European Geosciences Union

National Technical University of Athens
School of Civil Engineering

Investigating the water supply potential of traditional rainwater harvesting techniques used

Case study: Municipality of Western Mani

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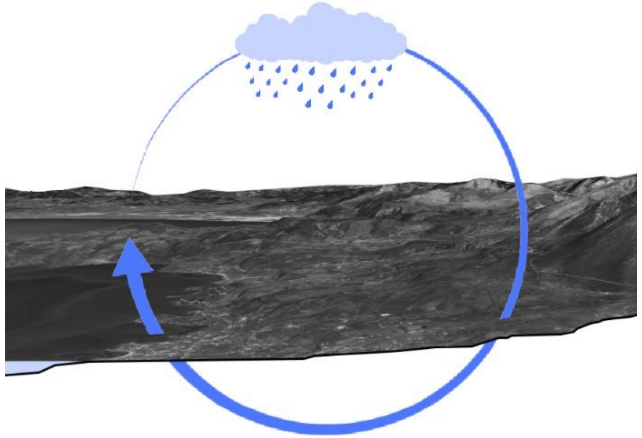
Introduction

- The Municipality of Western Mani (WM) is located in the southern part of Greece in Peloponnese. The region has a high rate of rainfalls mainly in the mountainous areas.
- Rainfall is mainly observed during the autumn and winter months, from October to March, while there is a significant decrease in the summer[1].
- The problems that arise mainly focus on the quantitative aspect [2-5]. The geological background is extremely permeable as it consists mainly of karstic limestone. Therefore, there are limited surfaces water resources with limited water supply[6].

Source : https://vemaps.com/europe-continent/eu-c-04#google_vignette

Source: https://www.vecteezy.com/vector-art/2292777-greece-detailed-map-with-states



The water cycle

General Elements of Cisterns

- Constitute an integral part of local tradition
- Enrich the cultural heritage
- Attract great architectural interest

Water Quality:

- Past → suitable for drinking
- Present → suitable for water supply

The cistern volume depends on:

- Water demand of the residents
- Potential rainwater yield
- Amount of possible concentration of water from rainfall

Types of cisterns:

- External : flat, waterlight from cement mortar
- Internal : the mouthpiece protrudes in order to save space in the house

Constructions details:

- Average capacity: 15-20 m^3
- Depth: 5-7 m
- Diameter of circular orifice: 0.7-1 m
- Materials of construction: reinforced concrete, cement block, stone with mortar

