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Estimating Biomass Carbon stocks in Agriculture Land for the Mediterranean using remote sensing data

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Abstract

Climate change has a crucial impact on European agriculture in plenty of ways. The role of land use systems, such as agriculture, as a climate change mitigation and adaptation strategy is important as these systems can collect atmospheric carbon dioxide (CO2) and store carbon (C). Although biomass carbon storage in agriculture has been highly neglected. The methodological difficulties in estimating the C stock of biomass and soil storage of Carbon are reinforced by the lack of reliable estimates of the agriculture area. This research analyses the relationship between changes in tree cover in agricultural areas of the Mediterranean area (more specifically in the regions of Spain, Italy and Greece) and the storage of biomass carbon (associated with the related mitigation of CO2 emissions). Remote sensing images have become a valuable source of data for this analysis. A set of remote sensing data with MODIS satellite images was used and was combined with Tier 1 carbon storage estimates to estimate carbon dioxide storage for the Mediterranean climate zones. The measurements for biomass carbon were made at the overall level for the Mediterranean but also separately for the national and regional levels of Italy, Greece and Spain. The findings of the research showed that the distribution of tree cover in agricultural areas widely followed the climatic zones. Most part of the agricultural land in Europe is estimated at levels around 10 t C / ha.

Keywords

Carbon stocks, agricultural land, MODIS satellite images, biomass, tree cover

Presenter Profile

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Introduction

Agriculture is a key sector as far as is concerned climate change. The main causes of climate change are the greenhouse effect and global warming. Global warming, the rise in the temperature of the Earth's atmosphere and oceans, is believed to be mainly due to rising atmospheric concentrations of so-called Green House Gases (GHG), and carbon dioxide (CO2) is a major GHG (Nair et al., 2009). Global land use change contributes to the effects of climate change. Climate change requires measures to reduce greenhouse gas emissions and adapt them globally and regionally. Agriculture is a factor that contributes significantly to climate change but has the potential to reduce climate change. Changing land use in agriculture and agricultural production has contributed and continues to contribute significantly to the effects of global warming. Agriculture and tree cover have the potential to alleviate climate change. Agricultural production and land use change significantly affect greenhouse gas (GHG) emissions (Zomer et al., 2016). To slow down the effects of climate change, greenhouse gas emissions must be reduced. Carbon dioxide (CO2) is the greenhouse gas most produced by human activities and is responsible for 63% of global warming due to these activities. Various factors determine the complex relationship between the influence of greenhouse gas emissions and the concentration of these gases in the atmosphere. However, there are two strategies available to mitigate CO2 growth: reducing emissions or increasing atmospheric CO2 uptake by plants through photosynthesis thus increasing biomass in terrestrial ecosystems (Zomer et al., 2008).

The global role of tree-based carbon sequestration on agricultural land has not been well understood and may have been significantly underestimated. According to the European Commission (2018), 16% of the current Mediterranean area is likely to become barren land by the end of the century and in many southern European countries, the productivity of rural work is to be reduced by 10-15% compared to current levels. Agricultural forestry (agroforestry) is often discussed as a strategy that can be used to both adapt to and mitigate climate change (Zomer et al., 2016). One of the approaches to reducing the concentration of CO2 in the atmosphere is the capture of carbon (C), the process of removing C from the atmosphere and depositing it in a tank (Nair et al., 2009; Ramachandran Nair et al., 2010). While the importance of biomass carbon in forests (above and below ground) is widely recognized, the biomass carbon reservoir on agricultural land is negligible. For these reasons, there is a suitable ground for investigating the carbon uptake of biomass in agricultural land (Smith, 2012).

The present study aims to assess the importance of trees in agricultural areas and their contribution to the Mediterranean lands for the capture of biomass carbon. This analysis concerns the Mediterranean region and more specifically estimates the biomass carbon at national and regional levels for the Mediterranean countries (Italy, Spain, Greece) and Europe as a whole. In addition, a comparison was implemented for the time periods 2000-2018 for the existence and detection of changes and to be pinpointed spatial patterns both within the country but also between countries and regions. These calculations were based on IPCC Tier 1 default estimates of carbon stored in different land types and bioclimatic zones and were combined with tree cover data based on MODIS satellite remote sensing images.

