988). Then, Fas reached its apogee. The city included a number of gardens, storage basins, surface aqueducts and *norias* still now existing as shown in Fig. 7 (Troin, 1995; Le Tourneau, 1949). In the XVIth century, the city extended extramuros northwest, incorporating five suburbs in the direction of upstream emerging water sources (Troin, 1995; Le Tourneau, 1949).

From the XIth century, Fas was no longer the capital city founded by Idrissid and was supplanted by Marrakesh, which was founded by the Almoravids by mid-XIth century (Troin, 1995; Najar and Misbah, 1967). However, the prestigious and flourishing city was still revered by successive governing dynasties as a religious and cultural hub (Almoravid, Almohad, Merinid, Saadid and Alawit) until the beginning of the XIXth century, when Rabat became the formal capital of Morocco under the French Protectorate (Troin, 1995; Le Tourneau, 1949).

By mid-XIVth century, when the geographer Abou al-Hasan Ali al-Djaznai visited Fas, the city was still mainly supplied by Wad Fas from the west, and a number of emerging water sources were collected in a single canal and then distributed through several channels crossing the city (Despois and Raynal, 1974; Al-Djaznai, 1923). However, the water flow velocity was controlled at the entrance of the city to mitigate any flood risk event (El-Hajjam, 1988). Indeed, the city used to suffer river floods generating notable material damages and likely victims, as noted by Al-Djaznai in 1324-25 (Al-Djaznai, 1923). Furthermore, the urban water system is based on two kinds of canals: the first was to supply mat'hara (ablution rooms) and houses, public fountains and basins; the second was to drain public and private latrines and wastewaters (Al-Djaznai, 1923). That description was still noticed in a formal document dating from the XVIIIth century (El-Hajjam, 1988). Waterworks consisted of pottery pipes, storage basins covered with protective screens, marble basins and bowls, and yellow copper taps (Al-Djaznai, 1923). Freshwater captured from sources or drawn from wells was used for drinking and ablution purposes while water captured from the river and tributaries was used for all other domestic and industrial purposes (El-Hajjam, 1988).

Currently, Fas bases its economy on agriculture and tourism. The city is suffering regular devastating floods, as in 1950, 1989, 2008 and 2010 (Zinoun, 2014), in addition to important water chemical and biological pollution and water scarcity (El-Ouali et al., 1994). In 2004, the sewage system required an urgent upgrading operation as Wad Fas had transformed into an open sewer threatening public health and hygiene. Informal urbanization seems to be the origin of an aggravated risk of flooding and water contamination (Zinun, 2014; Reynard et al., 2011). Fas was included in the world heritage list in 1981.

Qalat Bani-Hamad in Algeria (XIth century)

Qalat Bani-Hamad was founded by Hammad Ibn Bulughin in 1007-1008 on the Maadid mountainside overhanging Chott Hodna (Tawil, 2011; Beylié (de), 1909). The site has been selected for its natural defensive assets in addition to being close to Wad Frej and attributed to Wad Fadel (Tawil, 2011; Beylié (de), 1909). Hammad Ibn Bulughin would have promptly fortified the city capital and populated nearby towns including Qayrawan (Tawil, 2011). Up to Hammad's grandson's reign (~ end XIth century), the city grew up and was embellished by building a number of palaces, houses, mosques, funduqs, souqs, and factories in addition to wells, storing basins, cisterns and reservoirs (Tawil, 2011; Fairchild, 1994; Golvin, 1962). There were a number of palaces like Dar al-Bahr (the Sea

Palace) with its large artificial lake, 64 meters long on 45 meters large, Qasr al-Manar (Royal Palace), Qasr Salam (Peace Palace), and Qasr al-Kawkab (Star Palace) (Tawil, 2011; Marçais, 1954).

