Are Garden Cities in the Desert Sustainable?
The Oasis City of Al Ain in the Emirate of Abu Dhabi

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Abstract: The United Arab Emirates (UAE) has embarked on an ambitious plan of nation-building transforming the landscape of the country. Whereas Abu Dhabi and Dubai with their modern architecture promote an international urban lifestyle, the third largest city in UAE, Al-Ain offers a relaxed, Oasis/villa experience a form of revival to Andrea Palladio’s mansions during the Renaissance era. Recent housing developments segregate around the city’s mountain, and consist of about 11,000 large Mediterranean-styled villas with extensive green landscaping and an artificial canal in the desert. Although these developments are not culturally foreign, since they emulate decisions of Islamic/Arab palatial complexes such as Alhambra in Spain the scarcity of water resources and the growing interest in Western/Renaissance-styled landscaping question the notion of sustainability of a city in a desert environment. We examine urban expansion of Al Ain city in light of the constraints imposed by scarce water resources. As a case study, we investigate the water requirements for the central oasis area in Al Ain and simulate the flow condition in the *falaj* complex channel system using the 2D-hydrodynamic Finite Element Surface Water Modelling System (FESWMS). Today reviving ideas such as integration of nature into cities, green infrastructure constitutes the fundamentals of sustainable urbanism. Developing awareness of the importance of traditional landscape and reviving the *falaj* irrigation system offers a hybridization between societal needs for upscale Mediterranean styled villas and retention of Emirati cultural values and traditions. Our study offers alternative landscapes to open lawns irrigated by sprinkler systems and recommendations in line with the Estidama guidelines—the UAE’s Sustainability Design and Construction regulations guidelines.

1. INTRODUCTION

The United Arab Emirates (UAE) is a relatively modern nation-state with an area of 83,600 km² at the tip of the Arabian Peninsula with a 2016 population of 9.4 million people, about one million of which are Emiratis, and the rest expats of various nationalities. The largest cities are concentrated along the coast with the light clustering in Figure 1 indicating the location and relative size of each city, as well as the highway network...
connecting them. The UAE’s oil reserves are the 7th largest in the world and its gas reserves are 17th worldwide. The majority of oil and gas (over 92%) are owned by the Emirate of Abu Dhabi, the largest (86.7% of UAE’s area) of the seven emirates that constitute the federal system of the country. Non-oil related activities contributed approximately 72.5% of the total GDP of Abu Dhabi in 2016, partly because of their 24.5% increase from 2013 to 2016, but also due to a 60% drop in the oil-generated GDP during the same period. In 2016, apart from oil and gas, key economic sectors constituted: construction with 12.6%; finance and insurance with 9.8%; manufacturing with 6.9%; transportation and storage with 5.5%; electricity and water supply with 4.5%; and real estate with a 6.1% contribution to the total GDP, respectively (SCAD: Statistics Center Abu Dhabi, 2017, pp. 18–21).

The Abu Dhabi Emirate had an average precipitation of 6cm in 2016, during the rainy season that occurs from the end of November until the middle of April, and temperatures that reached an absolute maximum of 50.70°C in July and an absolute minimum of 3.90°C in January, both occurring in Al Ain (SCAD: Statistics Center Abu Dhabi, 2017, p. 258). The precipitation on the Emirate over the last forty years lies on the average between 5cm and 10cm, based on rainfall records and correlation of the vegetation with precipitation patterns (Brown et al., 1989, Figure 2). The evaporation rate is between 2 to 3m/yr. This results in a consistent negative water budget and miniscule infiltration recharging the local aquifers in a country that has no surface water resources. As a measure of comparison the cities of Phoenix and Tucson in the Sonora desert of Arizona, USA had about 208mm and 295mm annual average precipitation, respectively, and a similar to the UAE evaporation rate of about 2.5m per year during the period of 1920-2005.

Figure 1. UAE’s artificial lighting simulation (Authors’ elaborations on Google Earth image).