Methods

Remote sensing techniques have many advantages in estimating above ground biomass over traditional field measurement methods and provide the ability to estimate biomass at different scales, using either linear or non-linear regression models (Houghton, 2005; D. Lu, 2005; Dengsheng Lu, 2006; T. Vashum, 2012). Remote sensing images can be used to estimate biomass above ground in at least three ways: classification of vegetation cover and mapping of vegetation type, indirect estimation of biomass through some quantitative relation (regression equations, NDVI, etc.), dividing the spatial variability of vegetation cover into relatively zones or classes, which can be used as a sampling frame for soil identification and measurements (Ponce-Hernandez, 2004). Although there are no practical methods for directly measuring all forest carbon stocks in a country, both terrestrial measurements and remote sensing data on forest characteristics can be converted into estimates of national carbon stocks using allometric relationships and Optical satellite data systems (MODIS, Landsat, SPOT) commonly used for deforestation detection and can detect changes in forest area more accurately (Gibbs et al., 2007; West et al., 2010).

The research methodology which is followed in this study is based on the methods of the scientific article of Zomer et al. (2016). This study was undertaken to investigate the significance of agricultural land for carbon sequestration and to mitigate the effects of climate change in the Mediterranean zone. Estimating the carbon biomass; The first step was to be found the percentages of tree cover in the agricultural land. To estimate the percentage of tree cover only in agricultural areas, a set of remote sensing data with MODIS satellite images from 2000 to 2018 was used and combined with the Global Land Cover 2000 database (GLC 2000) to export only categories belonging to agricultural land. The data used to perform this procedure are as follows:

- MOD44B MODIS / Terra Vegetation Continuous Fields Yearly Global 250m - Collection 6 (2000 through to 2018):
- Percent Tree Cover
- Global Land Cover 2000 (GLC 2000) Database • Land-cover categories

Tree coverage has been recorded from the VCF-Collection 6 data set for the years 2000 - 2018, because the time period covered by the study is almost 20 years and to reduce the impact of this variability on the estimates of change during period and in order to the results are more reliable, the first three years of the data set (2000-2002), the three years (2008-2010) and the last three years (2016-2018) were calculated on average. In this way, the 3-year average for the different time periods was used to analyse the changes. In addition, three types of agricultural uses from the Global Land Cover 2000 land use database were used to export the categories belonging to agricultural land, which are the following:

- Cultivated and Managed Areas (agriculture - intensive),
- Cropland / Other Natural Vegetation (non-trees: mosaic agriculture / degraded vegetation)
- Cropland / Tree Cover Mosaic (agriculture / degraded forest)

With the help of ArcGIS software and after calculating the three-year average for the percentage of tree cover, the pixels were extracted for all three years (2000, 2010, 2018) where they belonged to the categories defined as agricultural land. Then, using the percentage of tree cover only for the agricultural land, the carbon estimates of the biomass in the specific areas were calculated. To quantify biomass carbon estimates on agricultural land, the default IPCC Tier 1 biomass carbon estimates stored in different types of soil cover depending on the climatic zones located and combined with the ground cover estimates were used. According to the IPCC Guidelines of 2006 (Chapter 5, section 5.2.1) changes in carbon in cultivated areas that remain in the same land use category can be estimated either by: (a) annual growth and loss rates of biomass or by (b) carbon stocks at two time points, depending on the Tier method used.

The "New Global Tier-1 Carbon Map for IPCC Tier-1 for the year of 2000" (available from the Carbon Dioxide Information Analysis Center (CDIAC) Oakridge National Laboratory) was used for global Tier 1 biomass estimates (Ruesch & Gibbs, 2008) synthesized and mapped the default IPCC Tier-1 values using a global land cover map stratified by continent, ecosystem, and forest disturbance, and aggregated a total of 124 carbon zones or areas with unique deposit values based on IPCC Tier-1 methods. In order to take into account the added contribution of tree cover to agricultural land, the default value of category 1 biomass carbon for agricultural land (5tC / ha) was used as the base value, when there are no trees in this area (tree cover = 0%), regardless of the climatic zone located receives a biomass carbon value of 5 tC / ha.

