LIFE

Climate Change Mitigation

Deliverable D.1: Evaluation of the effectiveness of the proposed policies and measures

April 2020

LIFE CLIMATREE (LIFE14 CCM/GR/ 000635)

A novel approach for accounting and monitoring carbon sequestration of tree crops and their potential as carbon sink areas

The **LIFE CLIMATREE** project "A novel approach for accounting and monitoring carbon sequestration of tree crops and their potential as carbon sink areas" (LIFE14 CCM/GR/000635) is co-funded by the EU Environmental Funding Programme **LIFE Climate Change Mitigation**.

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Participating Beneficiaries:

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0. Introduction

Agriculture is a key socio-economic industry and thus a driving force for sustainable development as it relates to a number of crucial conditions of sustainability and ecosystem services delivery including conservation of natural capital. It is therefore relevant also for reduction of GHG and increase of atmospheric CO_2 removal. The methodology issued by IPCC for National Greenhouse Gas Inventories[1] lists the main sectors grouping the various GHG source, sink processes for their removal/emissions estimates:

•Energy

•Industrial Processes and Product Use (IPPU)

•**Agriculture, Forestry and Other Land Use** (**AFOLU**)

•Waste

•Other

Each sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). For example, the **ENERGY** sector comprises the *Stationery Combustion* which includes emissions from fuel combustion in agriculture, forestry, fishing and fishing industries such as fish farms. For example, *Stationery Combustion includes* the emissions due to fuel combustion for pumping, grain drying, horticultural greenhouses and other agriculture prctices, forestry or stationary combustion in the fishing industry. Further, this category includes also emissions from fuels combusted in traction vehicles on farm land and in forests. (see Chapter 2, Vol 2 – Energy, IPCC 2006).

The AFOLU sector, collectively refer to Agriculture, Forestry and Other Land Use which include the six land use category as defined 2006 IPCC Guidelines for National GHG Inventories, Volume 4, Agriculture Forestry and Other Land Use:

• Forest land

• Cropland

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[1]IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan

• Grassland

• Wetlands

• Settlements

• Other lands (e.g. bare soil, rock, ice, etc.).

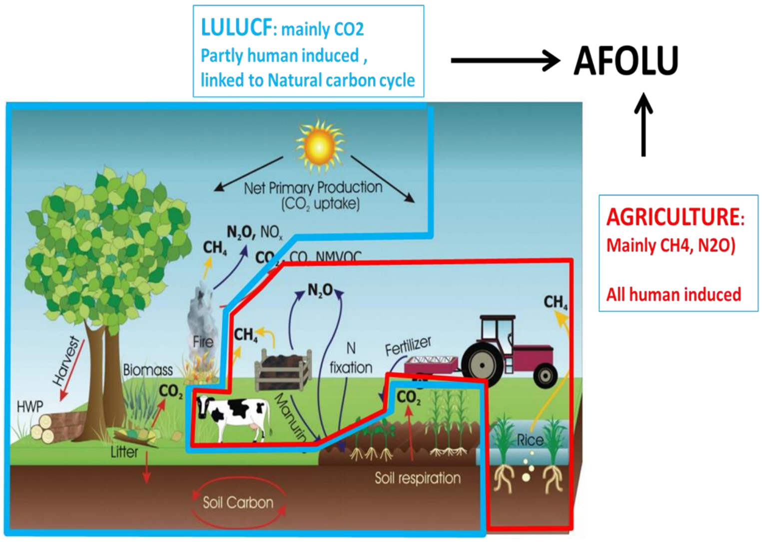
Fot the estimatin of the emissions and removals by each land-use category the following pools are considered:

• Living biomass (separate above- and below-ground values required by the KP)

• Dead organic matter (deadwood and litter)

• Soil organic carbon (mineral and organic)

However, there are **additional agricultural management practices** carried out at field scale including burning of crop residues, fertilizer application, rice cultivation, and emissions related to livestock (enteric fermentation and manure management) which produce emissions, mainly of methane and nitrous oxide. These emissions where reported in the sector "Agriculture" in the the Revised 1996 IPCC Guidelines for National GHG Inventories until the IPCC 2006 Guidelines were issued. The following Figure 1 illustrates the schematic of the AFOLU sector:



DOMAIN	CATEGORY		GAS reported
AGRICULTURE	Enteric Fermentation		CH_4
AGRICULTURE	Manure Management		CH_4, N_2O
AGRICULTURE	Rice Cultivation		CH_4
AGRICULTURE	Agricultural soils	Synthetic Fertilizers	N_2O
AGRICULTURE	Agricultural soils	Manure applied to soils	N_2O
AGRICULTURE	Agricultural soils	Manure left on pasture	N_2O
AGRICULTURE	Agricultural soils	Crop residues	N_2O
AGRICULTURE	Agricultural soils	Cultivated organic soils	N_2O
AGRICULTURE	Burning - Savanna		CH_4, N_2O
AGRICULTURE	Burning – Crop residues		CH_4, N_2O

DOMAIN	CATEGORY	GAS reported
LULUCF	Forest land	CO_2
LULUCF	Cropland	CO_2
LULUCF	Grassland	CO_2
LULUCF	Burning Biomass	CH_4, N_2O, CO_2
LULUCF	Wetlands	CO_2
LULUCF	Settlements	CO_2
LULUCF	Other land	CO_2

Figure 1. Schematic representation of the various components of the Agriculture, Forestry and Other Land Use (AFOLU) sector and the greenhouse gas associated to the various category of the Agriculture and LULUCF domain belonging the AFOLU sector (from IPCC 2006, with modifications).

