Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 44 (2020) 253–260

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

1st International Conference on Optimization-Driven Architectural Design (OPTARCH 2019)

Optimal utilization of water resources for local communities in mainland Greece (case study of Karyes, Peloponnese)

G.-Fivos Sargentis[a]*, Panayiotis Dimitriadis[a], Romanos Ioannidis[a], Theano Iliopoulou[a], Evangelia Frangedaki[b] and Demetris Koutsoyiannis[a]

[a]*School of Civil Engineering, Laboratory of Hydrology and Water Resources Development, National Technical University of Athens, Heroon Polytechneiou 9, 157 80 Zographou, Greece*

[b]*School of Architecture, National Technical University of Athens, Patission 42, 106 82 Athens, Greece*

Abstract

Water is the basis of our civilization and the development of society is intertwined with the exploitation of water resources in various scales, from a well dug to irrigate a garden, to a large dam providing water and energy for a large area. However, for remote mountainous areas, intermittent natural water resources and high seasonal demand the above tasks become challenging. Here we discuss various alternative management options and appropriate solutions on how to exploit water resources meeting the above restrictions under limited infrastructure budgets. As a case study we examine the area of Karyes in Peloponnese that meets the above criteria, exploring various solutions to satisfy the water demand.

*Keywords:*water development; small scale water infrastructures; optimization of water infrastructures; Greece mainland water supply system

* Corresponding author. Tel.: +306973029012.
E-mail address: fivos@itia.ntua.gr

2351-9789
10.1016/j.promfg.2020.02.229

1. Introduction

1.1. Water in mainland of Greece

Greece is characterized by a very long coastline of 14 800 km. However, there is a part of the mainland which is developed in mountainous terrain. Productive activities of this area are agriculture, livestock and tourism.

Greece has an area of 13 205 000 ha of which 4 415 000 ha are at altitudes greater than 500 m; thus mountainous areas constitute about 35% of the country see Fig. 1a.

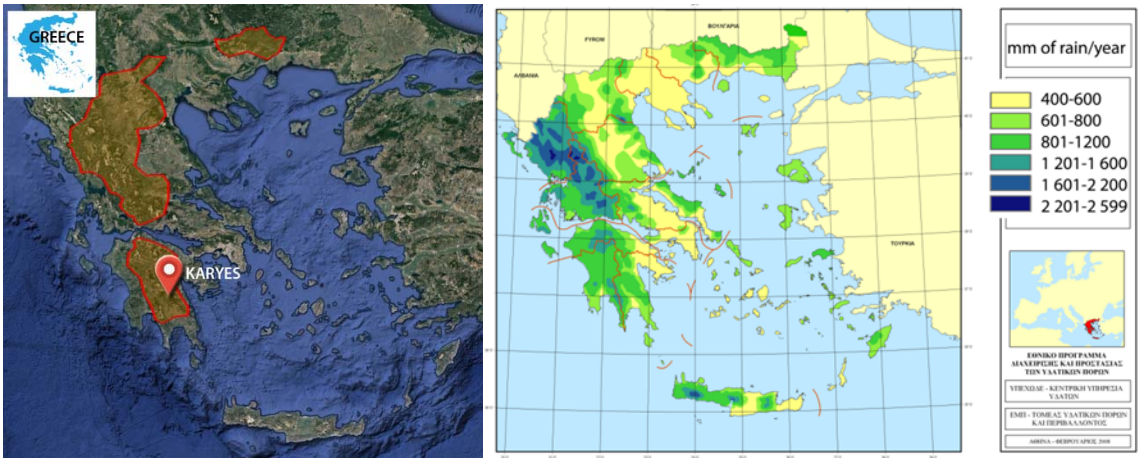

Fig. 1. (a) Mainland of Greece; (b) Rainfall in Greece [1].

The mountainous part of mainland of Greece has abundant water resources Fig. 1b and have thus served water transfer projects to supply dry areas, such as the greater area of the capital Athens. On the other hand, occasionally even these water rich areas suffer from lack of water to serve increased demands [2, 3, 4, 5].