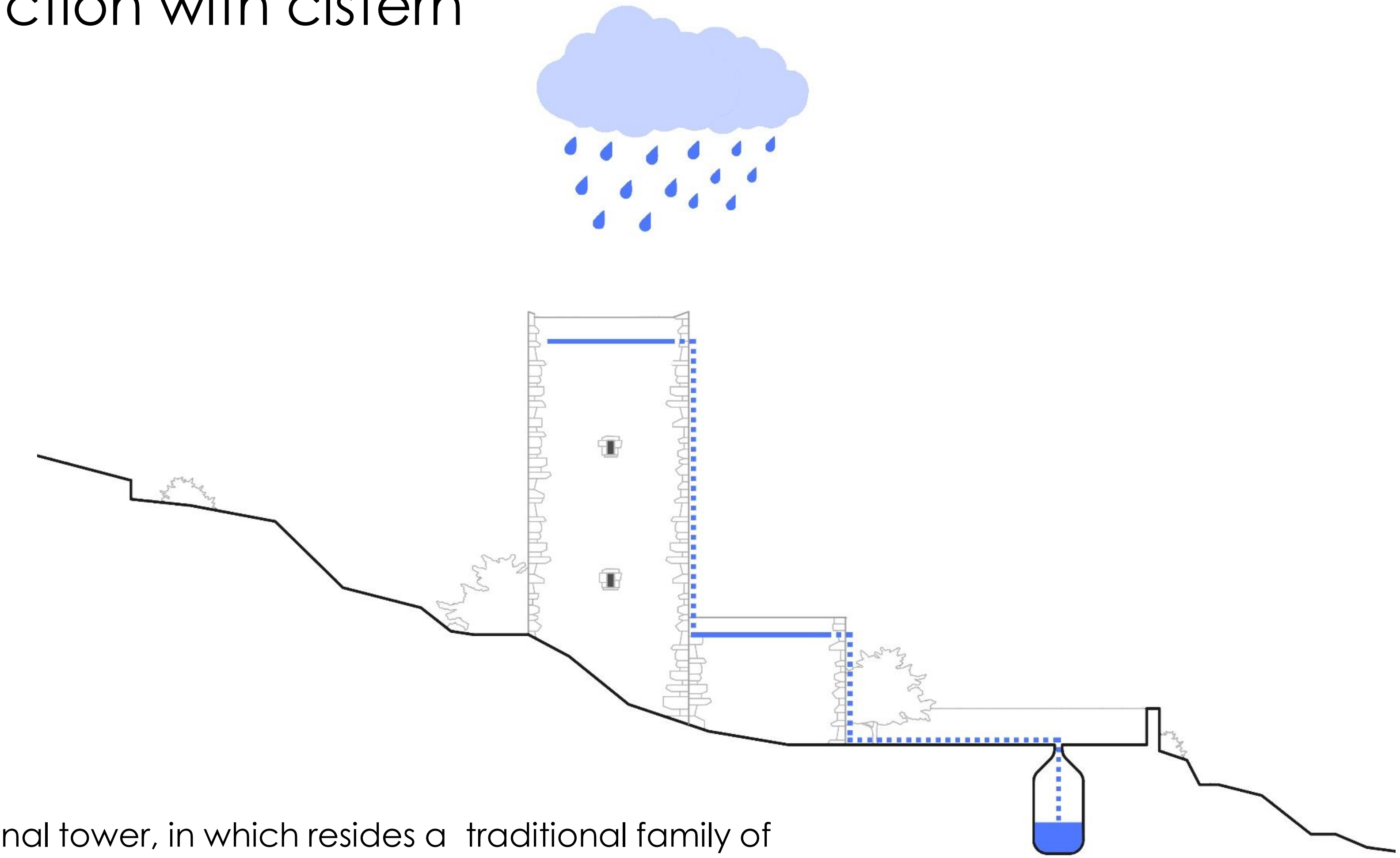
Cistern in Western Mani

Cistern on the plateau in Lagada

Source: Google Earth

These pictures show a cistern on plateau in Lagada where the water is collected and different settlements are fed.

Traditional construction with cistern



- This section depicts a traditional tower, in which resides a traditional family of 10 people, with an external cistern which fills with water and is used for storage so as to ensure the survival of the family.
- The blue line shows the water cycle of the rainwater.

Waterproofing of cisterns

Process of waterproofing of cisterns:

- Cleaning of inner surfaces of the underground water of cisterns with limewater
- Removal of the friable parts of mortars
- Stabilization of surfaces by applying a lime emulsion (galaktisma)
- Application three different layers of mortars with theran earth and aged lime putty

Layers:

- Petachto: very watery mortar with small ratio lime / theran earth
- Aspa and aged lime: mortars which are essentially the basic substrate with 1-2 layers
- Alima: the last mortar of lime and theran earth which is stirred for seven days prior the final application (the use of "kochlidi" is necessary) [7].

Materials of Waterproofing:

- Sifted theran earth
- Lime

Special tool, Kochlidi, available in:
https://www.youtube.com/watch?v=hSp40FHf8Hw&t=3s

Application of last layer with Kochlidi, available in:
https://www.youtube.com/watch?v=hSp40FHf8Hw&t=3s

Modeling the cisterns

Data:

- Very small time series, 68 years
- A stochastic synthetic time series of 500 years
- The Symmetric-Moving-Average (SMA) scheme was applied [8-9].