The scheme illustrates that farming determines also emissions associated with fuel combustion (e.g. machinery and transport of forestry and agriculture products); but these emissions are treated under the Energy sector. Within agriculture activities, there are also emissions associated with fuel combustion (e.g. machinery and transport of forestry and agriculture products); but these emissions are treated under the Energy sector. Hence, in the present Deliverable when not differently speciefid the term Agriculture is intended *sensu* guidelines Revised 1996 IPCC Guidelines for National GHG.

Agriculture is responsible for about 14% of the emissions of greenhouse gases (GHG) at global scale. Greenhouse gas emissions from agriculture contributes with approx. 10% to greenhouse gas emissions (GHGs) at European level (Figure 2). Such emissions increased by 1% between 1990 and 2017. Nevertheless agriculture can be defined as a key sector in the response to climate change **through both reduction of emissions and carbon (C) sequestration capabilities**. The latter is mainly expressed by means of photosynthesis and the retated accumulation of **C in permanent structures** of trees which greatly contributed to feed the **C accumulation in soil and in litter**.

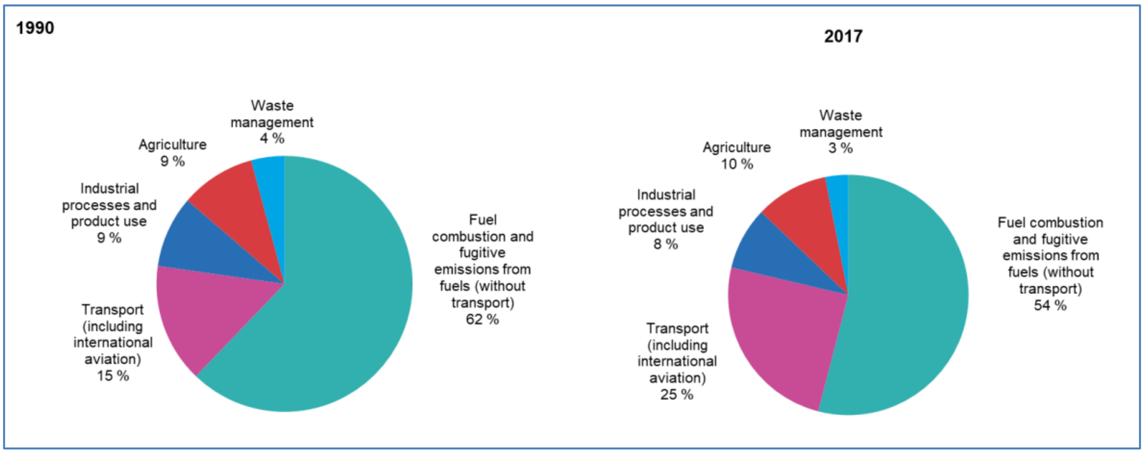


Figure 2. Greenhouse gas emissions, analysis by source sector, EU-28, 1990 and 2017. (Source: European Environment Agency). Note that the "Agriculture" sector is reported.

The AFOLU sector can also contribute to the mitigation of climate change **through GHG emissions reduction** operated at its "agriculture" compartement. For example, both microbial processes of organic matter decomposition and other agricultural practices (e.g. fertilization, irrigation, fuel consumption), that directly or indirectly contribute to GHG emissions, can be at least in part modulated by the management practices. The European Commission is taking various actions, including those in compliance with the Kyoto Protocol (KP), to reduce greenhouse gas emissions in all economic sectors.

In AFOLU sector, specific activities in the category of land use, land use change and forestry (LULUCF) can be used to achieve the goals of reduction of GHG emissions that the various member states have committed following the KP Kyoto Protocol. Emissions from agricultural soils are responsible for 37% of the direct European (EU28) agricultural GHG emissions, measured in CO_2 eq. (in 2015, (EEA, 2017)). GHG emissions can occur due to soil disturbance, hence adopting soil management that reduces (or zeroes) soil disturbance woud reduce CO_2 soil emission (Montanaro et al., 2012). Carbon sequestration due to soil conservation and Best Available Practices implementation can play an important role in reducing GHG emissions and can create a net carbon sink. However, this option has been poorly adopted so far for those LULUCF activities other than forestry. In 2013, the EU updated the regulatory framework of GHG emissions/absorption accounting procedures with the request for annual reporting and accounting on cropland management (CM) activities for the period 2014-2020 (Decision No 529/2013/EU). This represented an important point for the agricultural sector and in particular for the fruit and orchard sectors that it's linked to CM activities, in order to increase its role as a tool for mitigating GHG emissions due to the orchards and vineyards C sequestration capability. The Figure **3** shows the global GHG emissions by sector/category and by gas, estimated for the 2015.

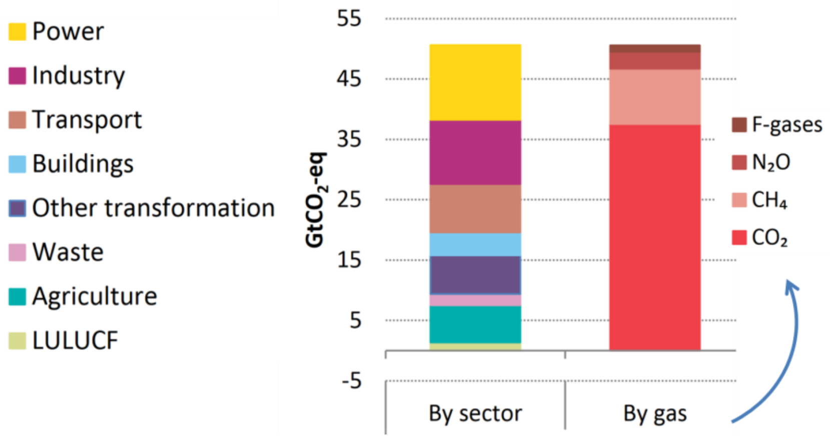


Figure **3** World GHG emissions by sector/category and by gas, in 2015 (source JRC[2])

