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Exploring the mitigation potential of tree crops ecosystems in the Mediterranean region

BITHAS K.[1], LATINOPOULOS D.[2,*], PETRIDOU F.[1], SPANOS I.[3], SOTIROPOULOS A.[3], HAROUTOUNIAN S.[4], ROUSSOS P.[5], MONTANARO G.[6], EVERGETIS E.[4], INTRIGLIOLO D.S.[7], MIMIS A.[8], SOTIROPOULOU R.E.[9], TAGARIS, E.[10]

[1] Institute of Urban Environment & Human Resources, Department of Economic and Regional Development, Panteion University, 14 Aristotelous St., GR-17671 Kallithea, Athens, Greece

[2] School of Spatial Planning and Development, Aristotle University of Thessaloniki, GR-54124, Thessaloniki, Greece

[3] TERRA NOVA Ltd., 39 Kaisareias str., GR-11527 Athens, Greece

[4] Laboratory of Nutritional Physiology and Feeding, Department of Animal Science, School of Animal Biosciences, Agricultural University of Athens, 75 Iera odos, GR-11855 Athens, Greece

[5] Laboratory of Pomology, Department of Crop Science, Agricultural University of Athens, 75 Iera odos, GR-11855 Athens, Greece

[6] Universita degli Studi della Basilicata, Via N. Sauro, 85100 Potenza, Italy

[7] Departamento de Ecología y Cambio Global, Centro de Investigación sobre Desertificación (CSIC-UV-GV), Carretera CV-315, km 10.7, 46113 Moncada, Valencia, Spain

[8] Department of Economic and Regional Development, Panteion University, 136 Syngrou Av., GR-17671 Athens, Greece

[9] Department of Mechanical Engineering, University of Western Macedonia, 50100 Kozani, Greece

[10] Department of Chemical Engineering, University of Western Macedonia, 50100 Kozani, Greece

*corresponding author

e-mail: dlatinop@plandevel.auth.gr

Abstract: Orchards agro-ecosystems display a significant potential to act a net sink for atmospheric carbon, offering significant land-based mitigation services. This mitigation potential depends greatly on cultivated species and applied cultivation practices. In this context, the study herein aims to explore the potentials arose regarding the removal of CO_2 from atmosphere by tree crops and to underline the significance of this type of cultivations in the field of climate change mitigation. For this purpose, the novel methodology (CO_2RCA) that was designed and developed in the context of the LIFE ClimaTree project (https://www.lifeclimatree.eu/) and later was further tested and optimized in the context of the Horizon 2020 Shui project (https://www.shui-eu.org/), will be used. This methodology aims at the detailed calculation of the CO_2 balance related to the trees of an orchard and the cultivation practices applied. Five typical tree crop species (orange, olive, apple, peach, almond) of southern Europe (Greece, Spain, Italy) are herein examined. The obtained results are capable to support the design of coupled climate and agricultural policies with significant contribution to the circular economy. Thus, our findings can inspire and be involved in future design of eco-schemes and CO_2 voluntary markets, in the context of the new Common Agricultural Policy (CAP) contributing to the Circular Economy pillar of the Mediterranean EU countries.

Keywords: Carbon sequestration, ecosystem services, climate policy, carbon farming, land-based mitigation.

1. Introduction

Land-based ecosystems like orchards, forests and agricultural lands play a crucial role in the process of CO_2 sequestration. Agricultural activities serve as both sources and sinks for greenhouse gases displaying the capability to simultaneously contribute to the anthropogenic global warming and to climate change mitigation. Tree crops can play a significant role in this prospect because of their perennial nature, i.e. due to the long-term carbon storage capacity of their soil and woody components. In this respect, there are several studies providing strong evidence that perennial agricultural systems and/or agroforestry systems are capable to sequester carbon at a higher rate as compared to other farming systems (Toensmeier, 2017). This function of tree orchards is enhanced with the adoption of practices complying with climate mitigation, i.e. land management and agronomic practices contributing towards the maximization of CO_2 sequestration and creating a net carbon sink (Bithas and Latinopoulos, 2021; Montanaro et al., 2017). Orchards cover a large portion of Mediterranean regions' cultivated lands, playing thus a fundamental role in their economic development.