The importance of the construction and real estate sectors in the economy indicate the magnitude of nation-and city-building taking place in the country. However, sustainable development requires better understanding of landscape choices and irrigation systems that are most suitable and more locally relevant and sustainable management. (Marry et
Especially that Abu Dhabi is located in a Desert region and tribal populations are becoming more and more urban, therefore as cities expand municipalities and urban planning counsels to optimize water resources develop strategies to achieve sustainable urban sprawl and landscape. The availability and consistency of freshwater resources had always been a critical factor for the selection of sites for human habitation in the desert (for example, the Anasazi sites in Arizona, USA). Gulf countries’ modern interpretation of this has been that proximity to the sea and availability of energy can provide enough desalinated water to sustain urban centers, and this was affirmed in the selection of a sustainable city in Jordan (Alkhalidi et al., 2018). Resilience related to water resources, in terms of adaptation to climatic changes that are anticipated to affect the UAE is of critical importance to UAE’s cities, and especially to those, as Al Ain, not located on the coast. Finally, comparisons with other desert cities in the world, specifically with Phoenix and Tucson in the desert Southwest of USA are expounded (Logan, 2006). Climate change issues and natural constraints, such as scarce water resources and poor soil to sustain agriculture, and grave challenges posed by the environment, such as the extensive presence of evaporites in the soil, the existence of sandstorms that degrade construction material, and extreme temperatures that require large energy inputs in order to sustain a controlled environment inside the buildings. Because the country had been the seabed of a shallow sea for millions of years where salts had been depositing, the subsequently uplifted land includes extensive layers of evaporites (salts) (Brown et al., 1989; Hellyer and Aspinall, 2005). Evaporites, with preeminent gypsum (CaSO4.2H2O) endanger the foundations of buildings (Müllauer et al., 2013; Murad et al., 2014) and these together with construction dewatering, and its concomitant salt water intrusion, are the main reasons that 82% of UAE’s groundwater is saline or brackish, making reliance on this water resource problematic.

The United Arab Emirates has developed its landscape in a desert region to have the largest number of fruit-bearing palm date trees in the Arab World, estimated at more than 16 million trees. Abu Dhabi’s hinterland city of Al Ain takes its name from the Arabic translation of the word spring or oasis because it includes vast freshwater reserves in its underground rock foundation. The Oasis in Al Ain has a falaj canalization system that distributes water through its networks via gravitational slope similar to Roman aqueducts, yet as more Mediterranean styled villas emerge with them evolved new kinds of landscape such as open lawns that are irrigated by sprinkler systems. This research article addresses the issue of the extensive construction taking place in Desert cities in the UAE and the role of water in this challenging environment, both as a necessary resource for human consumption, and also in landscaping. Our study concentrates on the new housing developments in the city of Al Ain, with large mansions and landscapes emerging that require large quantities of water not available on location.

2. LITERATURE REVIEW

The two major cities of the Emirate of Abu Dhabi, the cities of Al Ain and Abu Dhabi, manifest different planning modes of urban growth. The city of Abu Dhabi opted for vertical expansion and high-rise towers in its new urban islands and waterfront developments, while Al Ain has expanded
horizontally with low-rise buildings. These two opposing development schemes highlight the difference between an international/globalized urban lifestyle promoted by Abu Dhabi and a relaxed oasis/villa experience in Al Ain. Landscapes provide many different functions and services to society, landscape also has aesthetic values that can promote have ethical impacts in society as well as provisional values that support ecosystems (Marry et al., 2018). In order to understand the future of projects with water canals in Desert Cities, it is essential to examine the Al Ain Oasis and its irrigation system is known as falaj, that is similar to historic aqueducts and antecedents in the Islamic world such as Qasr Alhambra in Granada, Spain that also had a complex canalization system. In Al Ain, the opening of Jahili Park located in the downtown area next to Jahili Fort is indicative of the Emirate’s interest in the development of green infrastructures. The park, constructed next to one of the UAE’s historic landmarks, accentuates its visual identity and attraction to visitors through landscape. This open garden includes diverse type of trees, and water elements that cascade from geometric basins onto several levels.