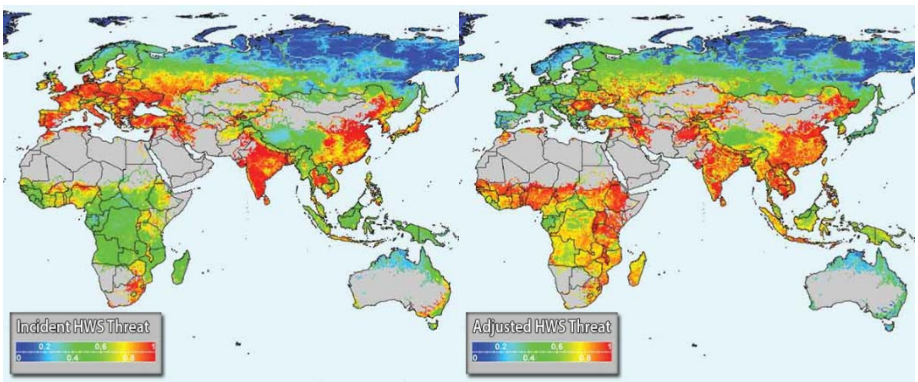

Fig. 2. World distribution of human water security (HWS) threat: (a) as appears naturally and (b) after accountingfor water technology benefits (source: Vörösmarty et al., 2010, as available for download in www.riverthreat.net/data.html).

Human societies need infrastructure to exploit water resources, not only abundance of water.For example, as seen in Fig. 2, in central Africa where there is natural abundance of water, human needs for water are not served because of lack of water infrastructures. Similar problems can be seen in the mainland of Greece which was not the focus of the country’s development.

1.2. Historic elements of water management in mainland of Greece

The villages in the mainland of Greece had been developed either around a spring that could supply homes (rarely), or close to a river. Fifty years ago, drinking water was transported from the springs to the house on foot, in jars, by women Fig. 3a, 3b. The only available energy, human energy, had to be properly channeled so mountaineers could distribute it to rural labor, livestock and water transportation Fig. 3c.

Fig. 3. Historical photos from Greek villages(a) Spring in the center of village [6]; (b)Women with jars [7]; (c) Rural labor [8].

Atypical family of this period had (6-8 persons)needed 10-20 liters per day of drinking water. This water should come (in average) from about 1 km transferred by the women. Low quality water was coming from open pipes for dishwashing and other functions.

The duty of water transfer was mainly assigned to women, meaning that they walked loaded 0.5-1h (if they needed to go twice a day) consuming 4kcal/min[9,10,11,12] i.e. 100-200 kcal per day for this activity when overall consuming 1800-2400kcal per day [13](~850kWh per year). Thus, the energy for drinking water was 50-100 kWh per year which means 5-10% of the total energy consumption of the women. As they carried this water for their families (6-8 people), the total energy per person was 5-15kWh per year which corresponds to 0.5-1% of total consuming energy for drinking water.

Modern Greeks use ~30.000 kWh per year [14]. The energy cost of 1 m^3 of drinking water in Athens is estimated as 0.1kWh/m^3 [15] and thus a modern Athenian who needs 100-120 m^3/year will consume 10-12kWh per year which corresponds to0.03% of total consuming energy for drinking water.

Now in mainland Greece proper water infrastructures for water supply have been developed and a modern life style of the developed world has been norm. Thus, modern mountaineers consume the same volume of water as the people in Athens 100-120 m^3/year but with less energy as there are richer water resources and the aqueducts are smaller. But mountaineers also use the water supply system to irrigate their gardens. Assuming that a small modern family of 4 persons irrigates a small garden of 0.1-0.2 ha, every year it will needabout200-400 m^3[16], [17].This shows that a modern mountaineer needs almost the twice as much water as an inhabitant of a city in summer period. In addition, in the last 20 years there has been a great tourist development in Greek mainland and the population is almost doubled during the tourist season.

In 1950 mountaineers were using 0.72 m^3/year for drinking water, but they also had lower quality water for other needs. Today in several villages mountaineers use the water from the network (drinking water) for all household needs and including irrigation of their yards. The water from network supports also the tourism. Infrastructures and networks have been built to support the needs of water of the mountainous people, but there are not designed to support the new needs as tourism and irrigation of yards Fig. 4.

