European Geosciences Union

National Technical University of Athens
School of Civil Engineering

Determining optimal scale of water infrastructure considering economical aspects with stochastic evaluation

Case study: Municipality of Western Mani

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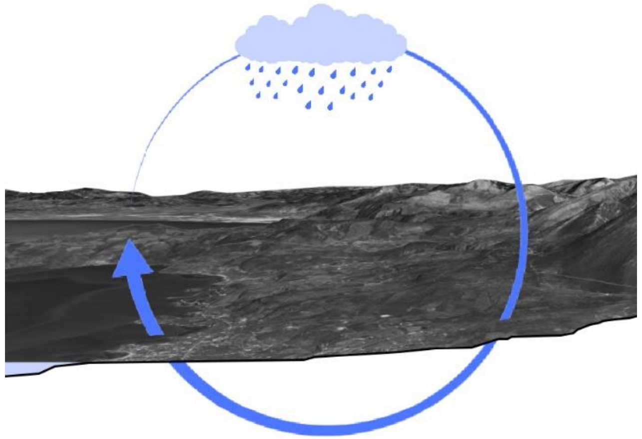
Introduction

- 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.

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

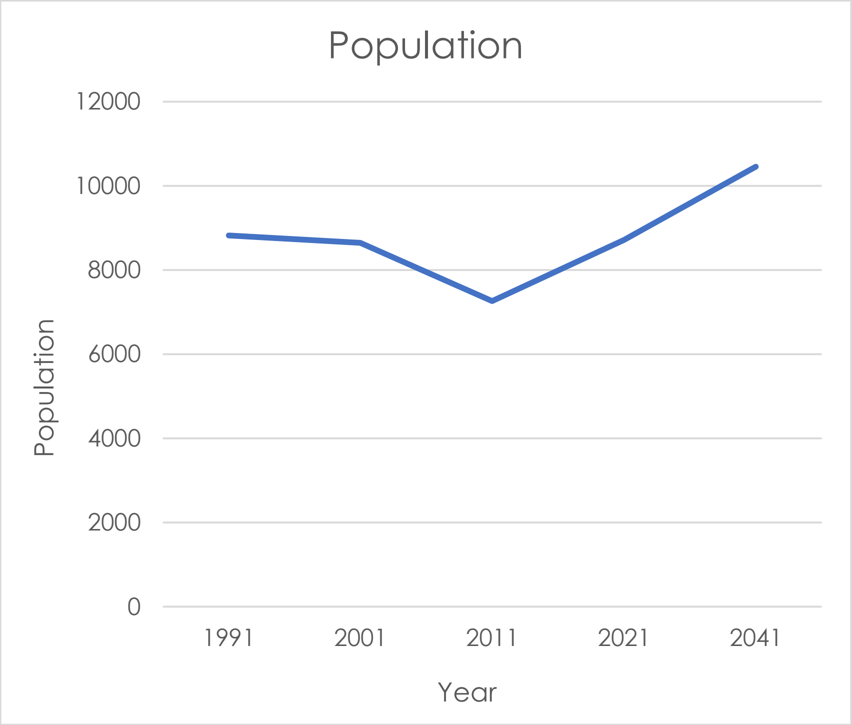
Source: https://www.vecteezy.com/vector-art/2292777-greece-detailed-map-with-states