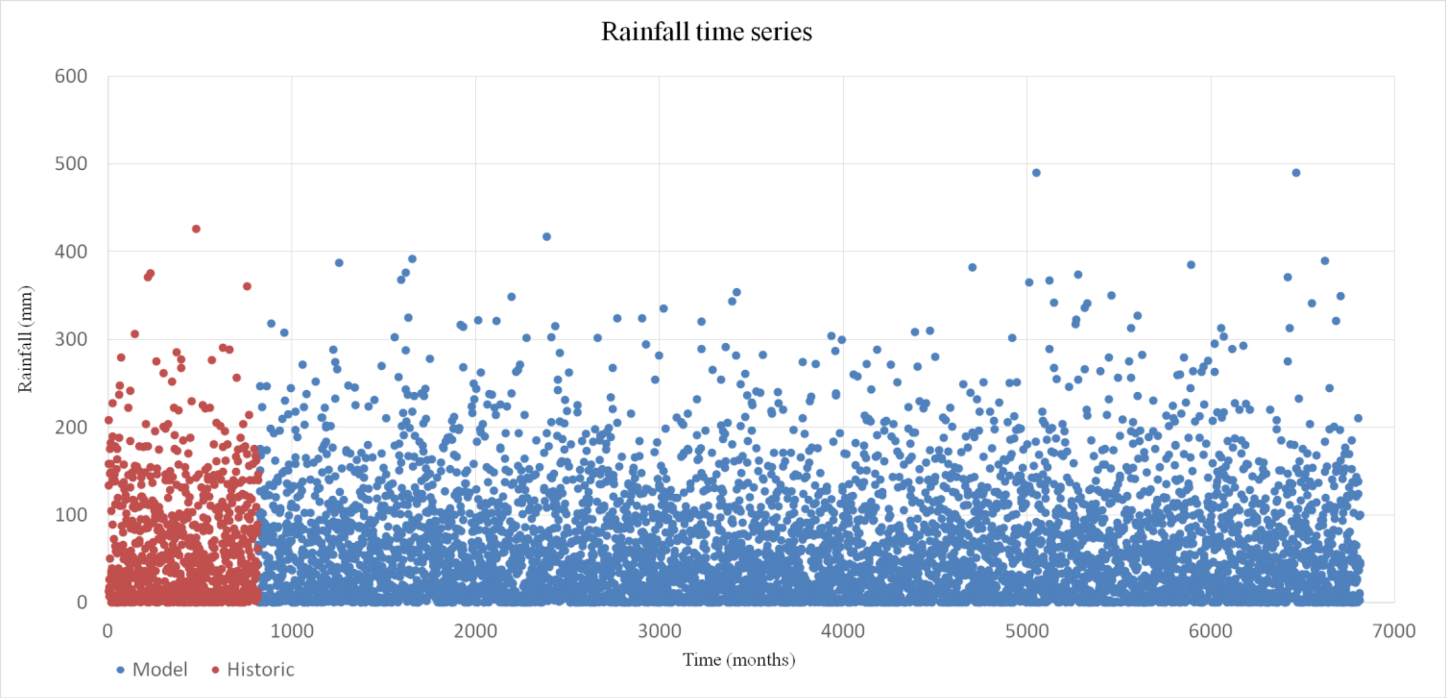


Diagram Rainfall – Time for historical and synthetic time series [10]

- Red depicts the historical time series and blue the synthetic time series

Equations of model

In our model:

- Water withdrawals depend on the availability of the resources
- The inflows are considered to be 90% of the rainfall in 100 m^2.
- The consumption is lower in the winter and higher (double consumption) in summer.

The process can be modeled by the following equations:

$$\underline{S}_T = \max\,(0, \min(K, \underline{S}_{T-1} + \underline{x}_T - \underline{R}_T)$$

$$\underline{R}_T = max(0, min\,(aR, \underline{S}_{T-1})$$

Where:

