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Research Article

Water harvesting in Archeological buildings in Jordan

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Abstract

This paper aims at investigating the major water harvesting schemes that were in the archeological buildings in Jordan, established by different ancient civilizations and the traditional techniques that were used by our grandparents in their traditional houses. Several examples were selected for the purpose of examination of how ancient people survived and flourished with lack of water resources, which can provide insight to measures that perhaps can be used today. This study should increase the attention to the importance of lessons learned from old civilizations including their solutions to water supply and management, and their water harvesting techniques, which provide us with valuable information that help to understand the parameters involved in water harvesting and how we can improve our recently implemented schemes, it's also can be adapted in current water management strategies in order to improve their efficiency, which making them a starting points for new solutions today.

Keywords: Water harvesting, Archeological buildings; Jordan; Ancient civilizations; traditional houses; water management

Introduction

Water harvesting (WH) defines as: "The collection and management of floodwater or rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance" [1]. Water harvesting systems are traditional technologies that have met the needs of local populations for many centuries indicating the systems are clearly sustainable. Several civilizations have started and flourished in a hard condition despite an arid to semi-arid climate, they were able to create a near-permanent water supply for themselves, in places where nature was not kind enough to place a river or a spring.

The practice of water harvesting has been around in Jordan for centuries, Jawa was a settlement in northern Jordan during the Bronze Age that built an extensive hydraulic system. At Um El Jimal, a city in northern.

Jordan during the Byzantine era, deflection dams, canals and reservoirs provided a local water supply. Neabateans excelled in water management using cut-stone reservoirs in their capital, Petra, their empire flourished more than 2500 years ago [2]. in what is now southern and central Jordan, and there is an abundance of historical structures that provide clear testimony to this practice, such historical examples as well as the underground cisterns found in the country's Umayyad desert palaces, Crusader castles, and traditional village houses. Examining the ancient water harvesting schemes (dams, barrages, channels, qanat systems), and the techniques used in the buildings, can improve our recently implemented schemes especially that ones in the buildings, it's also can be adapted in current water management strategies in order to improve their efficiency.

Water situation in Jordan

Jordan is ranked fourth in the world in water scarcity (Al-Weshah 2008). The Jordan's population reaches 10,188,250 in 2020 (worldometer,2020). The demand for water in this arid country is high and steadily growing with all sectors (Domestic, industrial and agricultural) competing for limited supplies of costly water. Water resources in Jordan depend mainly on rainfall precipitating during the winter season. More than 90% of the territory rainfall is flashy irregular and is below 200 mm per year [3]. Jordan depends on conventional (surface water, ground water) and non-conventional water resources (wastewater treatment, water harvesting and desalinated water) in an attempt to meet the increasing demands [4].

Study problem

Jordan suffers from water shortage, water becomes scarcer than ever before, and over the last decades the demand on water has increased due to population and economic growth. Water harvesting is one of the potential water resources in Jordan that can help to alleviate the water shortage problem, Jordan has had a long history of water harvesting and water control systems. Water resources were managed long ago, that can provide relevant information in facing the water-resources challenges of today in Jordan. It is believed that water harvesting techniques can solve part of the problem.

Literature Review

Rainwater harvesting in ancient civilizations in Jordan, A study led by [5], summarizes the types of (WH) systems that people have. Used in ancient civilization in Jordan. The study provides a valuable information about the ancient schemes, but our study is going deeply in the details of the used schemes in the archeological and traditional buildings.

Methods

The methodology of this study consists of a lot of case studies that were selected for the aim of examining the techniques used in historical structures that provide clear testimony to this practice, Such ancient schemes, archeological building examples as well as the traditional houses.

a) Jawa and Umm El-Jimal

Jawa and Umm El-Jimal water harvesting schemes were established 6000 and 2000 years ago [5] (Figure 1). They are considered as the most ancient water harvesting scheme. The engineering design and techniques used in those schemes are very unique.

