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Economic and Sustainable Development in Eastern Crete Through the Lithines Irrigation Dam

Georgios J. Tsikalakis[1]*, *Nikolaos J.* Makrinakis[2], *Panagiotis J.* Bourbourakis[3], and *Eleftheria D.* Neofotistou[1]

[1]Department of Nutrition and Dietetic Sciences, Hellenic Mediterranean University, 72300, Sitia, Greece

[2]Sitia Municipality, 72300, Sitia, Greece

[3] Department of Hydroelectric Projects, PPC Renewables S.A., Kapodistriou 3 Athens 15343, Greece

Abstract: Eastern Crete faces the greatest deficit of water resources in Crete due to the arid climate and reduced rainfall. Despite the magnitude of the problem, to date no reservoir has been constructed that will change the environmental image of the area while simultaneously changing the opportunities through sustainable development. Instead, water resources are derived from deep wells (55m -475m) with huge energy costs at a time when energy is expensive. The study examines and presents: a) the economic cost of water resources in the area due to the drilling, b) the study for the Lithines reservoir, with a total volume of 9.5 million cubic meters of water and the expected economic profit that will accrue through hydroelectric production of water intended for irrigation, c) The quality of water that is currently lost to the sea, d) the sustainable development deficit faced by the region in relation to the neighbouring regions of the municipalities of Ierapetra and Agios Nikolaos and e) The forecast of economic development in the region in agriculture and tourism sector through the increase of water resources.

Introduction

In 2005, for the first time, the intention of the then government to build a dam in Eastern Crete became known. It was the construction of the "Lithines Dam" as a means of improving irrigation in the area of the then municipality of Makris Gialos on the borders of the Local Community of Lithines. The project was designed by the Ministry of Agricultural Development and Food within the framework of planning and implementation of the 3rd Community Support Framework and in particular the Directorate of Technical Studies and Constructions (project number 2005 MM081 00003). The project was commissioned to a design company and in November 2005 it was presented to the local community. The total amount for the construction of the dam was €60,500,000.00. As already mentioned, the purpose of its construction was to solve the irrigation problem in the area, which was and is largely supported by agricultural crops, with the most important ones being olive growing and greenhouse crops [1]. The project then went through all the time-consuming bureaucratic procedures for inclusion in the "SHOAP"- Open City Spatial and Residential Organization Plan of Makris Gialos municipality in 2012 (decision number 3241/10-09-2012) and was published in the Government Gazette with number 363/ 26-11-2012.

In November 2014, the project was included in the funding program of the support package with code 081/8/0042 and a new budget of €69,150,000.00 [2]. Six months later the new government did not consider the project part of any program and announced that the project would be considered in the future. Despite the fact that there was a comprehensive Environmental Impact Study until today it has only remained in the plans, at the same time the local community (Municipality of Sitia - agencies and civil organizations) express their anxiety characterizing the project as one of the most basic economic and sustainable development projects for the area that will cover the needs for water supply and irrigation, contributing to the reduction of the cost of cultivation and the development of the tourism sector, which today often faces the problem of water shortage.

Today, at a time when anxiety about climate change is increasing and energy has become more expensive, how will the Lithines dam contribute to the economic and sustainable development of eastern Crete?

Methodology

Because the aim of the work is to prove that the dams as a multi-purpose project with great added value to a local community will methodologically: a) Present the existing use and consumption of water in the area and the estimated reduction in energy costs after the creation of the dam, b) The economic data of the area that show the necessity of increasing water resources, c) The possibility of energy production from the dam through hydroelectric calculations, d) The possibility of using the water for water supply through chemical measurements of the water quality of the "Maroulas" river, e) the financial benefit from flood protection through the presentation of disaster recovery costs made in 2019.

* Corresponding author: gtsikalakis@hmu.gr

To understand the current status and potential impact of the Lithines Dam in 2023, we would need to refer to more recent sources of information from local authorities, environmental agencies, and relevant news outlets.

