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# ESTIMATION OF CARBON SEQUESTRATION FROM OLIVE TREE GROVES IN THE ISLAND OF CRETE, GREECE

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## ABSTRACT

Tree plantations remove atmospheric carbon through photosynthesis, assisting in climate change mitigation. Olive oil is the main agricultural product produced in the island of Crete, Greece. The role of olive groves in carbon removal in the island has not been investigated so far. The current work aims in evaluating the annual carbon sequestration in Crete from olive groves. Existing data regarding carbon removal rate from olive trees have been used combined with the cultivated area of olive tree orchards in Crete. The annual carbon removal rate in olive groves is at 2.5 tC/ha while the area of olive tree plantations in Crete is estimated at 142,900 ha. The annual carbon sequestration rate due to olive groves in Crete is estimated at 1,310,393 $tCO_2$ or 1.92 $tCO_2$ per capita. This is compared with 3.03 $tCO_2$ per capita emitted during electricity generation in the island and 0.14 $tCO_2$ per capita emitted due to heating oil use in heating buildings. It corresponded at 32.54 % of the total $CO_2$ emissions per capita in the country in 2017. The results indicate that carbon sequestration due to olive groves in Crete is not negligible and it should be taken into account in designing the appropriate policies for reducing the carbon footprint in the island.

**Keywords:** Carbon emissions, carbon sequestration, olive trees, electricity, fossil fuels, heating, Crete

## 1. INTRODUCTION

Mitigation of climate change is of paramount importance in order to avoid the painful consequences of a global temperature increase. Atmospheric carbon sequestration from tree plantations through photosynthesis, combined with replacement of fossil fuels with renewable energies, is going to mitigate future temperature rise. The olive tree is extensively cultivated in the Mediterranean region producing the valuable, edible and nutritious olive oil. However studies in Greece and in other Mediterranean countries regarding the role of olive groves in the removal

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

of atmospheric carbon are limited so far. The olive tree is broadly cultivated in Crete, Greece producing high quality virgin olive oil which is exported all over the world. Fossil fuels are currently used in Crete for power generation as well as in buildings, in transport, in agriculture and in industry resulting in $CO_2$ emissions into the atmosphere. Reduction of carbon emissions could be achieved either by replacing fossil fuels with benign energy sources or by removing atmospheric carbon with tree plantations through photosynthesis. Estimation of the atmospheric carbon removal from the existing olive groves in the island of Crete is necessary and useful for evaluating the possibility of offsetting by tree plantations part of the carbon emissions due to fossil fuel use in the island. This is important in order to design the appropriate policies for reducing the overall $CO_2$ emissions in Crete, complying with the National, European and global targets regarding climate change mitigation.

## 2. LITERATURE SURVEY

### *2.1 Carbon sequestration from olive groves*

**Bateni et al, 2019** have studied the soil carbon stock in olive groves in the Umbria region, Italy. The authors mentioned that few studies are available so far examining the carbon stocks in olive orchards in Italy. They stated that their carbon stock has been reported in various published research in the range of 22.9 (+/-8) tC/ha to 95.4 (+/- 8.16) tC/ ha. **Lopez-Bellido et al, 2016** have assessed the carbon footprint in olive groves in Southern Spain. The authors estimated the net carbon balance in a plantation of 1,121 ha olive groves. They found that the net carbon balance in the plantations was positive while the annual carbon sequestration rate was in the range of 2.05 to 4.10 tC/ha. **Massaccesi et al, 2018** have evaluated the potential of olive tree cultivation to store soil organic carbon. The authors found that a 30 year old olive grove has stored the same amount of organic carbon in the soil like a cereal crop in a nearby site. **Proietti et al, 2014** have estimated the carbon footprint of an olive tree grove located in central Italy. The authors stated that the average annual $CO_2$ sequestration for the first 11 years of the olive grove was at 1.507 $tCO_2$ per ha. **Nieto et al, 2012** have investigated the carbon removal rate in Mediterranean olive tree cultivations. The authors experimented with olive groves located in Andalusia, Spain using two management systems including conventional tillage and cover crops. They found that the use of cover crops in olive groves increases the carbon storage in the soil. **Regni et al, 2017** investigated the impact of adding solid olive mill wastes in olive groves on carbon sequestration. The authors mentioned that adding these wastes in the olive tree cultivation increases the carbon sequestration by the trees. They estimated that approximately 50% of the carbon contained in the solid olive mill wastes was sequestered in olive groves, while most of it was stored in the soil. **Repullo-Ruiberriz de Torres et al, 2012** have studied the carbon sequestration potential of residues of four different types of cover crops in olive groves with

