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Could Photovoltaic Parks be More Profitable as an Investment Compared to Tree Crops in Mediterranean Water Scarce Regions?

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Abstract

Food security and access to electricity are considered core elements forthedevelopment of modern societies. In some cases, energy supplies are prioritized and therefore may compete with food resources. Since 2009, the sudden increase of photovoltaic system investments in Greece and particularly in Crete, as an effort to comply with the European directives on sustainable energy sources, led tothe replacement of many fieldsof traditional agricultural cultivations (such as olive and orange trees) with photovoltaic parks.The aim of this paper is to estimate the economic benefit of the investment of photovoltaic parks on farmlands compared to the cultivation of olive and citrus crops.To this end, two different scenarios were investigated. In the first scenario, the replacement of a 1000 m2 olive grove area,located in highly productive land, witha small photovoltaic park of 25 kW was investigated. The second scenarioconsidersa much larger photovoltaic park of 100 kW which replaces an orange grove of 3500 m2 at highly productive land. It was found that in both cases,the profitability of the investment, for a time span of 20 yrs, was highly dependent on the time when the power purchase agreement was signed. As a general rule, investments made before 2013 can be characterized as profitable. After 2013, the situation became more complex and the financial success of the investments is not guaranteed.

Keywords: Agricultural lands; Tree cultivations; Photovoltaic park; Financial comparison; Greece.

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1. Introduction

Nowadays, there is an increasing concern in the global community about greenhouse gas emissions and their impact on climate. Thus, an effort to substitute fossil fuels with alternative energy sources is under way [1].The main advantage of renewable energy sources istheir sustainability and as such they have the potential to help countries gain energy independence and disengage from fossil fuels. Solar power technologies in particular are becoming popular because they have minimal impact on the environment [2]. Their use can be even more beneficial on islands like Crete which are not connected to the central electrical grid of Greece [3, 4] and they experience increased water scarcity in the last decades. At the same time, producing enough food for the growing global populationis also top priority, which often competes with the need for more energy and water. It is a great challenge for scientists to create more effective cultivations and to promote a balanced water-energy-food nexus [5].

The increasing energy demands, the need to invest in low carbon energy sources and water scarcity, have caused a rapid rise in ground-mounted solar parks around the world which often replace water demanding crops. This land use change has created effects in hosting ecosystems which are new and not fully understood yet [6]. Among all renewable energy sources, photovoltaics appear to have the greatest potential. Their growth rate has rose in the recent years and the predictions show that it will keep growing [7]. In Europe, the majority of solar parks is located in converted arable land and grasslands. This represent a major change in land use given the relatively low energy density of solar parks [8]. The need for cleaner energy sources and food security by using farmlands more productively, resulted in the competition of these two factors, especially when it comes to photovoltaic parks that are located in areas that could be used for crop production.

In Greece, the expansion of renewable energy sources and especially the photovoltaics project had a large increase since 2009 as a result of favorable law amendments. According to the European Energy Roadmap 2050, EU member-states have to virtually eliminate greenhouse gas emissions. At the same time, they have to ensure

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their energy security and financial competitiveness [9]. Greek legislation attempted to comply with the European targets in harmonization with the EU directives and to persuade the investors towards renewable energy investments. In order to achieve this, it gave serious financial incentivesvia a series of laws (L.3468/2006, L.3734/2009, L.3851/2010) from 2006 to 2010. The main focus was given in photovoltaics by permitting the replacement of the original agricultural cultivations with them. However, the Statetariff policy for the electricity produced by photovoltaic installations created financial problems andthe inability of the State to pay the independent producers. Thus, this led the State to withdraw the privileges which had been given before. Moreover, via a series of laws and ministerial decisions (FEK B'/2317, FEK B'/1103, L. 4254/2014) from 2012 to 2014, the incentives for new investments were minimized while the current ones lost a substantial part of future profits.Thus, after 2014, the growth of photovoltaic investmentswas reduced and finally stopped. As a consequence, the investors face serious risks concerning the financial viability of their investments.