1 The Lithines dam location

Before referring to the economic activities of the area of economic and sustainable development contributed by the dam, we will make a small description of the geographical location and the reflection on the policy that exists in general not to protect the arid regions from the loss of water to the sea.

The Lithina Dam is concentrated in the Andromylus watershed, between the Libyan Sea downstream and the ridges of Mount Ornos. It is located at the geographical position 26th02' A.M. and 35th04' B.P. The basin has an apioidal shape and a main N-S axis orientation.

The mouth of the basin at the site of the project has an altitude of approximately 60 m. The hydrocrit, running clockwise through it, is defined to the SE from the Etiani Kefali peaks (+715) to the NE with the settlements of Armeni, Papagiannades and Sykia. To the N the peaks Krimiani (+751), Platy Sopata (+929) and Megali Mouri (+1179). To the W the peaks Gypsos (+649), Romanetis (+937) and Salamakos (+326). The eastern and western hydrocrites contribute southward to the site of the proposed dam. The mountain basin consists of two sub-basins:

• The Eastern which is crossed by the Kalyptra river which originates from the settlements of Sykia and Papagiannades and

• The West which is crossed by the r. Vasiliko Perasma which originates from the area of Krya and Dafni.

In terms of altitudes, the Andromylos river basin develops between approximately +60 and +1,179 altitudes.

The drainage basin of the Lithines dam, with a total area of 52 km2 and an average altitude of approximately 460, consists of the two individual basins we mentioned above. The two streams above contribute immediately downstream of Andromyla forming the stream of the same name with a total catchment area of 52.00 km2 at the location of the Lithines dam.

The pelvis rem. Kalyptras grows between altitudes of approximately 130 and 715, while that of the Vasiliko Perasma stream between 130 and 1,160.

The length of the main branch is approximately 11.5 km from the mouth of the basin to the farthest point of the hydrocrit (Vasiliko Perasma stream). The average slope of the main stream is moderate 52 m/km. Transverse slopes are high, more than about 15%. The relatively higher transverse gradients are observed in the northwestern half of the basin (subbasin r. Vassiliko Perasma) [1].

The basin is partly covered with crops and the rest with bushes. From the soil paper an estimated water capacity coefficient (260 mm) was derived taking into account the porosity for the different types of soil materials. These are mainly derived from weathering of shales, limestones, Tertiary, alluvium and peridotites. The location of the Lithines dam is located about 5 km north-east of Makrygialos village 3 km south-west of Lithines village despite the settlement of Azali. The main objective of the construction of the dam is to supply water to the settlements and coastal tourist units, and to irrigate the adjacent agricultural lands [4].

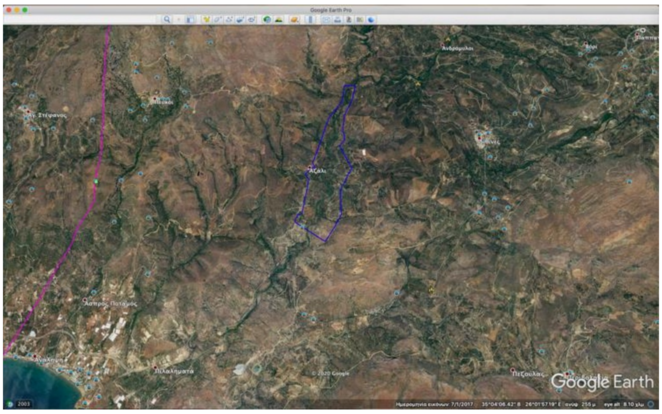

Fig. 1 Map of the area affected by the construction of the dam.

