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# Possibilities of Developing Agrivoltaics in Olive Groves in the Island of Crete, Greece

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**ABSTRACT:** Solar photovoltaics are in the forefront of clean energy technologies used in the decarbonization of the global power system. Agrivoltaics is an emerging solar energy technology that allows the dual production of electricity and agricultural products in the same land area. The island of Crete, Greece has abundant solar energy resources while cultivation of olive trees is an old tradition embedded in Cretan culture. The possibility of installing agrivoltaics in olive groves in the island of Crete, Greece has been studied. Several published papers assessing the use of agrivoltaics in olive groves in several countries have been reviewed while agrivoltaics' benefits and challenges have been stated. It has been estimated that installation of agrivoltaics in olive groves in Crete covering 1% of their surface, with coverage ratio at 15% and 30%, can generate electricity meeting 4.69% and 9.38% of Crete' annual electricity demand respectively. The generated solar electricity can cover the electricity demand in 37,537 and 75,075 households respectively in Crete while it will save the emission of 35,252 $tCO_2$ and 70,504 $tCO_2$ annually. Although there are not sufficient data assessing holistically the use of agrivoltaics in olive groves there are many indications that, under specific conditions, they have many benefits regarding the dual production of electricity and olives. Our results indicate that installation of agrivoltaics in Cretan olive groves, under limited shading, can offer an additional income to farmers increasing their resilience and their adaptation to climate change. The results of the current study could be useful to many stakeholders of Cretan olive industry.

**KEYWORDS**: agrivoltaics, climate change, Crete-Greece, electricity, olive grove, resilience

## 1. INTRODUCTION

Installation of solar photovoltaics in land areas used for food production has many advantages allowing the dual production of food and energy in the same land surface. However, the installation of agrivoltaics should not reduce crops' productivity. Several studies have been conducted worldwide regarding the use of agrivoltaics and their impacts in crops' productivity (1), (2), (3), (4), (5). The cultivation of olive trees is widespread in Mediterranean region including the island of Crete (6), (7). However, climate change alters the climate conditions in this area causing increasing temperatures, heat waves, lower precipitation and droughts. Changing climate conditions threaten the growth of olive trees and reduce their productivity (8), (9), (10). Agrivoltaics alter the microclimate in olive groves reduce their irrigation needs and increase their resilience to climate change and to extreme weather events (11), (12), (13), (14).

*The aim of the current work is the investigation of the possibility of installing agrivoltaics in olive groves in Crete and the estimation of solar electricity generation.*

The work is structured as follows: After the literature survey, the use of solar photovoltaics in Crete and the cultivation of olive trees in the island are stated. In the next two sections the agrivoltaics and the possibility of using agrivoltaics generating electricity in olive groves in Crete are analyzed. After that, their impacts on climate change mitigation and adaptation are mentioned while the text ends with discussion of the findings and the conclusions drawn.

The current work is innovative since there are no many studies related to the use of agrivoltaics in Crete while it covers the existing gap regarding the use of agrivoltaics in olive groves in the island. The study could be useful to policy makers, to public authorities, to energy companies and to all stakeholders of the olive industry in Crete.