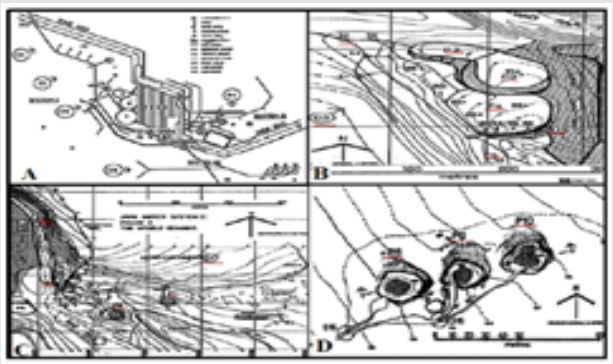

Figure 1: Jawa water harvesting scheme A: General overview of the system B, C: Storage scheme in system 1and 2 respectively D: Storage areas of system 3 (modified after Helms, 1981).

b) Petra The Nabataean civilization in south Jordan before more than 2,000 years-built dams to provide their capital city of Petra and other settlements with water for drinking and irrigation [5].

Jawa (Islamic house)

The various buildings at Jawa, some 60km south-east of Busra on the edge of the dry steppe, may have served such a 'badiya' function: the architecture is a mixture of urban (formal, even ceremonial) and vernacular (steppic: i.e. derived from the tent forms) [6], most of them especially the traditional houses depends mainly on reservoirs which located in the courtyard to collect rain water and use all over the year[7], building 600 is a good example (Figure 2).

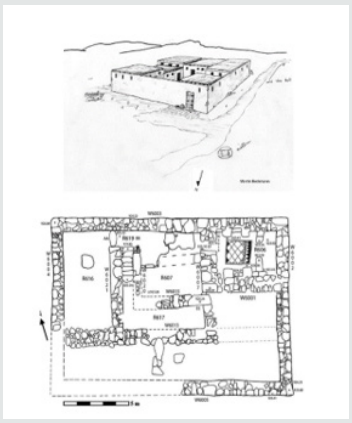

Figure 2: a) Building 600 at Tall Jawa; possible reconstruction, b) Building plan of lower storey.

source: Daviau, P. M.Michèle, and Martin Beckmann. Excavations at Tall Jawa, Jordan. Brill, 2010.

The cistern of the building

A bell-shaped cistern (Figure 3), covered by large boulders at ground level,67 was located outside the northwest corner of Building 600, the cistern has a depth of ca. 5.00 m12, The preserved edge of a plaster coating (0.02–0.03 m thick) [4].

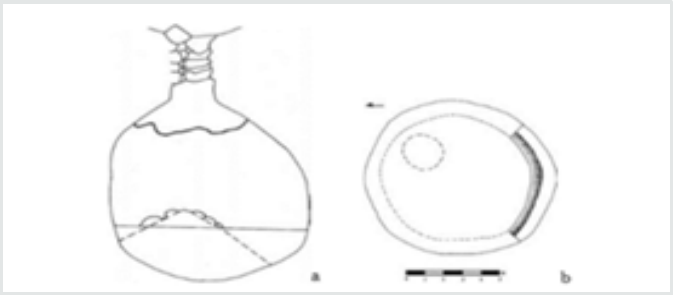

Figure 3: a) Section, b) Plan of Cistern

Source: Daviau, P. M.Michèle, and Martin Beckmann. Excavations at Tall Jawa, Jordan. Brill, 2010.

Traditional houses in Umm El-Jimal

The residents in Umm el-Jimal quarried the basalt rock they used to build their houses, the quarries were sealed and used as reservoirs for collecting water in their houses [8]. House XVII-XVIII is a classic example of Umm el-Jimal's unique regional architecture (Figure 4), a large domestic complex for a relatively wealthy ancient

family, this house was a two/three-story structure centered on two large courtyards with a private reservoir under the eastern wall [9].

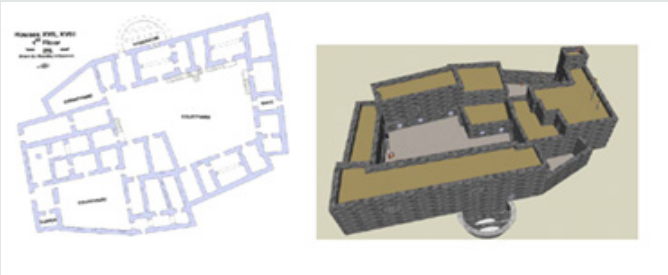

Figure 4: a) 1st Floor plan of house XVII, b) Schematic 3-D rendering of House XVII–XVIII Complex

Source: (drawing by Muwafaq Al Bataineh,2017)

Great Temple Complex at Petra

Pipelines reservoirs and cistern are hydraulic structures belonging to the archaeological complexes in Petra the Great Temple Garden and Pool Complex (Figures 5 & 6) [10].