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

reference to Southern Spain. The authors found that the maximum increase in the soil's organic carbon achieved in a period of three years was 7.69 tC/ha. **Chamizo et al, 2017** have studied the net ecosystem $CO_2$ exchange in an irrigated olive orchard in South East Spain. The authors measured the net ecosystem $CO_2$ exchange in an irrigated olive plantation with and without weed cover. The first olive orchard had weed cover from autumn to spring and the second did not have any cover. Their results indicated that the annual net ecosystem $CO_2$ exchange was 140 $gC/m^2$ in the weed cover treatment and 70 $gC/m^2$ in the weed free treatment. **Castro et al, 2008** have studied the impacts of different olive-grove management systems on the organic carbon of the soil in Jaen, Spain. The authors examined the impacts of five olive-grove soil management systems on soil organic carbon content over a period of 28 years. The highest value of soil carbon achieved was 42.1 tC/ha. **Brilli et al, 2018** have studied the carbon sequestration capacity and productivity responses of Mediterranean olive groves under future climate and management options. The authors experimented in two Italian olive groves, estimating their carbon sequestration capacity expressed by the net ecosystem exchange (NEE). The annual NEE in these olive groves was on average at 8.28 tC/ha. **Nardino et al, 2013** have reported on the annual and monthly carbon balance in an intensive managed Mediterranean olive orchard. The authors estimated that the net annual carbon exchange ranged between 13.45 tC per ha to 11.6 tC per ha. They mentioned that the intensive farming management of the olive trees resulted in higher carbon sequestration compared with other studies reported in the literature. A sectoral report on olive oil has been published by the **National Bank of Greece, 2015.** According to this report, the annual average olive oil production in Crete is 105,000 tons, corresponding at 30% of the national production. The results of the **European Life project "Olive4climate", 2019** mentioned that 252,713 tons$CO_2$ could be sequestrated annually in Greek olive orchards (which correspond at 75,814 tons$CO_2$ for Cretan olive orchards) while an increase of carbon storage could be achieved by better management of the olive tree's pruning and residues as well as with the creation of a green cover in the olive orchards.

### *2.2 Carbon sequestration by other tree plantations*

**Padilla et al, 2010** have studied carbon sequestration during the 20$^{th}$ century in a Mediterranean mountain ecosystem. The authors examined an area in south Eastern Spain of approximately 13,000 ha where dry land and pasture were replaced by forest during the second half of the 20$^{th}$ century. They found that the increase in carbon sequestration in this area exceeded 30,000 t$CO_2$ per year. **Geraldo et al, 2010** have studied the carbon storage in carob trees. The authors estimated the carbon assimilation by carbon trees in Algarve, Portugal. They found that the overall aboveground $CO_2$ fixation was 15.56 t$CO_2$ per ha which is low compared with other tree species but still important and valuable. Annual carbon removal has been estimated at 0.184 tC/ha (0.669 t$CO_2$/ha). **Correira et al, 2016** have studied two farming strategies in drought-

