

KERKENNAH, AN EXAMPLE OF RAINWATER REUSE TO MEET WATER CHALLENGES IN TUNISIA

Mourad **ARABI**¹, Mostafia **BOUGHALEM**², Farida **OUZAL**¹, Djamel **ANTEUR**³, Khadidja **BOUKHAROUBA**⁴

1 National Institute of forestry Research (INRF), almouraddz@yahoo.fr and farida.ouzal@gmail.com

2 University of Ain Temouchent, Laboratory of Applied Hydrology and Environment, boughalem_2000@yahoo.fr

3 University of Saida, Laboratory of Ressources in Water and Environment, anteurdjamel@yahoo.fr

4 University of Biskra, Faculty of STUSNV, Department of Natural and Life Sciences, Laboratory of Applied Chemistry, khadidja.boukharouba@univ-biskra.dz

Abstract

Between July 10 and 14, 2023, a team of Algerian researchers visited the Kerkennah archipelago (Tunisia) as part of a bilateral research project on green infrastructure for sustainable rainwater management in arid and semi-arid environments (2021-2024). This visit provided an opportunity to explore local rainwater harvesting techniques, combining ancestral farming know-how with conventional municipal methods. The study focused on mechanical processes (meadow ponds, cisterns) and biological/cultural practices (multistage, intercropping, hydroponics). The results demonstrate the effectiveness of these approaches to stormwater management and soil conservation, vital to face climate change. Domestic and agricultural cisterns (*Majels*) are essential for water storage and supply. Hydroponics, tested locally, offers the potential for water-efficient agricultural production. In addition, solutions based on adapted plant species are considered to manage flooding, and the geolocalization of green infrastructures aims to preserve biodiversity. The integration of solar water drilling for irrigation illustrates a promising energy transition. The Kerkennah experience exemplifies resilience, highlighting the necessity of rehabilitating traditional water management practices while embracing technological innovation. Securing water resources, combating rural exodus, and providing a sustainable development model for similar Maghreb regions requires robust public policy, including widespread cistern implementation and mandatory rainwater harvesting for new construction.

Key words: rainwater, green infrastructure, traditional methods, conventional techniques, organic or cultural practices, Kerkennah.

Introduction

Climate change is having a direct impact on people's lives: rising temperatures, rising sea levels, water shortages, recurrent droughts, floods and an increase in tropical cyclones.

Faced with these phenomena, proposed solutions are becoming an unavoidable issue (PNUE, 2021; COP27, 2022). For island territories like Kerkennah (161 km²), the priority is to predict and model these impacts in order to propose concrete actions to minimize their effect. For several years now, local authorities, researchers, farmers and planners have been working together, realizing the need to adapt their actions, review their methods and develop new green infrastructure projects, particularly in the reuse of rainwater. It is in this context of urgency and search for concrete solutions that, as part of the Algerian-Tunisian research project entitled “Green infrastructures for sustainable rainwater management in arid and semi- arid urban environments” currently under study, a team of Algerian researchers visited Kerkennah in Tunisia, from July 10 to 14, 2023. This study explores how local communities adapt to climate change by leveraging ancestral knowledge to conserve and reuse rainwater. It examines both mechanical (e.g., ponds, cisterns) and biological/cultural practices (e.g., green spaces, multi-stage cropping) employed by farmers to manage rainwater and conserve soil in anticipation of climate change. The analysis focuses on the operation and components of these systems through shared knowledge and experiences, highlighting valuable technical insights for improvement.

Although the challenge has been partially met, the archipelago is nevertheless confronted with other challenges, such as the sterilization of the soil by marine saline intrusion (Takrouni et al., 2003), the extension of Sebkhass (Etienne, 2012), and the anthropogenic impact on the environment (Fehri, 2011).

1. Context

The Kerkennah archipelago (Figure 1) is located in the Gulf of Gabes, 20 km from Sfax and 260 km southeast of Tunis (Coordinates: 34° 39' 29" N and 11°04' 07" E). It extends over a strip of 3.5 km wide and 45 km long) with an almost flat relief of no more than 13 m in altitude (Dahech, 2007). However, this apparently featureless territory is marked by a succession of imperceptible hills that form low lagoons. Flat areas of land with slight elevations are the source of diffuse runoff, which is not very abrasive and does not pose a danger to soil water erosion.