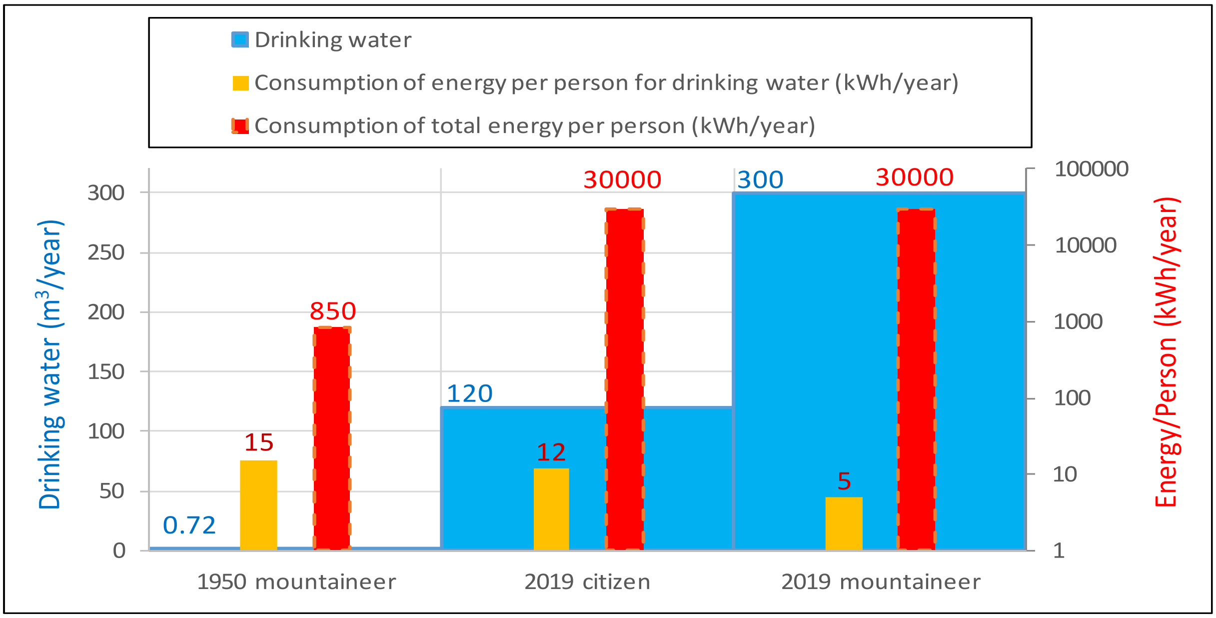

Fig. 4.Consumption of water and energy for water in 1950 and 2019

2. Case study of Karyes Peloponnese

The village Karyes, has three thousand years of history. Karyes are located in mountain Parnon between the cities of Sparta and Tegea, in an altitude of 900 meters. Karyes are connected with the famous sculptures of Caryatides [18].In the last few years there were problems in the water supply system with interruption for few hours for ~10 days in summer.

2.1. The needs

The population of Karyes varies, thus the water needs of the village varies with season Fig. 5. In order to determine the needs for irrigation we assume that the area of the yards and gardens is about 10% of the area of the entire village (20ha), or 2 ha. According to[16] and [17], every hectare needs for irrigation ~25m^3/d and thus the water needs for that are approximately 50m^3/d for the summer period.

People in Karyes are also active in agriculture. There are 2.2 ha near the vilage (irrigated by an existing irrigation tank), 24 ha and 496 ha of cultivated land.

2.2. Drinking water supply system

The water supply system is fed by groundwater from a drill at a rate of 360m^3/d which in August drops to 96m^3/d. A network of springs provides an additional supply and thus in the critical period of summer the Karyes has 350-400m^3/d of high quality water. The main water tank is 300 m^3 at an altitude 1 000 m and feeds two smaller tanks of 150 m^3 at an altitude 950 m Fig.6. Obviously the system is not reliable as needs exceed supplies during summer.

Sakali spring is a water source out of the network in the lowest altitude of Karyes (850m)Fig. 6. The power needed to pump water from Sakali spring (120 m^3/d) to the small tanks (100 m higher) is 1.7kW resulting in an energy cost of 43 kWh per day Fig.7, 8. This additional water supply could support hosting of 500 more visitors in summer.