## 2. LITERATURE SURVEY

The growth of vegetables under agrivoltaics in varying transparencies in USA has been studied (1). The authors stated that air temperature was 0.5°C lower than in full sun while soil temperature was cooler at 5.8°C to 14.4°C under bifacial, semi-transparent and opaque silicon modules. They mentioned that statistically it was not significant decrease of yield for pepper, tomatoes and lettuce crops. The development of agrivoltaics around the world has been explored (2). The authors analyzed 160 peer-reviewed studies stating that they did not find a model capturing holistically the energy, water and crops dynamics of agrivoltaics. They mentioned that the cost of agrivoltaics is higher than the cost of ground-mounted photovoltaics. The agrivoltaics as a new tool for energy and food production have been reviewed (3). The authors analyzing 54 papers stated that the success of crops under agrivoltaics depend on many factors, mainly on location and season. They proposed to define an optimal daily light integral for each species instead of a shade level. The role of agrivoltaics in sustainable development has been examined (4). The authors stated that agrivoltaics reduce the heat stress and decrease soil drying. They mentioned that solar eclipses are rare but their impacts on electricity generation are significant. They also added that in Czech Republic a solar eclipse on October 25, 2022 reduced the daily solar electricity generation by 5.52%-5.84%. The development of agrivoltaics has been explored (5). The authors stated that success of agrivoltaics is related with climate, their configuration, the cultivated crops, the compatibility and the collaboration among several stakeholders. They mentioned that growth of agrivoltaics requires more research, more innovation, development of a workforce and training. The productivity and profitability of olive groves in Crete have been studied (6). The authors examined several types of olive groves including organic, conservation, low-input and standard farms stating that organic farms have higher productivity, profitability and technical efficiency. The implications of climate change to olive flowering in Greece have been examined (7). The authors mentioned that olive's flowering was estimated to occur between 6 to 10 days earlier in the near future and between 12 and 26 days earlier in the far future. The adaptation of Mediterranean olive groves to climate change has been analyzed (8). The authors described sustainable olive crop management practices applied in 120 olive groves in Crete for five years. They stated that olive cultivation can adapt to climate change by applying two pillars: a) improving soil fertility through soil organic matter rise, and b) pruning-induced adjustment of tree growth and fruit load. The enhancement of sustainability in olive groves in Mediterranean region through adaptation measures has been studied (9). The authors proposed: a) The irrigation of the trees, b) the use of cultivars with low chilling requirements, and c) the increase in orchard density to improve the climate change adaptation of olive groves. The adaptation mechanisms of olive tree under drought stress have been explored (10). The authors stated that olive oil production is adversely affected by climate change. They mentioned that drought is considered a limiting factor in olives production. They proposed that drought-resistant varieties and sustainable irrigation strategies should be developed to mitigate the impacts of droughts to olives' productivity. The potential of installing agrivoltaics into olive groves in Mediterranean region has been studied (11). The authors stated that suitable photovoltaic transparency levels are in the range of 57% and 71% while the electricity generation is 65.9 kWh/m$^2$ of ground. They mentioned that installing agrivoltaics into 1% of total olive surface area would generate 1.8% of the current electricity demand in some Mediterranean countries. The generation of solar-PV electricity in olive groves in southern Italy has been explored (12). The authors stated that their simulations indicated that combined production of photovoltaic electricity and olives is possible with a noticeable land saving. They mentioned that agrivoltaics technology has satisfactory results in various cases. The integration of bifacial solar-PVs with olive trees in southern Spain has been examined (13). The authors stated that the variation in tilt angle has a greater impact on solar electricity generation while the variation on solar panels' height primarily affects the yield of olive trees. The enhancement of olive production in olive groves with agrivoltaics in southern Italy has been examined (14). The authors stated that agrivoltaics influence the local microclimate affecting the air and soil temperature, wind speed and groundwater retention. They mentioned that solar panels were located at 12 meters spacing while the panels' height was 2.6 meters. A report regarding the use of agrivoltaics in UK has been published (15). The report stated that soil temperature was reduced under the shade of agrivoltaics while the growth rate and the crop temperature were not statistically affected. It was also mentioned that the yield of several crops such as potatoes, tomatoes, peppers and lettuces was not significantly affected. The regenerative agrivoltaics offering the potential to achieve reduced environmental and social outcomes compared to conventional agriculture have been studied (16). The authors stated that agrivoltaics are in the intersection of agriculture, renewable energy and sustainability improving land use and resource management. The impacts of agrivoltaics on several crops in Korea have been explored (17). The authors compared the yield of several crops such as rice, onion, garlic, rye, soybean under the agrivoltaics and their cultivation in open field. They mentioned that agrivoltaics did not have negative impacts on the yield of rye and corn while they had adverse impacts on rice's yield. The development of net-zero emissions olive oil mills in Crete, Greece has been studied (18). The author stated that olive oil mills in Crete can eliminate their annual net-carbon emissions using solar photovoltaic energy and solid biomass. The carbon sequestration from olive tree groves in Crete has been estimated (19). The author stated that the annual carbon removal rate in olive groves is at 2.5 tC/ha while the total annual carbon sequestration rate due to olive groves in Crete is 1,310,393 $tCO_2$. The policy landscape of agrivoltaics has been analyzed (20). The authors stated that there is a lack of policy integration of agrivoltaics across the energy, agriculture and land use sectors. They mentioned that the fragmented nature of agrivoltaics policy does not favor their promotion. The sustainable management of olive groves in Spain has been examined (21). The authors stated that 95% of all olive trees in the world are grown in Mediterranean region while droughts and heatwaves have significantly reduced the olives' production. They also mentioned that sustainable management of olive groves in Spain have increased their resilience to climate change. A model to estimate the quantity of olives and electricity produced by agrivoltaics systems in olive groves has been developed (22). The authors have produced two equations evaluating the olive oil and the electricity produced in olive groves with agrivoltaics installations. The installation of agrivoltaics in vineyards in Crete has been studied (23). The author stated that agrivoltaics allow the dual production of electricity and grapes in the same land surface. He mentioned that covering with agrivoltaics 1% of the area of Cretan vineyards with coverage ratio 15% the generated electricity corresponds at 2.6% of the annual electricity demand in the island. An overview of agrivoltaics in olive farming has been reported (24). It is stated that olive trees thrive in partial shade and they are ideal for agrivoltaics systems. It is stated that agrivoltaics can achieve: a) up to 29% water saving, b) increased land productivity by 35-73%, and c) reduced carbon emissions. The use of bifacial agrivoltaics in olive groves has been reported (25). The authors stated that the tilt angle has a significant impact on power yield while the modules height plays a crucial role on increasing agricultural yield.