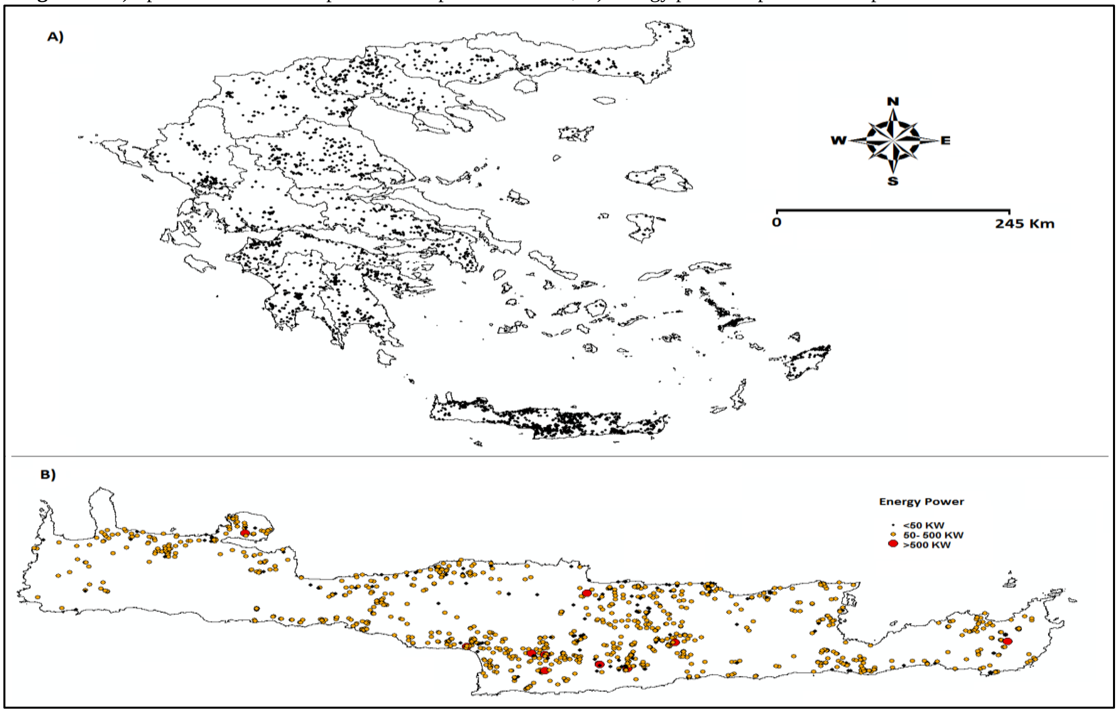
Given the current state of photovoltaic investments in Greece described above, this workinvestigates the conditions under which the replacement of crops by photovoltaics is considered profitable. The comparison is made using data from the Chania Prefecture where the mountainous lands are dominant and thus the available areas for cultivation are limited. In order to accomplish this goal, the first step was to collect data on the two dominant trees crops (olive trees and orange trees) and photovoltaic parks. Then, economic data were collected to enable the comparison of crop and photovoltaic park profitability, based on two different realistic scenarios. The comparison takes place for a 20 year time periodat a 10 year time step between the operation time of the photovoltaic investment and the corresponding time of tree cultivation.

2. Study Case

2.1. Area of Study

Figure 1A represents the spatial distribution of photovoltaic parks in Greece. Based on Figure 1 significant density of photovoltaic parks is presented in the island of Crete (Water district of Crete), (Figure 1A). In Crete, agricultural land reaches about 3,000,000 hectares, of which tree crops are about 2,000,000 hectares. Photovoltaic parks in Crete today occupy an area of about 16,500 hectares with an upward trend, replacing horticultural crops (mainly citrus and olive trees) in agricultural land of high productivity [10]. The energy power of photovoltaic parks in the island of Crete is represented in Figure 1B. The study area is the ChaniaPrefecture, located at the western part of Crete, Greece (Figure 1B). It has a population of 156.585 and an area of 2.376 km^2. The Chania Prefecture's land is mountainous (63%) in the biggest part, hilly (19%) and lowland (18%). The areas that are available for cultivation are 612.2 km^2. The majority of the cultivated areas are covered with tree crops, with olive and citrus trees to be the most common. Chania prefecture is the third biggest prefecture in Greece at olive oil production and the fourth biggest at citrus fruits production. The climate is primarily Mediterranean with mild-rainy winter and hot-dry summer. The annual sunshine is high and covers approximately 70% of the year. This makes the power production from photovoltaics very profitable in comparison with the rest of the country and even more so with the rest of Europe. It seems that the great potential of photovoltaic in Greece in conjunction with appropriate energy policies can really benefit the country's economy [4].