For the calculation of biomass, the percentage of tree coverage was divided according to the climatic zone (carbon zone) to which it belongs. In the context of this dissertation, the values for the Mixed Classes Forests (GLC2000 Classes 6-¬8) for 5 climate zones were used for Europe by the New Global Tier-1 Carbon Map for IPCC Tier-1 for the year of 2000 which are the following:

- Subtropical Dry Forest
- Subtropical Mountain Systems
- Oceanic Forest Temperate
- Continental Forest Temperate
- Temperate Mountain Systems

According to the climate zone and the default carbon value obtained by the above climate zones according to the table from the New Global Tier-1 Carbon Map for IPCC Tier-1 for the year 2000 a linear increase of biomass carbon from 0% was calculated up to 100% tree coverage depending on the climatic zone to which it belongs. Practically, using as a basis the percentage of tree cover for each year was reclassified in tC from the minimum value of 5t C / ha to the maximum value obtained by biomass carbon in the 5 different climatic zones used, biomass carbon values in agricultural areas if there is 100% tree coverage is equal to the relative price for Mixed Forest Classes, in each climate zone. The results of the estimates were calculated in tC / km2 and then converted to t C / ha. In addition, the difference in the carbon level of biomass was calculated both for the decade 2000-2010 and for almost twenty years from 2000-2018. For the calculation of biomass carbon for each country and its regions, the geographical-administrative limits of Eurostat - Nuts 2016 were used. The calculation both at country and region level was done in t C / km2 and then converted to tC / ha.

Results

Areas that are either non-agricultural or urban areas have been excluded from the tree cover data. The area of agricultural land has been stratified for each value of tree cover from 0 to

100. The Mediterranean countries seem to have a low rate of tree cover up to 15%, a pattern that is followed over time for all 3 years under consideration. Over a period of almost twenty years (2000-2018), most European countries have low to moderate tree cover rates (10% - 30%) on agricultural land. Nevertheless, between years 2000 - 2018, there is a small decrease of 2% of the tree coverage both between 2000 - 2010 and 2010 - 2018. More specifically, 82%

was the maximum value of the percentage of tree cover in 2000, in 2018 the maximum value is at 78%. Over time, as shown in Figure 1, in Europe the percentage of tree cover in almost twenty years (2000-2018) shows a decrease of up to -8% while the difference in the percentage of tree coverage shows values from -72% to + 65%. In addition, it is found that a small part of Greece and Italy show an increase of up to 15%. Between the years 2000-2018, Europe has a low rate of tree coverage of up to 20%, a fact that is a following pattern in the Mediterranean countries as well.