Although it is widely recognized that tree cover of agricultural land can contribute greatly to climate change mitigation, this is not systematically accounted in either global carbon balance or in national carbon accounting systems (Zoomer et al., 2016). However, in recent years the interest for accounting the carbon sequestration by tree plantations is receiving an increasing attention, both globally and in the Mediterranean area.

The present study aims to investigate the mitigation rich agricultural practices in tree crop ecosystems in the Mediterranean countries of Greece, Italy and Spain. For this purpose, the novel CO_2 Removal Capacity Algorithm (CO_2RCA) for calculating the CO_2 balance of tree crops (Spanos et al., 2021; Spanos et al., 2019) was used. Specifically, this algorithm was applied at regional (NUTS3) level in order to examine the spatial patterns of tree crops annual removal capacity.

2. Methodology

The first step was to identify the representative tree crops for the Mediterranean countries. The main criteria for selecting the representative tree crops are: (a) the total cultivated area, (b) the average tree crop lifespan, and (c) the annual crop yield. We identify five (5) tree-crops: Orange, Olive, Apple, Peach and Almond trees, which cover about 8% of the total area of the three countries.

The calculation of the CO_2 balance of the selected tree crop types in Greece, Italy and Spain was performed by using the CO_2RCA Algorithm. This algorithm calculates the capacity of tree crops to remove CO_2 from the atmosphere in terms of the balance between: (a) the CO_2 abstracted from the air to develop the new wood biomass of the tree and (b) the CO_2 emitted to atmosphere due to the applied cultivation practices. For this purpose, a Life Cycle Analysis approach is used specifically regarding the CO_2 emissions. Namely, the Greenhouse Gases emissions, expressed as equivalent CO_2 mass, are calculated for each material (fertilizers, agrochemicals) and energy type (fossil fuels, electricity) used in the orchard for its cultivation, protection, maintenance and harvesting. The following data were introduced to the CO_2RCA in order to obtain accurate results, representative of each tree species (orange, olive, apple, peach and almond) in combination to the respective country (Greece, Italy, Spain) for which the calculation is performed:

• tree planting density of the orchard,

• yield,

• surface of the orchard,

• development phase of the orchard's trees,

• mass of produced prunings and management practices,

• annual mass and type of the specific fertilizers and agrochemicals used,

• annual energy consumption (fossil fuels and electricity),

• soil characteristics and climatic conditions (based on the geographical location of each cultivated land).

The CO2 removals are calculated yearly for the NUTS 3 regions in Italy, Greece and Spain (it is also possible to aggregate these findings in NUTS 2 and NUTS1 levels).

Furthermore, the CO_2RCA takes into account the potential for applying a series of alternative cultivation practices, which can result to a significant overall reduction of the CO_2 emitted by the orchard, and subsequently, they can lead to a respective increase of the orchard's capacity to abstract CO_2 from the atmosphere in terms of CO_2 balance. The main categories of these mitigation rich agricultural practices that are incorporated into the CO_2RCA (Spanos et al., 2021; Spanos et al., 2019; Aguilera et al., 2015; Vicente-Vicente et al., 2016) are the following:

• use of cover crops

• use of (Leguminosae) cover crops

• application of mulching

• application of fertilizers via fertigation

• application of insects monitoring and/or mass trapping

• valorization of pruning as solid fuel instead of diesel

• use of Renewable Energy Sources.

For the above purposes, the tool that was developed based on the CO_2RCA (https://climatree.uehr.gr/) was used for the calculation of the CO_2 balance under various scenarios. For a given region the subtraction of a baseline scenario calculation ($ARCbase_{region\_i}$) from an optimum (adopting best practices) estimation ($ARCopt_{region\_i}$) provides the annual CO_2 Removal Capacity potential induced by the application of best environmental mitigation practices ($CO_2seq_{best\_practices}$):

$$CO_2seq_{best\_practices} = ARCopt_{region\_i} - ARCbase_{region\_i} \quad [1]$$

3. Results

According to our results (Figure 1), there are significant differences in carbon removal capacities depending on the country, region and crop, while the application of average mitigation rich practices seems to provide an additional net annual removal capacity ranging from 1 up to 2 tn C/ha. Olive and orange tree crops display a higher CO_2 sequestration capacity, as compared to the other crops studied. Among countries, the respective comparisons pointed out that Greece and Spain display a higher capacity to sequester carbon. On the other hand, the respective moderate results for Italy mainly reflect a higher actual emission due to the currently applied agricultural practices (especially for olive, peach and almond trees).