This potential C sequestration is possible through the increasing C content of the three main pools of C (soil, above ground and below ground biomass and litter), but with a weak response, few years after 529/2013/EU, for Member States' GHG accounting report due to limited existing information. A significant signal is expected on the effective inclusion of the orchards and the entire CM activity in the national GHG accounting and reporting procedures following the implementation of the European Reg. 2018/8413 of

[2] Keramidas, K., Tchung-Ming, S., Diaz-Vazquez, A. R., Weitzel, M., Vandyck, T., Després, J., Schmitz, A., Rey Los Santos, L., Wojtowicz, K., Schade, B., Saveyn, B., Soria-Ramirez, A., Global Energy and Climate Outlook 2018: Sectoral mitigation options towards a low-emissions economy – Global context to the EU strategy for long-term greenhouse gas emissions reduction, EUR 29462 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92- 79-97462-5, doi:10.2760/67475, JRC113

30 May 2018, establishing for the first time that "cultivated land and forests (e.g. the LULUCF sector) contribute to achieving the goals of the Paris Agreement and to ensuring compliance with the Union's GHG reduction target for the period from 2021 to 2030". This new aspects highlighted the need to improve both the organizational and governance aspects at national level on the issue of accounting and reporting of emissions/removals in various sectors (e.g. agriculture, LULUCF). Between the innovations introduced by Reg. 2018/841 has to be mentioned the commitment for each Member State to ensure that LULUCF sector reach at least "net zero emissions" (no-debt rule) and the flexibility to use any other credits in case of higher CO_2 absorption. This flexibility will consent the use of carbon credits, generated in the LULUCF sector, to offset the debt of emissions generated in other sectors such as agriculture, waste, residential and transport sector in the non-ETS (Emission Trading System). It remains unclear whether other forms of remuneration (e.g. economic) will be combined with the offsetting of credit/debt issues.

According to Regulation (EU) 2018/841 of the European parliament and of the council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU Regulation, it is stated that "The land use, land use change and forestry ('LULUCF') sector has the potential to provide long-term climate benefits, and thereby to contribute to the achievement of the Union's greenhouse gas emissions reduction target, as well as to the long-term climate goals of the Paris Agreement" highlighting the net climatic benefit of tree-crops. Hence, Regulation (EU) 2018/841 of the European Parliament foreseen to include emissions/absorption accounting procedure coming from changes in the carbon sink stored in various compartments including above ground and below ground biomass, litter, soil organic carbon (Annex I of Reg. 2018/841).

LIFE CLIMATREE project focuses on the efficiency of perennial fruit tree species as CO2 sequestration tools and on proposing viable cultivation management techniques, which will increase carbon sequestration in orchards and simultaneously decrease its emission. The project focused on five main fruit tree species, with great impact and importance on the Mediterranean region, i.e. olive, orange, apple, peach and almond. In the contest of

LIFE CLIMATREE, D1 Action is committed to the evaluation of the policies for the "best cultivation practices" (BCP) to help climate change mitigation considering also the strategies descripted in the C1 Action deliverable “Best Available Practices Guide for Tree-Crops Carbon Sequestration.”

The evaluation of the performance of suggested policies will be based on the following indicators:

- Impact of reduction of Greenhouse Gas (GHG) emissions related to orchard management;

- Improve the potential of agricultural tree crops land use as carbon sink area.

The approach to be used will be a comparative analysis of CO_2 fluxes between “conventional” and “Climatree BCP” showing potential practices that will be encouraged/discourage through appropriate policies as developed in C5 Action.

1. Best Available Practices (BAP)

1.1. Definition of impact category of the BAP

Fruit tree ecosystems have the potential to sequester atmospheric CO2 into soil, tree biomass and litter which are recognised the main carbon (C) pools of cultivated land (IPCC, 2006). Intricately increasing soil organic carbon (SOC) stocks by 0.4% a year (1 m depth) has the potential to compensate 20-35% of greenhouse gases (GHG) emissions this have boosted a global initiative around the “4 per mille” initiative (Minasny et al., 2017).

The C capture capacity of orchards might be influenced by the management practices that collectively impact the C budget (Montanaro et al., 2017a). Photosynthesis allows the C to be incorporated in the annual increase of the aboveground bomass (e.g., leaf, shoot, fruit) and belowground biomass (young roots) organs and through the growth of the coarse tree structures (e.g., trunk, permanent branch and roots); in addition the fate of this C includes components which are very difficult to assess (e.g., volatile organic compounds, leaching of carbon, mycorrhizal associations) (Chapin III et al., 2006). In the latest Italian report on GHG emissions 1990-2015 (Ispra, 2017), with regard to perennial tree crops, it is stated that for the purpose of calculating the removals of C by cultivated tree crops, only the above ground biomass was estimated through a generic value of 10 t C ha-1 without the appropriate distinctions between the various tree species. In addition to the biomass soil emerges as a potential C pool. The Italian report complains about the absence of data on the impact of the types of management adopted (e.g. soil tillage, no soil tillage, grassing/ No weed control) on C soil sequestration; therefore the contribution of the soil to C sequestration has been reported equal to zero on the basis of the IPCC methodology which identifies agricultural practices as the main driver for the changes in soil organic content. The need to increase and spread knowledge on this specific issue emerges, considering the different variables that can affect the C sequestration capacity of the orchards (e.g. type of management, climatic characteristics).