## 3. SOLAR PHOTOVOLTAICS IN THE ISLAND OF CRETE

The development of solar photovoltaics in Crete reflects both the island’s exceptional natural advantages and the broader evolution of renewable energy policy in Greece. Over the past two decades, Crete has moved from limited, localized solar use to becoming a promising case study for large-scale renewable integration in island energy systems. Crete possesses one of the highest solar irradiation levels in Europe, making it particularly suitable for photovoltaic energy generation. This natural advantage has long been recognized, but early adoption was relatively slow. Before the 2000s, solar use in Crete was largely confined to solar thermal systems—especially rooftop water heaters—rather than electricity-producing solar-PV systems. The broader development of photovoltaics in Greece began in the late 2000s, driven by government incentives such as feed-in tariffs that encouraged investment in solar installations. These policies led to a rapid increase in solar-PV deployment nationwide, with solar electricity growing from negligible levels in 2000 to a significant share of the energy mix by the 2010s . In Crete, early photovoltaic projects included small- to medium-scale solar parks. For example, around 2010, several solar parks were constructed across the island, demonstrating both the technical feasibility and economic potential of solar-PV systems in the region. These installations benefited from the island’s high sunshine hours and helped reduce greenhouse gas emissions while supplying clean electricity to the local grid. However, Crete’s electricity system historically operated in isolation from mainland Greece, relying heavily on expensive and polluting diesel-fired power plants. This autonomy posed challenges for integrating variable renewable energy sources like solar-PV.