Subsequently, our results were imported into a GIS environment in order to estimate the aggregate regional values (corresponding to the NUTS3 level) of the ecosystem service studied. Since the olive tree cultivation constitute by far the most widespread and socio-economically important permanent tree crop of the Mediterranean region and especially for the three under study countries, the spatial results of the CO_2RCA tool have been generated and illustrated for the following two classes of tree crops: (a) for olive trees and (b) for the remaining four tree crops (i.e. orange, apple, peach and almond).

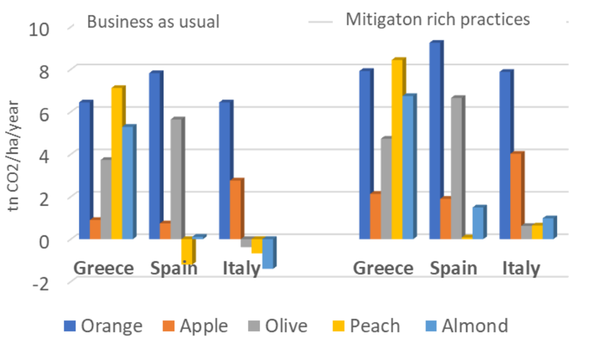

Figure 1. Average Net Removal Capacity of each tree crop cultivation, in each country for both management scenarios

Figure 2 illustrates the spatial pattern (per NUTS3 region) of the improved carbon sequestration potential (i.e. the net removal capacity) for olive crops cultivated with the application of (best) practices favoring the climate change mitigation. It must be noted that these three countries display comparable annual net removal capacity per hectare (about 1 tn CO_2/ha). It is also evident that a significant spatial variation is determined for the CO_2 net removal capacity across different regions, which can be attributed to the total olive trees cultivated area of each individual region. In all three countries, northern regions hosting fewer olive groves and/or smaller olive tree orchards display a quite moderate carbon sequestration potential from the application of the selected agricultural practices and therefore lower net benefit estimates, as compared to the southern regions. Higher aggregate values of Spain can be rationalized considering that the average NUTS3 regions of Spain are quite larger as compared to other two countries. In respect to the national level (NUTS1) calculations, the aggregate net removal capacity is 810,000 tones for Greece, 2,456,159 tones for Spain and 1,133,821 tones for Italy.

Figure 3 illustrates the spatial patterns of the net removal capacity from the potential application of mitigation rich practices to the remaining four tree crop cultivations. The spatial variation of their CO_2 net removal capacity indicates that eastern regions in Spain exhibit the largest deviation from the baseline scenario (i.e., the higher CO_2 sequestration potential). Furthermore, it is worth noting that for some central and northern regions of Italy and Greece, where best practices in olive trees are expected to have negligible carbon sequestration potential, the adoption of climate mitigation complied cultivation practices for these tree crops can provide significant climate mitigation benefits.