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

ridden carob-tree orchards in Mediterranean ecosystems. One farming system contained purely carob trees while the other contained carobs, figs, almonds and olive trees. The authors estimated the benefits due to carbon sequestration by the trees, mentioning that the resulting income was important for the farmers. **Bravo et al, 2008** have studied carbon sequestration in Spanish pine forests under different management alternatives. The authors mentioned that the annual carbon fixation rate was in the range of 1-3 tC/ha. They also stated that these forests could be used for carbon offsetting and payments, complementing other uses like timber production. **Ramachandran Nair et al, 2009** have reported on the climate mitigation impacts of agro-forestry. The authors mentioned that agro-forestry has a high potential for carbon sequestration with low cost. They also stated that the profitability of carbon removal in agro-forest systems depends on the market prices of carbon and the additional income that the system could offer to farmers. **Kaul et al, 2010** have evaluated the carbon sequestration potential of various tree species in India including sal, eucalyptus, poplar and teak species. The authors stated that the net annual carbon sequestration rate was 8 tC/ha for poplar, 6 tC/ha for eucalyptus, 2 tC/ha for teak and 1 tC/ha for sal forests. **Scandellari et al, 2016** have studied the carbon sequestration potential of orchards and vineyards in Italy. The authors evaluated the carbon removal from vineyards and orchards with apples, citrus, olives and peaches, which are grown in Southern Italy. They found that the annual carbon sequestration rate was in the range from 0.6 to 5.9 tC per ha. **Du et al, 2015** have investigated carbon storage in eucalyptus plantations in Southern China. The authors studied carbon storage in eucalyptus species, which grow rapidly and accumulate large quantities of biomass carbon. They found that the average annual carbon sequestration rate of trees between one and eight years old was at 8.8 tC per ha. They also mentioned that more carbon was stored below ground than above ground.

### *2.3 Carbon emissions due to energy use in Crete*

Heating oil consumption in Greece has been significantly reduced due to the economic crisis during the last decade while it is currently the main fossil fuel used in Crete for heating buildings. Heating oil consumption used in buildings in Crete during 2018 was at 29,881 tons (**www.statistics.gr**). Electricity generation and fossil fuel consumption in Crete has been reported by **DEDDIE, 2018**. Total electricity generation in Crete during 2018 was 3,042.8 GWh while most of it was generated in thermal power stations fueled by heating oil and diesel oil. Heating oil consumption in 2018 in Crete was at 455,684 tons while diesel oil consumption was at 195,055 tons. **Vourdoubas, 2016** has studied the reduction of $CO_2$ emissions in Crete, Greece during the period 2007-2013 when Greece underwent a severe economic crisis. The author estimated that $CO_2$ emissions due to energy use in Crete decreased at this period by 25.90 % while the Greek GDP was reduced in the same period by 25.45%, indicating the coupling between those two parameters. Carbon emissions for Greece (2017) have been reported at 5.9

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

$tCO_2$/capita, **OECD**. Carbon sequestration rate in olive groves reported in various studies so far is presented in Table 1.

**Table 1: Carbon sequestration in olive groves according to published studies.**

| Author, year | Country | Annual carbon sequestration |
|---|---|---|
| Lopez-Bellido et al, 2016 | Southern Spain | 2.05-4.10 tC/ha |
| Proietti et al, 2014 | Central Italy | 1.507 tC/ha |
| Brilli et al, 2018 | Italy | 8.28 tC/ha |
| Nardino et al, 2013 | Italy | 11.6- 13.45 tC/ha |
| Chamizo et al, 2017 | South East Spain | 0.7-1.4 tC/ha |

Source: published literature

*The aims of the current work are:*

a) *The assessment of the carbon sequestration rate in olive groves from existing published data,*

b) *The estimation of the annual carbon sequestration from the existing olive groves in the island of Crete, Greece, and*

c) *The comparison of the carbon sequestrated annually in olive orchards in Crete with the annual carbon emissions due to electricity generation and to fossil fuels use in heating buildings in the island.*

The methodology used includes initially the estimation of the carbon sequestration rate in olive groves as well as the estimation of the cultivated area of existing olive groves in Crete. The annual carbon sequestration in existing olive orchards in Crete is then estimated followed by the calculation of the annual carbon emissions due to electricity generation and to heating buildings in the island. Finally the carbon sequestrated by olive groves in Crete is compared with the carbon emissions due to electricity generation and to heating buildings followed by the discussion of the findings and the conclusions drawn. Limitations in our work are related with our assumption regarding the carbon sequestration rate in olive groves due to the high variation in the values reported in published research.