A major turning point came with the gradual interconnection of Crete’s grid to the mainland. This development has enabled greater penetration of renewable energy by stabilizing supply and allowing excess generation to be exported. Grid interconnection is widely seen as a key enabler for scaling up solar and wind power on the island and reducing reliance on fossil fuels. As a result, photovoltaic deployment in Crete is increasingly aligned with national and European decarbonization goals. Technological innovation has also played a significant role in the evolution of solar-PV on the island. While early systems were primarily ground-mounted, recent research and pilot projects have explored alternative configurations to overcome land-use constraints. These include rooftop installations, agrivoltaics (combining agriculture and solar panels), and floating photovoltaic systems on reservoirs and lakes. Such approaches aim to maximize energy production while minimizing conflicts with agriculture and tourism—both vital sectors of Crete’s economy. For instance, studies have shown that floating solar-PV installations on water bodies could generate substantial electricity without occupying valuable land resources. Despite these advances, challenges remain. The island’s mountainous terrain and limited flat land can restrict the development of large solar farms. Additionally, administrative barriers, grid capacity limitations, and financial constraints have slowed the widespread adoption of rooftop solar-PV systems among households and businesses. Nevertheless, policy mechanisms such as net metering—allowing consumers to offset their electricity bills with self-generated solar power—have begun to encourage decentralized installations. Looking ahead, the potential for solar photovoltaics in Crete is substantial. Studies suggest that, with sufficient investment and planning, solar-PV alone could theoretically meet the island’s entire electricity demand, requiring installed capacity in the range of a few gigawatts. Combined with energy storage and complementary renewable sources like wind energy, this could enable Crete to achieve a near-zero emission electricity system. Therefore, the development of solar photovoltaics in Crete has progressed from small-scale, policy-driven beginnings to a more mature and diversified sector. While technical and institutional challenges persist, ongoing grid integration, technological innovation, and supportive policies position the island as a key player in Greece’s renewable energy transition. Crete’s experience highlights both the opportunities and complexities of deploying solar energy in island environments, offering valuable lessons for similar regions worldwide. Table 1 indicates the installed solar-PV systems in 2018 in Crete.

**Table 1. Electricity generation from solar photovoltaics in Crete (2018)**

| Energy technology | Installed capacity ($MW_p$) | Generated electricity (MWh) | %, of total generated electricity in Crete |
|---|---|---|---|
| Solar-PV installed on the fields | 78 | 109,531 | 3.60 |
| Solar-PV installed on rooftop of buildings | 18 | 25,277 | 0.83 |
| Total solar-PV installations | 96 | 134,808 | 4.43 |

## 4. CULTIVATION OF OLIVE TREES IN CRETE

The cultivation of olive trees in Crete is deeply intertwined with the island's history, economy, and cultural identity. For thousands of years, olives have been a central agricultural product, shaping not only the landscape but also the daily life and traditions of Cretan society. Today, Crete remains one of the most important olive oil-producing regions in Greece, renowned for both the quality and quantity of its production. The origins of olive cultivation in Crete date back to the ancient Minoan civilization (circa 3000–1100 BCE). Archaeological findings, including storage jars and olive presses, indicate that olives and olive oil were already significant commodities during this period. Olive oil was used for food, religious rituals, cosmetics, and trade, and it played a vital role in the economic prosperity of the island. This long tradition has continued uninterrupted, making olive cultivation one of the oldest agricultural practices in Crete. Crete's natural environment is particularly well suited for olive trees. The island enjoys a typical Mediterranean climate, characterized by hot, dry summers and mild, wet winters. Such conditions are ideal for olive cultivation, as olive trees are highly resistant to drought and thrive in well-drained soils. Much of Crete's terrain is mountainous or semi-arid, which limits other types of agriculture but favors cultivation of olives. As a result, olive groves dominate the landscape, with millions of trees spread across the island.