Figure 1. Location of the Kerkennah Archipelago (In Etienne et al., 2015).

The climate is semi-arid Mediterranean; hot and dry in summer, mild and rainy in winter. The average annual rainfall is 224 mm at the Kellabine station (**Table 1**).

Table 1: Rainfall and Evapotranspiration in the Kerkennah archipelago (1965-2009). (sources : DGRE and CRDA, Sfax, Tunisia, 2009). (In Fehri, 2011).

Value	J	F	M	A	M	J	J	A	S	O	N	D	Σ
P [mm]	23,7	14	27	17	4,5	0,9	0,5	1,1	21,5	44	33,7	35,7	223,6
ETP[mm]	37,4	49,6	77,5	107,7	152,2	184,4	199,6	170,2	116,2	83,3	48,5	36,4	1260,0
ETP-P[mm]	13,7	35,6	50,5	90,7	147,7	183,5	199,1	169,1	94,7	36,3	14,8	0,7	1036,4
P/ETP	0,63	0,28	0,35	0,16	0,03	0,00	0,00	0,01	0,19	0,55	0,69	0,98	0,18

In addition, this precipitation is distinguished by its inter-annual irregularity. An annual precipitation total of 591 mm was recorded during the period from 1995 to 1996 (**Figure 2**), compared to only 87 mm in 1987-1988 (Fehri, 2011).

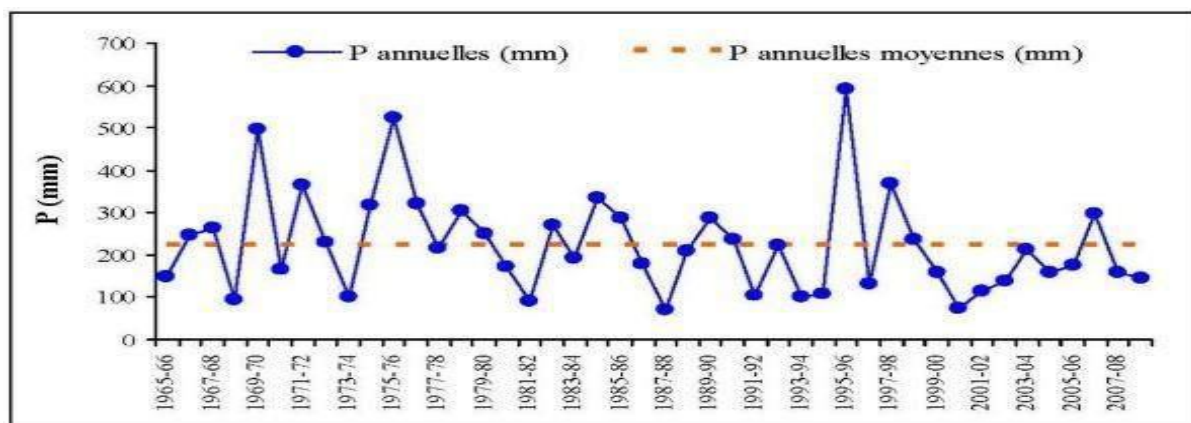


Figure 2 . Variation in annual rainfall (from September to August) at the Kellabine station over the period 1965-2009. (source: DGRE , Sfax, Tunisia, 2009) (In Fehri, 2011).

In addition to this inter-annual irregularity, there is annual variability, so October is the rainiest month (44 mm on average), on the other hand July is the driest month with less than 1 mm on average.

Geological surveys indicate that the substrate is composed on the surface mainly of silt and sand, giving rise to crusting films (Ben Hassine, 1994). The gentle slope of the land allows water to stagnate in the form of Sebkhass (Taglioni, 2007). The rise of salts by capillary action limits the choice of plant species (Etienne, 2014). The lowlands are home to a lagoon ecosystem based on halophytic plants (Salicornia) and salt marsh grasses.

Agriculture developed around freshwater aquifers or pockets of slightly salty water adapted to the immersion of brackish water. The typical trees of the archipelago are the palm tree, the olive tree, the vine and the fig tree (Ben Saâd, 2001).