Figure-1. A) Spatial distribution of photovoltaic parks in Greece, B) Energy power of photovoltaic parks in the island of Crete



Olive treesare the most important trees in the area around Mediterranean Sea. Olive oil is a vital ingredient of the Mediterranean diet and it is known for its great benefits for human health [11]. The majority of olive trees in

Crete (75%-80%) belong to the variety of Koroneiki, the most commercially important variety in Greeece.This variety is well known for its great endurance to the dry and hot climate and its high productivity [12]. Inmany regions of Greece, including Crete, olive trees are traditionallyrain-fed with no artificial irrigation applied. Nevertheless, when olive trees have sufficient quantities of water their yield oil quality increase significantly [11]. In addition, pruning is often applied to extend the productive period.

Citrus trees are also of great importance for the agricultural production in Crete. Specifically, orange trees are the dominant species of citrus trees (86%-90%), with mandarin trees accounting for 6%-8% and lemon trees 2%-4% [13]. Citrus trees are considered water demanding in terms of quantity and quality.The amount of water needed varies through the year and depends on variables like the size and variety of the tree. In general, in citrus groves, an average amount of 3600 m3/ha/year of irrigation water is commonly applied [14]. For the best irrigation of citrus trees, advanced systems like mini sprinklers are preferred. The season of irrigation starts right after the rain stops in the spring and ends with the first rains in autumn. Furthermore, fertilizer is used to increase production, from October to December, every 2,3 or 4 years depending on the needs of the soil. In most cases, a nitrogenous fertilization is applied once per year and a fertilization with phosphorus and potassium every three years.

3. Methodology

The aim of this work is to make aneconomic comparison betweenthe profits of a photovoltaic park replacing a cultivation of olive or citrus trees in a highly productive land. To accomplice this, two different realistic scenarios were investigated. In the first scenario, a photovoltaic park of 25 kW and initial cost of 50.000-65.000 euro was compared with the profit from the crop yield of 13 olive trees, cultivated in a field of 1000 m^2. In the second scenario, a photovoltaic park of 100 kW and initial cost of 250.000-325.000 euro was compared with the profit from the crop yield of 140 orange trees, cultivated in a field of 3500 m^2. In both scenarios, the soil is assumed fertile and the slope of the plot 0%. A smaller field area was selected for olive tree cultivation in the first scenario as compared to the citrus tree cultivation in the second, based on socioeconomic factors: it has been observed that olive tree farmers are more reluctant to switch their traditional cultivations to photovoltaic parks and thus larger areas of citrus trees are often being replaced in comparison to olive trees.

For the economic comparison, data was collected from various sources in order to get an estimateof the average profit expected in each case. In the case of photovoltaics, the annual profit of the investor for each scenario was calculated with the following process. First, the initial cost of the investment was estimated usingdata from top construction companies in Greece (Solar Cells Hellas, Art Line Constructions, Dionic Energy). Next, the annual energy production in each scenario was estimated using the appropriate online software(solar.com.gr). The price paid to the investor for the produced energy was found by analyzing and examining a number of Greek laws and ministerial decisions from 2006 to 2015. The maintenance cost was minor and does not play a significant role to the total expenses of a photovoltaic park. In both cases, the repayment period for the investor was assumed 10 years and no interest rates were added to the initial loan. The contract between the investor and the PPC (Public Power Corporation S.A.-Hellas) has 20 year duration.

For the olive and orange trees cultivations, the initial cost of planting the trees was not taken into considerationsince the trees are assumed to be present in the field and the question is if it is profitable to replace them. The annual cost of production was estimated based on a survey overview that was conducted in the target area. Specifically,forty olive and citrus local farmers were interviewed about their annual cost of production. In addition,a relevant study was considered: « *International olive oil production costs study: results, conclusions and recommendations* » [15]. The annual production of fruits from the orange trees and the area needed by each tree was estimated from a studyby the Ministry of Rural Development and Food [16].The price paid to the farmers for the fruits was estimated by the data from the Organization of Main Markets and Fishing(www.okaa.gr) and from elies-ladikalamatiano.gr [17].

Overall, the annual profit from the investment of photovoltaics in each case was calculated by the following equations:

Annual profit of the first decade = (E * P) - (C / 10) - (M) (eq. 1)

Annual profit of the second decade = (E * P) - (M) (eq. 2)

where, *E = Production of energy, P = Price paid to the investor, C = Initial cost, M = Maintenancecost.*

The annual profit from the trees in each case was calculated by the following equation

$(((L / D) * (T)) * F) - R$ (eq. 3)

where, *L = Available land, D = Area that each tree demand, T = Production of each tree, F = Price paid to the farmers, R = Annual cost of productio*

Appropriate taxes were also included in the results. According to the current taxation, the net profits from energy production for photovoltaic parks are taxed by 26% and the net profits from the cultivation of olive or citrus trees are taxed by13%.