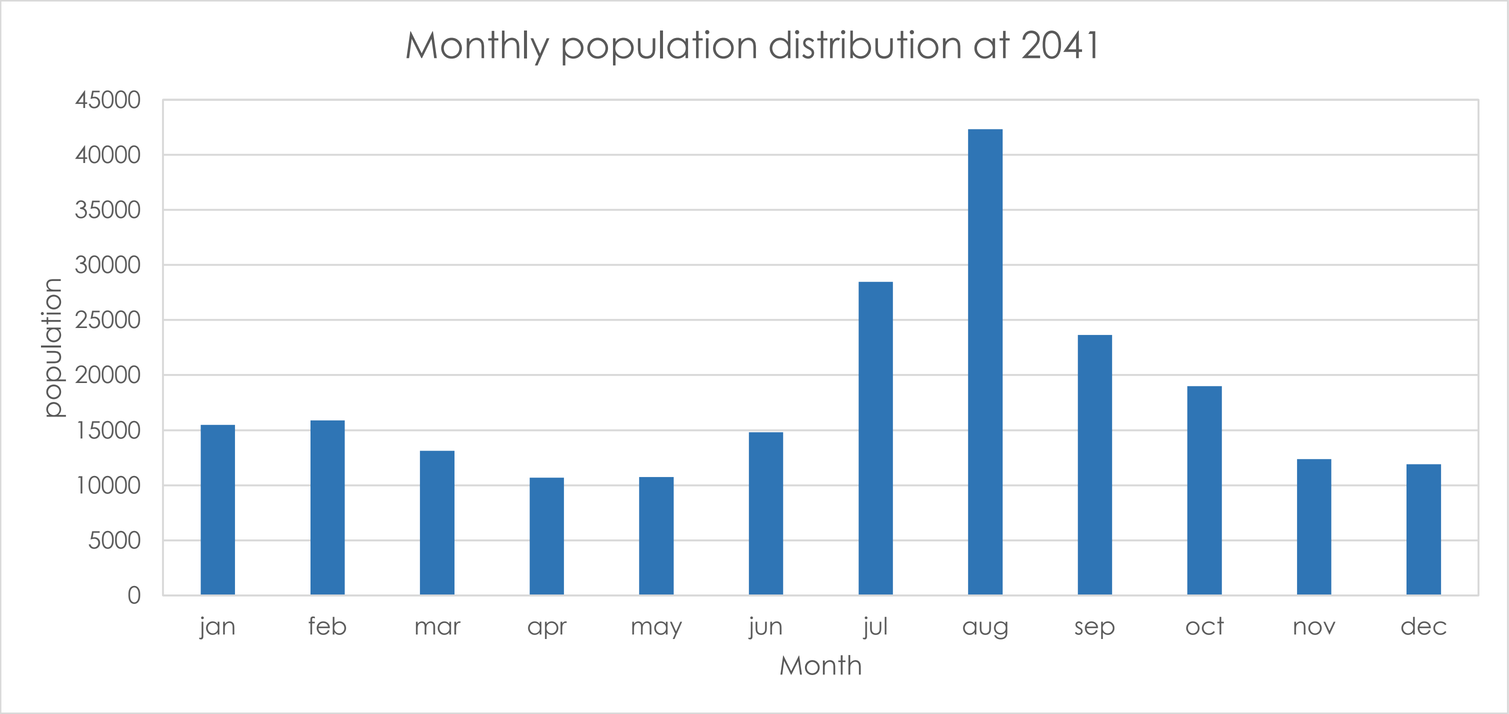
The water cycle

Population / Tourism

- According to demographical data [6] , West Mani's population decreased from the year 2001 to the year 2011. However, it is estimated that an increase will take place in the next decades.
- Taking that into consideration, in order to hypothesize the future number of inhabitants in 20 years, we design our infrastructures to accommodate a 20% population increase.
- In the past few years, the meteoric rise of the activity of tourism has also been observed during the summer months.



Water consumption



- Lack of data throughout the past few years. In particular, the only data that have been found refer to the year 2019.
- Most of the data are available only on an annual basis → impossible to use them reliably
- Estimated aggregate water consumption in our study area is about 300 L / d / inhabitant.

Methodology

- 3 different solutions have been studied.
- The costs of each individual solution have been determined.
- The cost was determined with the assumption of 6% capital recovery rate.
- For Greece, as well as for other randomly selected countries, a stochastic process has been used to examine the average price of water considering variable interest rates.