Water needs with irrigation and supply of ~700 people in summer correspond to 200m^3/year per each of the 300 permanent inhabitants.

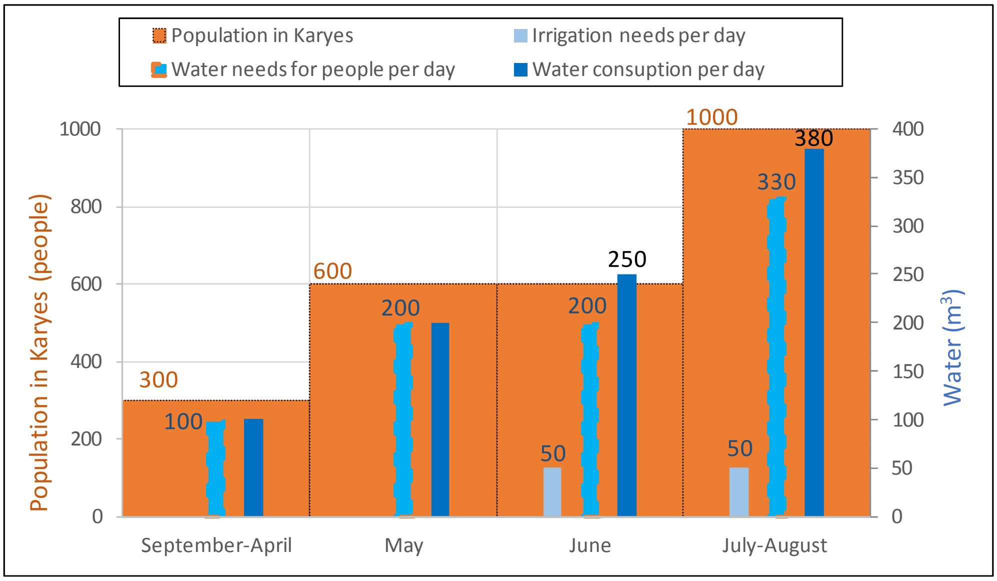

Fig. 5. Variance of the population of Karyes and water needs.

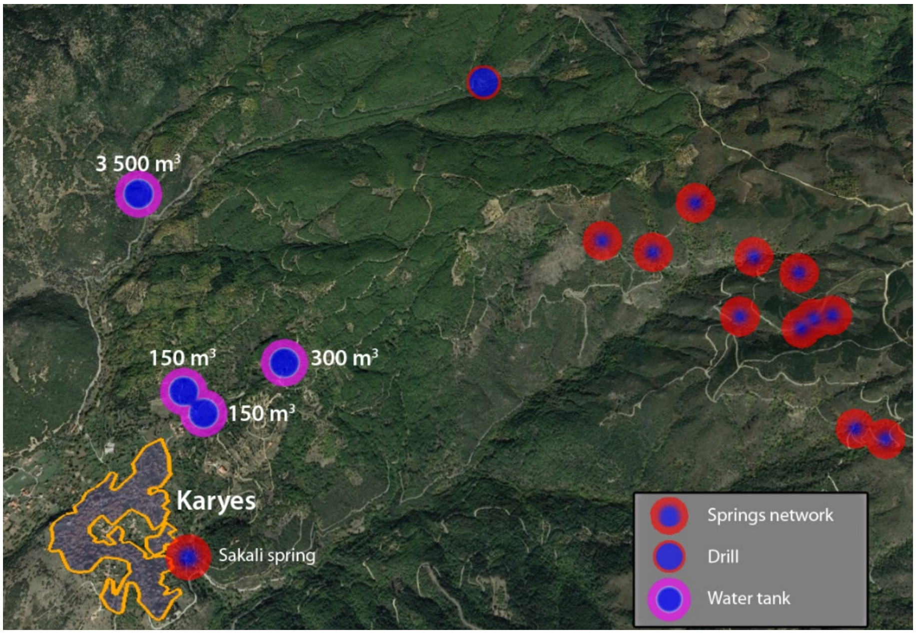

Fig. 6. Water sources of Karyes.