One of the most widely cultivated olive varieties in Crete is the Koroneiki olive. This variety is particularly valued for its ability to produce high-quality olive oil with low acidity and a rich, fruity flavor. Although the fruits themselves are small, they have a high oil content, making them ideal for oil production rather than table consumption. The resulting olive oil is often classified as extra virgin and is internationally recognized for its nutritional and sensory qualities. Traditional cultivation methods still play a significant role in Cretan olive farming. Many groves are family-owned and have been passed down through generations. Farmers often rely on manual or semi-mechanized harvesting techniques, such as hand-picking or using small tools to shake olives from the branches. These practices, while labor-intensive, help preserve the quality of the fruit and minimize damage to the trees. In recent years, however, there has been a gradual shift toward more modern techniques, including mechanized harvesting and improved irrigation systems, aimed at increasing efficiency and productivity. Olive oil production is a crucial part of Crete's economy. The island produces a substantial share of Greece's total olive oil, much of which is exported to international markets. Beyond its economic importance, olive oil is also central to the local diet, particularly within the framework of the Mediterranean diet. This diet, widely regarded as one of the healthiest in the world, emphasizes the use of olive oil as a primary source of fat, contributing to its global reputation. Despite its strengths, olive cultivation in Crete faces several challenges. Climate change poses a growing threat, with rising temperatures and irregular rainfall patterns affecting yields and increasing the risk of pests and diseases. Additionally, economic pressures and global competition can impact local producers, particularly small-scale farmers. Fluctuating market prices and the cost of maintaining traditional practices can make olive cultivation less profitable. To address these issues, there is increasing emphasis on quality certification, organic farming, and branding strategies that highlight the unique characteristics of Cretan olive oil. Therefore, the cultivation of olive trees in Crete is a practice rooted in ancient history and sustained by favorable natural conditions and cultural traditions. While modern challenges require adaptation and innovation, the resilience of the olive tree and the enduring importance of olive oil ensure that this agricultural heritage will continue to thrive. As both a symbol of continuity and a driver of economic activity, olive cultivation remains at the heart of life in Crete. Taking into account that the total area of olive groves in Greece in 2020 was 584,242 ha (26) and the area of olive groves in Crete corresponds at 26% of the area of olive groves in Greece (6) it is concluded that the area of olive groves in Crete is 151,920 ha.

## 5. AGRIVOLTAICS

Agrivoltaics, also known as agro-photovoltaics, is an innovative approach that combines agricultural production with solar energy generation on the same land. Rather than treating farming and energy production as competing land uses, agrivoltaics integrates solar photovoltaic panels into agricultural systems, creating a dual-use model that can enhance both food and energy output. As global demand for renewable energy rises alongside concerns about food security and land scarcity, agrivoltaics has emerged as a promising solution. The concept of agrivoltaics was first proposed in the early 1980s but only in recent decades—due to falling solar technology costs and growing environmental awareness—that the idea has gained practical traction. Today, agrivoltaics are being tested and implemented in countries such as Japan, Germany, France, and the United States. At its core, agrivoltaics relies on a careful balance between sunlight allocation and crop needs. Solar panels are typically mounted at a height or spacing that allows sufficient light to reach the plants below. Interestingly, partial shading from the panels can benefit certain crops, especially in regions with intense sunlight. Reduced exposure can lower water evaporation, decrease heat stress, and improve soil moisture retention. Studies have shown that crops like lettuce, spinach, and some herbs can thrive under these conditions, sometimes even yielding better results than in full sunlight. From an energy perspective, agrivoltaics offers significant advantages. By installing photovoltaic systems over farmland, land-use efficiency increases, as a single area produces both food and electricity. This is particularly valuable in regions where land is limited or highly contested. Moreover, the cooling effect from vegetation can improve the efficiency of solar panels, as lower temperatures help maintain optimal performance. Thus, the interaction between crops and solar-PV systems can be mutually beneficial.