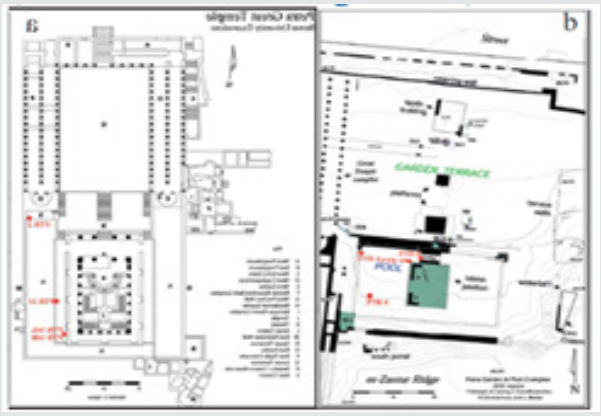

Figure 5: a) the plan of Petra Great Temple site (L great cistern), b) the plan of Petra Garden and Pool Complex.

Source: [10].

Figure 6: Cistern-Reservoir to south in petra great timple.

Source: The Brown University 2005 Petra Great Temple Excavations.

Water harvesting system in Archeological buildings

a) Ummayyad desert castles

Jordan has the largest concentration of Umayyad complexes usually referred to as "desert palaces" or "desert castles" [11].

Umayyad desert castles mark a period of flourishing Arab civilization. They were built mostly by the Ummayads (AD 661–750), Muslim Arabs who succeeded in transforming the fringes of the deserts into habitable settlements with their water management systems. Desert castles are found mainly to the east and south of Amman [5], Examples of those desert castles are:

b) Qasr Al kharaneh

Qasr Al kharaneh which is situated about 65 km east of Amman. It consists of 61

rooms arranged into two levels surrounded by a central courtyard [11], (Figure 7). This desert castle has a small water tank standing in the middle of the courtyard to collect rainwater from roof tops. Additional water was obtained from seep-holes dug in the adjacent wadi bed.

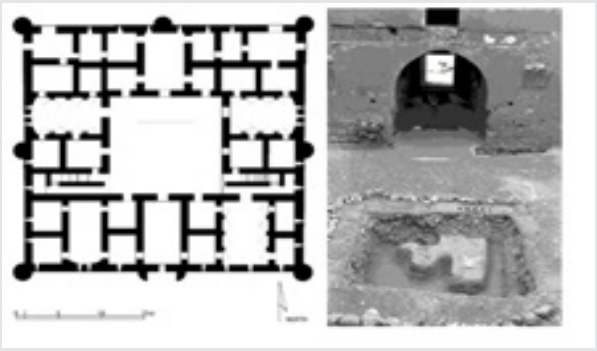

Figure 7: floor plan of Kharanah on the left, the right picture is a view of the courtyard from the north with the cistern and drain in the entry passage.

Source: Fine Arts Library, Harvard College Library.

c) The Umayyad Palace Complex in Amman Citadel

Positioned at the northern section of the upper level of the Jabal al-Qal'a in Amman. The Complex included a mosque, an Entrance Hall, residential and administrative buildings and a water cistern. (Zayadine, et al., 2000).

The Audience Hall of the Palace

The citadel of Amman never had a natural spring and depended on the careful collection and storage of rainwater, not a drop was wasted, and sophisticated underground stone channels for recycling water characteristics the site [12]. The excavated water channels and cisterns have often been built and reused by different civilization through the centuries. Seventh-eighth centuries A.D. (After Harding, 1951). Water harvesting in the Audience Hall of the Palace:

Water collected from roof down pipes at the Amman Citadel,

then directed through channels towards water storage areas (cistern), (Figure 8).