T : time

S_T : stock in the reservoir

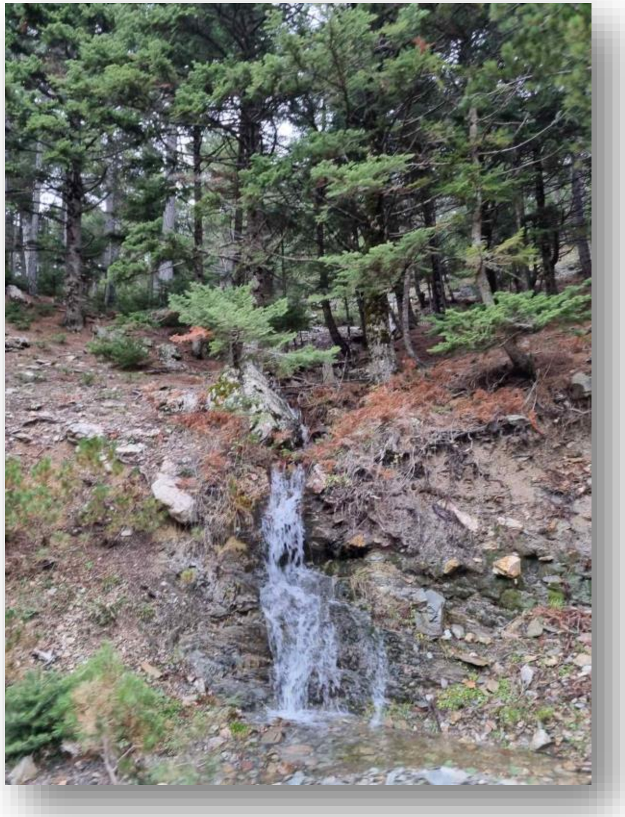
X_T : inflow

R_T : considered consumption

R : standard consumption depended by a

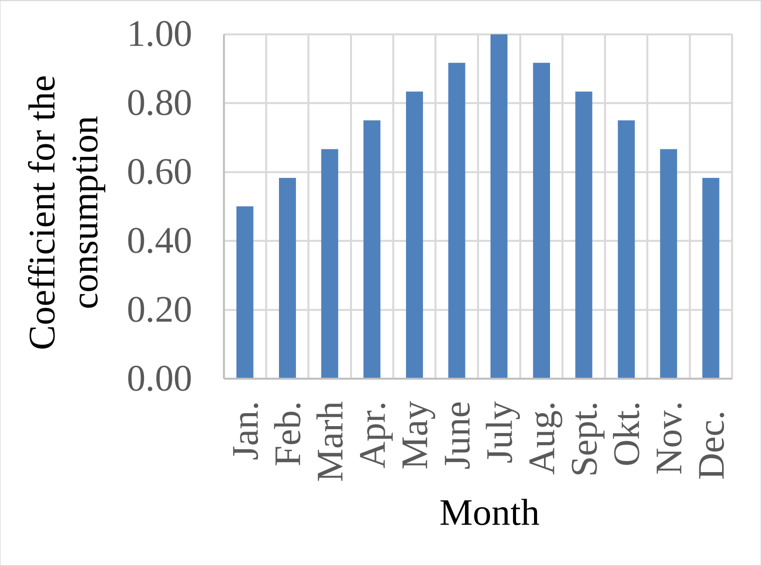
a : a coefficient determining the withdrawal for each month

K : storage capacity

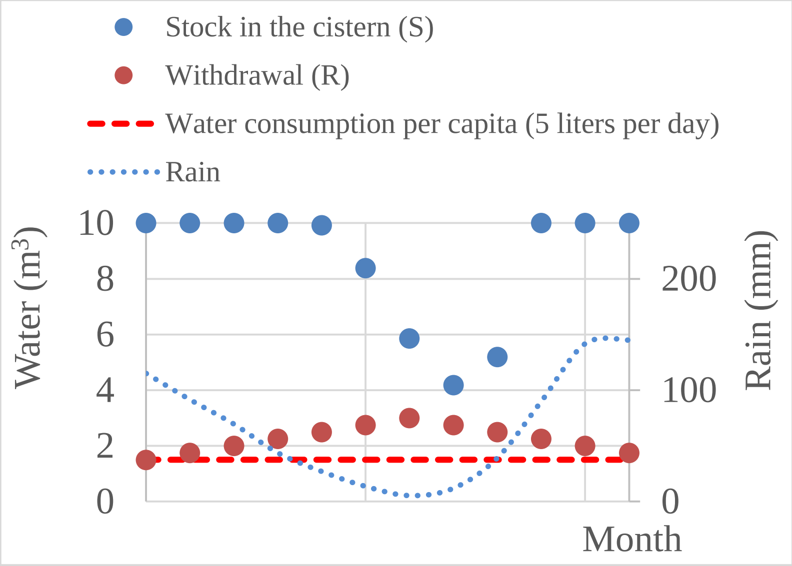


Small stream in the Taygetos mountain

Function of the cistern



Coefficient for the consumption of each month



The function of the cistern according the average inflows

- The coefficient for the consumption is at a peak in July and it is equal to 1.
- The minimum limits for survival are 5L/ inhabitant /day.

Simulation of function of cistern

In each diagram the withdrawal (R) changes and the following arise:

- Considering R=3 m^3 the average consumption is 2.2m^3 per month and the system failure is about 1.2%.