The city of Al Ain takes its name from the oasis around which a tribe settled, transforming it into what is regarded as the “Garden City” of the UAE. Al Ain has a history of habitation of over 4,000 years, and it plays an important role in UAE’s modern history by being the birthplace of Sheikh Zayed Al Nahyan, the founder of the country. It is the location of several UNESCO World Heritage Sites, of UAE’s first national university, and it has the largest concentration of Emiratis from any other UAE city. The city was planned similar to Abu Dhabi on a grid street pattern, but with a restriction of G+4 (ground plus four floors) or maximum building height of 20 meters. A policy that promoted “greening the desert” resulted in massive afforestation, with the total area of forestry, agriculture and landscaping having reached over 5.35% of the total area of the Emirate of Abu Dhabi. Forests account for 70%, farms for 28%, and amenities for about 2% of the total greenery of the Emirate, respectively (Abu Dhabi Digital Government, 2018).

Water production in 2016 in the Emirate of Abu Dhabi from desalination plants on the Arabian Gulf was 887 Mm³, with another 342 Mm³ being imported from the Fujairah station that accesses the Gulf of Oman. Of the total 1,229 Mm³ of desalinated water, 90.8% or 1,116 Mm³ were consumed, with 297 Mm³ utilized in Al Ain, which means that the Fujairah station covered fully the needs for desalinated water of Al Ain (ADWEC 2015; SCAD 2017). Based on the 2016 population data that record 1.8 million people in Abu Dhabi and about 767,000 in entire Al Ain’s area, average desalinated-only water consumption in these two cities was approximately 270 gallons/capita/day. The official data for the whole Emirate quote a consumption of 231 gallons/capita/day or 874 lt/capita/day (SCAD 2017; pp. 114 and 296). In either case, this is an extremely high rate of consumption considering, not only the scarce water resources of the country, but that in comparison, Amsterdam, which tops the list of developed green cities, has a total water consumption of 146 lt/capita/day; New York City 262 lt/capita/day, the lowest in North America; and Yokohama 300 lt/capita/day, leading water conservation in Asia (Siemens AG 2012, p. 15). Even cities, such as Phoenix, Arizona, which have been criticized for their use of water to irrigate extensive lawns and golf courses in the desert, consume less at 108 gallons/capita/day (Santos F., June 16, 2013, NY Times http://www.nytimes.com/2013/06/17/us/an-arid-arizona-city-manages-its-thirst.html).
Al Ain is an important centre of agricultural production for the country with over 24,000 farms located around the city. It contains 12 million square meters of green space, an average of 32 m² per person, more than any other Arab city (Yagoub, 2014). According to the World Health Organization (WHO) healthy cities should contain a minimum of 9 m² of green space per person. Cities that rank high according to the Green City Index - an index that rates cities according to CO₂ emissions, energy use, buildings, land use, transportation, water and sanitation, waste management, air quality and environmental governance - have a much higher percentage of green space than that quoted by WHO. Green City Index (GCI) cities in Latin America were found to contain 255 m² of green space/person, in Africa 74 m²/person, and in Asia 39 m²/person, respectively (Siemens AG, 2102). The water budget in the Emirate of Abu Dhabi has little connection with the actual water resources of the country and water consumption patterns (Figure 6) do not correspond to an arid country’s need for parsimonious water management (McDonnell, 2014). The situation reminds of earlier stages in the water conservation history of the desert Southwest of USA, where for example in 1990, Phoenix had a water consumption of 250 gallons/capita/day and Tucson, Arizona stood at 111 gallons/capita/day. The city of Phoenix gets most of its water from external sources, the Colorado, Verde, and Salt Rivers, and in that respect Al Ain counts on seawater from the Gulf of Oman, with its access to the Indian Ocean, as its external source of water. The only other source of water for the Emirate is groundwater. The quality of groundwater in Al Ain is appropriate for agriculture and from a total water supply of 3,335 Mm³ in 2009 for the whole Emirate 29% was provided by desalination, 6% by recycling, and 65% by groundwater (EAD 2013). Groundwater was used exclusively for agriculture, forestry, and parks. The fact that many wells have become dry as a result of over-pumping (Brook et al. 2006) has led to restrictions in groundwater extraction in Al Ain. The city is topping the Emirate in recycled water use, having reached a 70% recycling rate, but, given the small contribution of recycled water in the total water budget and the high level of efficiency already achieved it does not appear that recycling can be an answer to the water and landscaping needs of Al Ain. Given the scarce water resources and that predicted precipitation variations from global climate change models for the UAE have ranged from -21.20% to +10.33% by the year 2050, significant water savings must be implemented (EAD 2009). These may include the use of non-conventional water sources, such as those in Egypt to pump water up from drainage ditches and direct it back to irrigation canals for reuse in agriculture, which increased agricultural water by 20% (Barnes, 2014).