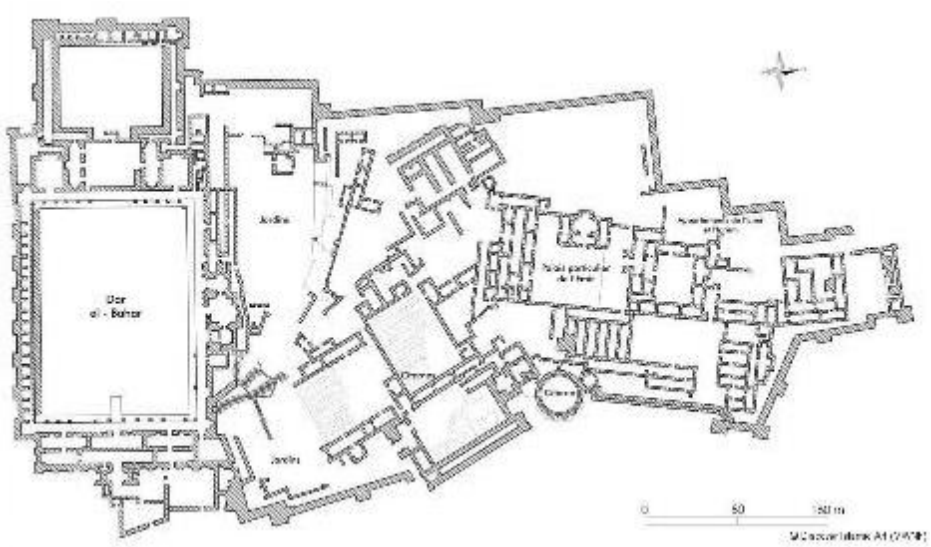

Figure 8: Qalat Bani Hammad (www.whc.unesco.org)

The water supply system is used based on canals draining water from nearby rivers to the public basins and cisterns and from there to the apartments while other canals drain wastewater out (Tawil, 2011). The topography would have facilitated the draining process from the highest to the lowest part of the city (Fairchild, 1994).

There were two kinds of reservoirs: first for water decanting and second for water storage, as in Qayrawan (Marçais, 1954). The city was crossed by canals irrigating gardens and riads while supplying public buildings such as the famous artificial lake in Qasr al-Bahr (Sea Palace). After De Beylié, during the dry season, likely between April and September, local populations would have to use stored cistern water or bring water from Wad Frej and Wad Fadel *extra muros* (Tawil, 2011).

Social-economic development used to be based on trade and industry (Tawil, 2011). After al-Idrissi cited by De Beylié, the city was prosperous, being self-sufficient, populated and having remarkable public and private buildings (Beylié (de), 1909). However, in 1089, the Hammadid capital was transferred from the northern to the Bejaya coastal city (Fairchild, 1994). The decline of Qalat Bani-Hamad then started, albeit the city remained populated until the end of the XIIthc as a military fort as noticed in a document dating from the XVIth century cited by De Beylié (Beylié (de), 1909). Qalat Bani Hammad was included in the world heritage list in 1980 as an archaeological site.

DISCUSSION

During the low Middle Age, almost all water technology fundamentals would have been mastered and put into practice over the Mediterranean (Angelakis et al., 2015; Viollet, 2000; Jawdat, 1992). By the end of the XIth century, Islamic cities had even developed a specific water governance strategy combining three active and complementary features: technology, jurisprudence and water-sensitive urban design. This kind of integrated water strategy naturally mixes structural with nonstructural measures for mobilizing available resources, coping with hydrometeorological hazards and mitigating associated risks.

As per technology, structural measures for either irrigation or urban supply called upon rainwater, emerging sources, rivers and groundwater (El-Faiz, 2005; Abu Mustapha, 1997). Surface resources were generally mobilized via dams and norias, while groundwater was drawn via wells and underground aqueducts (El-Faiz, 2005; Jawdat, 1992). Mobilized water used to be drained through surface aqueducts and canals and then stored in basins and cisterns. Basins would have been used to regulate and decant the water flow, playing a notable role in mitigating flood and contamination risks in the meantime (El-Faiz, 2005). Such measures naturally contributed to facing drought while dams and dikes contributed to reducing flood risk (El-Faiz, 2005; Cressier, 1989).

Nonstructural measures consisted of a specific jurisprudence applied to water and urban design through *al-hisba* and *al-waqf* religious institutions. They were, respectively i) to control the urban growth and design patterns through the zoning process by setting a set of specific water space servitudes and ii) to provide the water sector with a perpetual funding resource (Aroua, 2014; El-Faiz, 2005). Several water-related jurisprudence, *qanun al-ma'*, proceeding from rules, *ahkam*, and decisions, *nawazil* or *fatwa* have been issued then to manage the sector and resolve conflicts associated with urban and rural usages. Legislation used to be water-specific considering various final uses either for domestic or manufacture or irrigation purposes, on the one hand, and the kind of water source (rainwater, rivers, and groundwater) and infrastructure (wells, basins, aqueducts, canals) on the other handand (El-Faiz, 2005; Abu Mustapha, 1997). Ultimately, *qanun al-ma'* is based on the zoning urban design process in addition to the systemic urban and rural linkages to preserve the whole water system qualitatively and quantitatively while protecting human well being, security and comfort. For example, proceeding from *al-hisba*, many urban-related jurisprudence documents included necessary space servitudes for selecting manufacturing locations, setting sewage canals and a protecting perimeter around wells, aqueducts and emerging water sources (Ibn Abdun, 2009; Bouleqtib, 2001; Ibn Rami, 1999).

