

Drought-proof communities: Learning from vernacular architecture and adopting contemporary solutions to tackle desertification

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ABSTRACT: Desertification is among the most pressing risks of climate change and environmental crisis. Longer and more frequent water-stress periods have been experienced not only in Sub-Saharan countries but also in southern Europe. This is increasingly affecting the way people live, including their health and the balance between natural and built environments. Water management and hygrothermal strategies from the vernacular architecture of arid areas can provide vital lessons to those territories that are starting now to face droughts as a climate-related damage. At the same time, smart strategies and new technologies can be effectively combined in contemporary architecture to face it. The study proposes an investigation in both vernacular strategies and new solutions to cope with water-stress in the built environment, assuming the cactus plant and its capacity to capture and store water as a reference concept. The methodology includes a deep investigation of vernacular and contemporary solutions from arid climates, to be applied in areas that will increasingly be affected by the issue; then, on this basis, the definition of guidelines and an adaptable preparedness plan for these communities, and a third piloting phase for a selected community in Italy. The first stage of the research is presented in the text. It derives that reflecting on vernacular water storage and sedimentation methods, applying and innovatively improving these methods to meet contemporary livelihood, health, and water quality standards could highly contribute to solving water scarcity problems and preparing these communities for expected drought periods.

Keywords: Vernacular Architecture, Water Stress, Water Management, Innovation, Preparedness

1 INTRODUCTION

Climate change is increasingly affecting rainwater and freshwater availability, not only in sub-Saharan countries, but also in northern ones, and areas subjected to water stress and desertification are expanding (Mirzabaev et al., 2019; UNEP, 2020).

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South-European countries, among which Italy, are progressively experiencing long periods of drought that impact agriculture, but also livability in the built environment (CMCC, 2021). The G20 Climate Risk Atlas estimates that with an expected 1.5°C average increase in temperature at 2050, Europe will experience +30% both in drought time and frequency, and +63% heatwave duration with a +19% frequency. Several effects have been also experienced by Europeans, such as severe restrictions on irrigation and water consumption, or, on the other hand, dramatic flooding, due to the large amount of impervious surfaces in cities and short duration of extreme rainfall events.

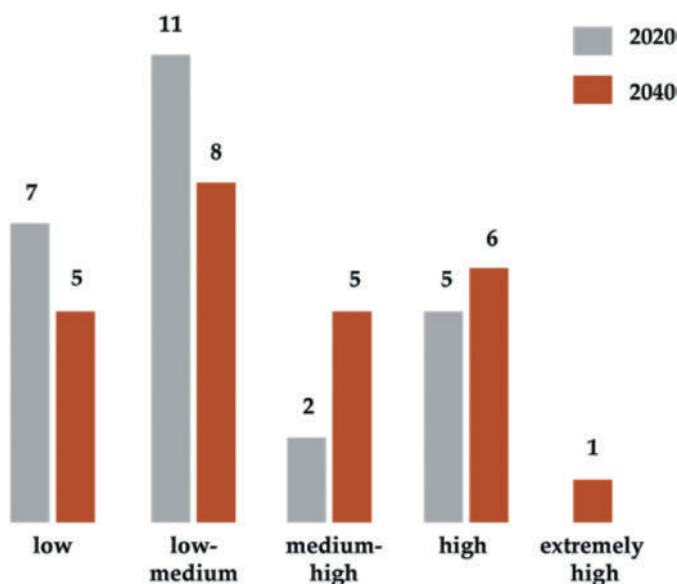


Figure 1. Water stress per number of European countries (Source: elaborated by L.M. based on CMCC 2021).

Thus desertification represents a climate risk that will become harsher and wider. Since in many parts of Europe the trend towards drought can still be slowed down, within the context of the After the Damages Academy, a heterogeneous group of researchers and students decided to reflect on drought as a present and future form of “damage” for the built environment and its inhabitants. Even if it deals with prevention rather than on backup solutions in emergency situations, coping with water stress and related side-effects will increasingly require all to be prepared, and strive to lessen the impact.