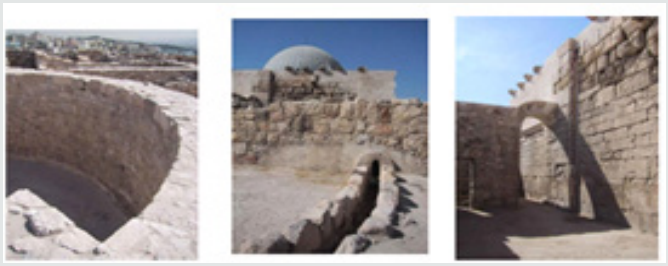

Figure 8: water harvesting in the audience hall, a) Down pipe collecting rainwater from roof, b) canals directed water to the cistern, c) View of cistern that functions as main water storage area.

Source: https://www.csbe.org/water-harvesting-i / (image credit: Dalia al-Husseini)

a) Qusayr 'Amra

Is 80 km. east of Amman and 16 km. The palace is small in scale, consist of two main components: an audience hall and a bath Near the palace there is artificial water well that serve the function of this Umayyad path (De Palma, et al. ,2013). A hydraulic complex with a water wheel worked by animal power, a 40 m. deep stone circular well and a cistern provide ample water [13]. (Figure 9).

Figure 9: Qusayr 'Amra plan, (Creswell, 1989), b) Waterwheel, Qusayr Amra.

Water system

A tunnel-vaulted passage to the east side of the third room leads to the stoke-hole and furnace, which once had a water tank above it to supply the third room with water. A well and a water tank are located by the main entrance. The well has a system for drawing water. Two pipes lead from the elevated tank to the shallow fountain in the audience hall and the tank above the furnace passage [13].

a) Qasr al-Tubah

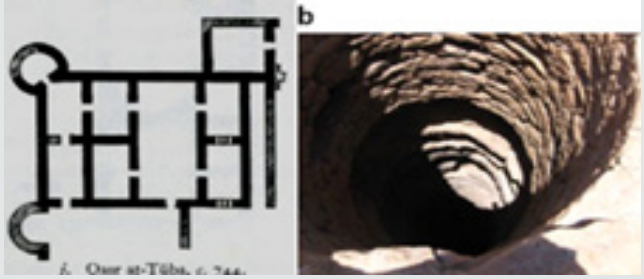

Figure 10: a) Qasr Tubah, b) Well at qasr Tubah

Source: [13].

Tuba is located about 140 km southeast of Amman, the palace have an ancient water supply -three massive wells built of stone (Figure 10), with adjacent plastered pools and round structures designed for use by the animals that powered the water-lifting devices [13].

b) Al-Hallabat Archaeological Site- Qaser Al-Hallabat

The complex of the Qasr is located 60 km northeast of Amman (Arce 2007: 325), Al-Hallabat was built on a gently sloping ground, dissected by shallow rainwater gullies which drain the land to the south. The site lies on the top of a mound situated in a semi-arid zone with annual precipitation rate of less than 100 mm (Bisheh 1985:265).The complex occupies an area of 50 acres which comprises a group of discrete, widely separated units. These include a castle, a mosque, a huge reservoir, eight cisterns dug into the western slopes of the Qasr, in addition to a cluster of houses which extend to the northwest of the reservoir [14]. with an area of numerous springs and water sources, with the Qasr located on the top of the mound, dominating the site (Ghrayib, 2003). In addition to a complex water system with channels, cisterns and a big reservoir cut in the bedrock down in the valley (Arce, 2007). There is a huge reservoir (Figure 11a), and numerous cisterns in the wadi to the north and west and the channels system were probably connected in order to store the water and distribute it to the Qasr, to the houses, and to the agricultural land (Bisheh, 1989). Qaser Al-Hallabat have two courtyard each one has a cistern (Figure 11(b),12).

Figure11: a) The reservoir in Al-Hallabat archaeological site, b) Plan of the Qasr at al- Hallabat.

Source: (Arce, 2007).