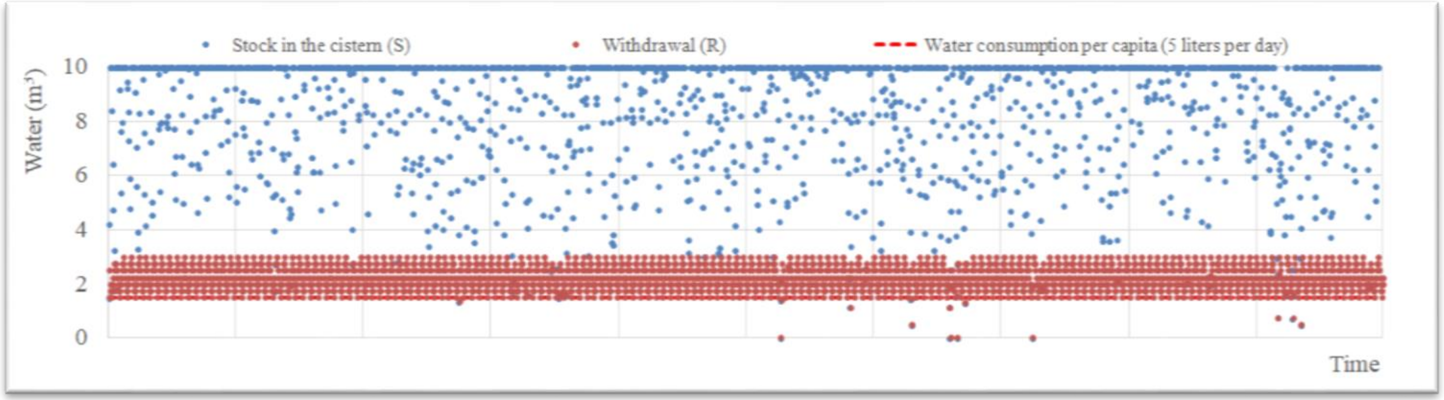


Diagram water-time for R=3 m^3

- Considering R=4 m^3 the average consumption is 2.8m^3 per month and the system failure is about 8%.

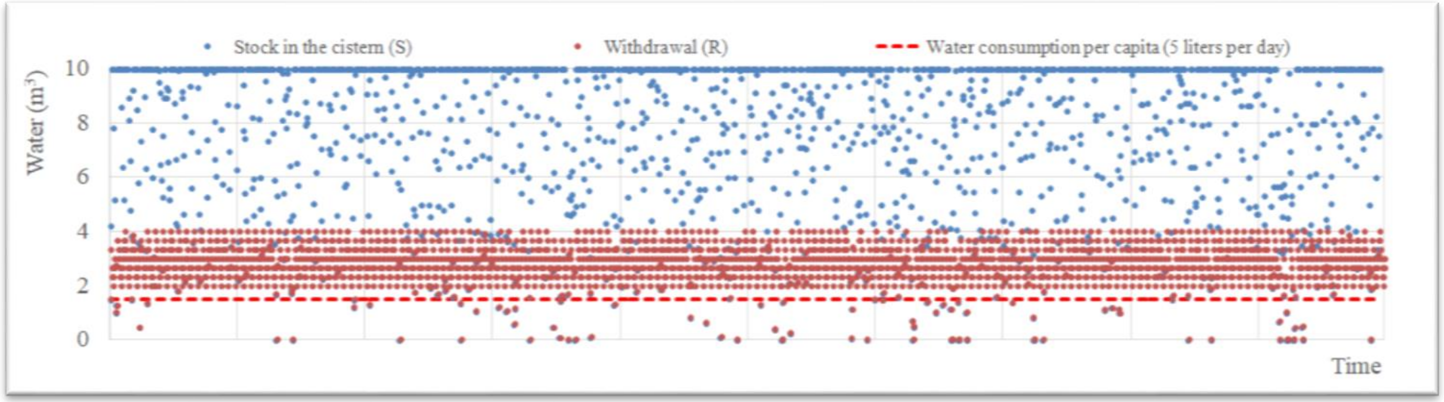


Diagram water-time for R=4 m^3

Simulation of function of cistern

In each diagram the withdrawal (R) changes and the following arise:

- Considering R=5 m^3 the average consumption is 3.2m^3 per month and the system failure is about 17.8%.