Several strategies can in fact be applied to limit water stress in urban environments, acting on some of the most recurrent causes: from reducing urban heat island and micro temperature, to reducing energy demand at building scale; from reducing wastewater sources to mitigating soil deterioration and soil erosion. At building level as well, by implementing passive cooling solutions, or rainwater harvesting and reuse, biomimicry solutions such as fog harvesting, or use of native plants and xeriscape for gardening.

Despite several technical solutions available nowadays, a general knowledge and coherent strategy to implement them effectively in existing buildings is lacking.

2 THE IDEA OF CACTUS COMMUNITIES

Interesting hints on how to tackle this challenge can be taken from cactus and its multifaceted capacity to manage water stress, as it is capable of storing water in its stems and enlarged roots that contain collapsible water storage cells, where water is collected through the roots,

stems and spines. This suggestion gave the group of researchers the start for reflecting on drought-proof communities in Europe and beyond, by investigating water-related strategies applicable at several scales: from water-management tactics at district level to innovative materials for building constructions.

The idea is that vernacular architecture (and related water collection and efficient-usage methods) in arid regions can provide vital lessons to those territories that are just beginning to experience this, as well as combining traditional strategies smartly and effectively with modern ones.

So the proposed methodology is broken down into three main stages:

1. Analysis, by documenting and studying possible strategies to cope with lack of water in the built environment. This includes: i) vernacular architecture in dry climates, based on a selection of relevant case studies, and ii) contemporary strategies.
2. Selection of design strategies and tactics, and thus definition of guidelines and an adaptable preparedness plan for communities, in terms of desertification and related effects on the built environment.
3. Dissemination and awareness raising, consisting in the selection of a pilot community in Italy, where to communicate selected strategies to policymakers, urban planners, designers, and inhabitants.

Accordingly the research expected outputs are:

1. Guidelines for cactus communities, to implement in the short, and medium-long term, strategies and tactics to transform the built environment into drought-proof communities.
2. A pilot preparedness plan, designed and implemented through a participatory process into a specific Italian community selected as pilot case. This in turn can feed improvements to guidelines, based on an iterative design process.

Results from the first stage of the research are presented and discussed in the following sections.

3 THE FORGOTTEN LESSON FROM VERNACULAR ARCHITECTURE AND INSIGHTS FROM NEW TECHNOLOGIES

The first stage of the study focuses on analyzing vernacular architecture and new technologies for extracting passive, low energy, and re-adjustable strategies implementable nowadays in cities that face increasing droughts.

3.1 *Vernacular water management methods*

In arid climates, people used the site topography, natural materials, and their observations of natural phenomena, to channel springs and rivers water or harvest rainwater in wet seasons and store water for further use in the dry season. From surface open-air reservoirs supplied by dug channels, and underground cisterns, to multi-functional water cisterns.

Surface Reservoirs

Excavating open-air reservoirs for rainwater harvesting and storage was a common method in many civilizations; they were located in the path of flood channels to harvest rainwater in the rainy season for later redistribution via small water channels for irrigation and domestic use. In pre-Arabian Yemen, in the 7th century BC, open-air reservoirs were a part of an irrigation and water supply hydraulic system, e.g. Wadi Surjan (Kirchner, 2003).

In Petra, between the 4th and 2nd BC, the “open-air reservoir/ pipeline” hydraulic system was more developed, as additional sedimentation tanks were integrated into the system to reduce sediments and provide high-quality potable water for the community (Ortloff CR., 2020).