Proposed Best Available Practices

Action C.1 and C.5 gave and overview of the Best Available Practices (BAP) for Tree Crops category that are relevant for improved carbon sequestration (Table 1) and reduced GHG emissions due to the orchard management practices (Table 2).

Table 1. BAP associated to increased carbon sequestration

category	Best Available Practices (BAP)
Management of Agro-Industrial Waste	Raw Material recovery (e.g. Wood, Oils, Fibers, Sugars, etc)
	Energy Use (e.g. wood, biofuel, biogas etc)
	Safe Subteranean Storage
Tree Crop Biomass Carbon Sequestration	Adopt appropriate Plantation Density (above 300 and below 550 plants per hectare)
	Prunning Manipulation (Low Intensity, Wood recovery, Grinding)
	Biomass management beyond TC's life span (Wood recovery)
Tree Crop Litterfal Carbon Sequestration	Intermediate to high Plantation Density (above 300 plants per hectare)
	Pruning Manipulation (Wood recovery, Grinding)
	Crop Loss management (Grinding)
	Fallen Leaves management (Grinding)
	Seed coatings management (Grinding)

Table 2. BAP linked to avoided carbon emission

Orchard management Practice	Suggested Best Available Practices (BAP)
Soil mangement	No Tillage
	Soil Surface cultivation measures distributed within Fall and/or Spring
Irrigation management	Natural Flow, depended on water sources

Orchard management Practice	Suggested Best Available Practices (BAP)
	Moving Sprinkler, depended on terrain slope.
	Sprinkler Network.
Pruning	By Hand.
Fertilization	Spray of Foliar Fertilizers.
Plant Protection	Reducing Machinery Operations

2. Policies and measures

2.1.Introduction and method

Action C.1. and C.5 focus on the connection between adoption of sustainable agricultural practices and CO_2 sequestration. Sustainable management practices was proposed, in order to increase tree productivity per cultivated area, reduce CO_2 emissions from orchard management practices and increase CO_2 sequestration by orchards. For each proposed practice a preliminary estimation was made on how much it may influence CO_2 sequestration on either a quantitative or qualitative basis. Table 3 summarized the proposed sustainable management practices giving information on:

- Description of the main impacts of the proposed BAP on water and energy saving, yield, carbon gain/loss processes, ect. that collectively affect orchard's ecosystem functioning and its C capture ability;

- Impact on farmer income (yield, costs, ect.);

- Qualitative evaluation for the impact on CO2 sequestration (during the first 5-7 years), implementation easiness, application cost, impact on yield and farmer income;

- Quantitative evaluation for the benefits in terms of carbon sequestration, CO2 reduction, ecc.

Proposed policies and measures

Table 3. Summary of the proposed policies and measures at farm scale

Sustainable Management Practices	Potential impacts	Impacts for the grower	Impact on CO2 sequestration – during the first 5-7 years	Implementation easiness	Application cost	Impact on yield – farmer income	Benefits in terms of Carbon Sequestration, CO2 reduction, ecc	IPCC Sector for GHG gas inventory to be potentially influenced
High density plantations	higher CO2 sequestration during the early years of orchard planting	management techniques will be executed more efficiently and cheaper, since the size of the trees will be severely reduced, facilitating thus any agricultural practice	Medium	Medium	High	Medium	higher soil coverage: about 60%	AFOLU (LULUCF)
Adaptation of training systems with higher solar interception	higher CO_2 sequestration rates throughout the lifespan of the orchard, higher yield efficiency, better fruit quality. increase photosynthetic rates and thus CO2 assimilation	fruits are growing better, achieving better quality characteristics. Yield may increase slightly (approximately 5-15%) compared to similar training systems	Medium	Medium	Medium	Medium	two-fold increase of leaf area index, 30-50% or even much higher light interception CO2 assimilation almost twice (2x)	AFOLU (LULUCF)
Use of mulching material (natural or not) on the planting row and fertigation	lower needs for water, fertilizers and herbicides, reduction of emissions in the production, transport and application of fertilizers and herbicides	reduced costs for herbicide application or weed cutting, reduced cost of water application and savings of water supplies and more efficient use of fertilizers	Low	High	Medium	Medium	reduced water volume application: 1/3	ENERGY, AFOLU (agriculture)
Implementation of cover crops between planting rows.	lower SOM oxidation rate leading to higher SOM concentration, soil structure preservation, minor soil disturbance, reduction of soil erosion	increase of soil organic matter,improved soil biological and physicochemical properties, aiding at a better plant nutrition and development and higher yields	Medium	High	Low	Low	Carbon Sequestration: from 0 to 600 kg C/ha	AFOLU (LULUCF)