3. METHODOLOGY

The introduction of new landscape areas in the city consumes water in a very different system than those in regional practices in desert environments, therefore the scope of this study is the traditional irrigational system known as the falaj in the Oasis in the center of Al Ain (Fig. 2). We study the water flow system in the falaj canalization system in the oasis by conducting a hydrologic study to quantify the amounts of water needed to irrigate these green areas and simulate the flow condition in the falaj complex channel system using the 2D-hydrodynamic Finite Element Surface Water Modelling System (FESWMS). The aim and scope of this research is
to highlight the *falaj* as cultural heritage and promote the plantation of fruit bearing trees in place of open lawns. We build our discussion through literature review that covers precedent studies such as Qasr Alhambra and its canal irrigation system, and highlights the importance of sustaining water resources in desert environments.

Al Ain’s complex *falaj* canalization system is supplied by groundwater via submersible pumps between rock formations in Buraimi region, a shared borderland region between the United Arab Emirates and Oman. The *Falaj Alaini* and *Falaj Daoudi* are the main water supply systems for the palm oasis located in the city centre of Al Ain, hence they represent a valuable reserve of water, and a resource of symbolic and cultural value for the community. The *falaj* canalization system distributes water through its networks via gravitational slope similar to Roman aqueducts, set amidst palm tree plantations. The traditional fruit bearing garden with canals and flowing water, has a prominent place in the Arab culture because of associations with paradisical metaphors and has been prominent in historical texts, miniature paintings, and mosaic panels. (Fig. 2)

The *falaj* canal system existing in Al Ain obtains its water from a relatively high precipitation in the mountainous area between UAE and Oman, with wells tapping groundwater found in fractured rock formations, but now it is supplemented by pumping wells and desalinated water transported from the Fujairah desalination plant. Due to the complex landscape geometry of the *falaj* irrigation system (canals), the 2D Finite Element Surface Water Modeling System (FESWMS) is used to investigate the flow pattern in the channels.

FESWMS solves the following equations simultaneously:

\[
\begin{align*}
\frac{\partial z_w}{\partial t} + \frac{\partial q_1}{\partial x} + \frac{\partial q_2}{\partial y} - q_w &= 0 \\
\frac{\partial q_1}{\partial t} + \frac{\partial}{\partial x} \left( q_1 \frac{d}{d} + \frac{1}{2} gd^2 \right) + \frac{\partial}{\partial y} \left( q_1 q_2 \right) + gd \frac{dz_w}{dx} + gn^2 q_1 \frac{d}{d} \frac{q_1^2 + q_2^2}{d+1} 
&+ \left( \frac{\partial z_w}{\partial x} \right)^2 + \left( \frac{\partial z_w}{\partial y} \right)^2 \\
-2 de_{uv} \frac{\partial^2 \Pi}{\partial x^2} - \varepsilon_{uv} \left( \frac{\partial \Pi}{\partial x} + \frac{\partial \Pi}{\partial y} \right) &= 0
\end{align*}
\]
\[
\begin{align*}
\frac{\partial q_x}{\partial t} + \frac{\partial}{\partial x} \left( q_x \frac{d}{d} + q_y \frac{d^2}{d^2} \right) + gd \frac{d^2}{d^2} + gn^2 \frac{q_x^2}{d} + q_y^2 \frac{d^2}{d^2} \sqrt{1 + \left( \frac{\partial q_x}{\partial x} \right)^2 + \left( \frac{\partial q_y}{\partial y} \right)^2} = 0
\end{align*}
\]

Eq. (1) is the continuity and Eqs. (2) and (3) are the momentum equations in \( x \) and \( y \) directions, respectively. In the equations, \( t \) is time (s), \( d \) is water depth (m), \( \rho \) is water density (kg/m\(^3\)), \( g \) is the acceleration due to gravity (m/s\(^2\)), \( n \) is Manning’s coefficient of roughness, \( z_w \) and \( z_b \) are water surface elevation and bed elevation above certain datum (m), \( q_1 \) and \( q_2 \) are the unit discharge fluxes (m\(^2\)/s) defined as \( u \) and \( v \), respectively, \( u \) and \( v \) (m/s) are the depth-averaged velocities of an element in the stream wise and transverse directions, respectively, \( q_m \) is the resultant inflow or outflow from that element (m/s), \( v_{xx} \) and \( v_{yy} \) are the normal components of the eddy viscosity (m\(^2\)/s) in the \( x \) and \( y \) directions, respectively, and \( v_{xy} \) and \( v_{yx} \) are the shear components of the eddy viscosity (m\(^2\)/s) applied to the \( x-y \) plane.