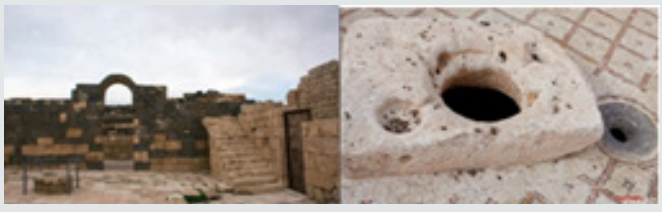

Figure 12: Waterworks at Qaser Al-Hallabat courtyards.

source: https://henkbos.com/p715654472

c) Qasr Burqu

QASR BURQU' some 200km east of Amman, it lies in the dry steppe (areas receiving less than 100mm of rainfall per annum) of

the badiyat al-Sam (literally, the steppe lands of Damascus). Qasr Burqu and the modem reservoir which is used to harvest water (Figures 12 & 13), stand at the crossroads of several ancient routes and guards one of the main water sources of the region, a large seasonal rain pool augmented by a dam constructed for the use of occupants of the Qasr The pool has the potential to fill quickly when the Wadi is in flood. Burqu has long been a key water source in the eastern badiya [14]. The qaser have a private pool to collect the water (Figure 14).

Figure 13: Qasr Burquc and the modem reservoir (after S. W. Helms, AntJ 71,1991)[14].

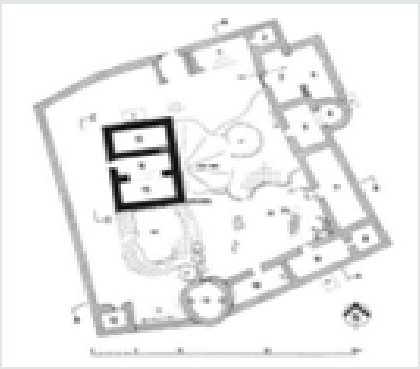

Figure 14: General plan of Qasr Burquc (after S. W. Helms, AntJ7\, 1991)

Source: thesacredcity.ca/burqu.html

Traditional village house

In some arid regions, rainfall harvesting was the sole sources of potable water. Until the development of well drilling and piping, which is started in 1940, people living in Jordan were totally dependent on rainfall harvesting for domestic uses [15]. In Jordanian traditional houses water harvesting were done by cisterns which located in the middle of the courtyard , the cistern was a big pit digged in the land with a cylinder or pear shape , the walls and floor polished in order to make them smoosh and clean , and to have a walls prevent water permeability , the process of plastering the walls of the cistern through using a mixer of mud and goats hair were added , the walls massaged after that by oil in order to reducing water permeability, water provided through collected rainwater in winter, then the water is used throughout the year, the family daily needs of clean water were filled (Al-jarad.2007.p.7) (Figure 15).

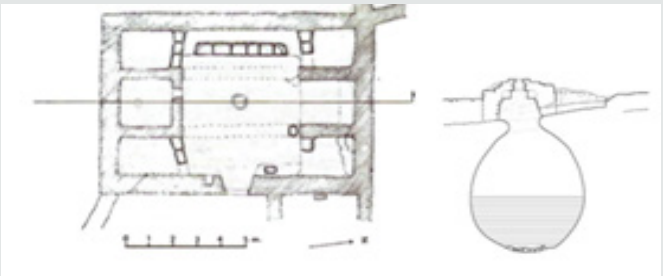

Figure 15: a) The house of khalaf khalil Al-Halsheh-Ajloun, b) The cistern

Source: notes on village Architecture in Jordan – Ammaar Khammash 1995.

Water harvesting in Jordan at the present time

Potential rainwater harvesting in Jordan- Residence

The total renewable freshwater resources of the country amount to an average of 750×106 m3/y. Current water availability in Jordan amounts to about 170 m3 per capita per year, but it is predicted to be lower than 91 m3 per capita per year by the year 2025 (Ministry of Water and Irrigation, Amman, Jordan, 2005).The increasing need for potable water due to urbanization and population increase demands development another water resources for domestic uses. According to that, the last researches gave attention to the importance of implementing Roof top rainwater harvesting (RWH) technique in Jordanian residences as a viable alternative for ensuring a continued source of potable /non-potable water [16]. A similar method of rooftop open yard rainfall harvesting water that gained interest in arid countries like Jordan since the past, as "The Audience Hall" in Amman citadel, and several of traditional houses. The concept of RWH has been proven a promising potential alternative water source for domestic use in areas with scarce and/or contaminated water (Islam et al., 2010). It has also been shown that a significant percentage of the non-potable water needs of multifamily residential buildings, such as flushing toilets, irrigating gardens, and topping off air-conditioner, can be supplied with rooftop harvested runoff (Basinger et al., 2010).