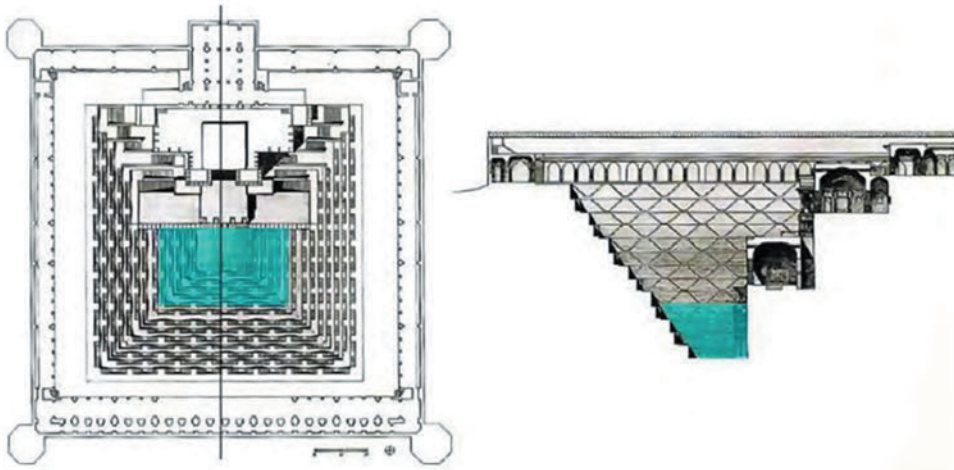
In India, stepwells were used to provide people with water for drinking, irrigation, and domestic use in the dry season. They had the negative form of an up-side-down pyramid and, according to their location, they can be social gathering spaces, if it is located on a trade route, rest spots for travelers and caravansaries (Dhiman and Gupta, 2011).



Figures 2-3. Up: Urban open-air reservoir in Tulu Acropolis, Yemen (Source: <http://www.ericlafforgue.com/>) Down: Open-air reservoir in Petra (Source: <http://www.pangea-project.org/>).



Figure 4. Chand Baori, Bandikui, Rajasthan. (Source: wikipedia).

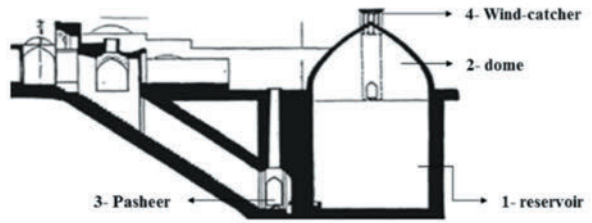


Figures 5-6. Illustration: plan and section of the Baoli. (Source: www.rebloggy.com).

Covered And Underground Cisterns

The Iranian vented cistern i.e. *Ab Anbar* is distinguished by its ventilation system and water distribution taps. *Ab Anbar* components are a water storage tank, dome, *Badgir* i.e. wind-catcher tower, staircase, and entrance, to provide fresh cool air to the underground water tank void to reduce contamination possibilities, avert stagnant water, and keep it fresh for drinking (Yousefi & Nocera, 2021) and *Pasheer* i.e water taps.

Italy as well has a vibrant history of water management. Romans were able to make complex systems of cisterns, aqueducts, water pipes, and wells. One of the giant Roman cisterns is *Piscina Mirabilis*, in Naples, with its capacity of 12600 cubic meters of water, or *Cisterna delle Sette Sale*, in Rome, with its 2600 square meters large space, which served the baths of Trajan.



Figures 7-8. Left: Main parts of Ab Anbar (Source: Fazeleh Yousefi et al., 2016) Right: Ab Anbar stairway and windcatcher in Yazd (Source: Alfaee, 2009).