Solutions

- Dam
- Water ponds
- Desalination

Desalination Plant, Pafos, Cyprus [7]

Dam, Ikaria, Greece [8]

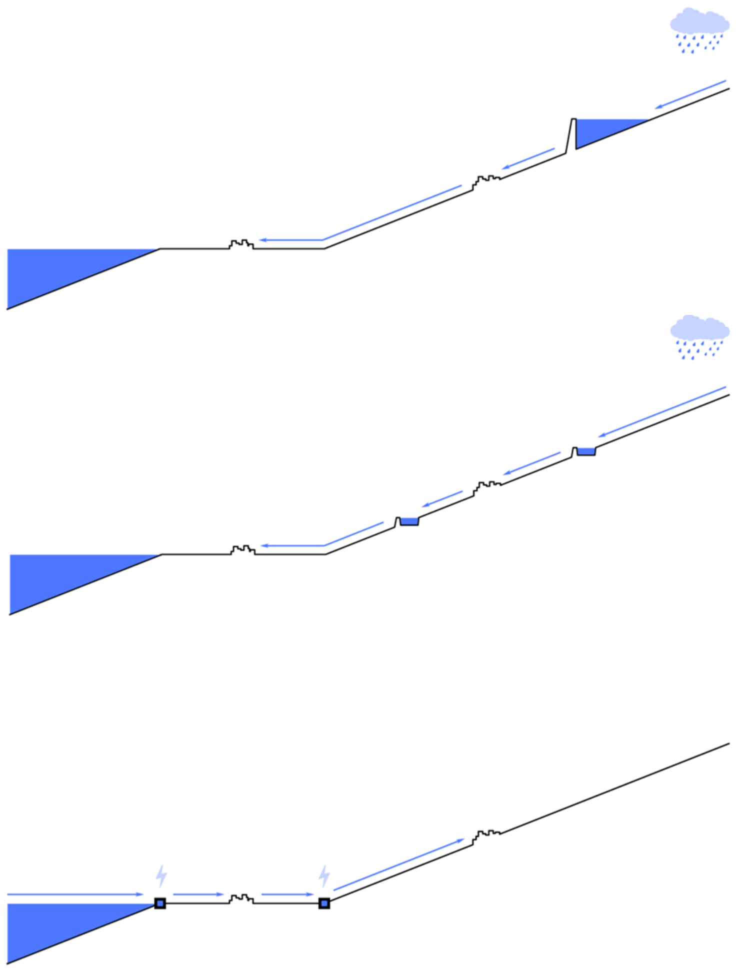
Water pond, Chania, Greece [8]

Solutions – Cross Section

Dam: Nedontas river
- An appropriate position for a dam has been chosen, such that the catchment area is adequate to service the needs of our area.
- The water is stored for up to a few years and then transported via pipe when needed to our area. The whole system is gravity operated.

Water ponds: local streams
- Water is captured at appropriate positions from local streams.
- It is then transported via pipe to a number o water ponds where it is stored for up to a few months until its use. The whole system is gravity operated.

Desalination: sea
- Sea water is desalinated via reverse osmosis in several coastal desalination plants.
- Afterwards it is pumped uphill to the settlements where it is stored for up to a few hours before its consumption.



Solutions - Top view

Nedontas Dam

Small diameter pipes: 12.6 km
Large diameter pipes: 42.0 km

Water ponds

Small diameter pipes: 21.7 km
Large diameter pipes: 17.1 km

Desalination

Small diameter pipes: 43.7 km
Large diameter pipes: 00.0 km

Components of economic calculations

Dam (construction period: 4 years)

- Dam construction [8] (lifespan 50 years)
- Pipe network construction (lifespan 50 years)
- Dam maintenance [9]

Water ponds (construction period: 2 years)

- Ponds construction [10] (lifespan 50 years)
- Pipe network construction (lifespan 50 years)

Desalination (construction period: 1 year)