Recent studies about RWH in Jordan- residance

A recent study by [17], indicates that a potential of annual 15.5 million m3 rainwater (representing about 5.6% of the total household water supply of the year 2005 from groundwater) can be harvested from the roofs of the residential buildings [17]. A study by [18], indicates that Rooftop rainfall volume in Jordan can increase domestic water supply by about 14.7 MCM/year comprising 6% of the annual domestic national water supply.

Analysis of number of cisterns, rainfall depth and public water supply among governorates have shown that people have developed an adaptation behavior and self-reliance to water supply as the public water .

Results & Recommendations

a) Water harvesting is one of the most effective methods to contribute in lowering the water shortage in Jordan.

b) Lessons learned from old civilizations surviving and flourishing in arid zones

including their solutions to water supply,can be starting points for new solutions today.

c) The old techniques used can be adapted in current water management strategies in order to improve their efficiency. They use water that otherwise would evaporate, or perhaps use to recharge the ground-water system.

d) People have to think how to combine modern supply systems with old harvesting methods, like thinking about suitable and healthy material that used in the pipes which transform water from the roof tops to the ground cistern, and it must be a low absorption material like the plastic lava tubes that had been used in Umm el-Jimal.

e) Harvesting rainwater also can reduce citizens dependence on municipal water supplies and therefore result in considerable savings in their water bills.

f) The greater attraction of a rainwater harvesting system is the low cost, accessibility and easy maintenance at the household level, that was improved by using it form the past especially in the traditional village houses, by the cisterns in the courtyard.

g) Responding to chronic water crises, the government of Jordan should adopt an intensive awareness, financial, and technical programs to spread the use of rooftop rainfall harvesting in the country.

h) Harvesting water contributes to controlling off-site flooding and erosion by holding rainwater on the site, and also to reducing the load on the municipal storm water lines.

i) RWH is helpful technique to be applied in houses for the domestic uses, it's provided a source of water that is ideal for plants since it is clean, salt-free, and has a hardness of zero.

j) Rooftop and catchment area must be cleaned before the rainfall season in order to have a better quality of harvested water, adding some disinfecting agents such as chlorine might help in reducing the risk of biological contamination.

k) promotion of water harvesting should be acknowledged by governmental institutions and become an integral part of water development policies. Therefore, government support is essential in encouraging the public to install rainwater-harvesting systems. Grants would be necessary to encourage people to harvest rainwater.

Discussion

Water harvesting have a special importance to Jordan since the past decades, because of the lack of water resources, for centuries people have relied on rainwater collected from surfaces and stored in cisterns to supply water before water supply systems were developed. people living in Jordan were totally dependent on rainfall harvesting for domestic uses [15]. Building dams to tap runoff, channeling it through canals and storing it in reservoirs, was practiced by ancient Jordanians about 5,000 years ago, to provide drinking water to the old city of Jawa, northeast of Jordan using deflection dams [5] and Umm el-Jimal city in the Early Roman period (de Vries, 1997). Roof top rainwater harvesting (RWH) technique is similar method of rooftop open yard rainfall harvesting water that gained interest in arid countries like Jordan since the past, as several of traditional houses, RHW as a viable alternative for ensuring a continued source of potable /non-potable water. A rainwater harvesting systems can be constructed from inexpensive local materials and is likely to be successful in most housing sites [20,21]. The technique that collected water from rooftops can provide an important contribution to the provision of potable water and can be also considered an effective way to solve the problem of water shortage to some extent if implemented and managed appropriately.

Conclusion

The increasing water demands and the shortage of current water supplies to meet those demands made looking into how water resources were managed in the past inspiring in facing the challenges of managing today's water resources. The technique used in the ancient water harvesting techniques in Jordan provide us with valuable information, which will help us to understand the parameters involved in water harvesting and how we can improve our recently implemented schemes. A number of ancient examples of effective water harvesting systems have survived in the country and are examples of the successful efforts that peoples have made to live and survive in this part of the world.

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