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

## 3. OLIVE GROVES IN THE ISLAND OF CRETE

Greece is the third largest world producer of olive oil (11% of total volume production) following Spain (40 %) and Italy (14 %). The island of Crete produces 30% of the Greek production while most of it is of excellent quality. Olive tree plantations in Greece correspond approximately to 14% of total plantations while in the island of Crete olive tree is the dominant cultivated tree in an area of 142,900 ha (tree plantations in Greece, 2016, www.statistics.gr). Annual olive oil production in Crete varies according to climate conditions and an average annual production at 105,000 tons has been reported. It should be noted that the olive tree's farming management and the number of olive trees per ha differs significantly depending on various parameters including the variety of olive's tree, type of soil, landscape structure, age of the trees, use of irrigation etc.

## 4. CARBON SEQUESTRATION IN OLIVE GROVES IN CRETE

Atmospheric carbon is removed through photosynthesis and it is stored in the plants and the trees either aboveground or belowground in the roots as well as in the soil. Carbon sequestration rates in olive orchards reported in published studies varies significantly, in the range at 0.7 to 13.45 tC/ha, as presented in Table 1. Carbon removal rates depend on the farming management of the grove and the irrigation of the olive trees. Intensive cultivation increases the carbon removal rate. Creation of a green cover in the olive field and grinding the tree pruning and residues in order to remain in the field also increases the sequestration rate. In order to estimate the carbon sequestration in olive groves in the island and due to lack of experimental data for Crete, it has been assumed that their annual carbon sequestration rate is 2.5 tC/ha or 9.17 $tCO_2$/ha. Therefore, the annual carbon sequestration from the existing olive groves in the island is estimated at 357,250 tC or 1,310,393 $tCO_2$. This value is significantly higher than the value reported in other studies (LIFE project Olive4climate, 2019). Taking into account that the population of Crete is 682,928 inhabitants (Census 2011, www.statistics.gr), it is concluded that the carbon sequestration rate from the Cretan olive groves is 1.92 $tCO_2$ per inhabitant. This corresponds to 32.54 % of the total $CO_2$ emissions per capita in Greece in 2017.

## 5. ELECTRICITY GENERATION AND CARBON EMISSIONS IN THE ISLAND OF CRETE

Electricity is mainly generated in Crete with fossil fuels (heating oil and diesel oil) as well as with renewable energies mainly from solar-PV and wind energy. During 2018, 21% of total electricity in Crete was generated by renewable energies and the remaining 79% by fossil fuels. The electricity grid of Crete is not currently interconnected with the grid of continental Greece.

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

The quantities of fossil fuels used in Crete for electricity generation in 2018 as well as their $CO_2$ emissions are presented in Table 2.

**Table 2: Heating oil and diesel oil used in 2018 in Crete for electricity generation [1].**

| Fossil fuel used | Annual consumption | Annual $CO_2$ emissions |
|---|---|---|
| Heating oil | 455,684 tons | 1,458,189 $tCO_2$ |
| Diesel oil | 195,055 tons | 614,423 $tCO_2$ |
| Total | 650,739 tons | 2,072,612 $tCO_2$ |
| Total annual consumption per capita | 0.95 tons/capita | 3.03 $tCO_2$/capita |

[1] $CO_2$ emissions of heating oil 3.2 $kgCO_2/kg$, $CO_2$ emissions of diesel oil 3.15 $kgCO_2/kg$

Source: DEDDIE and own estimations

## 6. USE OF HEATING OIL FOR HEATING BUILDINGS IN THE ISLAND OF CRETE

Public and private buildings consume energy for heating purposes. The main energy sources used for that in Crete include: a) electricity, b) heating oil, and c) solid biomass. Natural gas is not currently available in the island. During the recent economic crisis in Greece, heating oil consumption in buildings in Crete has been significantly reduced compared with its consumption before 2010. The quantity of heating oil used in buildings in Crete during 2018 as well as the $CO_2$ emissions due to its use is presented in Table 3.