FESWMS inputs are the Manning’s coefficient of roughness \( n \), and the eddy viscosity \( \nu \). Model inputs must be assigned correctly to represent the physical processes occurring in the model reach and to produce accurate model predictions. Manning’s \( n \) is an empirical coefficient that accounts for the total flow resistance caused by flow interaction with the boundary (Hicks and Mason, 1991). FESWMS utilizes Manning’s \( n \) to account for momentum loss due to bed-shear, which may vary significantly in a stream reach in accordance with bed-bathymetry and roughness. The second input variable used by FESWMS is the eddy viscosity \( \nu \). Eddy viscosity accounts for flow resistance due to the internal shear stresses, or the Reynolds’ stresses of the fluid incorporating the added energy dissipation due to turbulence in the flow (Papanicolaou and Hilldale, 2002). Therefore, eddy viscosity is not a physical property of the fluid, but rather a turbulent characteristic of the flow. For isotropic flows in prismatic channels, a single eddy viscosity value is sufficient to describe the turbulence flow characteristics within the modeled reach. Although FESWMS possesses the capability of spatially distributing both Manning’s \( n \) and eddy viscosity in the computational mesh, it is common to use averaged values for Manning’s \( n \) and eddy viscosity. In prismatic channels under uniform flow conditions, an average eddy viscosity value can be assigned to the study reach as a function of depth and bed slope (Richards, 1990)

Fig. 3 shows the model simulation for velocity and the flow direction in the irrigation system of falaj in Al Ain.

The falaj water system in the Al Ain Oasis reflects an understanding of the importance of retaining gardens in the city while preserving water resources. The system consists of one main canal contributing to three other branches with 19 outlets that are controlled by sluice gates (Fig. 2). The canals were updated by concrete of rectangular cross-sectional area with a width of 1.0 m and height of 0.5 m. The channel flow patterns were investigated here through the use of the Depth-averaged Flow and Sediment Transport Model (FST2DH), a US Federal Highway Administration code that simulates water movement and sediment transport in rivers, estuaries, and coastal water bodies of low vertical velocities compared to those in the horizontal directions (Froehlich, 2002). Details of our simulations include a Manning’s roughness coefficient of 0.025 and an eddy viscosity of 0.05.
m²/s; flow rate at the inlet was set at 0.25 m³/s, flow depth at the outlets was 0.4 m, and the simulation was conducted under the extreme assumption that all gates remained open. The recommended range of water velocity in rigid boundary channels is 0.2-6 m/s so that sediment is not deposited; aquatic growth is inhibited; sulphide formation does not occur; and boundary erosion is avoided. Our simulations (Fig. 3) indicated that velocities are within the range of 0.1 to 0.5 m/s with higher values in the main canal and lower values in the branches, and clearly the assumption of all gates open affecting the velocity field at the later part of the branches.

Figure 3. Al-Ain Oasis and velocity field simulation of the falaj irrigation system.

4. URBAN SPRAWL AND CHALLENGING LANDSCAPES IN DESERT ENVIRONMENTS

The role of the oasis in the centre of Al Ain city has been and remains crucial in the development of the green infrastructure of the city as a whole and its conservation from unplanned urban sprawl. The other oases present in Al Ain urban area, such as Al-Jahili, Al-Qattara, Al-Mutaredh, Al-Jimi, Al-Muaiji, and Hili, followed a similar plan. In the case of Al-Qattara Oasis, traditional market and the Arts and Crafts centre manifest a consistent urban strategy that follows the Abu Dhabi 2030 Vision for the development of green infrastructure in the Emirate, and Al Ain in particular. Green infrastructure as an interconnected network of green spaces conserves the natural ecosystem, and transitions from socially segregated metropolis towards greener cities with more spaces for socialization (Benedict and McMahon, 2006; Mohamed and Paleologos, 2017). Therefore, policies, urban planning councils and the construction industry must take in consideration sustainable landscaping that would lead to urban resilience into account, to ensure that enhancements in resilience are optimized across whole cities especially in light of rapid urban sprawl. (Lee, 2017) Especially water canals with the multiple opportunities afforded for recreation have been found to develop a sense of permanency in desert communities by encouraging social interaction (Yabes et al., 1997).