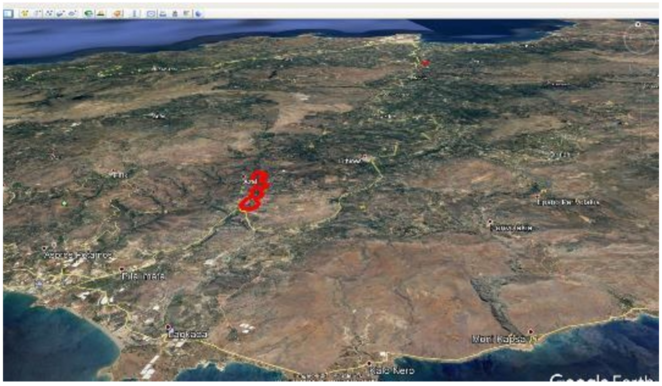

Fig. 2. Map of the area affected by the construction of the dam in relief.

Due to the geophysical environment and the geographical location (SE tip of Europe, east-west direction) of the island of Crete, along with the existence of high mountain ranges, the water management on the island is of crucial importance. A moto like “no drop of water ending up in the sea” should spread be considered as a social issue [5].

The need to manage water resources is at the heart of the global debate. Not only those involved in regional development or the improvement and development of agricultural production but all those who realize that the effects of climate change are a fact. [6] Such discussions are common in Greece and concern not only the implications nationally but also internationally [7]. Moreover, Crete is a place with combined water use, including agricultural, touristic, domestic and industry use.

Can the planned but not built Lithines dam, change these facts through the management of a significant amount of water that is lost to the sea?

Eastern Crete has been facing the problem even more acutely for many years. This does not allow for greater development in an area based on the agricultural economy and tourism. In the context of agricultural crops, olive cultivation is a dominant species with more than 320,000 olive trees [8], while important infrastructure exists in the field of greenhouse cultivation. Tourism is the second most important sector in the area with more than 3,000 main accommodation beds and 3,300 non-main accommodation beds [9]. But the most important thing is that in both of these sectors the region has room for development with one basic condition: greater and more convenient water management!

2 The current use-cost of water in the area of operation of the dam and the estimated cost reduction since its creation

One of the most important problem for water consumption in the region of Crete in general, is the cost of water. Today, water supply and irrigation in the area is done by water wells. The cost of pumping water is extremely high since the water reserves are at depths starting from 50m to 300m [9].

Pumping water from such great depths requires a lot of energy which we get from electricity. The cost of electricity becomes higher in the summer season since the crops in the area (olive production and greenhouses) require more water in the summer months. In addition, the area is highly touristic with the population quadrupling in the tourist season and from 1,661 people to up to 7,500 people (high season) [10].

The monthly energy cost for pumping water in average ranges from €49,500 in the winter season to €120,664 in the summer season [11]. Details for each local community can be seen in table 1.

Table 1. Number of wells per community and average cost winter-summer 2022.

Local community	Number of Drilling	Total average consumption of Electricity in winter/ per month in €	Total average electricity consumption Summer/ per month in €
Apidia	5	8.500	27.000
Lithines	9	15.000	35.064
Pervolakia	4	7.000	11.100
Pefkoi	8	19.000	47.500
Total	26	49.500	120.664

Given that the cost of energy for pumping water in the area for the year 2022 amounted to €876,000, we notice that only from the energy consumed for water the cost is quite high.

Another problem that arises, and unfortunately cannot be easily recorded economically, is the fact that water during the summer season, when tourism is at its peak, is not sufficient. The daily interruptions in the water supply limit the prospect for an even greater increase in tourism investments. Today the area has 50% of the tourist facilities of the Municipality of Sitia main and non-primary accommodations [12] (see table 2).

Table 2. Tourist infrastructures in the entire municipality of Sitia and the city section of Makry Gialos.

Region	Main accommodations	Non-primary accommodations
Sitia Munisipality	6.854	3.300
Analypsi	3.080	875

The cost of water in the area due to the conditions is quite high as in all municipal units of the municipality of Sitia [11].

However, apart from irrigation, and given that the type of agricultural production in the area was mentioned several times, tables 4 and 5 show the number of olive trees that exist and are irrigated at a rate of 65%, as well as the acres of greenhouses that exist in the area. It should be noted that for the greenhouses there is no official registration of the acres in the rural development services of the Ministry of Agricultural Policy or the Municipality of Sitia. The measurement of the greenhouses of the region, was carried out by orthophotography of 92 points, through the open service of the national land register gisk.ktimanet.gr.