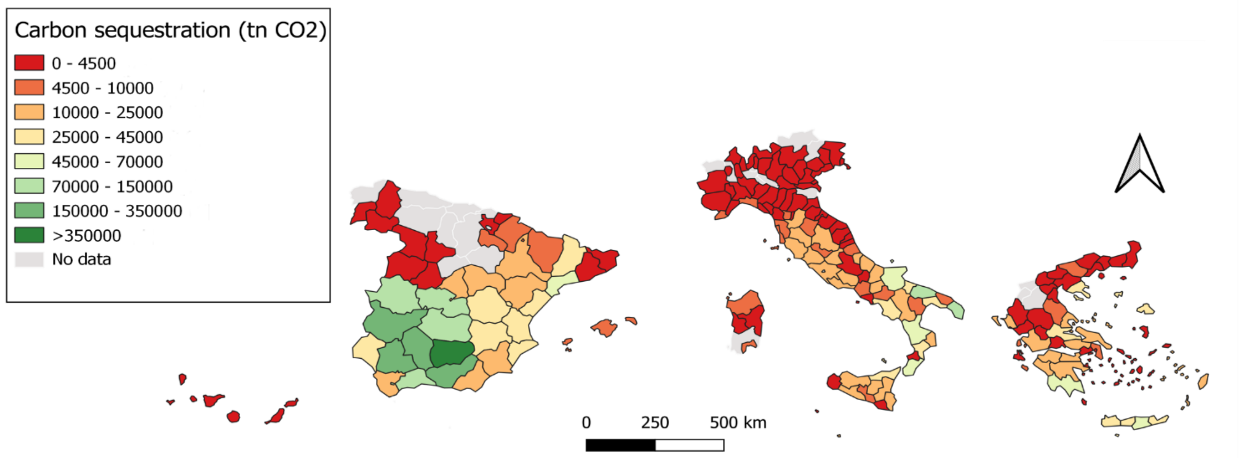

Figure 2. Net removal capacity (expressed in tonnes CO_2) of olive trees per NUTS3 region.

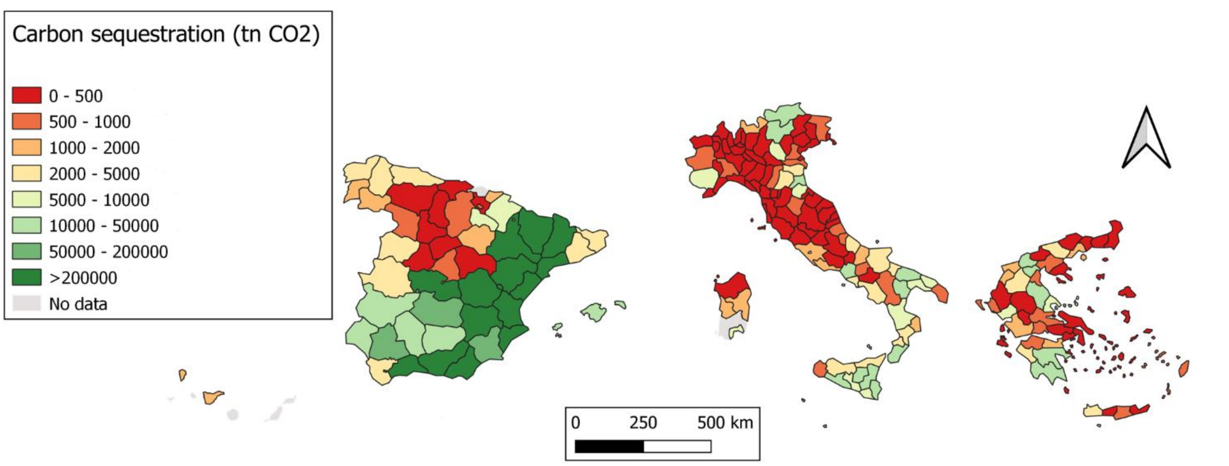

Figure 3. Net removal capacity (in tonnes CO_2) of the other trees (peach, orange, apple and almond) per NUTS3 region

4. Discussion and conclusions

AFOLU (Agriculture, Forestry and other Land Uses) sector's large and potentially growing contribution to total emissions, is indicative of a potential to contribute significantly towards the achievement of the climate stabilization objectives of the Paris Agreement (Henderson et al., 2021). Specifically, AFOLU sector can play a crucial role to enable EU to achieve net zero emissions. So far, the carbon sequestration capacities of tree plants have not received the appropriate policy attention and support. Consequently, the role of agriculture for mitigation of climate crisis is also underestimated (Bithas and Latinopoulos, 2021), although it is well established that tree crops are capable to significantly contribute to climate change mitigation via the accumulation of carbon stocks in agricultural land. Thus, the continuously increasing trend in emissions within the farm gate emerges the need to adopt environmentally friendly agricultural management practices for the reduction of emissions and for increasing the future carbon removals.

Findings herein highlight the strong connection between adoption of sustainable agricultural practices and CO_2 sequestration. On the other hand, the evaluation of the economic benefits from CO_2 sequestration provides a proxy value for this ecosystem service, which may support its inclusion into operational plans. Hence, financial instruments, such as eco-schemes which are envisaged as a major instrument in the context of the new Common Agricultural Policy may be developed, aiming to provide incentives to farmers to adopt farm-based mitigation actions.

Finally, the spatial variability of the results can play an important role by: (a) providing recommendations to national governments concerning the design of appropriate eco-schemes and by (b) setting the environmental performance targets for key regions (NUTS3 areas), where policy makers should focus their efforts to foster carbon mitigation in the agricultural sector.

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