Sustainable Management Practices	Potential impacts	Impacts for the grower	Impact on CO2 sequestration – during the first 5-7 years	Implementation easiness	Application cost	Impact on yield – farmer income	Benefits in terms of Carbon Sequestration, CO2 reduction, ecc	IPCC Sector for GHG gas inventory to be potentially influenced
Implementation of minimum tillage	soil structure preservation, lower SOM oxidation, reduction of soil CO_2 emission and fast increase of soil organic carbon pool	increase of soil organic matter, improved soil biological and physicochemical properties, aiding at a better plant nutrition and development and higher yields.	Medium	High	0	Low	emission reduction by 30 to 35 kg C/ha	AFOLU (LULUCF)
Implementation of deficit irrigation	water saving, less CO2 emissions er growing period due to irrigation.	lower cost for irrigation without any significant loss of the yield	Low	High	0	Low	reduce irrigation events by 20-30%	ENERGY
Monitoring climate and meteorological data for on time applications against fungi – resistant cultivars	reduced use of pesticides, protection of the environment and farmer, reduced risk of pesticide residues, reduced use of tractor for insecticide application and thus CO2 emissions	reduced cost of pesticide applications and preservation of the healthy status of the orchard.	Low	High	Low	Medium	decrease phytosanitary products applications by at least 50% use of tolerant or resistant cultivars may also decrease pesticide applications by 50-80%	ENERGY
Monitoring or controlling pests with traps or bait applications	reduced use of pesticides, protection of the environment and farmer, reduced risk of pesticide residues, reduced use of tractor for insecticide application and thus CO2 emissions	reduced use of pesticides, lower cost of pest control	Low	High	Low	Medium	reduce the insecticide applications by almost 50%	ENERGY
Pruning’s residues used as compost or energy source	increase of soil carbon (CO2 sequestration into the soil), reduced use of herbicides, reduced CO2 emissions from the use of fossil fuels.	increased SOM will lead to an increased yield, due to improved soil fertility	Medium	High	Low	Low	gain of approximately 1.5-2 tn CO2/ha/year can	ENERGY, AFOLU (ma)

Sustainable Management Practices	Potential impacts	Impacts for the grower	Impact on CO2 sequestration – during the first 5-7 years	Implementation easiness	Application cost	Impact on yield – farmer income	Benefits in terms of Carbon Sequestration, CO2 reduction, ecc	IPCC Sector for GHG gas inventory to be potentially influenced
Use of renewable energy sources (RES) for electricity power for orchard equipment	zero CO2 emissions for energy production, minimization of fossil fuel use for orchard management.	reduced cost for electricity	Medium	Low	high	Low	zero CO2 emissions for energy production	ENERGY
Use of alleviating products during the hotter months of the growing period	direct higher CO2 assimilation by tree leaves and higher yield, both quantitatively and qualitatively.	yield increases (either quantitatively and/or qualitatively)	Medium	High	Low	Medium	increase of CO2 assimilation of 10-15%	ENERGY, AFOLU (LULUCF)
Rejuvenation of old, neglected olive orchards	increase of CO2 sequestration in an old olive orchard with previously minimum CO2 assimilation, improvement of soil structure and increase of soil organic carbon, reduction of the use of fossil fuels.	rejuvenated trees can be more effectively harvested, reducing thus harvest costs	Medium	High	Low	Medium	two fold (2x) increase of CO2 assimilation	AFOLU (LULUCF)
Different uses of leaves and stems in order to change their use as biosources and drive the production to different pathways forcing annual shoot production (oleuropein in leaves etc).	increase of CO2 sequestration by annual pruning keeping the trees in a constant juvenile phase with higher CO2 assimilation rates	less effort on keeping the fruit intact from pests and diseases, a new source of income.	Medium	Low	Low	Medium	CO2 assimilation rates: 1.5-2x that of mature leaves	AFOLU (LULUCF)

3. Evaluation of the implementation and effectiveness assessment of BAP

3.1. Introduction and method

We attempt to evaluate the implementation and the effectiveness of the Best Available Practice both qualitative and quantitation terms approch has been used. Data of the outcomes of Action C.1 and Action C.5 has been analized and treated with the aim to have:

i. Qualitative evalutation useful for undestanding the implementation easyness and feasibility of the proposed BAP and policies considering the main factor that could affect the proper implementation by farmer. Environmental and socio- economic factors has been also considered in order to express a univocal level ranging from high-medium-low;

ii. Quantitative evaluation in order to have a numeric estimation of the Carbon absorptions from the atmosphere and the CO2 emission reduction.

In order to assess the performance of the proposed polices and measure, two representative indicators has been considered:

- Reduction of Greenhouse Gas emissions (GHG) due to orchard management practices;

- Increase C sink capacity of tree crops.

Through the indicators continuous control it will be possible to evaluate the effectiveness of the BAP, at tree crop cultivation field scale, with the aim to promote and assess the role of BAP application in terms of CO2 balance necessary to achieve climate change mitigation targets in southern Europe areas.

3.2. Qualitative Evaluation

In the following chapters, the proposed BAP at farm level are evaluated. For each BAP the following aspects are analysed:

- impact category: identifies the impact of BAP on the two indicative indicators considering the mitigation impact in terms of increase C sink capacity of land or reduction of GHG emissions;

- implementation ratio: explains the feasibility of the implementation of the BAP taking into account the implementation easyness from a technical point of view, costs and benefit coming from CO2 sequestation and yield.

Table 4. Summary of the BAP qualitative evaluation

Best Available Practices (BAP)	Impact Category	Implementation Ratio LOW = difficult to achieve HIGH= easy to achieve
High density plantations	Increase C sink capacity of land	Medium
Canopy management for higher solar interception	Reduction of GHG emissions	Medium
Use of mulching material on the planting row and fertigation	Reduction of GHG emissions	High
Implementation of cover crops between planting rows.	Increase C sink capacity of land	High
Minimum tillage	Increase C sink capacity of land	High
Deficit irrigation	Reduction of GHG emissions	High
Monitoring (meteo/insects) DSS spray	Reduction of GHG emissions	Medium
Recycling in loco pruning residuals	Increase C sink capacity of land	High
Use of renewable energy sources	Reduction of GHG emissions	Low
Recovery of abandon orchards	Increase C sink capacity of land	Medium
Canopy management for high foliage production in olive	Increase C sink capacity of land	Low

Table 4 shows the qualitative evaluations' outcome:

- 6 out of 11 BAP are contributing to the increase C sink capacity of land impact category while 5 out of 11 BAP are contributing to the reduction of GHG emissions impact category;

- 5 BAP were evaluated of high implementation since the BAP are currently adopted in the mediterrenean area and can be easily replicated by other farmers;

- 4 BAP were evaluated with a medium implementation because they need some efforts by the farmers in terms of deviation from the common agricultural practices, in addition these require some financial investement that might hamper the introduction of the BAP; 2 BAP were labelled as slow implementation due to financial, culture and time investments barriers of the farmers implementing the measures.