In winter, the archipelago has 14500 inhabitants grouped in large numbers in the villages (**Figure 1**), i.e. a density of 90.6 inhabitants/km² higher than that of the mainland 65 to 75 inhabitants/km². This figure can rise significantly in summer to 625 inhabitants/km² with a harmful impact on the environment (Souissi, 2000). The Tunisian government wants to keep the population in the countryside and intensify agriculture, without increasing land degradation or water pollution.

2. Farmers initiatives

The traditional methods used in rainwater harvesting are ancient. These methods express here, as in other latitudes, the fact that climate change was first felt by the farmers themselves, at the regional level as well as on the planetary scale, as a lasting change in climate due to the natural intensification of the greenhouse effect, which is caused by certain atmospheric gases (CO₂, CH₄, N₂O, and some fluorinated gases).

Most of the measures that can be observed today thus, testify to the desire to cope with and better control rainwater management, at a given time. The traditional methods used are sufficiently widespread throughout the country to have been cited by a good number of authors (El Ammani, 1984; Moussa, 2012).

2.1. Intercropping

Intercropping is often practiced in agricultural plots in Kerkennah. The cropping system consists of the olive tree as the main tree combining a rotation of cereals/legumes. These intercropping agro-forestry systems have their roots in traditional agricultural systems where the presence of trees was not necessarily linked to timber production, but often to fruit production (Dupraz, 1994). In the past, the practice of intercropping was quite common around the Mediterranean, but a certain number of prejudices had made this practice regress to avoid water competition. The CIRAD research works (Remix project, 2022) on the agricultural practice of mixtures, combining various species makes it possible to increase the productivity of crops while reducing their environmental impact. It is now accepted that intercropping offers considerable economic advantages: It optimizes cultivable space and increases yields. As can be seen here in this territory, the yields of the two distinct productions (olive and herbaceous crops) may be lower than those obtained in monoculture, but their combined production per hectare is often higher than that of monoculture due to the reduction of production costs. This combination of crops increases economic performance and environmental sustainability (Garrett et al., 2000).

Most of the orchards visited in Kerkennah do not have windbreaks. To protect fruit trees from the prevailing westerly winds, it is recommended to design a good windbreak and to establish it in the right place.

2.2. Multistage crops

As with intercropping, multistage cropping is not strictly speaking "development" but agricultural practices and must be added to the range of traditional techniques because of their aspect that is just as beneficial, if not more so, than mechanical processes. They are present everywhere and occupy a privileged place in the fields of the farmers of Kerkennah. Most often, the following three crops have been observed in farmers' fields: at the top, the palm tree, then the olive tree, and at the base, fodder crops of bladder and oats.

These "oases" are subject to strong pressures such as water scarcity, the extension of Sebkhass, the salinization of groundwater, the infestation of certain invasive species, the cramped properties and their extreme fragmentation, a consequence of the rules for the transmission of inheritance, have led to a drop in income. It should be remembered that the market economy has favoured the exaggerated extension of certain varieties such as Déglet Nour. This is done to the detriment of local cultivars and ethno varieties, which are nevertheless more adapted to the rigour of the environment. Several landraces of palm trees are abandoned and are being uprooted. Faced with this situation, the prospection, conservation and reintroduction of the oasis phyto-genetic heritage is necessary to maintain the importance of local cropping systems (agro-diversity), (Aljan et al. 2017).

In Kerkennah, the research effort must be directed towards production systems which would have the effect of increasing farmers' income and mitigating their risks and which would be based mainly on perennial vegetation. These are decisive technical instruments for achieving an economically and environmentally sustainable improvement in agricultural production (Arabi et al., 2017).

For farmers in Kerkennah, xerophytic fruit trees other than olives, including apricots, almonds, and apples, offer interesting prospects. They are versatile species that provide direct economic benefits and also have ecological value. Trials to introduce other hardy species such as the pistachio tree and the prickly pear cactus (*Opuntia ficus-indica*) are to be carried out in this area. While it is clear that trees alone cannot halt soil degradation, they are instrumental in establishing the more permanent and profitable farming system in question. In this respect, the contribution of fruit trees is important because they promote the integration of food crops and livestock as well as the establishment of a more permanent vegetation cover in the archipelago. These "oasis" plots are also devoid of windbreaks. Thus, the experimentation of orchards in association with other crops protected by windbreaks is a serious avenue for future research in this territory.