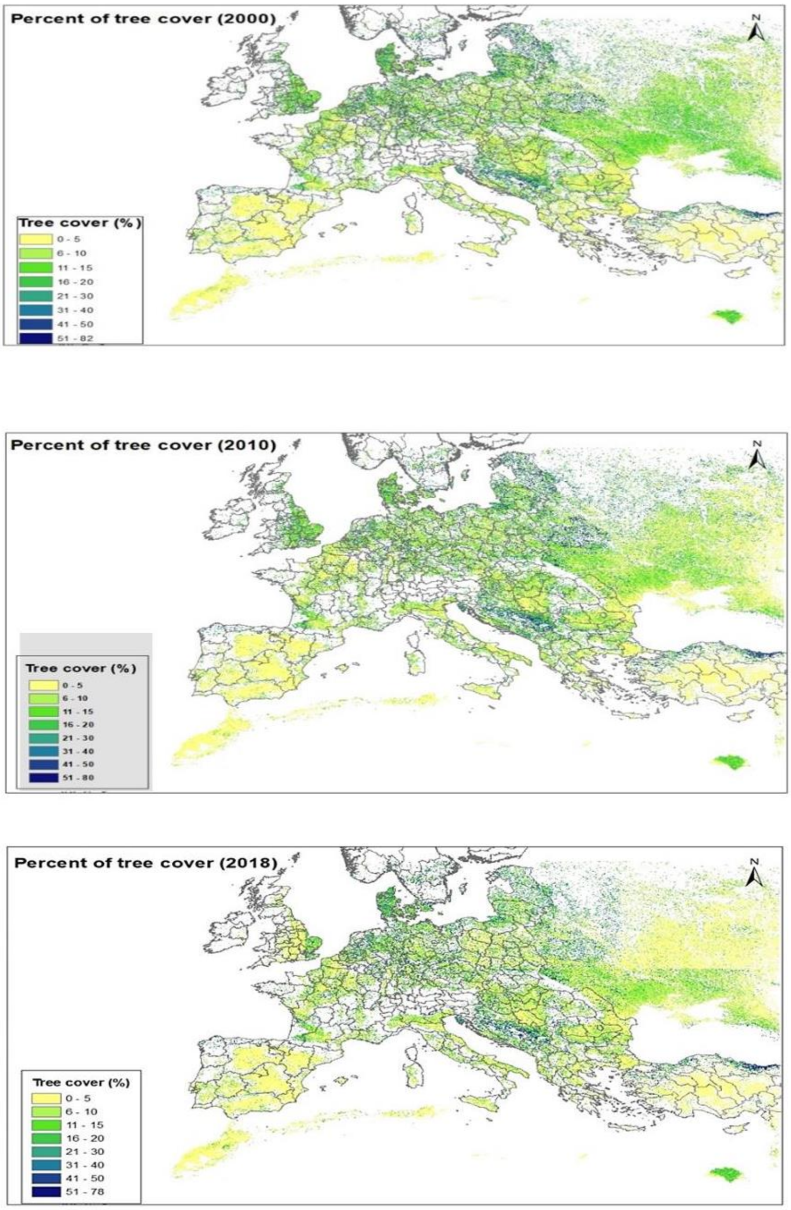


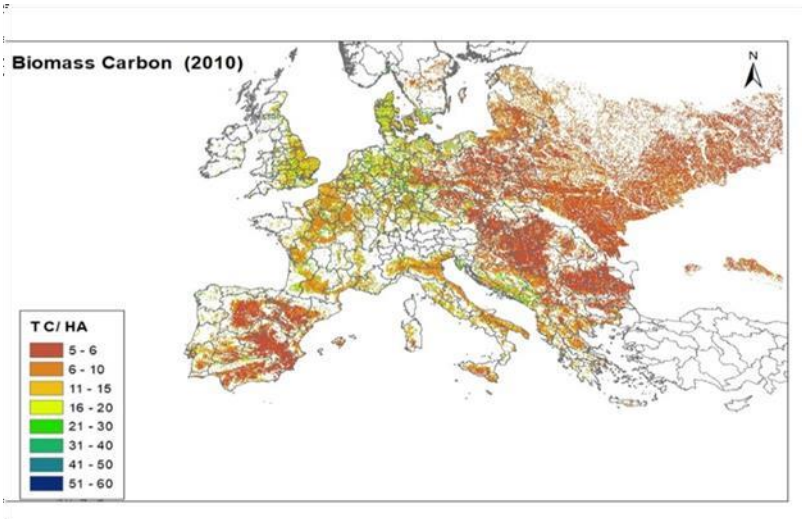
Figure 1: Percent of tree cover in agricultural areas for the years 2000, 2010 and 2018 respectively and change in the percentage of tree cover for the years 2000 – 2018.

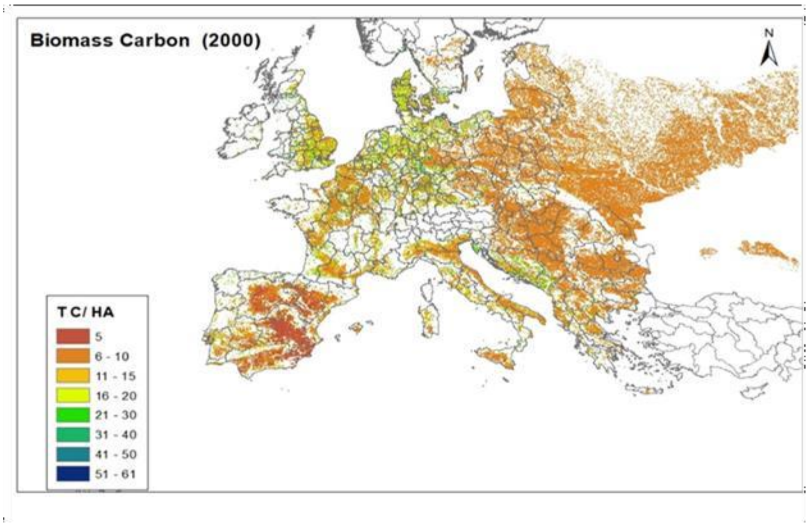
Europe shows a low reduction in biomass carbon, this same pattern is followed and comparing the changes between the years 2010-2018 and 2000-2018 (Table 1). However, observing the changes from 2000 to 2018, it seems that Greece, Spain and Italy have an increase in biomass carbon levels.