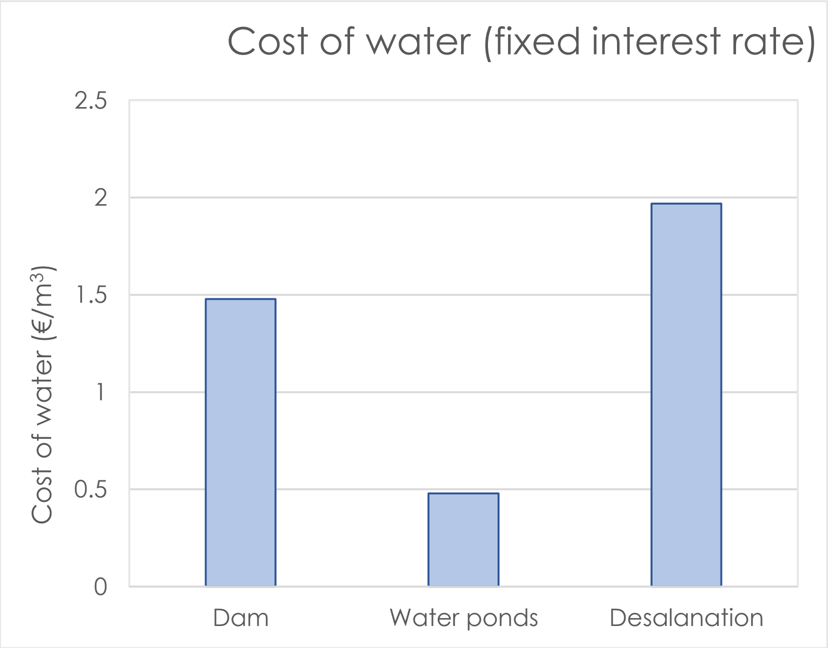
- Desalination plant construction and equipment [11] (lifespan 25 years)
- Desalination plant maintenance [12]
- Pipe network (lifespan 50 years)
- Pumping equipment (lifespan 25 years)
- Electricity for desalination [13] (electricity cost: 0.15 €/kwh)
- Electricity for pumping (electricity cost: 0.15 €/kwh)

Calculaltion of cost with fixed interest rate

- Assumption: 6% capital recovery rate
- The cost of water is calculated [14] for the 3 different solutions

Observation:

- The Water Ponds are clearly the preferred solution in terms of cost
- In addition, when considering other factors such as their environmental impact, water ponds remain the preferred solution [15]



Stochastic modeling methodology

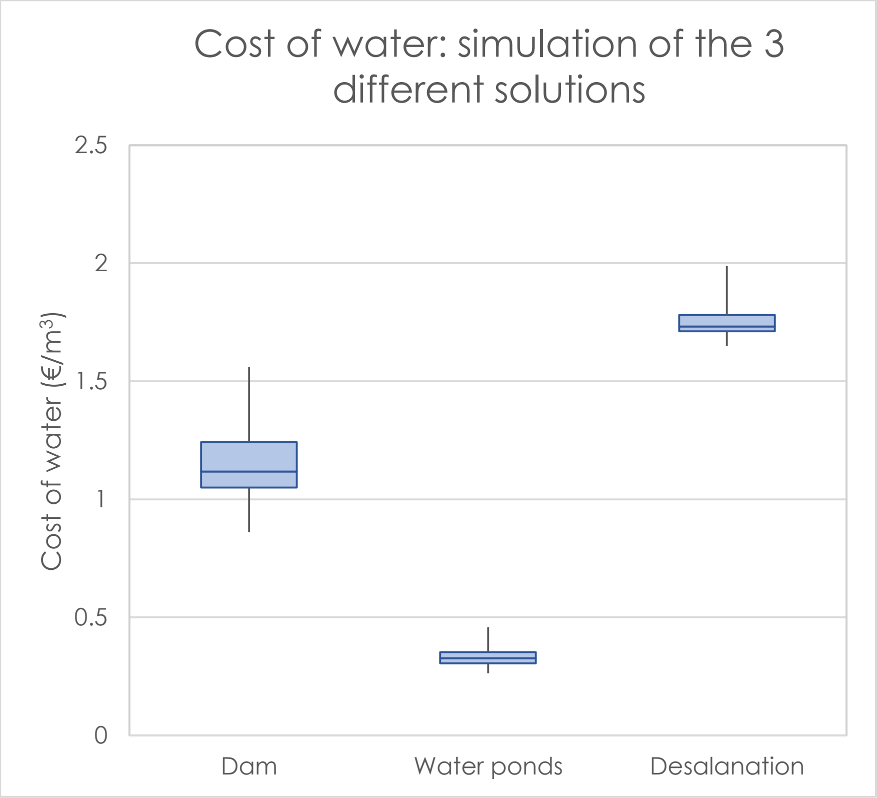
- Data: Real interest rates [14] of selected countries
- The AR(1) Markov process is used [15].
- Multiple unique timeseries of interest rates are generated (50 years each).
- The cost of water for each individual timeseries is calculated.
- The results are presented as a distribution of probability.