3. Conventional and traditional structures

Other projects, more specific and recent but using the same techniques, are the result of an external initiative, adapted to regional particularities, and are implemented by the region's technical services in consultation with the actors of the agricultural sector. These works enjoyed relative autonomy from the central government.

3.1 The Lataya Experimental Pond

The Lataya experimental pond is an open-air rainwater recovery reservoir with a retention basin containing approximately 420 m³ (**Figure 3**). It was created near the agricultural meadows, part of which has been transformed into an impluvium; Runoff from rainwater feeds the pond. The bottom of the pond is covered with a geotextile membrane lined with a geotextile felt that ensures waterproofing and acts as an obstacle against the rise of roots and abrasive elements.

Ponds still exist and are used in Tunisia for watering animals when they are grazing. It is a pity that these ancestral know-how are disappearing; We should rather think about their rehabilitation, especially in the current circumstances of water shortages, by equipping it with a filter for the supply of water for the benefit of local residents.

On the other hand, the pond brings a richness from the floristic and faunal point of view and also contributes to the diversity of the landscapes.



Figure 3. The experimental plot of Lataya, with geo-membrane and geotextile felt. Kerkennah, July 2023 (Photo: Boughalem).

3.2 Cisterns

We observed two types of cisterns: agricultural cisterns and domestic cisterns. The agricultural cisterns were designed to store storm water runoff for irrigation and livestock watering. These structures are the markers of a sedentary human presence (Blanchemanche, 1990). The cistern is located in the middle of agricultural fields, part of which has been transformed into an impluvium (**Figure 4** and **Figure 5**).



(a)



(b)

Figure 4. Agricultural cistern for rainwater collection. In general, cisterns are built for the supply of drinking water to local residents (a), irrigation and watering for livestock(b). Kerkennah, July 2023 (Photo: Boughalem).



Figure 5. The agricultural tanks are managed together by the farmers' collective. This management still obeys local customs which are based on Islamic legislation that is still in force (El Amami, 1983).

Domestic cisterns, commonly known as Majel or Fesguia according to the geometric shape of the basin (Moussa, 2013), call on local know-how to compensate for the lack of water, especially in summer. These are underground reservoirs built of reinforced concrete under the dwellings which consist of collecting rainwater that has fallen on the terraces and connected to the reservoirs by hydraulic pipe (**Figure 6**). Their volume of water depends on rainfall and

the surface area of the terraces. It varies from 20 to 200 m³ with an average of 80 m³ (Chahbani, 2003). The terraces are limed before each rainy season to make the water "drinkable". The drawing and distribution of water is generally done manually. But improvements were introduced to draw water directly from an electric motor pump.



Figure 6. Domestic masonry cistern made by a private individual whose water is drawn manually. Kerkennah, July 2023 (Photo: Boughalem).

Some archaeological sites in Meninx and Zaghuan-Carthage bear witness to cisterns for the storage of rainwater dating from ancient times (Beschaouch, 2001). A tradition that seems to continue today (**Figure 5**).

Is rainwater safe to drink? Even though its composition remains variable due to various environmental factors and human activities, rainwater is known for its acidity and low mineral composition. Similarly, this practice is not without risk since nowadays it is known that rainwater can be contaminated by pathogenic microorganisms in suspension everywhere in the air (Baudarta et al., 2014). Recent technologies are used to detect the potability of water on site (OPUE, 2020). The improvement of the water supply through the cistern technique and better management of water resources have enabled the inhabitants of Kerkennah to meet their water requirement (180 l/d/inhabitant), to maintain the economic growth of the territory and to make a significant contribution to the reduction of diseases and poverty in the region.

Current Maghreb legislation is not very precise on rainwater management, insofar as it is scattered throughout several legislative texts. A joint decree between Algeria and Tunisia would make it possible to establish the list of authorized uses of rainwater. Research by the Tunisian partner of the Chott Meriem research centre is underway to improve natural filtration and runoff water retention techniques.

In conclusion, the various hydraulic rainwater retention structures built, inspired by ancient traditions, bear witness to the awareness of the population of the need to deal with the irregularity of water resources. It would nevertheless be necessary to integrate them into a general urban planning and water management plan, which will make it possible to size them and situate them in relation to runoff and rainwater.