Agrivoltaics also contributes to sustainability goals. It aligns closely with the principles of sustainable development by addressing multiple challenges simultaneously: renewable energy generation, climate change mitigation, and agricultural resilience. Farmers can diversify their income by producing electricity in addition to crops, which can provide financial stability in the face of unpredictable weather or market fluctuations. In some cases, excess electricity can be sold back to the grid, creating an additional revenue stream. Despite its advantages, agrivoltaics faces several challenges. One of the main issues is the initial cost of installation, which can be higher than conventional solar farms due to the need for elevated or specially designed structures. There are also technical considerations, such as optimizing panel placement to balance light distribution and energy output. Not all crops are suitable for agrivoltaics, and careful selection is required to ensure compatibility. Furthermore, regulatory frameworks in many countries are not yet fully adapted to dual-use land systems, which can complicate project approval and funding. Another concern is the potential impact on traditional farming practices. Farmers may need training to manage agrivoltaics effectively, and the presence of solar infrastructure can limit the use of large agricultural machinery. However, ongoing research and technological advancements are addressing these issues, making systems more adaptable and farmer-friendly. In regions like Crete and other Mediterranean areas, agrivoltaics holds particular promise. These regions experience high solar radiation and increasing water scarcity, making the combination of shading and energy production especially beneficial. Integrating agrivoltaics into existing agricultural systems, such as olive groves, could help maintain productivity while supporting the transition to renewable energy. Therefore, agrivoltaics represents a forward-thinking approach to land use that bridges the gap between agriculture and energy production. By enabling the simultaneous generation of food and clean electricity, it offers a practical pathway toward a more sustainable and resilient future. While challenges remain in terms of cost, design, and policy measures, the growing interest and successful pilot projects worldwide suggest that agrivoltaics could play a significant role in the global transition to renewable energy and sustainable agriculture. Table 2 indicates the benefits of using agrivoltaics in olive groves while Table 3 the challenges in using agrivoltaics in olive groves.

**Table 2. Benefits of using agrivoltaics in olive groves**

| | |
|---|---|
| 1 | Regulate the microclimate in olive groves |
| 2 | Reduce the excessive water losses in the soil |
| 3 | Generates electricity offering an additional income to farmers |
| 4 | Increase the resilience of olive groves in extreme weather events |
| 5 | Reduce the water needs in olive trees |
| 6 | Reduce the carbon emissions in olive groves producing on-site solar electricity |
| 7 | Reduce the dependence on the grid |
| 8 | Reduce the wind speed compared to conventional olive groves |

**Source:** own estimations

**Table 3. Challenges in using agrivoltaics in olive groves**

| | |
|---|---|
| 1 | Requires an upfront cost for the installation of the panels which might be prohibitive to small-size farm owners |
| 2 | Requires specific expertise to obtain the right balance between shade and sunlight which might be not available |
| 3 | Due to aesthetic and cultural considerations local communities may resist in solar-PV installations in olive groves |

**Source:** own estimations

## 6. POSSIBILITIES OF USING AGRIVOLTAICS IN OLIVE GROVES IN CRETE

### *6.1 Use of agrivoltaics in olive groves*

Olive cultivation, deeply rooted in regions characterized by intense sunlight and periodic drought, presents an ideal context for integrating photovoltaic panels without compromising agricultural productivity. One of the key advantages of agrivoltaics in olive groves is the creation of a microclimate that can benefit both trees and soil. Solar panels provide partial shading, which can reduce extreme heat stress on olive trees during peak summer months. This moderated environment may help maintain soil moisture levels, reduce evaporation, and potentially improve water-use efficiency—an increasingly critical factor under climate change conditions. In some cases, this shading can even enhance olive yields or stabilize production during particularly harsh seasons. Additionally, agrivoltaics offer farmers a diversified income stream. Beyond olive oil production, farmers can generate revenue from solar energy, either through direct use, storage, or sale to the grid. This dual-purpose land use can increase economic resilience, especially in regions where agricultural income alone is uncertain due to fluctuating weather patterns or market prices. However, challenges remain. The installation of solar infrastructure must be carefully designed to avoid interfering with traditional farming practices such as harvesting and pruning. There are also concerns about initial investment costs, visual impact on landscapes, and the need for supportive policy frameworks. Overall, installation of agrivoltaics in olive groves represents a compelling synergy between renewable energy and traditional agriculture.