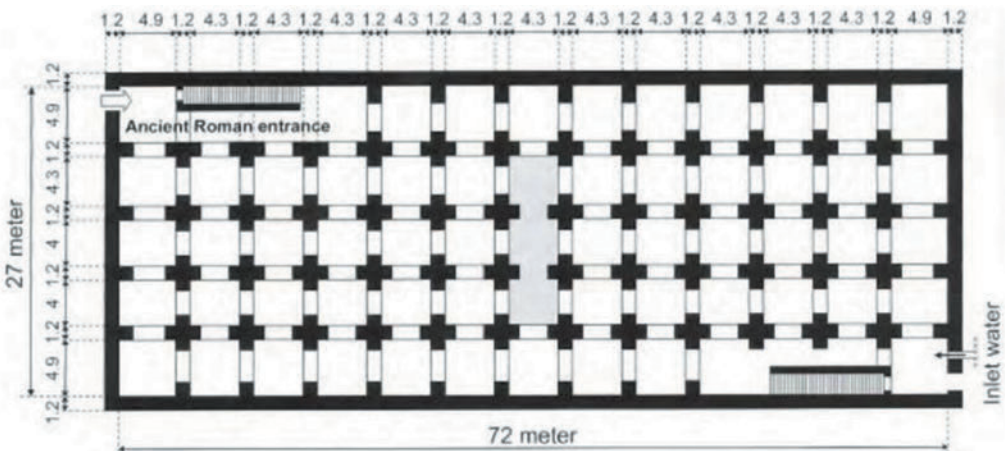


Figure 9. The Piscina Mirabilis Cistern's plan (Mays et al. 2013).

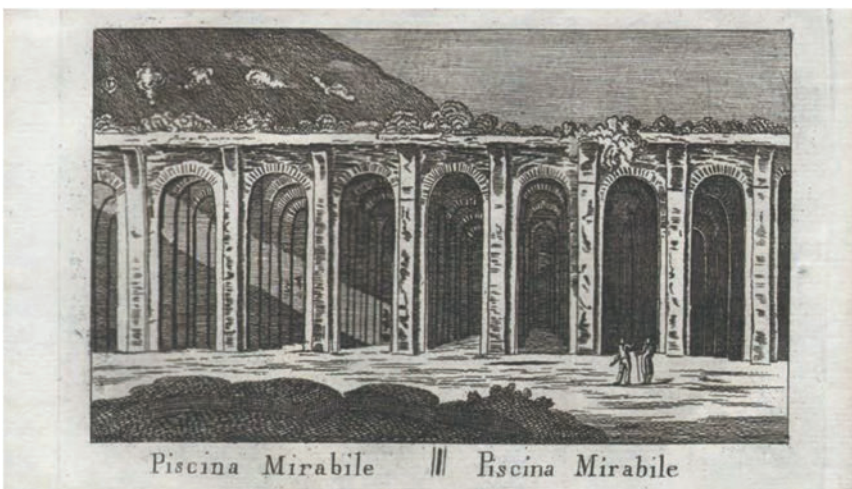


Figure 10. The Piscina Mirabilis Cistern's interior. (Mays et al. 2013).

Beyond public cisterns, Italy has a long history of water supply systems integrated with rural architecture (Pagano & Daniel, 1936). For example, in the spontaneous houses of Amalfi roofs were built with cross vaults made of stone ashlar that allowed rainwater to run off into the corner channels in order to accumulate it in tanks integrated into the architecture of the houses and placed below the floors.