3.3 The flood in Ramla in December 2013

Between 20 and 24 December 2013, extremely violent rains fell on the Kerkennah archipelago. Parts of the archipelago received more than 250 mm, exceeding the average annual rainfall total. This kind of paroxysmic event is characterized by its brutality and its high spatial variability. Despite the slight slope of the land, they triggered enormous floods that caused considerable damage to the main towns of the municipality. Meteorological records indicate 60 mm in Ramla, 45 mm and 40 mm respectively in Ataya and Mellita. These rains have waterproofed the soil, making it completely saturated. The last day of this rainy episode, 24 December, was marked by impressive amounts of rain: 80 mm in Ramla, 70 mm in Mellita and 50 mm in Ataya (**Figure 7**). They were more intense on 23 December, especially in Mellita where they exceeded 140 mm/h compared to about 110mm/h in Ramla and 80 mm/h in Ataya. A phenomenon that is set to become more frequent due to climate change.

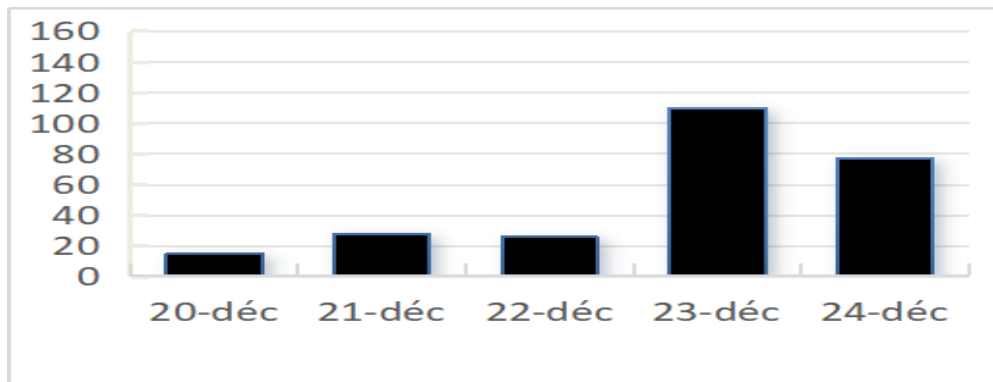


Figure 7. Amount of precipitation rainfall (mm) from 20 to 24 December, 2013 at the Kerkennah Archipelago Ramla Meteorological Station (In Dahech et al., 2015).

The city of Ramla has experienced many floods throughout its history. The objective stated by the public authorities is clear: How to reduce the scale of flooding in urban and peri-urban areas and present solutions against the risk of flooding in the targeted areas? Faced with this cyclone event, the city of Ramla, to protect itself from flooding, dug a canal through the city to the sea for the evacuation of excess water. Because the topography was very plain, some of the water stagnated in the canal and on the land below sea level, resulting in unpleasant odours and the proliferation of harmful mosquitoes. For these reasons, the canal was redeveloped and covered with concrete, but the problem of stagnant water in the pool persists .

At the end of this outing, we proposed as solutions to the local officials, the transformation of this pond into a green infrastructure lined with a range of halophytic plant species with high absorbency and which are adapted to saline soils. Among the species plantations are:

- Eucalyptus species are vigorous, fast-growing trees that tolerate poor soils and are resistant to excess water. Some Eucalyptus varieties (e.g. *Sargentii*, *Gomphocephala* and *Astringens*) can withstand doses of 10/g/l of salt without altering their evaporation power. In addition, Eucalyptus shrubs can be used in green infrastructure as decorative varieties.

- Plantations of poplar species whose ecological requirements vary according to species and cultivars. Poplar is a robust tree that adapts to excess moisture. In particular, the variety *Populus euphratica* or *Euphrates poplar* which, successfully tested in the semi-arid region of Boughezoul, has been satisfactory by withstanding soil stagnation and excess salt.
- Finally, plantations of local species adapted to marshes and excess salt such as *Tamarix articulata*, *gallica*, *africana* varieties, etc.) or introduced species such as Vetiver (*Chrysopogon zizanioides*) or the Provence cane, *Arundo donax* (reed). The latter two species which grow in our wadis and water treatment stations, are also part of the arsenal of traditional flood control techniques.
- Another solution is the recovery of rainwater in large ponds or rainwater collection basins and its development into green infrastructure through various uses: irrigation, agriculture, domestic use, municipal beautification park in the city of Ramla.