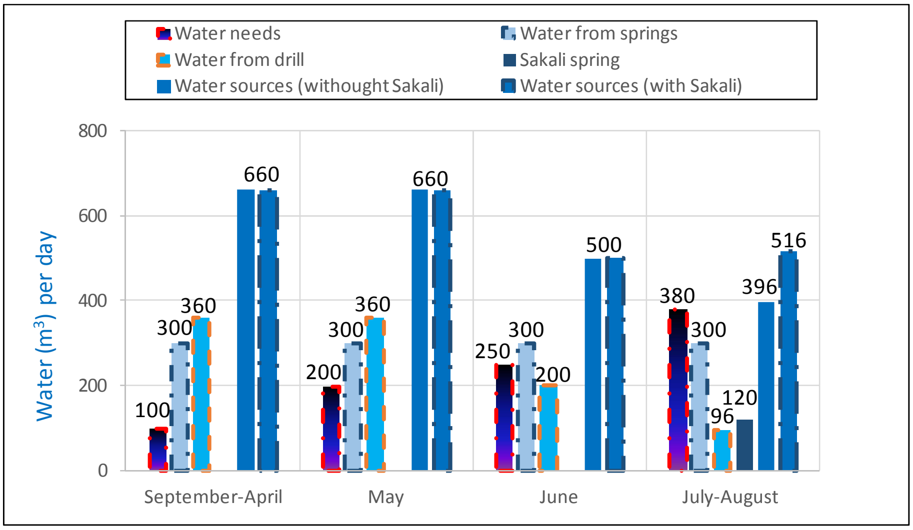

Fig. 7: Needs and water resources within and without Sakali spring.

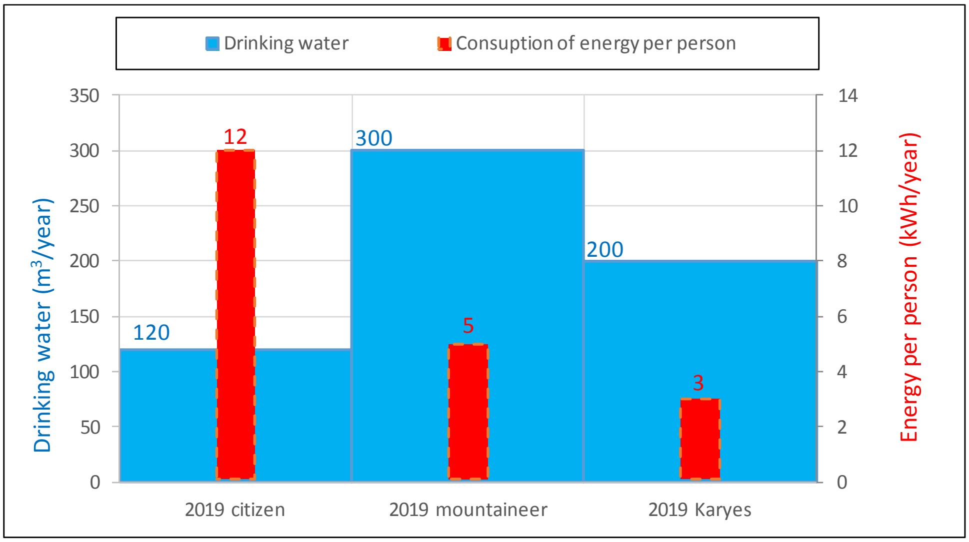

Fig. 8.Energy needs for drinking water with Sakali spring.

2.3. Irrigation system

In Karyes an existing reservoir of 3 500 m^3 irrigates the area of 2.2 ha and there is a need to irrigate500 hamore; this would require a new reservoir with storage capacity of about 1 000 000 m^3.

Even if the anaglyph is suitable for the construction of a small dam, the geomorphology and geology do not favour a new dam, because of the karstic subsurface. In addition, a major obstacle for the solution of such a small dam is the fact that it would fill by river sediments in very short time. Thus, the construction of an out-of-river reservoir, possibly in the area of cultivated land, is preferred.