3.3. Reduction of Greenhouse Gas emissions

GHG emissions reduction and adaptation to climate change are major challenges that European agriculture will have to face over the coming years. Agriculture compartment of the AFOLU sector (hence excluding LULUCF), accounts for 10.1 % of the total GHG emissions in the EU-28 which corresponds to 464.3 million tCO2e. Despite a decreasing trend in GHG emissions from the agricultural sector registered during the last decade, the EU and the Member States will have to adopt further mitigation measures specifically focused on the farming sector in order to fulfil their global climate commitments. Table 5 shows a relatively small difference (or even comparable) in term of amount of diesel used (and in turn CO_2 emissions) in the two scenarios, however interpretation of the effectiveness of practices will be performed considering the impact of the practices on C sequestration.

Table 5. fuel use comparison between conventional and sustainable management practiceses

CLIMATREE BCP	
	Kg DIESEL PER YEAR
pest/disease spray	100.20
compost distribution	40.08
mulching of winter pruning residues	33.40
mulching of summer pruning residues	25.05
cover crops mowing	50.10
Harvest	80.16
TOTAL	**328.99**

CONVENTIONAL	
pest/disease spray	100.20
mineral fertilisers distribution	20.04
soil tillage to cover mineral fertilisers	20.04
moving pruning residues outside the orchard	26.72
soil tillage	53.44
mulching of summer pruning residuals	33.40
harvest	80.16
TOTAL	**334.00**

The estimation approch for the total GHG emissions avoided and for the increase C sink capacity of land per crops, that could occur when implementing a BAP, was performed based on the knowledge developed in Action C.3 "Action C3: Interface development of a software application for accounting tree-crop carbon sequestration" and in Action C.1 "Action C1: LCA of carbon cycle in tree-crop categories". Field data, data coming from the relevant literatures and outcomes of the CO2 Removal Capacity Calculation Tool simulation were merged in order to obtain the quantitive results presented in Table 6 and in Agriculture industry might be both a source of greenhouse gas (GHGs: CO_2, N_2O, CH_4) emissions through farming operations (e.g., pest application, fertilization, irrigation, tillage) but it also might be a CO_2 sink (through changes in soil and phytomass C stocks), hence it is pivotal to mitigate climate change (Smith et al., 2014). More than half the emissions are related to soil disturbance of agricultural soils, one third to enteric fermentation and one sixth to manure management. According to IPCC (2006), in cultivated land (annual and perennial crops) the soil organic carbon (SOC), the dead organic matter (litter and dead wood) and crop phytomass represent the carbon (C) pools that can be monitored for GHGs national accounting purposes according to Kyoto Protocol commitments. Stock changes in these three organic C pools provide information on the biological ability of a crop system to sequester/release C. By maintaining soil carbon land use does not lead to GHG emissions. When soil carbon content is increased, a net carbon sink is created.

Table 7.

Table 6. Summary of the BAP reduction of GHG emissions

Best Available Practices (BAP)	**Crop**	**Tot GHG Emissions Avoided [t CO^2 ha^{-1} y^{-1}]**	**Tot GHG Emissions Avoided - Average [t CO^2 ha^{-1} y^{-1}]**
Use of mulching material on the planting row and fertigation	Olive	0.422	**0,095**
	Apple	0.013	
	Orange	0.022	
	Peach	0.014	
	Almond	0.004	
Minimum tillage	Generic estimation	**8.2 - 9.6**	
Deficit irrigation	Generic estimation	**0.03 - 0.002**	
Monitoring (meteo/insects) DSS spray	Olive	0.010	**0.133**
	Apple	0.003	
	Orange	0.272	
	Peach	0.101	

	Almond	0.278	
Use of renewable energy sources	Olive	0.004	**0,052**
	Apple	0.031	
	Orange	0.054	
	Peach	0.032	
	Almond	0.142	

Figure 4 highlights the effectiveness of the suggested policies and in details the potential reduction of GHG emissions in terms of total GHG emissions avoided average that consists of use of mulching material on the planting row and fertigation (1.03%), minimum tillage (96.78%), deficit irrigation (0.17%), monitoring (meteo/insects) DSS spray (1.44%), use of renewable energy sources (0.57%).

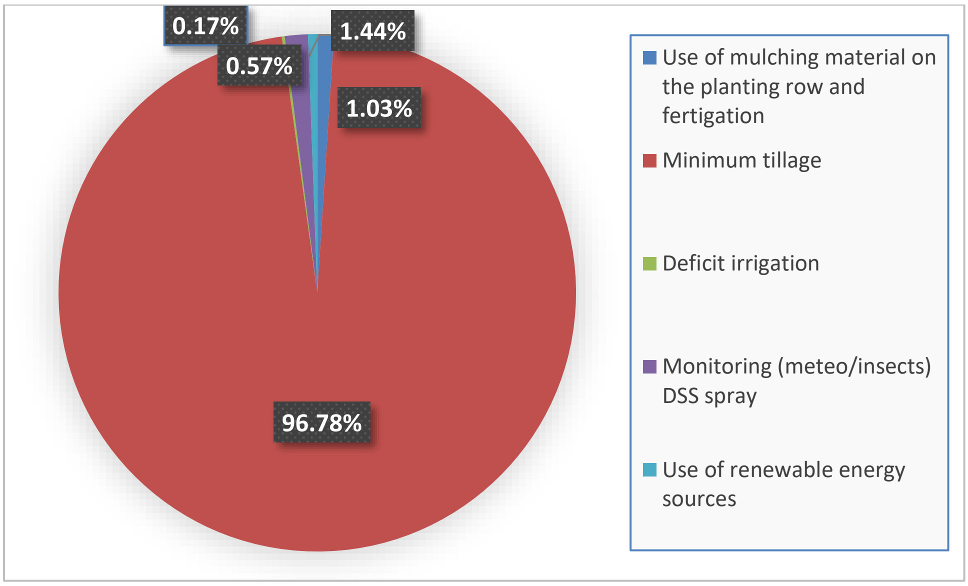


Figure 4. BAP total GHG emissions avoided average (percentages)