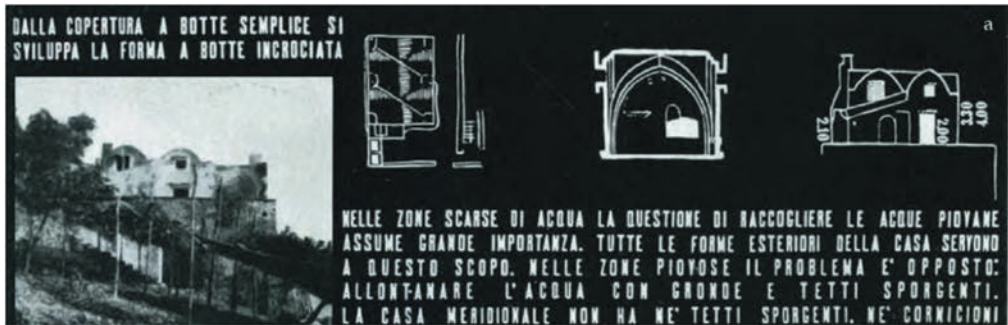
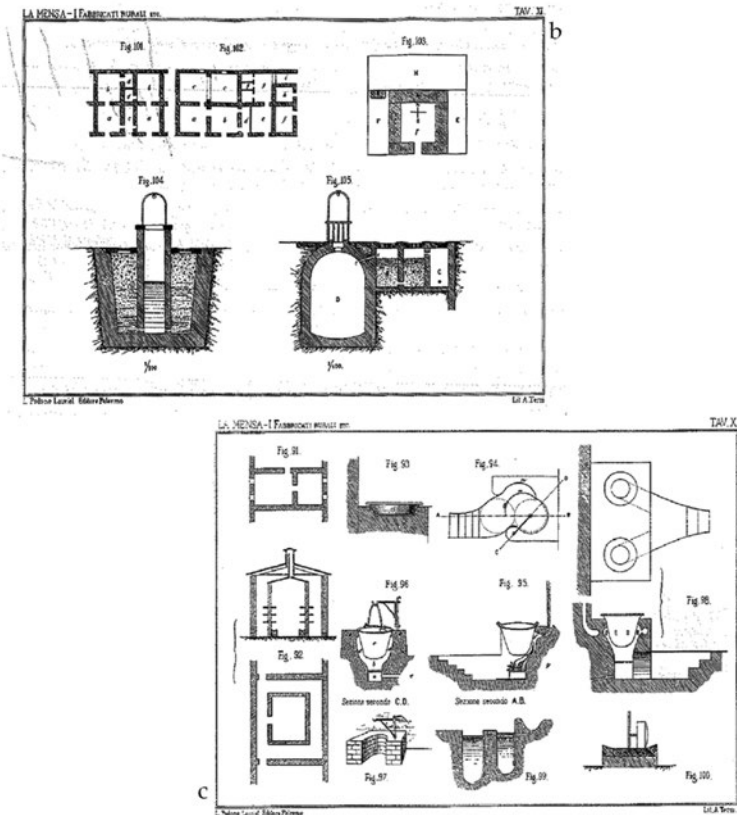


Figure 11. Survey of a vernacular building in Amalfi, in which the stone cross-vaulted roof serves to collect rainwater (Source: Pagano & Guarniero 1936).

As well as the masserias in Sicily were frequently equipped with ingenious systems for the extraction and subsequent treatment of groundwater. These activities exploit the laws of physics, i.e. through the use of communicating vessel systems or settling tanks (La Mensa, 1880).



Figures 12-13. Systems for extracting water and decanting or heating for agriculture or food preparation (Source: La Mensa, 1880).

Similar strategies were implemented in Alexandria, in Egypt. Underground the city was hollow, where cisterns were located under houses and buildings, and water supply aqueducts and sewage systems were located under streets. Cisterns of Alexandria were developed over the ages, from a “bottle” shape cistern that was dug into the rock to well-constructed cisterns made of bricks covered with plaster and ceramic fragments to be water-resistant, accounting for 144 cisterns with a total capacity of 131050-165000 cubic meters (Spanoudi et al., 2021).

Complex Cisterns. More than store and supply functions.

Venice, like Alexandria, was located in a saltwater region where freshwater was not available. One of the interesting methods used here is the Venetian-style well, which was a system of rainwater harvesting, filtering, and storing. The well was positioned in the middle of a private courtyard or a public local piazza, the only visible part being the marble or brick well-head. The cistern was filled with sand to filter water imitating the natural water table (Mays et al., 2013; Gentilcore, D., 2021).