4. Results and Discussion

4.1. Scenario 1

The first scenario assumes a flat field of 1000 m^2 with fertile soil. The specific characteristics of the photovoltaic park (investment cost, power generated, efficiency etc.) and the olive tree grove (tree age, number of trees, fruit production and cost etc.) for the first scenario are presented in Table 1. Figure 2 shows the total profit of the olive grove for the first 10 years and for the entire 20 years of cultivation. As seen in Figure 2, the annual profit from the olive tree investment is approximately 1264 euros for the first (blue bar) and second decades (red bar) and 2527 euros for the entire duration of the investment (green bars), corresponding to steady profit of 126.4 euros per year, assuming the taxation and fruit price stays the same. In reality there is a fluctuation in fruit prices every year, which will affect the result slightly. It represents an overall steady but low profitinvestment in comparison with the profits from photovoltaic parks in most cases.

Table-1. Characteristics of photovoltaic park and olive grove in scenario 1

Photovoltaic Park Scenario 1		**Olive Trees Scenario 1**	
Area (m^2)	1000	Area (m^2)	1000
Power (Kw)	25	Slope	Flat
Angle / Orientation	Steady/South	Altitude	Low
Dust losings (%)	0.50%	Age of trees	Prime age
European Efficiency Grade of Photovoltaic Converter (%)	95.00%	Variety	Koroneiki
Investment cost (euro)	50000 - 65000	Number of trees	13
Repayment period (years)	10	Fruit production (kg)	550
Production of energy (kWh/year)	31393 - 37998	Olive oil production (kg)	143
Price paid to the investor (euro)	Depends on the period	Investment cost (euro)	-
Maintaining cost (euro)	-	Cost of production (euro/kg)	1.8
Interest rates of initial loan	0%	Price paid to the farmer (euro/kg)	2.63
Tax on the net profit (euro)	26% of net profits	Tax on the net profit (euro)	13% of net profits

Figure-2. Net profit in Euro (vertical axis) from olive tree cultivation (Scenario 1)