The total estimated average mitigation potenzial of adopting BAP identifies minimum tillage or the no tillage practices as the most impacting measure in terms of total GHG emissions avoided.

3.4. Increase in agricultural land used as carbon sink

Agriculture industry might be both a source of greenhouse gas (GHGs: CO2, N2O, CH4) emissions through farming operations (e.g., pest application, fertilization, irrigation, tillage) but it also might be a CO2 sink (through changes in soil and phytomass C stocks), hence it is pivotal to mitigate climate change (Smith et al., 2014). More than half the emissions are related to soil disturbance of agricultural soils, one third to enteric fermentation and one sixth to manure management. According to IPCC (2006), in cultivated land (annual and perennial crops) the soil organic carbon (SOC), the dead organic matter (litter and dead wood) and crop phytomass represent the carbon (C) pools that can be monitored for GHGs national accounting purposes according to Kyoto Protocol commitments. Stock changes in these three organic C pools provide information on the biological ability of a crop system to sequester/release C. By maintaining soil carbon land use does not lead to GHG emissions. When soil carbon content is increased, a net carbon sink is created.

Table 7. Effect of the introduction of the BAP on the overall orchard CO_2 removal capacity and SOC calculated as Δ between values pre- and those post- introduction of the BAP. Calculations of pre- and post- values are performed using the CLIMATREE algorithm.

Best Available Practices (BAP)	Crop	Increase C Sink Capacity Of Land [1 ha]		SOC Stock Change - Average [t C ha^{-1} y]
		[t C02 y-1] Total removal – Total emissions	SOC Stock Change [t C ha^{-1} y]	
High density plantations (Δ between low and high density)	Olive (from 330 to 2254 trees ha^{-1})	33.858	0.233	**0.197**
	Apple (from 3333 to 10000 trees ha^{-1})	20.564	0.379	
	Orange (from 660 to 952 trees ha^{-1})	12.263	0.040	
	Peach (from 500 to 1500	6.634	0.006	

Best Available Practices (BAP)	Crop	Increase C Sink Capacity Of Land [1 ha]		SOC Stock Change - Average [t C ha^{-1} y]
		[t C02 y-1] Total removal – Total emissions	SOC Stock Change [t C ha^{-1} y]	
	trees ha^{-1})			
	Almond (from 278 to 2000 trees ha^{-1})	18.874	0.326	
Canopy management for higher solar interception	Olive	9.478	0.467	**0.393**
	Apple	19.480	0.758	
	Orange	48.780	0.080	
	Peach	3.788	0.011	
	Almond	2.215	0.651	
Implementation of cover crops between planting rows.	Olive	0.422	0.029	**0.039**
	Apple	1.267	0.073	
	Orange	0.391	0.046	
	Peach	0.507	0.016	
	Almond	0.422	0.029	
Recycling in loco pruning residuals	Olive	0.253	0.016	**0.019**
	Apple	1.266	0.038	
	Orange	0.380	0.015	
	Peach	0.135	0.014	
	Almond	0.248	0.014	
Recovery of abandon orchards	Olive	0.718	0.196	**2.563**
	Apple	20.944	5.707	
	Orange	27.229	5.936	
	Peach	3.052	0.582	
	Almond	0.752	0.396	
Canopy management for high foliage production in olive	Olive	0.380	0.024	**0.024**

The impact of the "Recovery of abandon orchards" has been estimated assuming that after a sever pruning operated to stimulate a regeneration of the vegetation, the tree developed as in a new junevile stage pruding nee biomass which has been quantified according to the CLIMATREE algorithm (see Tree data sheet).

As showed in Figure 5, the effectiveness of the suggested policies and in this case the increase C sink capacity of land in terms of SOC stock change average consists of high density plantation (39.1%), canopy mangement for higher solar interception (35.5%), implementation of cover crops between planting rows (1.3%), recycling in loco pruning residuals (1.0%), recovery of abandon orchards (22.3%), canopy management for high foliage production in olive (0.8%).