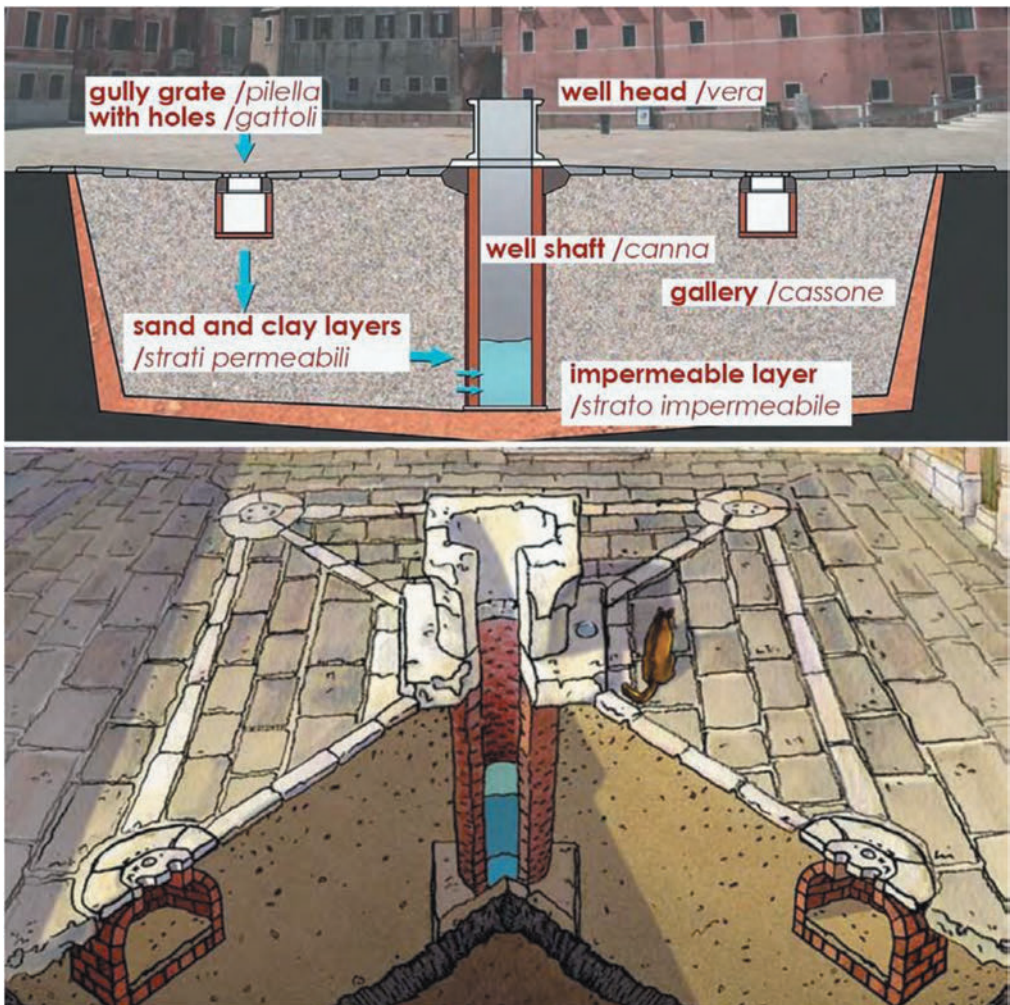


Figure 14. How wells were built in Venice (Source: Francesco Paolo Colucci - Vere da pozzo: silent witnesses of the history of Venice).

Similarly *Sabil*, a water dispensary in Cairo, Egypt, was a multi-functional public water facility, to provide water to inhabitants and animals passing by streets, besides education to local orphans. Providing water for those who ask for is a praised philanthropic act, *kuttab*

was made to “dispense” education in a symbolic act of dispensing water, to reflect the significance of education to people as much as water is (Alaa el-Habashi et al. 2011).

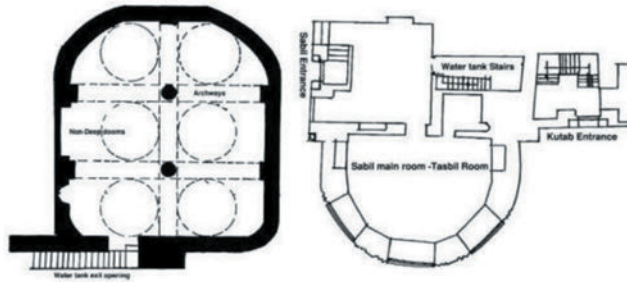


Figure 15. Sultan Mahmoud Sabil’s cisterns. (Source: El Shakhs, A., Ezzat, D. (2018) after Hosseini, 1987).

Wilson (2011) portrays a multi-stage filtration cistern in *Dar Saniat, Tunisia*, which consisted of three sections: a sedimentation section (A, B, and C), a water storage section - a once-filtered water tanks (E and D) connected to settling tank (A), and a twice-filtered water tanks (F and G) connected to settling tank (C) after settling tank (B). Finally, the tap chamber for water distribution, where were taps of different water qualities each one for particular use e.g. drinking, bathing, washing, fountains, and pool.