Nonstructural measures implementation closely depended upon the collaboration of public governing entities with local communities and professional corporations. The regulation was an independent sector coming to *al-qadi* authority and assistants such as al-mohtassib who used to monitor various obvious urban life aspects such as social-economic activities, public hygiene, public social behaviors, etc. (Ibn Abdun, 2009). It is of great interest to note that *al-hisba* necessarily referred to both Islamic religious precepts

and expert technical opinion in that case involving engineers and doctors in medicine with regard to specific technical and health requirements.

Likewise, the water sector used to be funded by public and private contributions dedicated to financing the construction and maintenance of water infrastructure and networks. It is of great interest to note that private funds mainly consisted of nonprofit sources, namely, *al-waqf* and *al-habus*, the perpetual independent usufruct that did not give any decisive influence or lobbying power to its author. For instance, Al-Maghreb and even more al-Andalus used to develop that strategy, as noted in a number of historical documents and archaeological excavation reports dating from the modern period.

During the study time interval, the technological progress would have been widely disseminated over the subregion being adjusted locally following the water context and the social-economic development requirements. Additionally, it is worth noting the eastern influence through engineers and multiethnic migrant communities either Muslims or not coming from all over the Umayyad and later the Abbasid Caliphate, setting first in Qayrawan and then in al-Andalus before moving to other western Mediterranean cities (El-Faiz, 2005). For example, Qayrawan and Andalusian refugees played a notable role in improving local water systems in Fas and Qalat Bani Hammad by introducing advanced hydraulic processes (Tawil, 2011; Mahfoudh and al, 2004; Najar and Misbah, 1967; Le Tourneau, 1949; Al- Djaznai, 1923).

With respect to that time means, skills and knowledge, whatever it is difficult to appreciate the local population's water needs satisfaction quantitatively, it seems that local water availabilities mobilization and hydrometeorological hazards (flood, drought) mitigation would have been efficient within the case studies. The easiest operation seems to have been to supply cities with drinking water even from afar or deep distances, while protecting against flood and drought and wastewater disagreements (contamination, foul smells) seem to have been more critical. Indeed, even if the supply and sanitation systems were both based on canal networks caring about public hygiene *intra muros*, negative impacts on the hydro system integrity must have been difficult to control or even to avoid – similar to the current situation. For instance, water was captured from various neighboring sources (surface or groundwater) and then used for different purposes and then wastewater was simply discharged (gravity drainage) far from residential areas into almost the same river or attributes. Moreover, sometimes public hygiene shortcomings would have been at the origin of a massive exodus as well as epidemics and famine (Jawdat, 1992).

At least that was the general attitude worldwide up to the advent of the modern sewage system in the mid-19th century (Angelakis and Zheng, 2015; Angelakis and Snyder, 2015; De Feo et al., 2014). For example, Fas and Qalat Bani Hammad took profit from the natural land slope for draining wastewaters *extra muros* and discharge into the river downstream, as noted above. Scientific excavations and conservation fieldwork showed that wastewaters were transferred *extra muros* via specific canals disposed above the supply canals, as in Algiers (Aroua, 2005; Aroua, 1998). However, whatever solid and liquid wastes were very likely to consist of organic biodegradable materials, but it can be

imagined that the sewage system would become progressively worse resulting from increasing domestic and manufacturing discharge into inner canals and direct transfer to nearby watercourses. On the other hand, local populations would have notably suffered drought and consecutive water scarcity. At that time, the drought would have generated the most disastrous damages impacting socioeconomic life by disrupting agricultural, trade and manufacturing activities (Al-Bayadh, 2008; Bouleqtib, 2001; Jawdat, 1992). Moreover, such extremes were often followed by famine and epidemics (Al-Bayadh, 2008; Jawdat, 1992). For example, the central Maghreb (Algeria) would have experienced long drought events at least four times between 867 and 1004 resulting in a great famine and epidemic diseases and even plague (Jawdat, 1992). Likewise, by 1004 and 1022, Qalat bani Hammad faced similar events as well as an important inflation process following an epidemic episode (Tawil, 2011). Fas would have suffered such events following attacks when *extra muros* canals were diverted or put out of service by enemies (Jawdat, 1992). In 997, an unusual storm event generated a flood event resulting in notable human and material damage (e.g., arches, bridges, houses, crops) (Jawdat, 1992). Some hydrometeorological hazards and associated water-related risks (e.g., waterborne diseases, water scarcity, flooding) would have been suffered locally, while others rather were experienced by a number of cities and villages over al-Maghreb and even al-Andalus (e.g., drought, epidemics) (Al-Bayadh, 2008; Bouleqtib, 2001).