Al Ain’s urban growth is warranted as part of the development of cities in the UAE, as Abu Dhabi’s Urban Planning Council (UPC) established in
2007, aiming to improve the quality of life in the city through urban gardens and contextualized green infrastructure. However, management of ground and surface water resources is crucial because historically many cities have been deserted as a result of dilapidation of water resources. The UPC Plans exhibit support for the cohesive development of the Oasis and its integration in the modern city, through increased pedestrian access, shaded walkways, and extensive public landscapes. Palm trees in oasis-like gardens, parks, and other green open spaces offer attractive settings for outdoor recreation. Urban gardens can increase the amount of urban greening, reduce urban heat island effects, improve the quality of outdoor and indoor air, beautify urban landscape, lower indoor temperatures, increase energy efficiency, protect building structures and reduce noise. (Hung and Peng, 2017) The experience of nature in the urban environment has been interconnected to public health, the reduction of heat island effects, the awareness for water savings solutions, and the creation of a sense of quality of life in a city (Chiesura, 2004; Wu, 2014). Mekala et al. (2015) in a study of a suburb of Melbourne, Australia concluded that the economic benefits, which included avoided health costs, increased property values, recreational benefits, and ecosystem services through the reduction of heat island effect and carbon sequestration, could offset annual maintenance costs of green urban spaces. The role of green lawns and parks in desert environments appears to draw mixed feelings depending on social class and country. These range from negative, for residents in drought-prone areas in Australia (Tapsuwan et al., 2018), to breaking along socio-economic lines in USA, with desert and oasis landscaping preferable to higher income homeowners (Larsen and Harlan, 2006). Public perception of extensive lawns and green spaces appears to be overwhelmingly positive across all socio-economic lines in the Emirate of Abu Dhabi, with only very recently desert landscaping entering private garden considerations.

Today urbanization in desert environments is faced with complex social and ecological challenges caused by population growth, urbanization and depleting water resources. In envisaging these challenges, cities are increasingly concerned with providing innovation-driven, more environmentally-responsive landscapes (Hung and Peng, 2017). Urban parks together with land albedo modifications, such as for example, with cool roofs and cool pavements, may reduce air temperature in neighbourhoods located inside green spaces (Lu et al., 2017). In that respect, the planned new urban green spaces in Al Ain could assist in temperature amelioration, especially from the high 40 degrees Celsius experienced in Summer, and would provide the benefits of a healthier lifestyle and a sense of identity for the community. Of course, the issue lies in the water needs to sustain such a green infrastructure, given the climatic conditions, the water resources of the country, and the competition for these limited water quantities by agriculture, industry, and human consumption (Yagoub, 2014).

The transformation of the urban landscape and the expansion of the green space in Al Ain can be seen by the two Landsat images of 1984 and 2017 (Fig. 4). In 1984 green areas concentrated around the large Oasis at the historic centre of the city that then had a population of about 70,000 people. By 2017 the population had increased by about tenfold (and expected to reach one million by 2030), with the expansion of the urban areas taking place southwest of the city centre. New housing developments in Al Ain concentrate on the southern part of the city around Jebel Hafeet Mountain and the Green Mubazzarah area (Fig. 4). Of those, the Sheibat Alwatah mixed-use project would consist of 1,580 one-to-three stories, five-bedroom
villas, serviced by schools, clinics, social clubs, and extensive infrastructure works that would include roads, power and telecommunication lines, sewage and rainwater systems, and landscaping. In addition, 600 (from a total of 1,022) villas were delivered in 2014, part of a master-planned community in a nearby location, which includes schools, mosques, and retail shops. The Jebel Hafeet project, which contains 3,000 villas and amenities, such as schools, health centers, and mosques, was due to be completed by the end of 2017. Furthermore, major residential and commercial projects are taking place in Ain Al Fayda (Al Qudra Holding, 2017). The area would host about 5,000 residential units set in a “lush vegetation and natural springs” environment with the Ain Al Fayda Lakes project, perhaps the most prominent of them, consisting of 24 deluxe Island Villas of 710 m² each, built on an artificial island with views of a constructed canal, and 165 Canal Villas of over 535 m² each, overlooking the canal (Thomson Reuters, 2015). The masterplan clearly evokes Frederick Law Olmsted’s concept in Central Park, New York, where a large lake, pedestrian path-making, and vegetation incorporates natural scenery in the urban fabric (Eisenman, 2013).