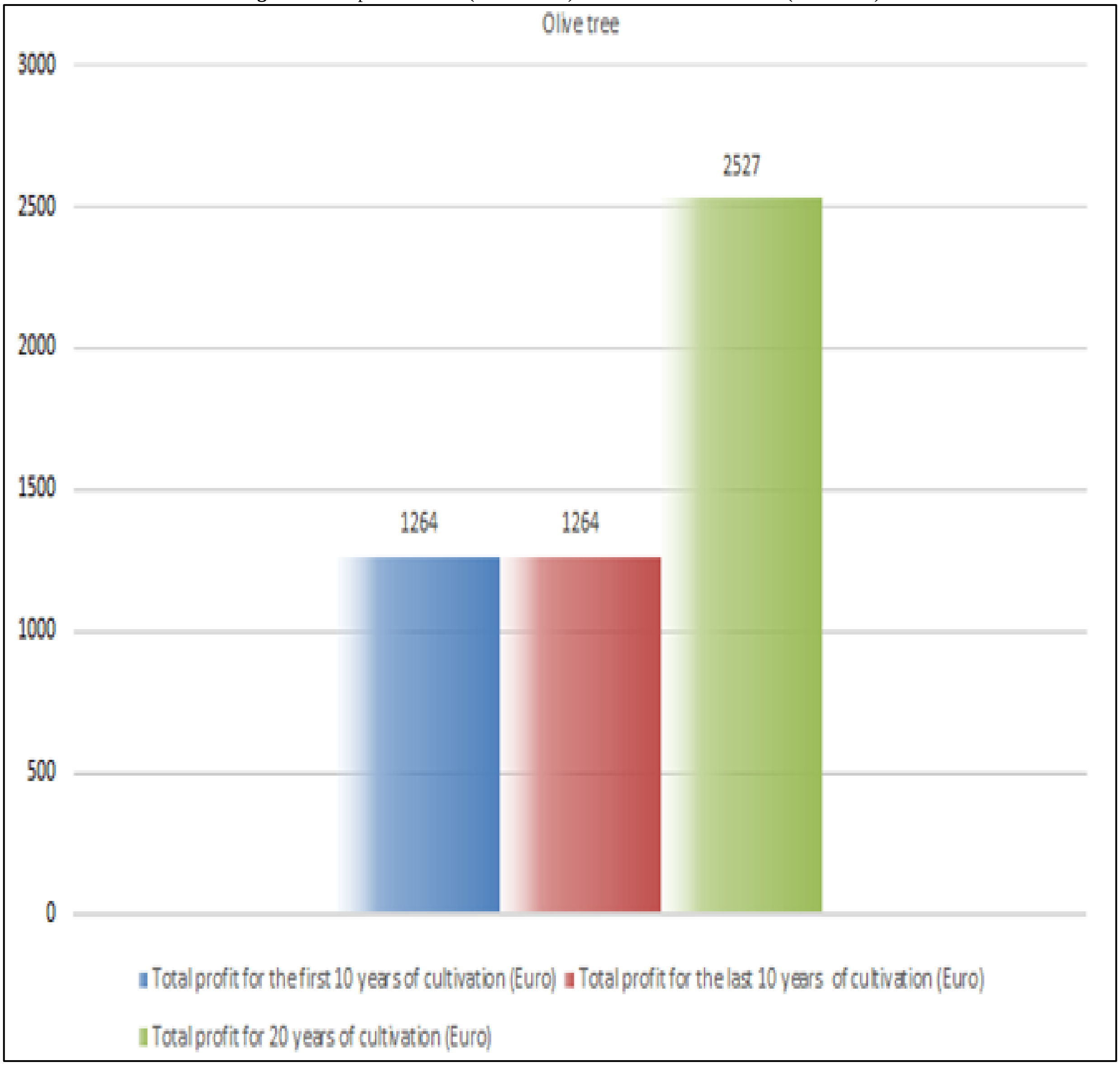
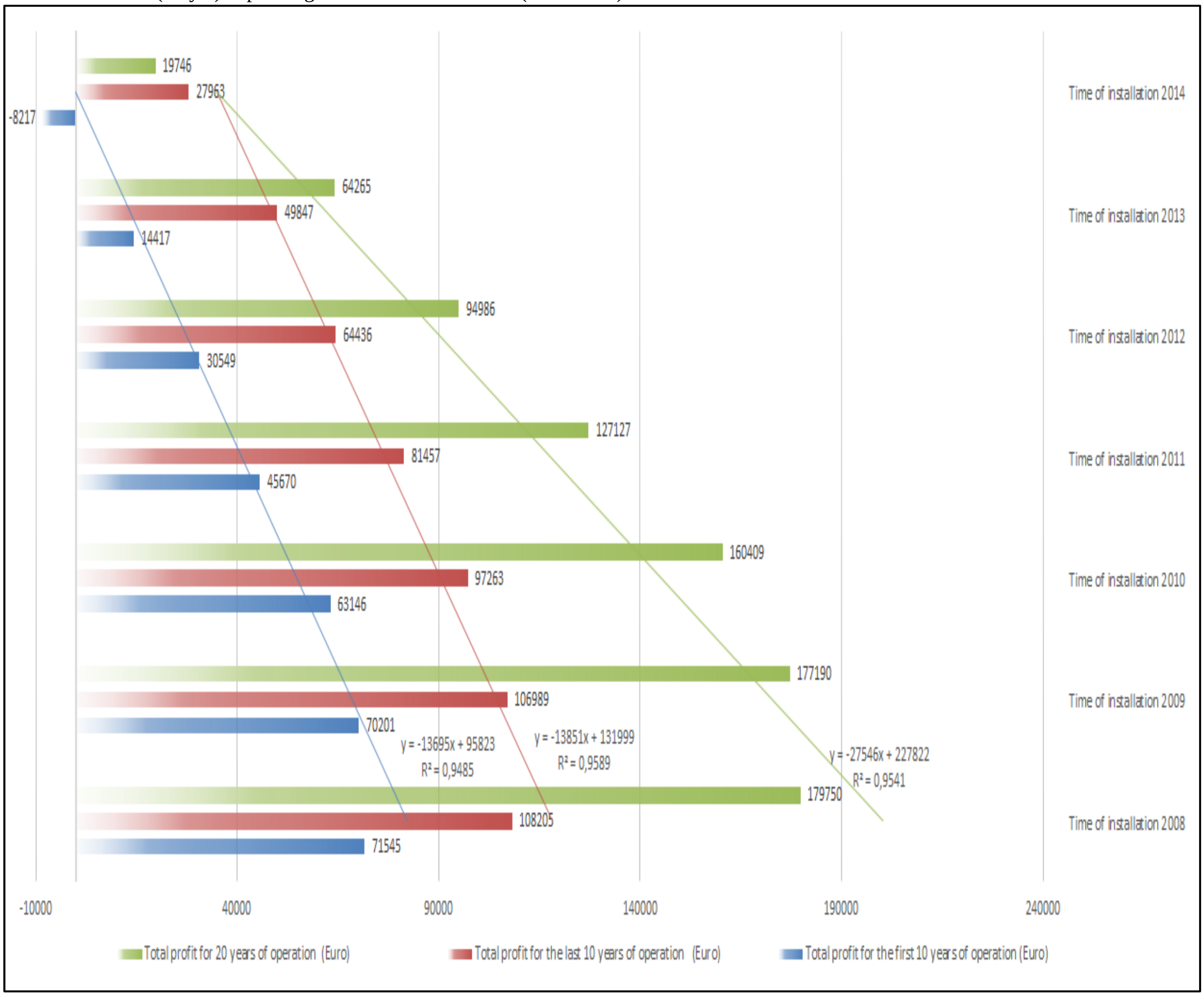