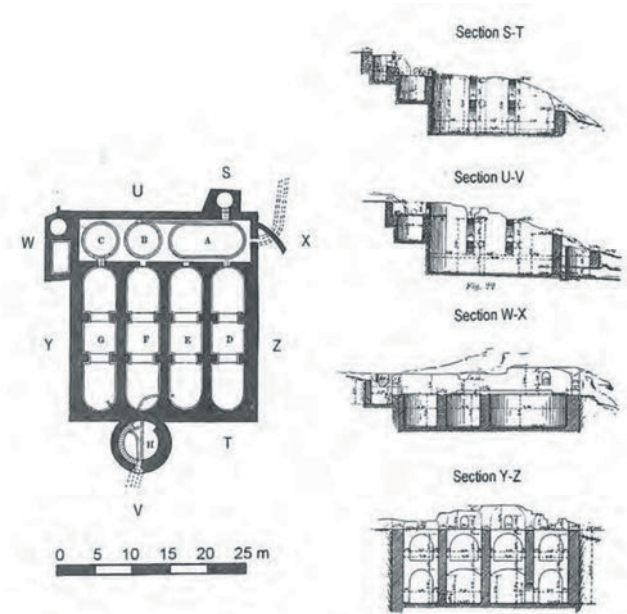
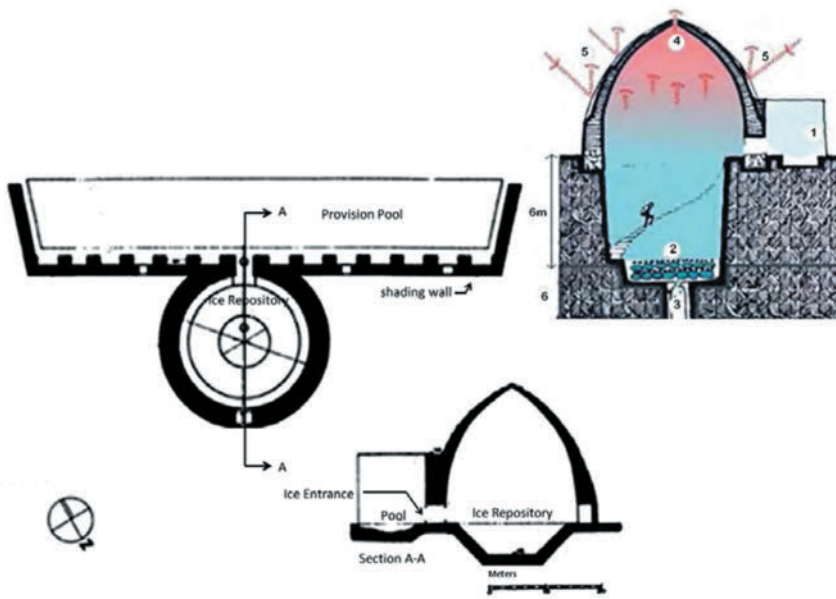


Figure 16. Plan and sections of the cisterns at Dar Saniat, Carthage (Wilson, 2011).

Another type of water collection strategy is related to ice houses i.e *Yakhchā*. The sophisticated technique of Persia provided ice in hot-arid climates via public ice houses. *Yakhchāl* was located in areas that had suitable conditions for ice production. Ice was collected from shadowed hillsides of the mountains and then transferred and stored in *Yakhchāl's ice reservoir, consisting of three architectural elements: Shading wall - Provision pool - Ice reservoir* (Hosseini, B. & Namazian, A., 2012.).

The shading wall is approximately 10 meters long and placed along the Ice reservoir, directed north-south to cast a shadow on the shallow Provision pool, with a temperature difference between sunny and shaded areas about 15-20°C. The ice reservoir is accessible from the poolside.



Figures 17-18. Yakhchāl architectural components.

(Source: Hosseini, & Namazian, 2012) Right: Generic section in the domed reservoir. (Source: Hosseini & Namazian, 2012 after Okhovat, 2011).