**Table 3: Heating oil used in buildings during 2018 in Crete**

| | |
|---|---|
| Annual consumption of heating oil in buildings | 29,881 tons |
| Annual consumption per capita | 0.044 tons/capita |
| Annual $CO_2$ emissions | 95,619 $tCO_2$ |
| Annual $CO_2$ emissions per capita | 0.36 $tCO_2$/capita |

Source: www.statistics.gr and own estimations

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

## 7. COMPARISON OF CARBON SEQUESTRATION IN OLIVE GROVES WITH CARBON EMISSIONS DUE TO ELECTRICITY GENERATION AND DUE TO USE OF HEATING FUELS IN BUILDINGS IN CRETE

Olive groves can sequester significant amounts of atmospheric carbon. The rate of removal depends on the cultivation management including irrigation of the trees, grinding of the pruning and tree residues in order to remain in the field and the creation of a green cover among the trees. Although studies regarding carbon removal in olive tree plantations are limited so far, the values reported in published literature differ significantly (Table 1). The estimated annual atmospheric carbon sequestration by olive orchards in the island of Crete is compared with the carbon emissions due to fossil fuel use for electricity generation in the island as well as the carbon emissions due to heating oil use for heating buildings. The results are presented in Table 4. It is indicated that the annual carbon sequestration in olive groves in Crete corresponds at 60.57% of the carbon emissions due to both electricity generation and heating oil use in buildings.

**Table 4: Comparison of carbon sequestration in olive groves with carbon emissions due to electricity generation and due to use of heating fuels in buildings in Crete (removal -, emissions +)**

| Source of $CO_2$ removal/emissions | Annual carbon balance | Annual carbon balance per capita |
|---|---|---|
| Existing olive groves in Crete | - 1,310,393 $tCO_2$ | - 1.92 $tCO_2$/capita |
| Use of fossil fuels for electricity generation in Crete | + 2,072,612 $tCO_2$ | + 3.03 $tCO_2$/capita |
| Use of heating oil for heating buildings in Crete | + 95,619 $tCO_2$ | + 0.14 $tCO_2$/capita |
| Fossil fuels use for electricity generation and heating oil use in buildings | + 2,168,231 $tCO_2$ | + 3.17 $tCO_2$/capita |
| Total emissions in the country [1] | | + 5.9 $tCO_2$/capita |

[1] OECD, Source: own estimations and www.statistics.gr

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

## 8. DISCUSSION

Our results indicate that olive orchards in Crete contribute to atmospheric carbon sequestration which is not negligible compared with the total carbon emissions in the island. Our estimations are based on published data regarding carbon removal in existing olive groves in Mediterranean countries. However carbon removal rates vary significantly in various studies and an average value has been used in our calculations. Our results indicate that existing tree plantations in Crete can be used for offsetting carbon emissions into the atmosphere additionally to replacement of fossil fuels with renewable energies. Carbon removal rates in olive groves are lower than the removal rates reported for various forest trees, including poplar and eucalyptus, as presented in Table 5, while they are higher than in orchards with carobs, apples, peaches and fig trees. Our results could also be used for the estimation of life cycle $CO_2$ emissions of olive oil in Crete. They are important since they can be used for the estimation of net carbon exchange in agriculture in the island. However our results do not indicate the carbon removal rates which are taking place aboveground, belowground and in the soil. Further research should be oriented towards the experimental evaluation of the carbon sequestration capacity of olive groves in Crete including the carbon storage aboveground, underground and in the soil. Additionally the impact of various farming procedures on the carbon sequestration rate should be investigated including intensive farming with irrigation of the olive trees, grinding and recycling the olive tree's pruning and residues in the field, as well as the creation of a green cover with weeds from October to May in the olive groves.

**Table 5: Carbon sequestration rates in various tree plantations**

| Authors, year | Country | Tree plantation | Annual carbon sequestration rate |
|---|---|---|---|
| Padilla et al, 2010 | Spain | Forest species | 0.63 tC/ha |
| Bravo et al, 2008 | Spain | Pine forest | 1-3 tC/ha |
| Kaul et al, 2010 | India | Poplar, Eucalyptus | 8 tC/ha, 6 tC/ha |
| Scandellari et al, 2016 | Italy | Figs, apples, vineyards | 0.6-5.9 tC/ha |
| Du et al, 2015 | Southern China | Eucalyptus | 8.8 tC/ha |
| Geraldo et al, 2010 | Portugal, Algarve | Carob | 0.182 tC/ha |