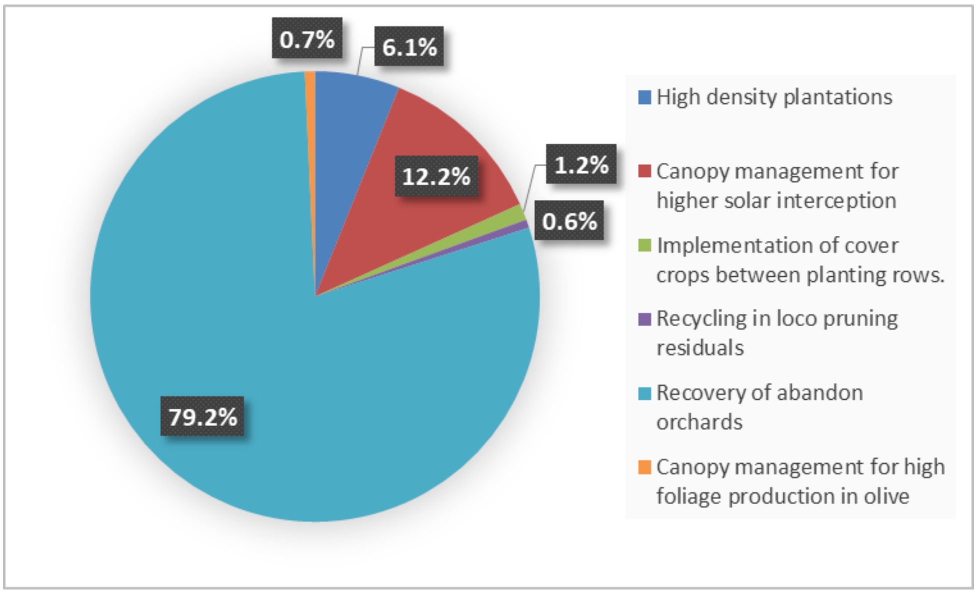


Figure 5. BAP Increase C sink capacity (percentages)

Results on the capacity of BAP implementation reflects the ability to increase the C sink capacity of Tree Crop. According to estimations, high density plantations, canopy management for higher solar interception and Recovery of abandon orchards are the measures, were the most impactful practices leading SOC stock change, highlithing the importance of both land use change and adoptin of sustainable manangement practices. Quantitative results could be transformed into potential mitigation proposals at farm level and presented to several European, national and regional authorities.

Following an example of carbon sequestration accounting. IPCC methodology was used in order to estimate the C sequestration amount by an orchard. This methodology examines the variations of the C stocks in 3 main pools (soil, above and belowground plant biomass and litter) in two different time periods. According to studies carried out in Basilicata the potential C sequestration was about 25 t C ha^{-1} (above and below ground biomass) for peach orchard.

Table 8: Carbon sequestered (t ha-1 C) in the aboveground and root biomass of peach trees at the end of their 14-year lifespan cycle.

4.	1-year (A)	15-year (B)	Carbon stored (B-A)
above	0.02	17.21	17.19
below	0.01	8.15	8.14
Total	**0.03**	**25.36**	**25.33**

In the case study, the C sequestration in the soil and in the litter was significantly influenced by the type of management adopted. In fact, in the case of "sustainable" management which includes the contribution of compost, grassing cut a few times a year, shredding of pruning residues in the field, the accumulation of C was greater than that recorded in the case of "conventional" management (processing, mineral fertilization, removal of pruning residues) (Table 8) (Figure 6).

Figure 6. During the production cycle a peach orchard stores C inside the aerial and radical coarse structures.

In that case study, the C sequestered the soil and in the litter was significantly influenced by the type of management adopted . In fact, in the case of sustainable management that includes the “Implementation of cover crops between planting rows” and “Recycling in loco pruning residuals” (Tab. 7), the accumulation of C is greater than that recorded in the case of conventional management (processing, fertilizing, removal of pruning residues).

5. Conclusion

Within the UN Framework Convention on Climate Change (UNFCCC), the European Commission (EC) is already taking actions to reduce GHG emissions in all economic sectors including agriculture as combined with the so-called LULUCF (land use, land-use change and forestry) in the AFOLU sector (EC, 2013). Although rigorous accounting of the C fluxes in the agricultural sector is of high significance, standard accounting methods fail to approximate the relevant characteristics of certain agricultural activities (EC, 2013). The potential of cultivated land and Tree Crops contributing to offset part of GHGs has drawn the attention of policymakers. For example, the European Commission within the Kyoto Protocol commitments has incorporated the management activity of cropland category (which includes orchards) within the accounting and reporting of national GHGs estimates by 2022 (EC, 2013). Until that year member states should prepare themselves for that accounting. Hence increasing knowledge on C fluxes (removal and emissions of CO2) of an Tree Crops might be favourable for both the improvement of the ecological function of the orchard and for the fulfilment of global environmental strategies.

Tree crops has the potential to remove atmospheric C at a rate variable with management options. **The delivarable reported the amount of total GHG emissions avoided ranged from 0,002 to 9,6 t CO_2 ha-1 y^{-1} and the SOC stock change ranged from 0,103 to 5,02 tCO2 ha-1 y^{-1} due to BAP application**. The outcomes discussed might strengthen the significance of measuring C fluxes in fruit tree ecosystems to support the implementation of environmentally friendly policy within the tree crops category and help the conservation or even the improvement of the soil natural capital. Hence, the orchard management choice of the farmer can be oriented towards the adoption of a sustainable set of practices that includes practices capable of favoring the storage of carbon in the soil such as recycling of pruning residues, the supply of external organic material (e.g., compost, manure) and use of cover crops ((Montanaro et al., 2017b).) .

This result highlights the critical role of appropriate management of the variable components on sustaining ecosystem resilience, including the management of pruning residues, the import of organic materials, and the maintenance of a cover crop. The outcomes presented may strengthen the significance of increasing SOC management practices for fruit tree crops and be supportive of the implementation of environmentally friendly policies assisting in the conservation or the improvement of the soil natural capital in order to support the inclusion of the above mentioned policies and measures within in European, national and/or regional Authorities regulations.

In conclusion BAP implementation for tree crop category might contribute to a reduction of GHGs emissions and to an increase of CO2 sequestration and make a positive difference to help mitigate climate change. Moreover this report could be supportive for analysing the effectiveness of the best available practices in Mediterranean tree crop systems with the aim to increase SOC and can be supportive for the implementation of environmentally friendly policy for a more solid contribution of agriculture sector to GHG mitigation and to the conservation or even the improvement of the soil natural capital.

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