Figure-3. Net Profits in Euro (left vertical axis) from the installation of the photovoltaic park of 100 KW for the first two decades and for the total investment duration (20 yrs) depending on the installation time (Scenario 1)



The net profits (including taxation) for the photovoltaic park investment are presented and compared in Figure 3. The blue bars represent the profits for the first decade of the investment, the red bars for the second decade and the green for the entire duration of the investment (20 years). The profit for the investor of the photovoltaic park depends on the time they signed the contract with the PPC (Public Power Corporation S.A.-Hellas). The profits are showing a decreasing trend with time. If, for example, they investors signed the contract in 2009, their profit for the first decade is 70201 euros, a substantial gain. If they signed the contract a year later, in 2010, their profits decrease significantly (63146 euros). Comparing the profits of the first and second decades, they are much higher for the second decade due to the full repayment of the initial investment in the first decade. The continuous decrease of the potential profits from 2008 to 2014 is the result of the changes in the payment policy of PPC. PPC was starting to pay the new investors less and less every year for purchasing their produced energy. In 2008, PPC paid a very high price for electric power produced by photovoltaic parks. This policy had as target to attract new investors into the sustainable energy business by offering them great profits. Due to this favorable policy, the private photovoltaic business grew fast. At the same time, PPC starting showing lossesfrom buying photovoltaic energy in a very high price. As a result, PPC began to lower the price on new contracts in an attempt to recover from its losses. Figure 3 shows that the new photovoltaic parks installed from 2013 and later cannot offer great financial profits, especially in the first decade during therepayment of the initial investment. For example, for new contracts signed in 2014, not only there is no profit in the first decade of investment, but there is actually a significant loss (8217 euros). In the next decade there is a small profit (27963 euros) but it is minor if we consider the loss from the first decade (reducing profits to 19746 euros for the duration of the investment corresponding to 987.3 euros per year), the potential interest rates of the initial loan which are not considered here and the potential increase in taxation in the next decade. This makes the investment risky and cannot fully justify the replacement of olive trees.

4.2. Scenario 2

The second scenario assumes a field of 3500m^2 with fertile soil and slope of 0%. The specific characteristics of the photovoltaic park (investment cost, power generated, efficiency, etc.) and the orange tree grove (tree age, number of trees, fruit production and cost, etc.) for the second scenario are presented in Table 2. Figure 4 shows the total profit from the cultivation of citrus trees in the field for the first and second decades and for the entire 20 years of cultivation. The net profits (including taxation) for the photovoltaic park investment are presented and compared in Figure 5.

Table-2. Characteristics of the photovoltaic park and orange grove for scenario 2

Photovoltaic Park Scenario 2		**Citrus Trees Scenario 2**	
Area (m^2)	3500	Area (m^2)	3500
Power (KW)	100	Slope	Flat
Angle / Orientation	2 Axis Tracking /South	Altitude	Low
Dust losings (%)	0.50%	Age of trees	Prime age
European Efficiency Grade of Photovoltaic Converter (%)	95.00%	Variety	Valencia
Investment cost (euro)	250000 - 325000	Number of trees	140
Repayment period (years)	10	Fruit production (kg)	8400
Production of energy (kWh/year)	159353 - 192882		
Price paid to the investor (euro)	Depends on the period	Cost of production (euro/kg)	0.21
Maintaining cost (euro)	-	Investment cost (euro)	-
Interest rates of initial loan	0%	Price paid to the farmer (euro/kg)	0.34
Tax on the net profit (euro)	26% of net profits	Tax on the net profit (euro)	13% of net profits