Table 3. Area of greenhouse crops in the dam benefit area in acres.

Local community	Number of acres
Apidia	240,949
Lithines	99,220
Pervolakia	3
Pefkoi	106,226
Total	449,441

Table 4. Olive trees in the water use area from the dam.

Local Community	Number of Olive trees
Apidia	50.000
Lithines	160.000
Pervolakia	41.000
Pefkoi	70.000
Total	**321.000**

Having a greater sufficiency of water resources is essential for sustainable agricultural growth, as water is a critical factor in crop production. Doubling the acres of greenhouse crops and increasing the number of olive trees from 321,000 to 500,000 demonstrates how improved water availability can directly contribute to expanding agricultural output [13].

In such cases, effective irrigation techniques play a pivotal role. If the current rate of irrigation can be maintained or even improved, it can further enhance crop yields and plant growth. However, it's important to consider sustainable water management practices to ensure that increased water usage doesn't lead to negative environmental consequences or depletion of water resources.

This precedent from the Bramiana dam area serves, in the Municipality of Ierapetra about 35km away which was constructed in 1975, as an inspiring example of what can be achieved with proper planning, investment, and utilization of water resources in agriculture. It also highlights the potential for economic and social development within the region, as increased agricultural productivity can lead to job creation, improved livelihoods, and overall economic growth.

3 What are the hydroelectric capacities of the dam?

The cost of energy is one of the first advantages noted for the Lithina dam. One of the advantages that until now the studies ignored, is the possibility of the irrigation dam to produce hydroelectric power. At a time when energy production is the most important topic of discussion at the global level, and even more important the production of energy through renewable sources, the dam is a project that will significantly reduce the cost of energy from the use of water pumping from drills, but in the same time we can get a small quantity of energy. Of course, we cannot claim that the project will yield large amounts of hydroelectric power but since we are talking about an irrigation project, even this small amount is considered significant [4].

In order to improve our theory, we present some part of the needed details: Technical Details: You can delve into the technical aspects of the dam, such as the average forebay and tailrace water levels, gross and net head, and specific consumption. These factors play a crucial role in determining the efficiency and capacity of the hydroelectric power generation.

Electricity Production: It is the presentation of the potential of the total electricity production of the dam, both in terms of GWh per year and the annual electricity production in euros. This can include how the hydroelectric plant operates to generate this power and how it contributes to the local electricity grid.

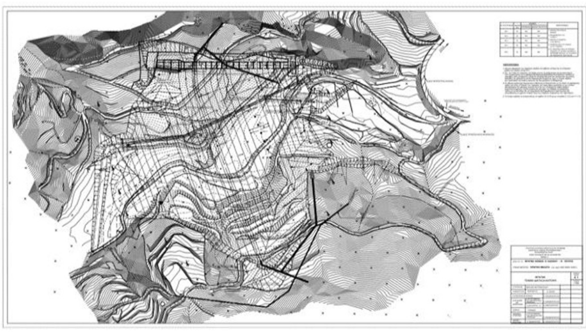

Fig. 3. General arrangement-distribution of Lithines dam.

To enable the investigation of the possibility of energy production from the dam's waters the construction plans were studied, and through hydroelectric calculations the basic data obtained for the measurements are presented in table 5 [4].

Table 5. Dam elements for computational hydroelectric study.

	Lithines
River/stream name	Maroulas
Dam Crest Length (m)	465
Dam Height (m)	58
Dam Crest Elevation (m)	122
Active Reservoir Capacity (m^2)	9.000.000
Irrigation Aria (ha)	2.000
Budget (M€)	69

In addition to the characteristics for the construction of the dam, a study was also made of the hydrological data of the area as a whole. Some of these were included in the study and others were searched through the National Weather Service data. [2].

Table 6. Hydrological data of the Lithina dam.