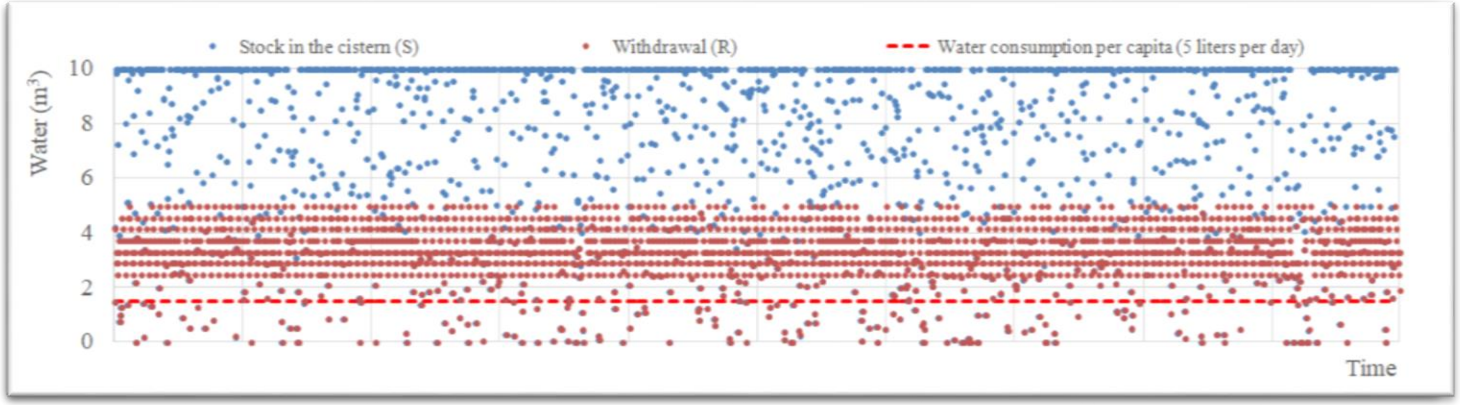


Diagram water-time for R=5 m^3

- Considering R=6 m^3 the average consumption is 3.6m^3 per month and the system failure is about 28%.