Figure-4. Net profit in Euro (vertical axis) from citrus tree cultivation (Scenario 2)

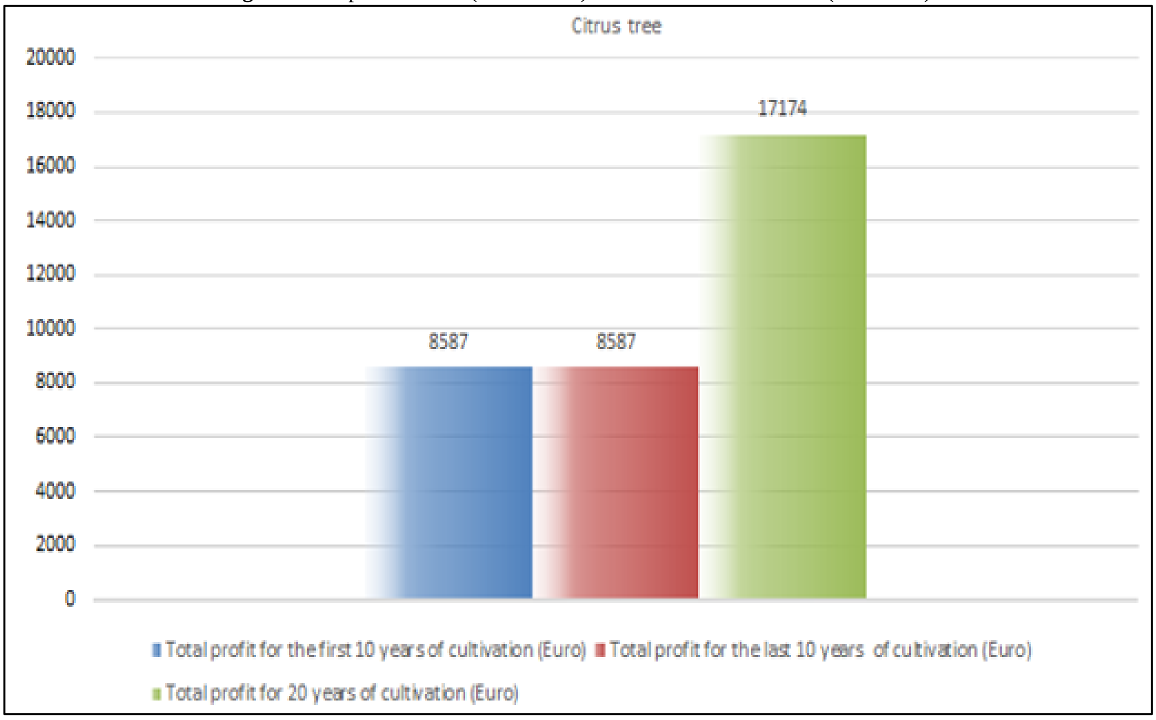
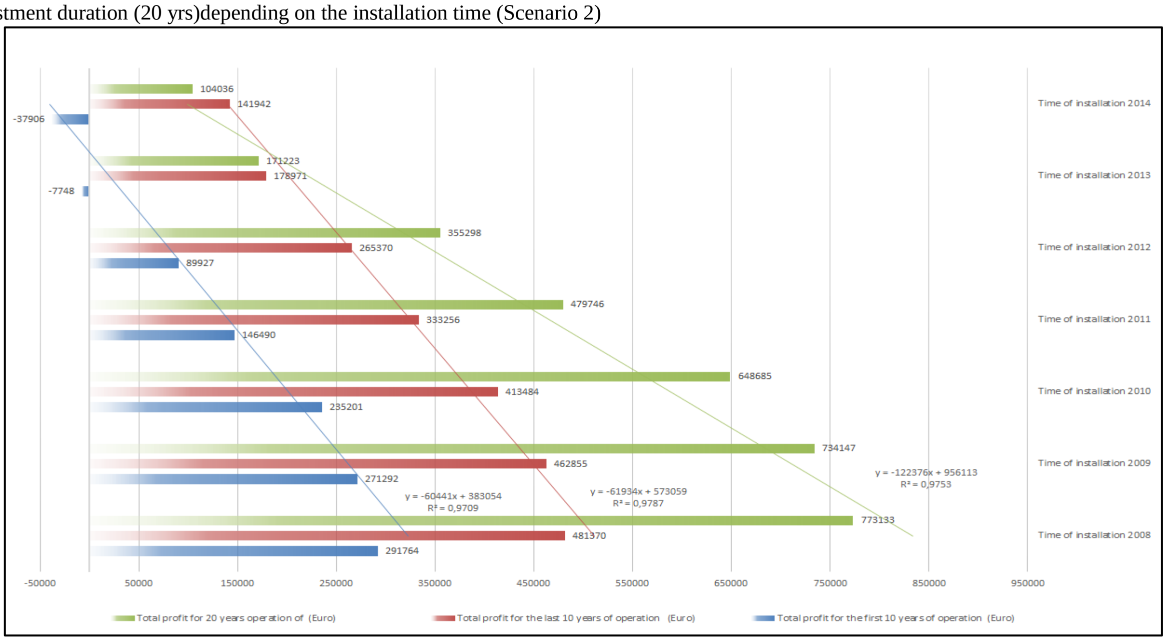