Hydrology	
Catchment basin	52 km^2
Average annual runoff	16.60 x $10^6 m^3$
Reservoir	
Water Level	+78 / +104 masl
Active Storage Capacity	8.25 x $10^6 m^3$
Total Storage Capacity	9.1 x $10^6 m^3$
Area @ 104 masl	55 ha
Dam	
Type	Earth – filled, with central impermeable core
Height	58m
Crest elevation	+110 masl
Crest dimensions	465 (L) / 10 (W)
Spillway	side overflow, without gates
Intake	Concrete tower - hexagonal trash rack scree arrangement

According to hydroelectric calculations (depending on the detailed design) the electricity production is presented in the table 7. [4] The financial Aspects can be delivered by the hydroelectric tariff and fees for local government organizations are important financial considerations. In this table, we explore how these financial factors impact the overall economic viability of the project. Of course, all this is connected with the Community Benefits as it mentioned fees for local government organizations.

Table 7. Hydroelectric Exploitation of the Lithina dam.

AVG Forebay Water Level	+91 masl	
AVG Tailrace Water Level	+52 masl / 27 masl	(dep. on detailed design)
H_{gross}	39m / 64m	(>>)
H_{net}	35m / 60m	(>>)
Specific Consumption	$12 m^3/kWh$ / $7 m^3/kWh$	(>>)

Total Electricity Production	1.4 GWh / 2.4GWh (/year)	(>>)
Hydroelectric Tariff	100€ / MWh	
Annual Electricity Production	121k€ / 220k€	(>>)
HydroPower Capacity	250kW / 400kW	(>>)
Capacity Factor	64% / 68%	(>>)
3% Fees for Local Gov. Organisations	3.524€- 5.825€	

Once again, the emphasis is placed on the fact that while the hydroelectric production may not be on a large scale, its significance derives from the context of the project being centered around irrigation rather than exclusively hydroelectric generation. Even though the amount of hydroelectric energy produced might be modest, it holds importance within the framework of the irrigation project itself.

Additionally, it's worth noting that a 3% fee of the revenue generated from Renewable Energy Sources (RES) is allocated to the local municipalities. This financial arrangement implies that, given today's price levels, the local municipality stands to benefit significantly. Instead of expending approximately €876,000 annually, it is projected to receive revenues ranging from €3,524 to €5,825. This financial dynamic further underscores the argument that the project is not only ecologically sound but also plays a substantial role in fostering economic growth and sustainable development within the region.

The revenue generated from this fee can provide a substantial financial boost to the local municipalities. This influx of funds can be used for various community projects, infrastructure development, public services, and other initiatives that can enhance the overall quality of life for residents. It contributes to local economic growth while also being ecologically sound aligns well with the goals of sustainable development. This approach supports both environmental conservation and economic progress, making it a win-win scenario for the community.

The hydroelectric potentials of the dam, also give a Long-Term Financial Stability because the consistent revenue stream from the RES fee can contribute to the long-term financial stability of local municipalities. This stability allows for better planning and allocation of resources for various projects and needs. It gives a Community Support for Renewable Energy because the financial benefit that the local community derives from the project can foster greater support and enthusiasm for renewable energy initiatives. When residents see tangible benefits from such projects, they are more likely to advocate for and embrace further renewable energy developments. Finally, the Positive Public Perception it works from the projected revenue increase underscores the positive impact of the hydroelectric project on the local community. This can enhance the public perception of the project and its stakeholders, making it a more welcomed endeavor within the community.

4 Can the Water of the Lithines Dam be used for drinkable in order to reduce the cost?

One of the main multi-purpose projects of dams is water supply, of course always provided that the existing water is suitable. To determine whether the water from the Lithines Dam is suitable for drinking, a comprehensive water quality analysis is required. This analysis would involve testing the water for various chemical, physical, and biological parameters to assess its safety for human consumption.

So far, some chemical parameters have been checked. Water samples were tested for:

free chlorine, total chlorine, nitrate anions, nitrite anions, iron cations, phosphate anions, ammonia. by the Hanna methods. All these measurements made with a HI83305 Multiparameter Photometer for Boiler & Cooling Tower spectrophotometer, Hanna Instruments by the Hanna methods.