Table 1: Average biomass carbon (tC / ha) for the years 2000, 2010 and 2018 and changes in Mediterranean countries and Europe.

Average Biomass Carbon (t C/ha)

Country	2000	2010	2018	Change (2000-2010)	Change (2010-2018)	Change (2000-2018)
Spain	7,5	7,71	7,9	0,21	0,19	0,4
Italy	11,05	11,45	11,39	0,4	-0,06	0,34
Greece	9,05	10,54	10,77	1,49	0,23	1,72
Europe	**9,14**	**9,08**	**8,86**	**-0,06**	**-0,22**	**-0,28**





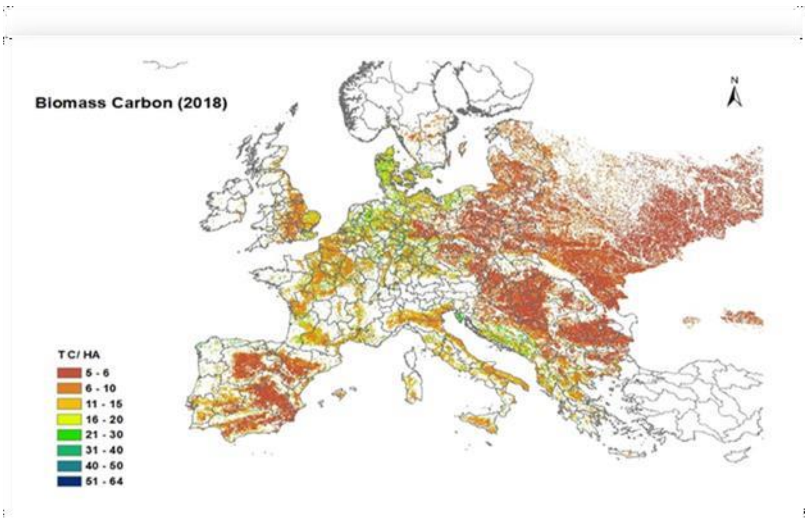


Figure 2: Biomass carbon for the years 2000, 2010 and 2018

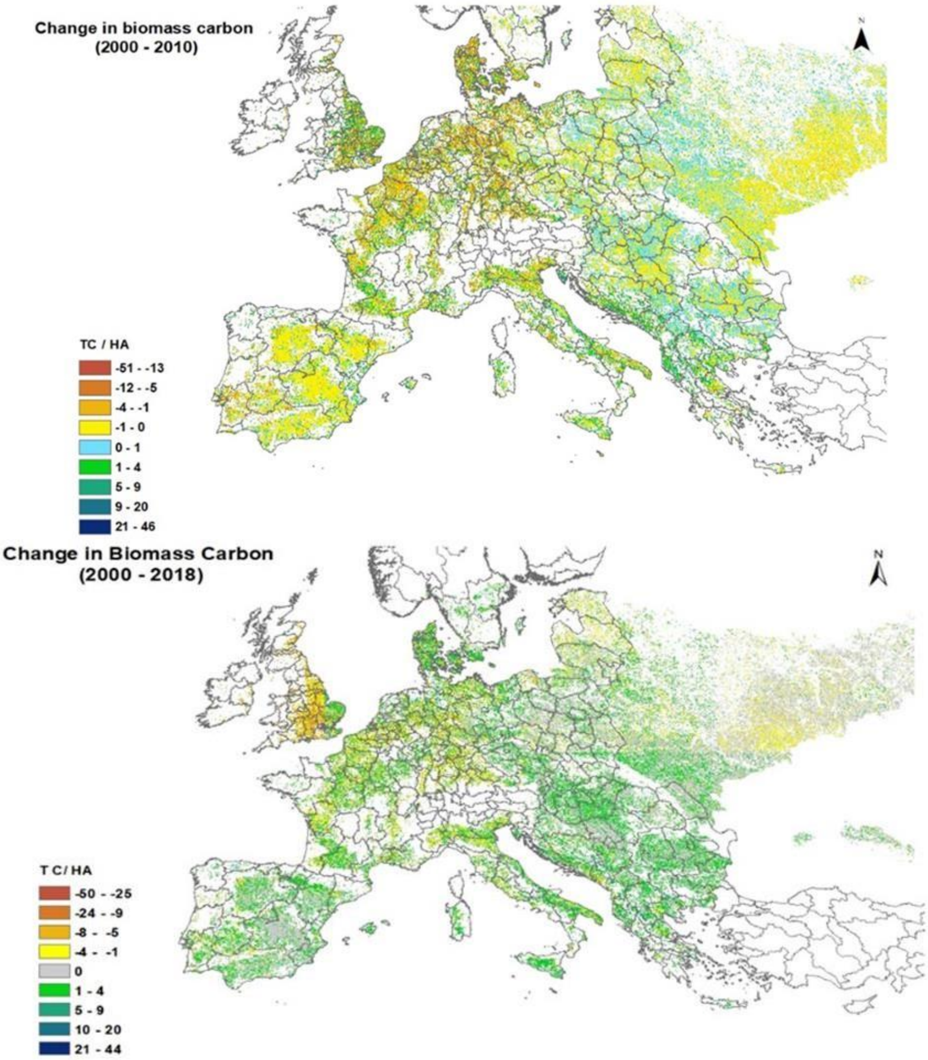


Figure 3. Change of biomass carbon between the years 2000 - 2010 and 2000 - 2018 respectively

Comparing the biomass carbon of the Mediterranean regions with the European average is observed that 16 of the 56 Mediterranean regions are below the European average in 2000.

More specifically, 11 of these regions are Spanish (see table 2 and Figure 3), 4 of these regions are in Greece while the only Italian region is Sicilia which is presented below the European average. The same pattern with slight differences seems to follow in 2010 as 16 regions are below the European average. The same 4 Greek regions (Attica, North Aegean, South Aegean, Eastern Macedonia and Thrace) continue to be lower than average, the Italian region of Sicilia is the only one of the Italian regions that in 2010 has lower biomass carbon levels from Europe. Spain follows similar patterns with 9 regions at lower levels than Europe. Apart from the regions of Illes Balears and Comunidad Valenciana which are at higher levels than Europe in 2010. In 2018, 12 regions are at lower levels of biomass carbon than the European average but none of the regions of Italy. The regions with the lowest levels belong to Greece and Spain; 4 of them are Greek and the remaining 8 are Spanish.

Table 2: Average biomass carbon (tC/ha) for the years 2000, 2010 and 2018 and its change