3.4 Geolocated green infrastructure

To conserve the biodiversity of the archipelago and protect the genetic variability of populations as well as the different habitats and ecosystems that host them, researchers at the Chott Meriem Research Institute are working on the geolocation of all the most interesting sites and green spaces to be protected. The network of green infrastructures connected in this way makes it possible to preserve the values and functions of natural ecosystems and moreover, an ecosystem tool whose ecological benefits benefit the communities of the archipelago. We have visited two geolocated sites:

- The esplanade of the Zaouïa of Sidi Mhamed Ezzorai.
- The Kellabine roundabout, Abbassiya, Ramla, Sidi Youssef.

The census operation is only at its beginning. All the sites that are of ecological interest are counted and geolocated, in particular the sanctuary of Sidi Mhamed Ezzorai. Similarly, the roundabout of the four-paths between Kellabine, El Abbassiya, Ramla and Sidi Youssef is also an interesting case to observe. In the middle of the road, the edges of the roundabout are angled inside to allow rainwater to flow directly into the space of the central circle of the roundabout, soaking the soil and reviving the plants.

3.5 The irrigation system in Ouled Azzedine

In areas where rainfall is subject to high seasonal and inter-annual variability, as is the case here in Kerkennah, irrigation is essential to support crop diversification, ensure yield and product quality. However, this dependence on irrigation is under increasing pressure. In Tunisia, as in the rest of the Maghreb, irrigation is of a strategic nature, as evidenced by the irrigation of agricultural plots in Kerkennah. Here in the archipelago, it is based on a communal exploitation of groundwater from boreholes, artesian wells or cisterns and ponds made in the middle of agricultural fields. Water management is entrusted to a "*Majmaa*" or office also called "*Elbaraka*" which includes adherent members and a technical director. The volume of water is distributed in proportion to the size of the plots. Given the small size of agricultural plots (less than 5 ha), each owner has a water distributor equipped with a meter whose consumption is paid according to the bill. Farmers who do not belong to "*Elbaraka*" buy water tanks towed by vehicles. The novelty in Kerkennah is the supply of solar-powered boreholes. Here, the roof of a building serves as a photovoltaic panel installation for electricity production.

Solar-powered irrigation systems are now a mature technology that can be deployed quickly. The sharp drop in the cost of photovoltaic panels encourages this type of installation to

become more and more affordable, including for small farms, although a more sustainable use of groundwater resources if it is carefully controlled. Indeed, it must be borne in mind that in countries where water reserves are depleted, it is necessary to make choices between crops, discarding those that are very water-intensive in order to control the rate of extraction of the precious liquid and avoid the depletion of the reserves. There are now electronic control devices for irrigation systems on the market, controlling both the level of nature reserves and the pumping flow; They can help maintain balance and limit abuse.

3.6 Hydroponic farming

Our last interview in Kerkennah led us to visit the training center for disabled children where hydroponic agriculture is practiced.

Hydroponic agriculture is an innovative model of agriculture adapted in particular to urban environments. It allows you to grow all year round in any environment and achieve higher yields while using less water. The example is given by the trial of hydroponic agriculture granted to the trainees of the center. On the wall of a building of the training centre, open to the courtyard, are installed the half-pipes that house the installation of the crops. The modern hydroponic green wall method still requires the installation of an electrical supply system to pump the water needed to feed the crops. The centre has opted for a closed circuit because it is more environmentally friendly. The water is pumped from a tank placed on the ground to the top of the wall, then it goes down drop by drop, soaking the substrate and finally falls back into the tank. Closed-loop water consumption is therefore less important. The green wall becomes a real small agro-system. The water is loaded with the nutrients contained in a solution enriched with essential nutrients such as nitrogen, phosphorus and potassium. These solutions are created from a combination of mineral salts and other organic materials, such as algae extract. The nutrient solution is then pumped directly onto the plant's roots using drip irrigation systems. Water is continually redistributed to plants to support growth and yield production. This growing method can be used to grow various plants. A variety of crops staggered on the height of the wall is tested: lettuce, basilica, mugwort. The technique can be extended to fruits and vegetables. It is also possible to transform these facilities into an aquarium with fish and turtles.

