LIFE

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Deliverable C.5: Economic Module

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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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1. Introduction

The European Council conclusions of 23-24 October 2014 stated that: *the emissions reduction target of at least 40 % should be delivered collectively by the Union in the most cost-effective manner possible*. Taking into account the fact that carbon sequestration by agriculture is considered as one of the most cost-effective climate change mitigation options (MacLeod et al., 2010), EU was already considering since 2010 to support the carbon sink function of some agricultural and forestry activities (EC, 2010). 8 years later, 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, and 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 in the Mediterranean.

According to the same Regulation what is equally very important is the aspect of tree-crops to contribute towards the food security and climate regulation nexus, *recognizing the fundamental priority of safeguarding food security and ending hunger, in the context of sustainable development and efforts to eradicate poverty, and the particular vulnerabilities of food production systems to the adverse impacts of climate change, thereby fostering climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production.*

A core subject of **LIFE CLIMATREE** "**Sustainable management practices**", is the maintenance of sinks and carbon stocks of agricultural land uses, while safeguarding the productivity, the regeneration capacity and the competitiveness of tree-crop agriculture. Though its implementation phase, from its kick off date (16/7/2015) until today, LIFE CLIMATREE has taken severe steps to address most of the aforementioned topics through its core deliverables and production of key outputs. Particularly, a significant development has taken place in regards to the development of the CO2 calculation algorithm as well as its replication of web format (namely the e-tool). Based on these results it is obvious that CO_2 sequestration in tree-crop agriculture is a technically feasible alternative. However, in order to know whether it is also a n economically viable and socially acceptable option, additional research was required. In this framework, are previous project's results should be coupled with a socio-economic analysis, which will be able to: (a) integrate some the aforementioned outcomes into an economic module for assessing the economic value of carbon sequestration of tree crops, and based on this assessment (b) to suggest some key economic policy instrument for climate change mitigation in the tree-crops sector.

In order to do so, a set of economic valuation methods, mainly focusing on the agricultural and forest sectors are revised in order to identify the monetary value of the ecosystem service of carbon sequestration. The identification of a value estimate can then contribute towards a better understanding concerning the (tree-crop) farmers' contribution to climate change mitigation potential, as well as, concerning the role of agricultural policy in promoting market-oriented tools in order to provide incentives for taking into account the mitigation potentials arising from tree cultivations. As a rule of thumb, the economic viability of strategies that can be implemented to mitigate climate change depends on the price/value of carbon. When prices/values are low, the strategies that can be implemented are those where production is maintained and where there is just a change in agricultural practices. When prices/values are higher, strategies that involve an initial investment (e.g. new tree plantings) can be envisaged.

The progress achieved in this report, can play an important role in boosting the contribution of the tree-crops sector in reaching the key mitigation goal of the EU for a 30% emissions' reduction by 2030 in the Effort Sharing Regulation.

2. Economic value of carbon sequestration in Agriculture

The assessment of economic benefits of carbon sequestration is based on the literature on the social cost of carbon that estimates welfare losses from emissions of GHG (Stern, 2006) or else, the external cost of burning carbon. The social cost of carbon (SCC) is defined by Nordhaus (2011) as the change in the discounted value of the utility induced by one unit of additional emissions (Nordhaus, 2011), and its estimate can be a key input to the development of any climate policy (Pindyck, 2019). The SCC covers the global effects over time caused by CO_2 emissions, regardless of where they occur. The reason is that a global externality is generated by greenhouse gas emissions, since the changes in climate caused by them have worldwide economic and societal consequences. deBruyn et al. (2010) described the SCC as a shadow price of CO_2 emissions, measured with the use of the damage cost method. Moreover, Pearce (2003) noted that the estimation of the SCC provides a basis for setting price incentives as a means to regulate greenhouse gas emissions, in particular, determining the value of a carbon tax or the price of an emission permit.

Therefore, a cost-benefit analysis can use these costs (SCCs) in order to determine an economically optimal investment or policy measure aiming to mitigate greenhouse gas emissions. Besides, as 1 ton of carbon sequestration compensates for 1 ton of carbon emitted, the information on damages/costs can be also used to estimate the benefits of sequestration. In this context, two approaches that can be used to assess the value of carbon sequestration by tree-crop ecosystems are the following (Aertsens et al., 2013): (a) an estimation of the avoided costs regarding the reduction of CO_2 emissions in other sectors (in order to achieve a certain target related to GHG emission), (b) an estimation of the avoided damage costs of additional global warming (as described by de Bruyn, 2010). The first approach can be connected with the standard value of traded markets for CO_2 (i.e. the price of buying emission allowances), due to the fact that the price of a permit (i.e. the marginal cost of buying a permit) theoretically equals the marginal benefit of reducing a ton of GhG emissions. The second approach is difficult to be estimated as there is a great uncertainty regarding the future costs of global warming.

However, a few established integrated assessment models were used so far to estimate the social cost of carbon. Another alternative method that can be used to estimate the value of avoiding damage costs is to estimate society's willingness to pay for the benefits provided by mitigation policies in agriculture[1]. All the aforementioned approaches and methods were used to provide a value estimate for offsetting one ton of CO_2 through the tree-crop sector. The following paragraphs will provide more details on each of these methods.