*6.2 Use of agrivoltaics in olive groves in Crete*

Crete's abundant sunshine, a defining feature of the Mediterranean climate, makes it particularly suitable for solar energy generation. At the same time, olive trees, known for their resilience, can adapt well to the partial shading created by elevated solar panels. In Crete, water scarcity and rising temperatures are growing concerns due to climate change. Agrivoltaics can help address these challenges by reducing soil evaporation and maintaining higher moisture levels beneath the panels. The moderated microclimate may also protect olive trees from heat stress during peak summer months, potentially stabilizing yields and preserving the quality of olive oil—an essential product for the island's economy and cultural identity. Moreover, agrivoltaics can provide Cretan farmers with an additional and reliable source of income. By generating electricity either for on-farm use or for sale to the grid, farmers can reduce dependence on fluctuating agricultural markets. This diversification is particularly valuable in rural areas where economic opportunities may be limited. However, successful implementation requires careful planning. Solar panel placement must allow for traditional farming practices such as pruning and harvesting, and should respect the visual character of Crete's historic landscapes. Upfront costs and regulatory barriers may also pose challenges, especially for small-scale farmers. Therefore, agrivoltaics represents a promising pathway for enhancing sustainability and resilience in Crete's olive groves. By combining renewable energy production with traditional agriculture, agrivoltaics support both environmental goals and rural livelihoods, aligning modern innovation with centuries-old farming heritage.

*6.3 Estimation of electricity generation from installation of agrivoltaics in olive groves in Crete*

For the estimation of the electricity generation from agrivoltaics installed in olive groves in Crete the following assumptions have been made.

1. The annual electricity generation by Solar-PV modules with nominal power 1 $kW_p$ in Crete is 1,500 kWh
2. The annual electricity generation from agrivoltaics in Crete is 65.9 $kWh/m^2$ (11)
3. The energy efficiency of mono-crystalline silicon solar-PV panels is 20%
4. The total area of olive groves in Crete is 151,920 ha
5. The area of Cretan olive groves covered by opaque solar-PV panels will be 1% or 1,519 ha
6. The covered area by solar-PV modules in olive groves - in two scenarios - are 15% and 30%
7. The average annual electricity consumption per household is 4,000 kWh
8. The annual electricity demand in Crete is 3,198.13 GWh (23)
9. The $CO_2$ emission coefficient is 234.78 $gCO_2/kWh$

The results of the estimation are presented in table 4.

**Table 4. Electricity generation by agrivoltaics installed in olive groves in Crete in two scenarios with covered area by solar-PV panels in olive groves at 15% and 30%**

| | | |
|---|---|---|
| Total area of olive groves in Crete | 151,920 ha | 151,920 ha |
| Area of 1% of the olive groves in Crete | 1,519 ha | 1,519 ha |
| Covered area by solar-PV modules in Cretan olive groves | 15% | 30% |
| Surface of solar-PV modules in olive groves in Crete | 227.85 ha | 455.70 ha |
| Electricity generated by solar-PV modules installed in olive groves annually | 150.15 GWh/year | 300.3 GWh/year |
| Average annual electricity consumption per household | 4,000 kWh | 4,000 kWh |
| Number of households which can be powered by solar electricity generated in olive groves | 37,537 | 75,075 |
| Annual electricity generation by solar-PV modules installed in olive groves to total annual electricity demand in Crete | 4.69% | 9.38% |
| Annual carbon emission savings due to solar electricity generation | 35,252 $tCO_2$ | 70,504 $tCO_2$ |