Hydroponic farming is an efficient method of growing plants indoors, in greenhouses, in vertical farms, or even at home, making it an ideal system for those who live in urban areas or have limited space. Also, this type of agriculture, which has proven itself in many advanced countries, has many advantages, including the possibility for the grower to control the environment in which the plants are grown by adjusting the inputs and controlling abiotic factors such as air temperature, light levels and humidity. This ensures that the plants have optimal conditions for their growth and development.

Overall conclusion

Given the climate crisis and the increasing threats to water resources, the Kerkennah archipelago is a living laboratory of resilience, showcasing adaptation to water challenges. The study reveals that the key to this adaptation lies on an integrated approach that enhances ancestral know-how while embracing innovative technological solutions. The Kerkennians have capitalized on tried and tested traditional practices, such as inter-cropping and multi-stage cultivation, as well as the use of ponds and cisterns, which constitute vital infrastructure for collecting and storing rainwater. Far from being obsolete, these methods need to be fully rehabilitated and integrated into a contemporary water strategy.

However, rehabilitation alone is not enough. The article underlines the imperative of adopting advanced technological solutions such as hydroponic agriculture, which offers high yields with reduced water consumption, or the use of solar energy for irrigation, symbolizing a promising energy transition. These innovations, combined with the geolocalization of green infrastructures to protect biodiversity and ecosystems, are forging a sustainable development model.

Finally, to ensure Kerkennah's water security and sustainable future, a strong political will is vital. This includes supporting farmers, expanding domestic cistern use, enforcing regulations, and mandating rainwater harvesting in new construction. This holistic approach, integrating tradition, innovation, and governance, will not only secure water for the population but also encourage residents to remain on the island, making Kerkennah a model for water-scarce regions.

Acknowledgments

This scientific tour was conducted within the framework of the research and bilateral cooperation project between Algeria and Tunisia: "Green infrastructure for the sustainable management of rainwater in arid and semi-arid urban environments" which benefits from the financial support of the Algerian DGRSDT and the Tunisian research authority. We extend our sincere thanks to all those who helped and supported us in the accomplishment of our stay from July 10 to 14, 2023, especially the technical staff of the Kerkennah archipelago. The plane tickets were supported by the University of Biskra, whereas the field trips were organized by the University of Sousse. We warmly thank the two anonymous rectors for their kindness as well as Professors Khadidja BOUKHAROUBA and Faïza KHEBOUR ALLOUCHE for their dedication as local project coordinators.

References

Aljane, F., Mokhtar, E., Hammadi, H., Benoune, A., & Neily, Y. H. Y. (2017). Prospection et inventaire de l'agrodiversité dans les oasis traditionnelles de Zarat, Nouiel et El Guettar. *Revue des Régions Arides*, 43(3), Numéro spécial – Actes du 5ème Meeting International sur l'Aridoculture et les Cultures Oasiennes : Biotechnologie végétale en zones arides et oasiennes, Zarzis (Tunisie), 19-21 décembre 2016. <http://www.ira.agrinet.tn/imgcommon/files/RRA%2043%20Tome%201.pdf>

Arabi, M., Bourougaa, L., & Kedaïd, O. (2017). Lutte antiérosive et intensification de l'agriculture en milieu steppique semi-aride (Boughezoul, Algérie). In *Restauration et conservation de la fertilité des sols tropicaux et méditerranéens* (pp. 1-15). IRD Éditions. <https://books.openedition.org/irdeditions/24504>

Baudarta, J., & Paniel, N. (2014). Sources et devenir des micro-organismes pathogènes dans les environnements aquatiques. *Revue Francophone des Laboratoires*, 459 (2014), 29-39. <https://www.em-consulte.com/article/871700/sources-et-devenir-des-micro-organismes-pathogenes>

Ben Hassine, H., & Besbes, M. (1994). *Étude pédologique des îles Kerkennah*. CRDA.

Ben Saâd, A. (2001). Les utilisations lucratives du palmier, l'exemple de Kerkena (in Arabic). In Kerkena, Histoire et Société (pp. 187-197). Centre Cercina & Faculté des Lettres et Sciences Humaines de Sfax.