Also, the content of chloride anions in the water samples was determined with Mohr method [15] [16].

Finally, the pH of water samples was measured with portable pHmeter by Hanna model phep.

As we observe from table 9, the findings in all chemical indices are lower than the highest normal. In fact, some of them were found in zero numbers (Free chlorine, total chlorine, nitrate anions, iron cations, phosphate anions, ammonia). Perhaps the only characteristic that was found slightly above normal, which was unstable in some measurements was the pH which instead of 7 was found to be 7.25 in its average value.

Table 9. Water chemical quality characteristics.

species	Values
Free chlorine	0.00 mg/L (ppm) as Cl_2
total chlorine	0.00 mg/L (ppm) as Cl_2
Chloride anions	86.09mg/L (ppm) as Cl^-
nitrate anions	0.00 mg/L (ppm) as NO_3^-
nitrite anions	11.0 μg/L (ppb) as NO_2^-
iron cations	0.000 mg/L (ppm) as Fe
phosphate anions	0.00 mg/L (ppm) as PO_4^{3-}
ammonia	0.00 mg/L (ppm) as NH_3
pH	7.25

According to the first analyses, we are seeing excellent water quality samples. The analysis must also be continued in biological markers to be complete.

5 The flood protection of the area

Flood protection, as emphasized at the outset, is one of the main advantages of dams as a multi-purpose project. The storage capacity - interception (absorption) of flood phenomena - of the dams' act as a means of protection in the downstream areas. For the Lithines dam, there has not been any study of the effects of flooding in the area. But the results of the 2019 flood showed in real numbers the financial costs that can be incurred and would have been avoided if the dam had been in place.

On April 1, 2019 flood event had significant consequences on the "Lagada" area due to heavy rainfall and the inability of the "Maroulas" river to absorb the water. The absence of a dam resulted in damage to crops, agricultural road infrastructure, and irrigation networks. The restoration cost of €230,000 was covered by the Region of Crete (€105,000) and the Greek Ministry of the Interior (€125,000), but this does not encompass the full economic impact, particularly the cost of crop damage.

Rainfall and Flooding: The heavy rainfall with a height of 110mm in a 7-hour period overwhelmed the "Maroulas" river's capacity to handle water, leading to flooding in the area. Unabsorbed Water: The river's inability to absorb around 1,000,000m2 of water highlights the insufficiency of the natural drainage system in managing such high-intensity rainfall events. Dam's Potential: The dam's storage capacity of 9,000,000m2 could have effectively managed the flood caused by the rainfall. This implies that a properly designed dam could mitigate the impact of such events in the future. Economic Damage: The flood resulted in damage to crops, agricultural road construction, and irrigation networks in the "Lagada" area. The restoration cost amounted to €230,000, with financial contributions from the Region of Crete and the Greek Ministry of the Interior. Inadequacy of Current Infrastructure: The existing infrastructure, including natural drainage systems, was insufficient to handle the flood event and prevent damage. Viability of the Area: The absence of measures to address the possibility of a recurrence of such flooding events leaves the area vulnerable. The construction of a dam is seen as a necessary solution to enhance the area's viability in the face of similar phenomena. Based on this information, it's evident that a more robust flood management solution is required for the "Lagada" area. The construction of a dam could provide the necessary storage capacity to mitigate flood impacts, prevent damage to infrastructure, and protect the region's economic interests. Further studies, cost-benefit analyses, and engineering assessments might be necessary to evaluate the feasibility and design of such a dam project. This case study highlights the importance of proactive measures to manage flood risks and protect vulnerable areas from the adverse effects of extreme weather events.

6 The role of infrastructure in the context of regional development theories and their correlation with the Lithines dam.

When the infrastructure contributes to its increase in the production process they contribute to the balancing process of regional inequality. The influence is greater since the project contributes as an "input" that will develop other sectors of the local economy.