Stochastic simulation: 3 different solutions

- The 1st series of simulations are conducted to determine the cost of water for each of the 3 solutions.
- Data : Real interest rates of Greece [18]

Observations

- The water ponds remain the preferred solution even in the most extreme cases.
- The costs of the Dam presents comparatively high variance. This can be explained by the fact that this solution is very capital heavy, therefore is the one most exposed to the variability of the interest rate timeseries.

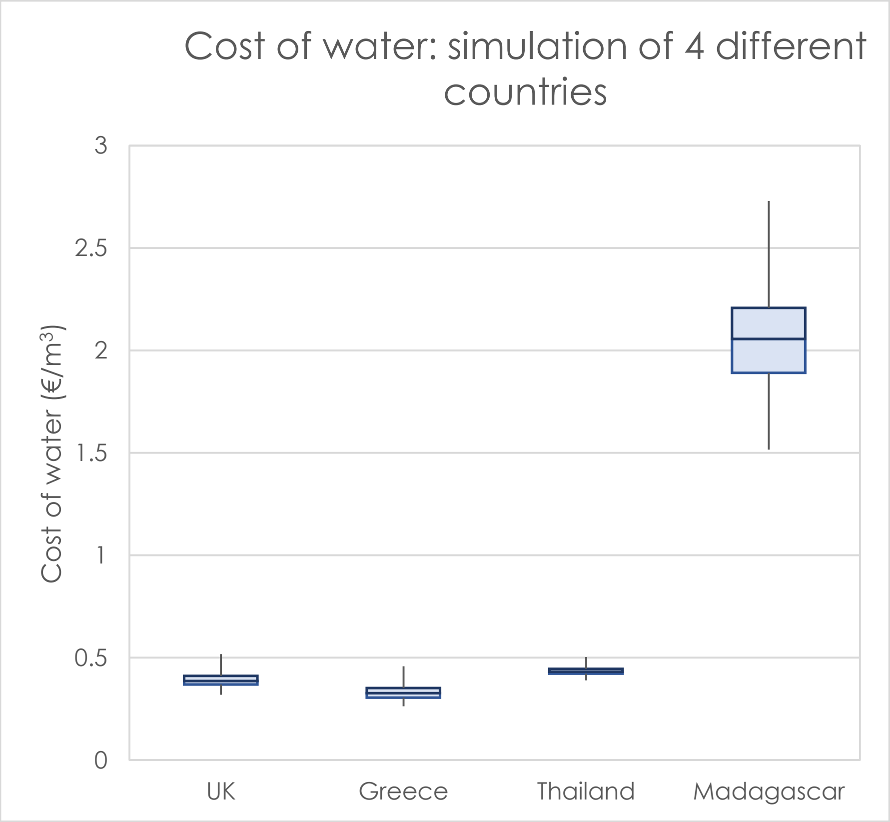


Stochastic simulation: 4 different countries

- The 2nd series of simulations are conducted to determine the cost of water in the case of the Water ponds. However, the simulations use data from 4 different countries.
- Data : Real interest rates of United Kingdom [19], Greece [18], Thailand [20], Madagascar [21]

Observations

- The results differ from country to country.
- Madagascar in particular stands as an outlier. When conducting such simulations, It is appropriate to use data from countries in similar stages of economic development.



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