		Average Biomass Carbon (t C/ha)			Change in Biomass Carbon (t C/ ha)		
Regions	**Code**	**2000**	**2010**	**2018**	**(2000 -2010)**	**(2010-2018)**	**(2000 -2018)**
Attica	EL30	6,1	7,0	8,0	0,9	1,0	1,9
North Aegean	EL41	10,7	11,4	11,6	0,7	0,2	0,9
South Aegean	EL42	6,2	7,0	7,2	0,7	0,3	1,0
Crete	EL43	7,2	7,2	8,4	0,1	1,2	1,3
Eastern Macedonia and Thrace	EL51	7,6	8,7	8,6	1,2	-0,1	1,0
Central Macedonia	EL52	9,1	10,9	10,7	1,7	-0,2	1,6
Western Macedonia	EL53	9,2	12,1	12,6	2,9	0,5	3,4
Epirus	EL54	11,4	14,9	14,3	3,5	-0,6	2,9
Thessaly	EL61	9,1	10,2	10,6	1,1	0,4	1,5
Ionian Islands	EL62	10,0	10,4	11,4	0,4	1,0	1,4
Western Greece	EL63	11,0	11,4	11,4	0,4	0,0	0,4
Central Greece	EL64	9,4	10,0	11,2	0,6	1,2	1,8
Peloponnese	EL65	9,8	10,6	11,2	0,8	0,6	1,4
Galicia	ES11	19,4	22,6	22,9	3,2	0,3	3,5
Principado de Asturias	ES12	21,6	22,6	24,7	1,0	2,1	3,1
Cantabria	ES13	17,1	17,8	18,0	0,7	0,2	0,9
Pais Vasco	ES21	10,7	11,1	11,5	0,3	0,4	0,8
Comunidad Foral de Navarra	ES22	7,9	8,2	9,0	0,3	0,8	1,1
La Rioja	ES23	7,5	7,7	8,1	0,2	0,4	0,6
Aragon	ES24	6,8	7,1	7,2	0,4	0,1	0,4
Comunidad de Madrid	ES30	7,1	7,1	7,3	0,0	0,3	0,2
Castilla y Leon	ES41	7,2	7,1	7,3	-0,1	0,2	0,1
Castilla-La Mancha	ES42	6,4	6,5	6,6	0,1	0,1	0,2
Extremadura	ES43	8,9	8,0	9,1	-1,0	1,1	0,1
Cataluna	ES51	9,3	9,8	9,7	0,5	-0,1	0,4
Comunidad Valenciana	ES52	7,5	9,5	8,5	1,9	-1,0	0,9
Illes Balears	ES53	8,1	9,4	9,6	1,4	0,2	1,6
Andalucia	ES61	7,6	7,5	7,8	-0,2	0,4	0,2
Region de Murcia	ES62	5,5	6,0	5,9	0,5	-0,1	0,3
Piemonte	ITC1	12,3	11,7	11,1	-0,6	-0,6	-1,2
Liguria	ITC3	19,0	21,9	20,1	3,0	-1,8	1,1
Lombardia	ITC4	11,4	11,2	11,1	-0,2	-0,1	-0,3
Abruzzo	ITF1	10,4	12,5	11,8	2,1	-0,7	1,4
Molise	ITF2	10,0	11,6	12,2	1,5	0,6	2,1
Campania	ITF3	12,0	13,6	13,1	1,6	-0,5	1,1
Puglia	ITF4	9,3	9,4	9,8	0,1	0,4	0,5
Basilicata	ITF5	9,7	10,8	11,2	1,1	0,4	1,5

Conclusion

The distribution of tree cover in agricultural areas widely followed the climatic zones. Mediterranean countries seem to have a low rate of tree cover up to 15%, a pattern followed over the years analysis (2000 - 2018). Between the years 2000-2018, Europe has a low percentage of tree cover up to 20%, a fact that is strongly prominent in the Mediterranean countries. The percentage of tree cover in the Mediterranean presents small percentage changes from - 8% to 6% between the years 2000 - 2018. As far as concerned biomass carbon, most agricultural areas have fairly low to moderate levels of biomass carbon. Most agricultural land in Europe is estimated at levels below 10 t C / ha. Mediterranean countries show an increase in biomass carbon in 2018 compared to the initial year 2000. In addition, Italy and Greece are at higher levels than the European average. Greece and Italy seem to have the largest increases in biomass carbon stored on agricultural land. At the regional level in the last twenty years (2000-2018) positive elements are identified as most of the Mediterranean regions have an increase in biomass carbon levels compared to 2000. The growth levels for the regions range from 0.1 - 3, 5 t C / ha. On average, the Mediterranean regions in the variable of biomass carbon per hectare in agricultural land follow an increasing trend of up to 3 t C / ha from 2000 to 2018. All regions of Greece and Spain have an increase in biomass carbon compared to 2000. This a trend that does not seem to be followed by the Italian regions.

Climate change is having an impact on European agriculture in several ways. Slowing down soil degradation and enhancing carbon sequestration on EU soil is a win-win climate and food security strategy that reduces CO2 emissions while increasing the fertility and productivity of EU agricultural land (Jacobs et al., 2019). The EU Climate Change Adaptation Strategy and the Common Agricultural Policy have enabled adaptation actions in the agricultural sector. The Common Agricultural Policy (CAP) constitutes the main framework of the European Union's agricultural policy. Policymakers can implement the potential of agroforestry as a strategy and a key component both for the adaptation and mitigation of climate change. Biomass carbon on agricultural land deserves attention for its mitigation potential.

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