Similar events naturally contributed to the demographic change either positively or negatively (resulting from either socioeconomic development or from deaths, migration, exodus) and subsequently called upon the regular adjustment of the urban design pattern. For example, Qayrawan should regularly reshape its road network following each flood event, while Fas and Qalat Bani Hammad had to adapt their urban layout and build dikes to facilitate draining runoff *extra muros* (Tawil, 2011; Al-Djaznai, 1923). Likewise, waterworks had to be enhanced or progressively enlarged along with the construction of new neighborhoods in the studied cities (Tawil, 2011, El-Faiz, 2005; Mahfoudh et al., 2004). This issue may be of good inspiration for contemporary urban risk management strategies based on a deeper analysis comparing natural disaster event history against urban history to better understand how the urban design pattern has been adapted to the local water geography and dynamics while meeting the population needs. For instance, the flooding risk threatening modern Fas would be due to the maladjustment of the sewage network capacity with the urban sprawl process (Zinoun, 2014).

CONCLUSION

Regarding case studies, the historical information collected in the framework of this study shows that the water context and the related governance strategy certainly influenced and supported their urban growth between the VIIth and XIth centuries. Like many medieval cities, Qayrawan, Fas and Qalat Bani Hammad have well adapted to the water context while meeting the socioeconomic development objectives. At least in technical words, water supply, sanitation and hydrometeorological hazards were efficiently addressed

according to that time's knowledge and skills. Rich regional water heritage has been well studied by a number of historians and partly archived by the International Council on Monuments and Sites (ICOMOS) in 2015. Insofar as empirical knowledge (as described by El-Faiz) has been locally developed and is well contextualized and action-oriented, it could well inspire Mediterranean cities in general and Maghreb cities in particular when dealing with water scarcity, contamination and extreme hydrometeorological hazards.

Likewise, social-cultural organizational measures based on autonomous legal and financial institutions are just what is highly needed and recommended to enhance local representatives' involvement, public-private partnerships and civil society participation. Over past governing and professional practices as much as community attitudes, water was considered not only a sacred resource but also a critical living system a kind of checkpoint federating urban and rural users while setting rights and duties to everyone. For instance, this integrated approach is in line with UN-Habitat urban-rural linkages principles and could well inspire local associations and governments in dealing with rapid urban sprawl and more particularly, non-sustainable urbanization (formal and informal) issues that critically threaten human and environmental integrity and challenge the urban governance process.

That multiobjective and cross-sectoral approach can enhance the critical role of cities in adapting to the current changing environmental context by considering water as an integral part of the natural ecosystem as well as a socioeconomic good having a strong specific ethical value, geography, dynamics and biodiversity. Indeed, by delineating a set of specific water space servitudes using the zoning process, past urban design praxis introduced the first water sensitive urban design and integrated water resources management principles simultaneously. So doing, it has contributed to preserving the resource quantitatively and qualitatively and mitigating associated hazards and risks. Moreover, the examination of the first urban history times has shown that modern strategic flood management principles were observed when selecting the city location and the urban sprawl direction.

With regard to their originality, the three studied cities certainly deserve to be included in the United Nations Educational, Scientific and Cultural Organization (UNESCO) world cultural heritage site. However, currently, Qayrawan and Fas are attractive touristic sites, while Qalat Bani Hammad is an uninhabited archaeological site. Namely, one is still alive when the other is desert. Seemingly, the urban growth process has been closely dependent on that time's socioeconomic conditions regardless of natural hazards but not of political conflicts and wars, which were much more disastrous, as highlighted in studies dedicated to natural disasters and epidemics in al-Maghreb starting from the XIth century. Past integrated water strategies seem to have been advantageous for the growth these cities without a decisive influence on their longevity. Ultimately, political causes have constituted radical changing factors with immediate effects while economic causes were long-standing with progressive effects. The question is to know whether that specific conclusion could be generalized to other contemporary cities and how much it remains valid today.

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