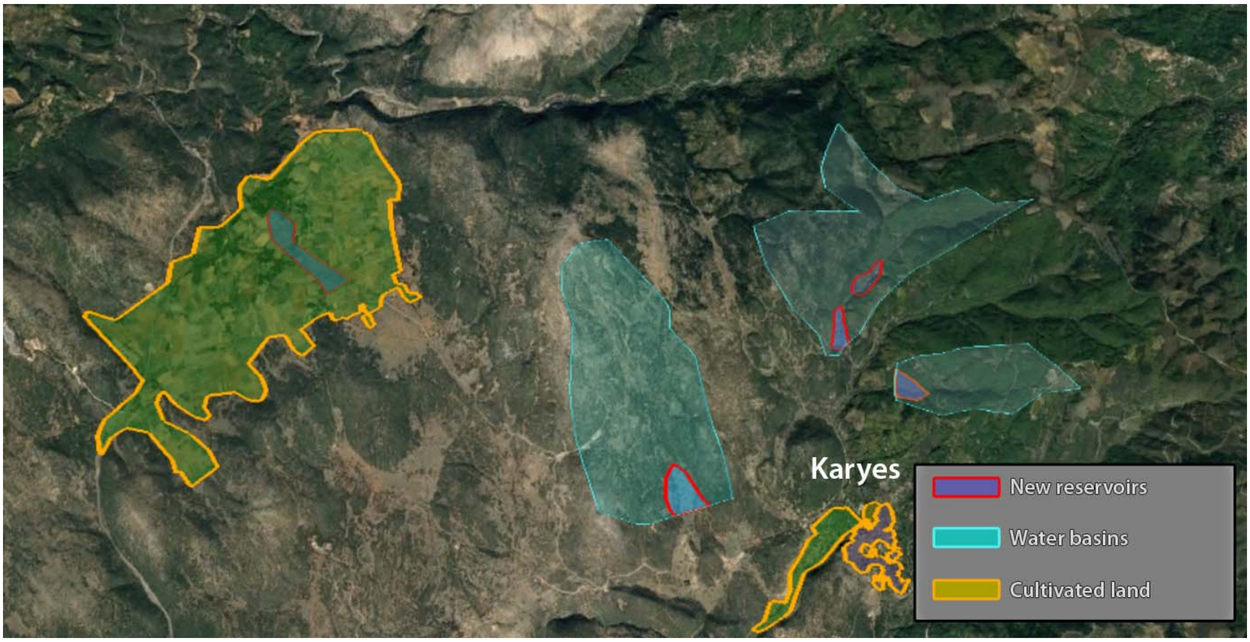

Fig. 9.Possible locations of new reservoirs.

3. Conclusions and criteria of the optimal solution

New needs (tourism, irrigation of yards and gardens) and new life style challenge the traditional water system of mountainous areas requiring proper new infrastructure to adapt to modern style. Some of the new solutions require additional energy supply (pumping groundwater or spring-water from lower elevations to tanks). Another solution is the construction of small reservoirs at higher elevations.

To tackle present issues related to water shortage mostly during the summer period as well as to support future needs relating to population increase, as well as agricultural and livestock water needs, we examine possible scenarios for the expansion of the existing system. Here, we explore an attractive solution for the construction of water-ponds in various candidate locations. We seek the optimal siting of the water-pond according to geomorphological, hydrological and techno-socio-economical and environmental criteria. This task entails the following studies:

1. Geomorphological survey based on geological properties (e.g. soil type, permeability) and topographical features (e.g. identification of sites suitable for reservoirs);
2. Hydrological analysis of the selected areas based on collection of hydrometeorological data and employing hydrological-balance models such as the lumped conceptual model ZYGOS (http://hydrognomon.org/);
3. Study on cultivation land and selection of proper crops;
4. Hydraulic design of the water-pond infrastructure including dimensioning of the pond, water-supply system, embankments, and drainage pipes;
5. Cost analysis of alternatives;
6. Analyses on feasibility of the construction (also related to their simplicity), safety andbackup solutions in case of failure;
7. Selection of optimal solution based on techno-socio-economical and environmental criteria considering future sustainability.

Acknowledgments

This research has been supported by the OptArch project: "Optimization Driven Architectural Design of Structures" (No: 689983) belonging to the Marie Skłodowska-Curie Actions (MSCA) Research and Innovation Staff Exchange (RISE) H2020-MSCA-RISE-2015.