These housing projects consist of large-scale villas built in modern, Mediterranean, and in many cases even Palladian style with pitched roofs, terracotta tiles and tri-partite windows. New urban developments in Al Ain did not attempt to reconstruct the past of a traditional Arab medina with narrow shaded pathways, thick adobe walled courtyard houses, nor did they follow Abu Dhabi’s neo-modernist glass and steel high-rise towers. The Ain Al Fayda projects with the adaptation of modern or classical western motifs, in the place of an Arabian-style reconstruction, appear to fall within the ideological parameters of another luxury, gated communities, such as those in Singapore, where transnational elite inhabitants reproduce a global rather than a local or national lifestyle (Pow, 2011).

The urban heat island effect, an influence in most major cities around the world, is well documented as an urban phenomenon. With warranted urban sprawl and change in lifestyles, buildings and paved surfaces in urban areas encourage the absorption of solar energy into building structures, roads and other hard-surfaces. This can be reduced significantly by well-designed and strategic locations of landscaping around single-family houses could potentially reduce heat build-up. (Misni et al, 2013). Al Ain builds its urban plan on the idea of a Garden City, therefore in comparison with cities such as Dubai it has a reduced heat island effect, however, as it expands horizontally, water resources to supply extensive gardens and landscapes are challenged. (Parsons and Schuyler, 2002). Planners of Al Ain comprehended the effect of the metropolis in attracting people with job and leisure opportunities, and
they attempted to combine the services of a city with the advantages of a suburban lifestyle of communal interaction, and larger family-oriented living spaces. Al Ain’s urban sprawl is developing with the Garden City concept in mind, along with Green Fingers, planted in intercessional spaces that connect each other. (Duken, 2015).

New developments at the foot of Jebel Hafeet Mountain, such as Ain Al Fayda Lakes development, compose of large-scaled Greco-Roman mansions which can benefit from applications of urban landscapes that would reduce the heat island effect, although the new style of Al Fayda villas recalls the Mediterranean classic style of Andrea Palladio’s villas (Loth, 2008), such as Villa La Rotonda and Villa Poiana in Italy (Fig. 5). The Al Ain Palladian style villas aim to communicate identity and status in the same way that Palladio’s villas manifested the rise of the mercantile class in Europe during the Renaissance era. Palladio’s influence is also visible in the three-bay windows, arched loggia, and terracotta roofs overlooking a man-made water canal in a surrounding desert environment (Garcia-Salgado, 2008). This contradicts any notion of sustainable development, especially within the context of traditional UAE buildings, where privacy and walled gardens dominated (Drexhage and Murphy, 2010), and signifies the wish to showcase the wealth of Emirati families.

![Figure 5. Ain Al Fayda new villas versus Palladian style villa (sketch by authors).](image)