Source: published literature

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

## 9. CONCLUSIONS

Tree plantations have an important role in mitigating climate change due to atmospheric carbon removal through photosynthesis. Olive trees are extensively cultivated in the island of Crete, Greece producing an excellent quality olive oil while the covered area with olive groves is estimated at 142,900 ha. Carbon sequestration rates in olive orchards reported in published studies so far vary significantly in the range at 0.7 to 13.45 tC/ha. Assuming an annual carbon removal rate in olive groves in Crete at 2.5 tC/ha, the annual $CO_2$ sequestrated quantity is estimated at 1,310,393 $tCO_2$ or 1.92 $tCO_2$ per inhabitant. The annual atmospheric carbon removal from olive groves in Crete corresponds at 60.57% of the sum of the carbon emissions due to electricity generation and due to heating oil use for heating buildings in the island. Annual $CO_2$ removal rate from olive groves per capita in Crete corresponds at 32.54 % of the annual $CO_2$ emissions per capita in Greece. This amount is not negligible and it should be taken into account for the creation of future policies aiming in the carbon neutrality of the island.

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## REFERENCES

Annual report on the energy system in Crete, (2018), Hellenic Electricity Distribution Network Operator (DEDDIE), (in Greek)

Bateni, C., Ventura, M., Tonon, G. & Pisanelli, A. (2019). Soil carbon stock in olive groves agroforestry systems under different management and soil characteristics, Agroforestry Systems, https://doi.org/10.1007/s10457-019-00367-7.

Bravo, F., Bravo-Oviedo, A. & Diaz-Balteiro, L. (2008). Carbon sequestration in Spanish Mediterranean forests under two management alternatives: a modeling approach, European Journal of Forest Resources, 127, 225-234. DOI 10.1007/s10342-007-0198-y

Brilli, L., Lugato, E., Moriondo, M., Gioli, B., Toscano, P. et al. (2018). Carbon sequestration capacity and productivity responses of Mediterranean olive groves under future climates and management options, Mitigation and Adaptation Strategies for Global Change. https://doi.org/10.1007/s11027-018-9824-x

  

Castro, J., Fernandez-Ondono, E., Rodriguez, C., Lallena, A.M., Sierra, M. & Aguilar, J. (2008). Effects of different olive-grove management systems on the organic carbon and nitrogen content of the soil in Jaen (Spain), Soil & Tillage Research, 98, 56-67. doi:10.1016/j.still.2007.10.002

Chamizo, S., Serrano-Ortiz, P., Lopez-Ballesteros, A., Sanchez-Canete, E.P., Vicente-Vicente, J.L. & Kowalski, A.S. (2017). Net ecosystem $CO_2$ exchange in an irrigated olive orchard of SE Spain: Influence of weed cover, Agriculture, Ecosystems and Environment, 239, 51-64. http://dx.doi.org/10.1016/j.agee.2017.01.016

Correira, P.J., Guerreiro, J.F., Pestana, M. & Martins-Loucao, M.A. (2016). Management of carob tree orchards in Mediterranean ecosystems: strategies for a carbon economy implementation, Agroforest Systems. DOI 10.1007/s10457-016-9929-8

Du, H., Zeng, F., Peng, W., Wang, K., Zhang, H., Liu, L. & Song, T. (2015). Carbon storage in a Eucalyptus plantation chronosequence in Southern China, Forests, 6, 1763-1778. doi:10.3390/f6061763

Geraldo, D., Correia, P.J. & Luis Nanes, J.F. (2010). Carob tree as $CO_2$ sink in the carbon market, Advances in Climate Changes, Global Warming, Biological Problems and Natural Hazards, pp. 119-122.