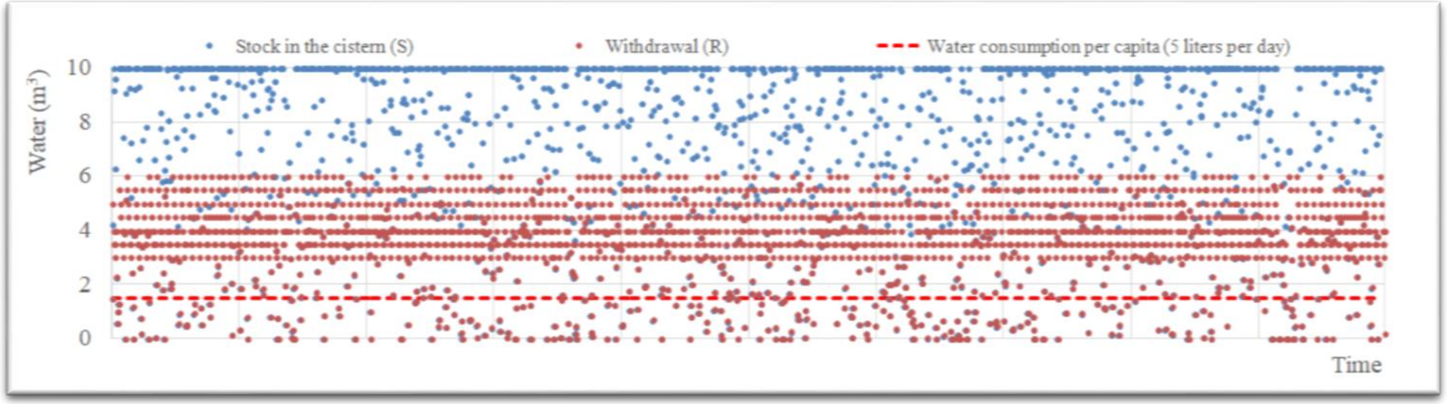


Diagram water-time for R=6 m^3

Conclusions

- Water constitutes the most valuable resource
- To each diagram we conclude that there are many systematic failures which are due to small changes of numbers of consumptions and water withdrawals. So the inhabitants deal with many difficulties and cannot survive.
- The water supply system failure is acceptable at 1% but as resources are limited, one could assume that the system could have a systematic failure.
- The availability of water resources is extremely limited. As a result, the local wars for water begin.
- However, this fact forced inhabitants to adopt a ‘fighting’ culture and they were the first population to enter to the Greek Revolution of 1821 [11-12].
- With the restoration of cisterns, there is drinking water.
- According to the model, after its restoration, a cistern can provide 50 L of drinking water per day minimum for a family of 10 people. In this way, each family that earns about 4000€ every year avoids having to buy bottled water.

References

1. Meteo,Climatic Data https://www.meteo.gr/ClimaticData.cfm
2. Sargentis, G.-F.; Defteraios, P.; Lagaros, N.D.; Mamassis, N. Values and Costs in History: A Case Study on Estimating the Cost of Hadrianic Aqueduct's Construction. World 2022, 3, 260-286. https://doi.org/10.3390/world3020014
3. Sargentis, G.-F.; Siamparina, P.; Sakki, G.-K.; Efstratiadis, A.;Chiotinis, M.; Koutsoyiannis, D. Agricultural Land or Photovoltaic Parks? The Water–Energy–Food Nexus and Land Development Perspectives in the Thessaly Plain, Greece. Sustainability 2021, 13, 8935. https://doi.org/10.3390/su13168935
4. Sargentis, G.-F.; Dimitriadis, P.; Ioannidis, R.; Iliopoulou, T.; Frangedaki, E.; Koutsoyiannis, D. Optimal utilization of water resources for local communities in mainland Greece (case study of Karyes, Peloponnese), Procedia Manufacturing, Volume 44, 2020, Pages 253-260, ISSN 2351-9789, https://doi.org/10.1016/j.promfg.2020.02.229.
5. Sargentis, G.-F.; Iliopoulou, T.; Dimitriadis, P.; Mamassis, N.; Koutsoyiannis, D. Stratification: An Entropic View of Society's Structure. World 2021, 2, 153-174. https://doi.org/10.3390/world2020011
6. Antonakos A. Specialist Hydrogeologist, Poly Potami Study, 19/10/2017
7. Participatory project Under the Landscape, Boulouki 2021, available in: https://www.youtube.com/watch?v=hSp40FHf8Hw&t=3s
8. Koutsoyiannis, D. A generalized mathematical framework for stochastic simulation and forecast of hydrologic time series, Water Resour. Res., 36(6), 1519– 1533, 2000. doi:10.1029/2000WR900044.
9. Koutsoyiannis, D.; Dimitriadis, P. Towards Generic Simulation for Demanding Stochastic Processes. Sci 2021, 3, 34. https://doi.org/10.3390/sci3030034
10. Siganou A., Nikolinakou M., Markantonis D., Moraiti K., Sargentis G.-F. , Iliopoulou T., Dimitriadis P., Chiotinis M., Mamassis N. and Koutsoyiannis D. Stochastic simulation of hydrological timeseries for data scarce regions - Case study at the Municipality of Western Mani
11. Basilatos G. N, The towers of Mani, date of release: November 2001.
12. Koutsilieri A., The history of Mani, published by Papadimas 1996
13. Markantonis D., Siganou A., Moraiti K., Nikolinakou M., Sargentis G.-F. , Dimitriadis P., Chiotinis M., Iliopoulou T., Mamassis N. and Koutsoyiannis D. ,Determining optimal scale of water infrastructure considering economical aspects with stochastic evaluation – Case study at the Municipality of Western Mani
14. Moraiti K., Markantonis D., Nikolinakou M., Siganou A., Sargentis G.-F. , Iliopoulou T., Dimitriadis P., Meletopoulos I.-T., Mamassis N. and Koutsoyiannis D., Optimizing water infrastructure solutions for small-scale distributed settlements – A case study for the Municipality of Western Mani
15. Sargentis, G.-F.; Iliopoulou, T.; Sigourou, S.; Dimitriadis, P.; Koutsoyiannis, D. Evolution of Clustering Quantified by a Stochastic Method—Case Studies on Natural and Human Social Structures. Sustainability 2020, 12, 7972. https://doi.org/10.3390/su12197972

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