Figure-5. Net Profits in Euro (left vertical axis) from the installation of the photovoltaic park of 100 KW for the first two decades and for the total investment duration (20 yrs)depending on the installation time (Scenario 2)



In the second scenario, the general conclusions are similar with some key differences. The area of the agricultural field is 3500 m^2 so the photovoltaic investment is far more expensive than in scenario 1 (287500 euro on average) and the traditional cultivation of orange trees is more profitable than the olive trees (858.7 euro/year compared to 126.4 euro/year) in general. If the field was cultivated with olive trees the expected profit would be $126.4 \times 3.5 = 379.2$ euros, making the production of oranges much more profitable. Of course, due to the larger capacity of the photovoltaic park in this scenario the profits are much higher. For example, if the contract is signed in 2009 the net profits in the first decade 291272 euros, the second decade 462855 euros with a total of 734148 euros, corresponding to an average annual profit of 29127.2 euros for the first decade and 46285.5 euros for the second decade, making this investment a highly profitable one. But for contracts since in 2013 and later, losses are expected in the first decade (investment repayment period) and minor earning for the second decade that can hardly justify the replacement of traditional tree cultivations.

5. Conclusion

In conclusion, the sustainability of a photovoltaic investment in a Mediterranean tree crop area in Chania, Crete is dependent highly on the time the power purchase agreementwith PPC (Public Power Corporation S.A.-Hellas) was signed. Two scenarios were examined; in the first scenario a 1000 m^2 olive grove cultivation, located in highly productive land, was replaced by a small photovoltaic park of 25 kW and in the second scenario a much larger photovoltaic park of 100 kW replaces an orange grove of 3500 m^2. Despite the various assumptions made in this work, some important conclusions were drawn. It is clear that as long as there are financial incentives, the investors can support a more sustainable model in the energy sector. In the scenarios investigated here, all the investors who adopted fast and replaced their traditional tree crops early, received sufficient earnings. On the other side, the investors who entered the photovoltaic business later and especially after 2014, did not manage to sign very profitable contracts. Thus, in their case the replacement of traditional tree crops with photovoltaic parks is not fully justified.

The two scenarios also reveal the influence of relative domestic laws and ministerial decisions on the expansion of photovoltaic installations in the Greek energy market. Until 2012, a number of incentives in photovoltaic electric tariffs and license policies favoredthe photovoltaic sector and trigged their rapid expansion. Nevertheless, the photovoltaic energy development model lacked long-term planning and organization.As a result, the unstable photovoltaic electric energy tariff policy created a dangerous investment environment and kept away all the future investments from photovoltaic energy.

Another conclusion that can be drawn from the two scenarios is that photovoltaic parks, when the energy purchase price is favorable, can produce far better profit in less area. This means that if a professional farmer owns a large agricultural area, it is possible to combine both photovoltaics and cultivation. For instance, he can install a photovoltaic park in a small part of his land, while continuing to cultivate agricultural crops in the other.

Finally, it is important to refer to the ethical dilemma of the replacement of tree crops for photovoltaic parks. Chania Prefecture and Greece in general do not have large fertile areas for cultivation like other countries. So, in order to fully understand the consequences of this replacement, it is important to consider all the disadvantages of the continuous decrease of cultivated land in such areas. For example, the olive oil is a signature product of Greece and it needs fertile lands to produce quality products and remain competitive against its main rivals like Italian and Spanish olive oil. The replacement of quality olive trees can decrease its overall value and damage its image. This can cause further economic consequences to the rest of the farmers and to the Greek economy in general.

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