Kaul, M., Mohren, G.M.J. & Dadhwal, V.K. (2010). Carbon storage and sequestration potential of selected tree species in India, Mitigation and Adaptation Strategies for Global Change, 15, 489-510. DOI 10.1007/s11027-010-9230-5

Life project, OLIVE4CLIMATE, LIFE 15CCM/IT/000141, PPT presentation in the final conference, Perugia, Italy, 3/12/2019. Retrieved at 8/6/2020 from https://olive4climate.eu/wp-content/uploads/presentazioni-Olive-Final-Conference_compressed.pdf

Lopez-Bellido, P.J., Lopez-Bellido, L., Fernandez-Garcia, P., Muñoz-Romero, V. & Lopez-Bellido, F.J. (2016). Assessment of carbon sequestration and the carbon footprint in olive groves in Southern Spain, Carbon Management, 7(3-4), 161-170. DOI: 10.1080/17583004.2016.1213126

Massaccesi, L., De Feudis, M., Agnelli, A.E., Nasini, L., Regni, L., D'Ascoli, R., Castaldi, S., Proietti, P. & Agnelli, A. (2018). Organic carbon pools and storage in the soil of olive groves of different age, Soil Science. https://doi.org/10.1111/ejss.12677

  

Nardino, M., Pernice, F., Rossi, F. *et al.* (2013). Annual and monthly carbon balance in an intensively managed Mediterranean olive orchard. Photosynthetica, 51, 63–74. https://doi.org/10.1007/s11099-012-0079-6

Nieto, O.M., Castro, J. & Fernandez-Ondono, E. (2012). Conventional tillage versus cover crops in relation to carbon fixation in Mediterranean olive cultivation, Plant Soil. DOI 10.1007/s11104-012-1395-0

Padilla, F.M., Vidal, B., Sanchez, J. & Pugnaire, F.I. (2010). Land-use changes and carbon sequestration through the twentieth century in a Mediterranean mountain ecosystem: Implications for land management, Journal of Environmental Management, 91, 2688-2695. doi:10.1016/j.jenvman.2010.07.031

Proietti, S., Sdringola, P., Desideri, U., Zepperelli, F., Brunori, A., Ilarioni, L., Nasini, L., Regni, L. & Proietti, P. (2014). Carbon footprint of an olive tree grove, Applied Energy, 127, 115-124. http://dx.doi.org/10.1016/j.apenergy.2014.04.019

Ramachandran Nair, P.K., Mohan Kumar, B. & Nair, V.D. (2009). Agroforestry as a strategy for carbon sequestration, Journal of Plant Nutrition and Soil Sciences, 172, 10-23. DOI: 10.1002/jpln.200800030

Regni, L., Nasini, L., Ilarioni, L., Brunori, A., Massaccesi, L., Agnelli, A. & Proietti, P. (2017). Long Term Amendment with Fresh and Composted Solid Olive Mill Waste on Olive Grove Affects Carbon Sequestration by Pruning, Fruits, and Soil, Frontiers in Plant Science, 7, 2042. doi: 10.3389/fpls.2016.02042

Repullo-Ruiberriz, M.A., Carbonell-Bojollo, R., Alcantara-Brana, C., Rodriguez-Lizana, A. & Ordonez-Fernandez, R. (2012). Carbon sequestration potential of residues of different types of cover crops in olive groves under Mediterranean climate, Spanish Journal of Agricultural Research, 10(3), 649-661. http://dx.doi.org/10.5424/sjar/2012103-562-11

Scandellari, F., Caruso, G., Liguori, G., Meggio, F., Palese, A.M., Zanotelli, D., Celano, G., Gucci, R., Inglese, P., Pitacco, A. & Tagliavini, M. (2016). A survey of carbon sequestration potential of orchards and vineyards in Italy, European Journal of Horticultural Science, 81(2), 106-114. http://dx.doi.org/10.17660/eJHS.2016/81.2.4

Sectoral report on olive oil production in Greece (2015). National Bank of Greece. Retrieved at 8/6/2020 from https://www.nbg.gr/greek/the-group/press-office/e-spot/reports/Documents/Olive%20Oil_2015.pdf

  

ISSN: 2455-6939

Volume: 06, Issue: 04 "July-August 2020"

Vourdoubas, J. (2016). Reduction of $CO_2$ emissions due to energy use in Crete-Greece, Energy and Environment Research, 6(1), 23-36. doi:10.5539/eer.v6n1p23

www.statistics.gr

https://data.oecd.org/greece.htm

  