3.2 Bioclimatic archetypes of ventilation systems and contemporary design applications

Beyond water collection, another important challenge related to desertification, but also health issues, is ventilation of indoor spaces. Most of the constructed buildings in Italy rely only on air exchange from window openings, which will no longer be sufficient after the introduction of Minimum Environmental Criteria for Buildings (CAM) (DM 11 October 2017).



Figure 19. BedZED (Source: Tom Chance., 2007).



Figure 20. Badgir (Source: unknown, Sirjan, Iran).

These request to verify the Indoor Environmental Quality, as a fundamental parameter to guarantee good health conditions for occupants, considering their physiological and psychological conditions (EN 15251-2008).

This gave momentum to rethink ventilation of indoors in the built environment, and led to research, design and realize mechanical ventilation systems that can be integrated into the skin of

the building: passive/hybrid and therefore unique for that place in terms of materials, form and functioning. Thus a process of rediscovery of passive natural ventilation archetypes has been initiated, leading to the reworking of vernacular ventilation systems for contemporary integration into buildings with very high energy performance. The archetypes come from the plant, animal (the termite mound) and anthropic worlds with reference to light constructions (American tepee), heavy constructions (e.g., Mexican Pueblo, Italian Trullo, the Fairy Chimneys of Cappadocia in Turkey) and ventilation and cooling control systems (most prevalent in Middle Eastern areas).

An excellent example is *BedZED*, designed by Dunster Architects & Ove Arup, in London (2002). It is in fact a modern reinterpretation of the Badgir with several heads bent at 90° to the zenith. Here is the wind itself, as it blows, that makes some chimney towers operate rather than others. They are not designed to perform a precise task because each one can have a capturing or emissive function depending on whether the heads are upwind or downwind.

In *BedZED*, this concept is reworked in a lighter version. Indoor air exchange takes place via natural ventilation chimneys that are designed with a capturing head. The coloured flaps direct the wind into the intake vents, then a heat exchanger has been associated with the passive chimneys to ensure the supply of clean air at a pleasant temperature inside the homes. The residences rely entirely on passive ventilation, which is guaranteed by laboratory tests, carried out at the project phase.

4 DISCUSSION AND CONCLUSIONS

During the first stage of the study several strategies and case studies have been collected, from many countries and scales. On the one hand, vernacular architecture can provide excellent examples of how to collect and reuse stormwater and how to manage hygrothermal conditions indoors accordingly. On the other hand, biomimicry and innovative technologies implemented in modern case studies demonstrate that water-related and ventilation strategies can be effectively integrated also in the buildings of today.

Beyond the excellent example of *BedZED*, other contemporary applications of these concepts were recently developed. Among the others, one is *Sponge city*, China (Yu Kongjian, 2006), whose concept is a contemporary implementation of harvesting rainwater in surface reservoirs, by reducing the runoff flow rate and controlling stormwater in separated subterranean open reservoirs to feed the underground aquifer and retrieve nature and green infrastructure. This acupuncture chronic diseases, e.g. urban heat islands, greenhouse gas, the lack of impermeable surfaces, biodiversity loss, etc.

Reflecting on vernacular water storage and sedimentation methods mentioned in this study, applying and innovatively improving these methods to meet contemporary livelihood, health, and water quality standards could solve water scarcity problems in water stress regions and prepare these communities for expected drought periods.

Therefore, the proposed study aims at diffusing a design culture based not only on preservation of vernacular architecture but also on promotion of these principles aligned with sustainable assumptions. The direct impact of this study can be to raise awareness on what is becoming a hot topic also in EU countries, thus to encourage the adoption of design approaches and preparedness plans which are based on vernacular plus contemporary knowledge.

AUTHORS CONTRIBUTION

Conceptualization, L.M., and A.R.; methodology, L.M., A.R. E.M., S.D. and P.S.; investigation, A.R., E.M., S.D. and P.S.; resources, A.R.; writing—original draft preparation, A.R., L.M., E.M., S.D. and P.S.; writing- review and editing, L.M. All authors have read and agreed to the published version of the manuscript.

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