Beschaouch, A. (2021). La légende de Carthage. Éditions Gallimard.
<https://www.gallimard.fr/catalogue/la-legende-de-carthage/9782070532124>

Blanchemanche, P. (1990). Bâisseurs de paysages : terrassement, épierrement et petite hydraulique agricoles en Europe, XVIIe-XIXe siècles. Éditions de la Maison des Sciences de l'Homme. <https://www.editions-msh.fr/livre/batisseurs-de-paysages/>

Chahbani, B. (2003). Innovations techniques et technologiques dans le domaine de mobilisation et de conservation des eaux pluviales et de ruissellement et dans le domaine d'économie d'eau. *Séries sciences humaines*, 233-249.

COP27. (2022, November 6). UN Climate Change Conference of the Parties (COP27). Charm El Cheikh, Egypt. <https://unfccc.int/cop27>

Dahech, S. (2007). Le vent à Sfax (Tunisie), impacts sur le climat et la pollution atmosphérique (Doctoral dissertation, University of Paris VII).

Dupraz, C. (1994). Les associations d'arbres et de cultures intercalaires annuelles sous climat tempéré. *Revue forestière française*, 46(spécial), 72-83. <https://hal.science/hal-03444484>

El Amami, S. (1984). Les aménagements hydrauliques traditionnels en Tunisie. Publication INRGREF.
https://books.google.dz/books/about/les_amenagements_hydrauliques_traditionnels.html

Etienne, L., Dahech, S., Beltrando, G., & Daoud, A. (2012). Dynamiques récentes des sebkhas littorales de l'archipel des Kerkennah (Tunisie Centro-méridionale) : apport de la télédétection. *Revue Télédétection*, 11(1), 273-281. <https://shs.hal.science/halshs-01134169>

Etienne, L. (2014). Accentuation récente de la vulnérabilité liée au recul du trait de côte et à l'extension des Sebkhass dans l'archipel de Kerkennah (Tunisie) (Doctoral dissertation, University of Paris Diderot). <https://theses.fr/2014PA070024>

Garrett, H. E., & McGraw, R. L. (2000). Alley cropping practices. In H. E. Garrett, W. J. Rietveld, & R. F. Fisher (Eds.), *North American agroforestry: an integrated land-use practice*. Doi: 10.1002/9780891183785.ch7

Moussa, M., Saidi, M., Jaouad, M., Rejeb, H., & Khatteli, H. (2012). Insertion des citernes de stockage des eaux pluviales dans le paysage aride de Beni Khedach, Sud Tunisie. *Les enjeux de l'eau dans la durabilité des paysages*, 191-208. <https://academia.edu/50402607>

OPUE. (2020). Results Pack CORDIS sur l'innovation dans le secteur de l'eau : Une collection thématique des résultats de la recherche et de l'innovation financées par l'UE. Office des publications Européennes.

PNUE. (2021). Rapport sur les infrastructures et la lutte contre les changements climatiques. Co-publié par l'UNOPS, le Programme des Nations Unies pour l'environnement (PNUE) et l'Université d'Oxford. <https://unops.org/fr/news-and-stories/news/infrastructure-for-climate-action>

Slim, H., Troussset, P., Paskoff, R., & Oueslati, A. (2004). Le littoral de la Tunisie : étude géoarchéologique et historique. CNRS Éditions. <https://academia.edu/2587474>

Souissi, M. (2000). Développement du tourisme dans les îles Kerkennah : d'un tourisme balnéaire à un tourisme écologique (Master's thesis, FLSH de Sfax).

Takrouni, M., Michelot, J. L., Maliki, A., & Zouari, K. (2003). Relation entre aquifère profond, nappes superficielles et intrusion marine dans le Bassin de Sfax (Tunisie). *Hydrology of the Mediterranean Regions*, 278, 515-524. [https://doi.org/10.1016/S1251-8050\(00\)01386-0](https://doi.org/10.1016/S1251-8050(00)01386-0)

Taglioni, F. (2007). Recherches sur les petits espaces insulaires et sur leurs organisations régionales (Habilitation à diriger des recherches, Université Paris-Sorbonne - Paris IV). <https://theses.hal.science/file/index/docid/47133/filename/these.pdf>