References

[1] D. Koutsoyiannis, A. Andreadakis, R. Mavrodimou, A. Christofides, N. Mamassis, A. Efstratiadis, A. Koukouvinos, G. Karavokiros, S. Kozanis, D. Mamais, and K. Noutsopoulos, National Programme for the Management and Protection of Water Resources, Support on the compilation of the national programme for water resources management and preservation, doi:10.13140/RG.2.2.25384.62727, Department of Water Resources and Environmental Engineering – National Technical University of Athens, Athens,, (2008) 748.

[2] Ethnos newspaper, "Η λειψυδρία απειλεί την Ήπειρο - Εκκλήσεις για περιορισμό της κατανάλωσης νερού", (Water scarcity threatens Epirus - Appeals to limit water consumption) 17.08.2019, (cited 5 October 2019), available:https://www.ethnos.gr/ellada/55841_i-leipsydria-apeilei-tin-ipeiro-ekkliseis-gia-periorismo-tis-katanalosis-neroy.

[3] Epirus Post, 18 Αυγ 2019, (cited 2 October 2019), available: https://www.epiruspost.gr/index.php?option=com_content&view=article&id=69117:elleipsi-neroy-kai-sta-xoria-tou-souliou&catid=89&Itemid=227.

[4] In news,17 Αυγ 2019, (cited 3 October 2019), available:https://www.in.gr/2019/08/17/greece/leipsydria-apeilei-tin-ipeiro-oi-ekkliseis-ton-arxon/.

[5] Ecozen, media press,17 Αυγούστου 2019, (cited 3 October 2019), available:https://ecozen.gr/2019/08/ipeiros-kathimerines-metafores-neroy-exaitias-tis-leipsydrias/.

[6] Thesprotia News, 17 Ιαν 2010, (cited 2 October 2019), available: http://thesprotia-news.blogspot.com/2010/01/frederic-boissonnas-1858-1946.html.

[7] Aspromavro, (cited 3 October 2019), available:http://www.aspromavro.net/2015/07/blog-post_26.html.

[8] 17 Ιαν 2010, (cited 7 October 2019), available: http://thesprotia-news.blogspot.com/2010/01/frederic-boissonnas-1858-1946.html.

[9] Public Health Nutrition, A compilation of energy costs of physical activities, (2005) (7A):1153-83 DOI: 10.1079/PHN2005802, (cited 5 October 2019).

[10] https://www.researchgate.net/publication/324092004_Energy_Consumption_by_Construction_Workers_for_On-Site_Activities.

[11] Physics Libretexts, (cited 3 October 2019)

[12] M.Vaz, N. Karaolis, A. Draper, Prakash Shetty, A compilation of energy costs of physical activities, Public Health Nutrition: 8(7A), 1153–118, DOI: 10.1079/PHN2005802, (2005).

[13] D. Dufour & B. Piperata, Energy expenditure among farmers in developing countries: What do we know? American journal of human biology: the official journal of the Human Biology Council, 249-58. 10.1002/ajhb.20764,20 (2008), available: https://www.researchgate.net/publication/5504649_Energy_expenditure_among_farmers_in_developing_countries_What_do_we_know.

[14] BP, Statistical review of world energy, (cited 25 September 2019), available:https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf.

[15] G.-F.Sargentis,.,R. Ioannidis,, G. Karakatsanis, S. Sigourou, N.D. Lagaros, D. Koutsoyiannis, The Development of the Athens Water Supply System and Inferences for Optimizing the Scale of Water Infrastructures, Sustainability 11, 2657 (2019).

[16] Joint Ministerial Decision, 16/6631/89: Determination of thresholds and ceilings for the rational use of water inirrigation, (cited 12 October 2019), available: http://new.ims.forth.gr/water/sites/new.ims.forth.gr.water/files/documents/laws/1989A.pdf.

[17] Dikaiologitika News,24 May 2017, (cited 8 September 2019), available:https://www.dikaiologitika.gr/eidhseis/oikonomia/157927/bainei-xaratsi-potismatos-sta-xorafia-kai-prasino-telos-stous-logariasmoys-neroy.

[18] Karyes Lakonias, (cited 2 October 2019), available: http://www.karyes.gr/index_en.html.