5. DISCUSSION

Traditional Arab/Islamic urban enclaves and cities have overtime responded to the harsh desert climatic conditions and scarce water resources by developing dense urban fabrics, with narrow shaded pedestrian pathways, and adobe courtyard houses with thick walls to protect its inhabitants from the heat. (Creswell, 1989) These urban settlements in challenging desert environments included small scale urban gardens and irrigation systems that optimized the use of water resources based on precedents and best practices which have always been an essential part of planning for better cities, and some, such as the Shalimar Gardens in Lahore designed in the 17th century, required extensive engineering works in order to create the cascading water elements in the composition (Ruggles, 2003). Similar ideas were exhibited at Generalife gardens in Granada, Spain (Fig. 6), where water in a network of canals, fountains, and pools was an essential element of the landscape and of the architectural elements around it. Here, water canals were integrated with Mediterranean styled buildings with pitched roofs and coved tiles, like in Al Fayda’s villas, a canalization system allowed water to be channeled through multiple divisions similar to the falaj system, then it cascaded to the
fruit bearing gardens (Rabbat, 1985; Chanson 2015). Today, reviving ideas such as integration of nature into cities and green infrastructure constitute the fundamentals of sustainable urbanism. Developing awareness of the importance of traditional landscape and reviving the *falaj* irrigation system offers a hybridization between societal needs for upscale Mediterranean styled villas and retention of Emirati cultural values and traditions. In that respect, the architectural choices for the housing projects in Ain Al Fayda, while at first glance appear foreign to the architectural traditions of the region, in real have historical precedents such as Qasr Alhambra in Spain, where hybridization in between architecture and landscape breached cultural boundaries between East and West in terms of building traditions, landscapes, and irrigation systems. Alhambra’s pavilions, fruit bearing *Bustan* gardens, and canal based irrigation system offers a worthy antecedent that can be used in Al Ain Al Fayda. A departure from the paramount criterion of proximity to water for human habitation in the desert appears to dominate current decisions, but as will be seen the concept of water availability has an interesting angle in the Gulf region. Other examples of landscape in challenging environments such as the city of Phoenix, manifests that modifications in irrigation practices and xeriscaping, though increasing slightly urban ambient temperatures, were found to assist the resilience of the city towards water stresses from droughts and population pressures (Yang and Wang, 2017). Placing water restrictions and strict pricing policies are some of the tools that have also been seen to affect individuals’ and communities’ water consumption habits and have started to be slowly implemented in the Emirate of Abu Dhabi recently (Lindsay and Supski, 2017; Soler-Garcia et al., 2018).

![Figure 6. Extensive use of sprinklers and open lawns (left) vs. Generalife gardens in Granada (right), the latter showing the canal/falaj irrigation system at the centre, and *bustan* landscapes at the sides. (photo and sketch by authors)](image)

### 6. CONCLUSION

The Abu Dhabi 2030 Vision highlights the importance of Sustainable Design and Green Infrastructure inside the UAE and internationally. The use of water elements in the urban fabric of the city is essential to create green infrastructure that reduces the heat island effect and creates a health city. Al Ain is known as the Garden city of the UAE, and its future development through a continuous network of green corridors that emanate from the Oasis to connect the major green areas of the city reinforces Abu Dhabi’s plans to create better living spaces for its communities. Moreover, Al Ain’s
future development plans manifest emerging interest in green infrastructure
and environmental planning. In terms of water use, reviving traditional
irrigation systems such as the falaj, and reducing the production of open
lawns as new forms of landscape may sustain Al Ain’s water resources and
develop it into a desert city similar to Tucson, Arizona, which does not
heavily rely on external water as Phoenix, and in order to address declining
groundwater levels it went from a high residential water use of 121
gallons/capita/day in 1996 to 80 in 2015, an almost 34% reduction in less
than twenty years (MAP, 2017). Tucson’s landscape contains hardly
anything else than desert plants, and the municipality promoted aggressive
water conservation campaigns with rebates for residents who harvest
rainwater, or use reclaimed bathroom water for landscaping (Nachshon et
al., 2016). Other desert cities, such as Scottsdale, Arizona, and Las Vegas,
Nevada, have offered monetary compensation to residents for every square
meter of grass removed and replaced by native plants. Some of these
practices are already contained in Estidama, the Emirate’s design and
construction regulations that are similar to LEED (Leadership in Energy and
Environmental Design), and need to be strengthened. The Pearl Rating
system of Estidama consists of seven categories, with detailed subcategories
and requirements, and optional credits. These seven categories are:
integrated development process; natural systems; liveable communities;
precious water; resourceful energy; stewarding materials; and innovative
practice. Regulatory improvements may include upgrading the credits
delivered by the category of Natural Systems (NS) that promotes native
plants, which appear to be low (ADUPC 2010a; ADUPC 2010b). Rainwater
harvesting, aggressive water awareness campaigns, and compensation
schemes for landscaping with selected plants appropriate for desert living,
are initiatives that can reduce the high use of water use in Al Ain, while
retaining a garden, native-plants, desert city environment.

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