**Source:** own estimations

## 7. CLIMATE CHANGE MITIGATION AND ADAPTATION IN OLIVE GROVES WITH AGRIVOLTAICS INSTALLATIONS

Agrivoltaics offer a promising pathway for climate change mitigation by maximizing land-use efficiency. When applied to olive groves, this approach creates a powerful dual-function system: generating solar electricity while simultaneously enhancing carbon sequestration through perennial biomass. Olive trees are well adapted to Mediterranean climates and have long lifespans, often spanning decades or even centuries. Their extensive root systems and woody biomass make them effective carbon sinks, capturing atmospheric carbon dioxide and storing it both above and below ground. Unlike annual crops, olive groves provide continuous carbon sequestration without the need for frequent soil disturbance, which helps preserve soil organic carbon and reduces emissions associated with tillage. The integration of photovoltaic panels into olive groves introduces an additional climate benefit: zero-carbon energy production. Solar panels convert sunlight into electricity without emitting greenhouse gases, displacing fossil fuel-based energy sources and contributing in climate change mitigation. In regions with high solar irradiance—such as southern Europe—agrivoltaics can significantly contribute to national renewable energy targets while maintaining agricultural productivity. Importantly, agrivoltaics can create synergistic effects within olive groves. Partial shading from solar panels may reduce water stress by lowering evapotranspiration rates, which is particularly valuable in drought-prone areas. This microclimate modification can improve tree resilience under rising temperatures, heat waves and shifting precipitation patterns associated with climate change. This helps the adaptation of olive trees to climate change. In some cases, it may even enhance olive yield stability, although outcomes depend on system design and local conditions. From a land-use perspective, agrivoltaics addresses the growing competition between energy and food production. Rather than converting agricultural land into solar farms, this approach enables simultaneous use, preserving rural livelihoods and cultural landscapes while advancing decarbonization goals. For olive-producing regions like Crete, where groves are integral to both economy and heritage, this is especially significant. Therefore, the combination of olive cultivation and solar energy generation represents a compelling climate mitigation strategy. By coupling carbon sequestration with solar electricity generation, agrivoltaics in olive groves exemplify how multifunctional land systems can contribute to a more sustainable and resilient future.

## 8. DISCUSSION

The possibility of developing agrivoltaics in olive groves in Crete has been examined. The results indicate that installation of agrivoltaics in olive groves without reducing the productivity of olive trees in Crete has many benefits. Firstlit offers an additional income to the farmer. Secondly it increases the resilience of olive groves to climate change which is expected to be less favorable to olive tree cultivation in the future. Taking into account that climate models predict that the air temperature is going to increase, the precipitation is going to decrease and the extreme weather events to become more frequent the need to adapt the olive trees in Crete to climate change is urgent. Several studies have proposed the development of cultivars that are heat resistant and the rational irrigation of the trees, in the case of water availability. Agrivoltaics reduce the water requirements of olive trees, reduce the water losses in the soil and decrease the wind speed regulating the local microclimate. However, more experimental work in the real fields is required to find the optimum characteristics of agrivoltaics, such as size, configuration, degree of shading et cetera, which can be installed in Cretan olive groves. The estimated electricity generation from agrivoltaics installed in olive groves in Crete is high indicating the potential of agrivoltaics technology in the island. The accuracy of our results depends on the accuracy of the assumptions made and the data used. It is recommended that future work should be focused in conducting pilot studies related with installation of agrivoltaics in olive groves in Crete monitoring their performance as well as the productivity of olive trees.

## 9. CONCLUSIONS

The present work has investigated the possibility of installing agrivoltaics in olive groves in Crete estimating the solar electricity generation. Climate change has adverse impacts to olive trees in Crete reducing their productivity and threatening trees' growth. The solar irradiance in Crete is high while there are currently many solar photovoltaic installations in the island. Installation of agrivoltaics in olive groves in Crete alters their microclimate having many benefits to olive trees. Agrivoltaics can generate an additional income to farmers, they increase the resilience of olive trees and promote their adaptation to climate change while they result in carbon emission savings. Installation of agrivoltaics in 1% of the surface area of olive groves in Crete, with coverage ratio 15%, can generate electricity equal to 4.69% of the annual electricity demand in the island. The percentage of generated electricity at 4.69% is higher than the value reported in literature at 1.8% (11). The generated electricity can cover the demand of 37,537 households while it will reduce the annual carbon emissions by 35,252 $tCO_2$. However, there is lack of experimental data related to the characteristics of agrivoltaics' installation in olive groves in Crete regarding the optimum coverage ratio, the height of the solar modules and the permissible shading rate. The current study concludes that development of agrivoltaics in olive groves in Crete can generate significant amount of solar electricity having many benefits to farmers, to olive trees and to environment.

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