Building the infrastructure can contribute to:

• In the utilization of natural water, water, in an arid region, as a wealth-producing resource in irrigation as a factor in expanding the productive base of the economy.

• Reduction of production costs, through the reduction of groundwater consumption (boreholes) for irrigation, since the water of the area comes from great depths of ≈350m which requires a large consumption of electricity to pump it. At the same time, the aquifer is protected from the risk of over-pumping and restoration of brackish water due to the inflow of seawater.

• To increase the supply of goods-services that will increase labor productivity.

• In the recovery of the local economy and the promotion of economic stability, since saving water will ensure a greater supply of water in dry periods.

In the present study they are not presented, although in general the infrastructures have multiplicative effects on all the branches of the economy with a developmental impetus on all the productive branches [17].

The increasing of competitiveness, limiting the dependence of the local economy since it develops productive activity while maintaining jobs for the population since it contributes to the residents' stay.

The project can be characterized as "fixed capital utilization infrastructure" and for this reason we can include it in projects considered essential by development theorists. However, it is not only a project that is a "promoting" development factor since it is estimated that it can create conditions for the "takeoff" of the economy and the more efficient operation of the economy. More generally, infrastructures are considered a key "tool" for exercising political, economic and regional development of a less developed, for Crete, region.

The impact of infrastructure on a regional economy is complex and multiple. And despite the fact that there is a dispute as to what is more important as an infrastructure project in a regional economy, the Lithines dam is not part of any such debate. It is not a soft infrastructures project in the field of education, health or public safety (we are not discussing whether they act adequately), but the creation of a hard infrastructures infrastructure is necessary when there are no other such projects in the area. The construction of irrigation dams and networks is not an intangible infrastructure but infrastructure with direct efficiency results. The project cannot be addressed through a study framework, e.g. Cobb-Douglas, to try to examine the effect of quantitative measurement indicators and production functions in relation to regional infrastructures, as examined in the studies of E.E.C. in the 1980s, when he tried to link geographical location, sectoral structures and economic concentration of the region [19]. Even if we follow the empirical findings of the study, the effect of infrastructure contributes to development, when factors other than infrastructure are included in a model [18].

7 Conclusions

Water Supply and Irrigation: Dams are often constructed to manage and regulate water resources in an area. If the Lithines Dam were to be completed, it could provide a reliable source of water for irrigation purposes. This could lead to increased agricultural productivity, particularly for crops like olive trees and greenhouse crops. Reliable water availability can enhance crop yields and reduce the risk of crop failure due to drought, thereby contributing to local food security and economic stability for farmers.

Reduced Water Shortages: Droughts and water shortages can be particularly damaging to the tourism industry. By securing a stable water supply for both agricultural needs and other uses, such as hotels, restaurants, and recreational facilities, the dam could help mitigate the impact of water shortages on the tourism sector. This stability might also attract investments in tourism infrastructure, as potential investors might be more willing to invest in areas with reliable water resources.

Energy Generation: Depending on the design and capacity of the dam, it might also have the potential to generate hydroelectric power. This could contribute to the local energy mix and potentially reduce the region's reliance on more carbon-intensive energy sources. In the context of concerns about climate change and rising energy costs, the integration of renewable energy sources like hydroelectric power could be seen as a positive step toward sustainability.

Environmental Impact: It's important to consider the potential environmental impacts of dam construction. Dams can have both positive and negative effects on ecosystems. While they can provide water storage and habitat for certain species.

Local Employment and Infrastructure: The construction and maintenance of the dam could create jobs in the local community. Moreover, the infrastructure built around the dam, such as roads and utilities, could improve local connectivity and accessibility, which might encourage further economic development.

However, it's essential to note that the impact of any large-scale infrastructure project, like the Lithines Dam, can be complex and multifaceted. The actual outcomes will depend on various factors including project management, environmental considerations, community engagement, and broader economic trends. Local authorities, stakeholders, and experts would need to carefully evaluate the potential benefits and risks to ensure that the dam's construction aligns with the long-term economic, social, and environmental goals of the region.

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