2.1 Estimating the monetary value of carbon sequestration based on CO_2 market prices

Carbon offsets are produced by projects that carry out on-the-ground emissions reduction activities, and are typically measured in metric tons of carbon dioxide equivalents, or tCO2e. They can either be traded as part of a compliance market, where government regulations require emitters not to overcome predefined CO_2 emissions targets. To achieve these target emitters face two options: reduce their emissions or purchase offsets in the regulated CO_2 markets where certified carbon offsets are traded. In addition, the voluntary CO_2 markets, where buyers and sellers trade on their own volition have been established where carbon offsets can be purchased in order to achieve CO2 reduction beyond the targets achieved by compliance markets (Ecosystem Marketplace, 2018).

The Clean Development Mechanism (CDM) and Joint Implementation (JI) are the compliance market's two traditional standards. The European Emission Trading Scheme (EU-ETS) is by far the largest **compliance market** (EU ETS), which caps (i.e. sets) the total amount of certain greenhouse gases that can be emitted by installations covered by the system. Within the cap companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value (https://ec.europa.eu/clima/policies/ets_en). In other words, by creating supply and

[1] In this respect, a specific study has been designed in the context of CLIMATREE with survey research that traces WTP values for the sequestration of CO2 by tree cultivations. This research is part of D2 Actions however, some results ought to be exploited in C5 Action, here, serving the needs of comprehensive consideration of the monetary value of CO2.

demand for emission allowances, an ETS establishes a market price for greenhouse gas emissions.

Figure 1 presents the historical prices (market-value) of the EU ETS system over the last decade. According to these values, the price of carbon allowances on the EU ETS currently stands at €26-27 per ton of CO_2 on the back of reforms agreed last year, after years of stagnation below €10 (It is worth noting that the price at the end of year 2017 was €9). Figure 2 presents the price forecast scenarios from different analysts (Marcu et al., 2019). Based on these forecasts, there is a general expectation that the carbon price of EU allowances will keep increasing in the next years. The trend upwards is particularly significant in the short-to-mid-term. Namely, EU carbon prices are likely to top above €40/tCO_2e by 2024. In the longer-term, expectations seems to converge in 2028, between €22 and €27, while diverging again at the end of Phase 4 (near 2030), when the price range widens between €15 and €35. Having these values in mind, and trying to simplify our model we used as a value estimate the current value, 24.2€ per ton of CO_2, which is quite close to the median projection values of 2019. We can also estimate the 95% confidence intervals of the 2019 projection values in order to treat future uncertainty (21.90 < value CO_2 < 26.58).

Figure 1: The EU-ETS carbon price trends (Source: Markets Insider).

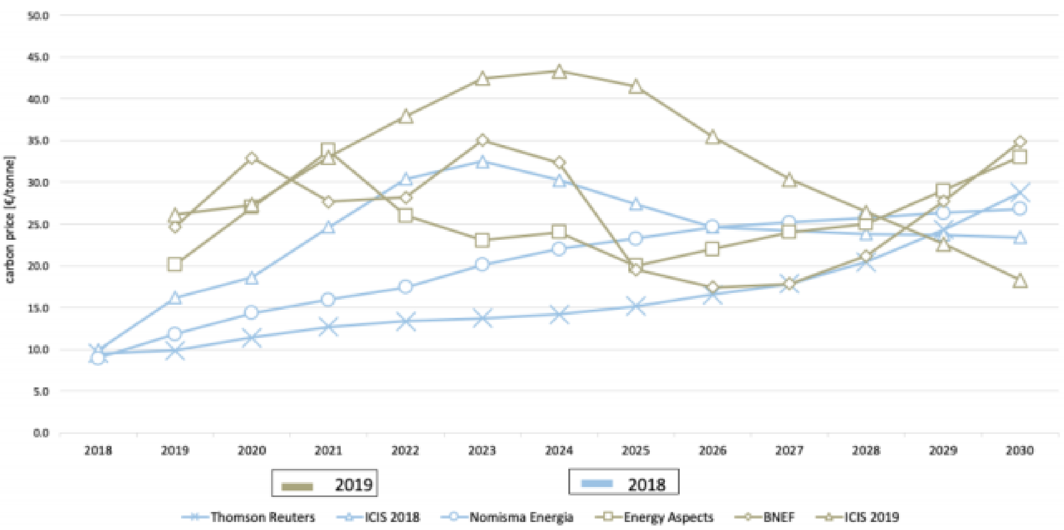

Figure 2: The EU-ETS carbon price projection (Source: Marku et al., 2019).

So far, the EU-ETS does not allow regulated corporations to purchase tree-crops and forestry-based carbon offsets to meet their obligations, because trees that sequester carbon don't do so permanently. However, apart from the compliance market it is also possible to use a **voluntary CO_2 market**, which can address the above-mentioned permanence issue. Namely, instead of undergoing the national approval from the project participants and the registration and verification process from the UNFCCC, the calculation and the certification of the emission reduction are implemented in accordance with a number of industry-created standards. Project developers can then transact these offsets and a buyer must be identified. Some project developers manage their own marketing and advertising teams in order to identify and promote their project directly to end buyers. Others prefer to sell their offsets to intermediaries like a broker or a retailer, who takes responsibility for marketing those offsets to end buyers. This process enables operators in a sector that is not included in cap-and-trade scheme to monetize their emission reductions if they wish to do so. Emission reductions in the agricultural sector are usually monetized in this way (Foucherot and Bellassen, 2011).

Compared to compliance markets like the ETS, the total size of the voluntary market is much smaller. The cumulative issuance on the voluntary market is 330 million credits, which is about one-eighth the volume of the Clean Development Mechanism (CDM) and Joint Implementation (JI) issuances. However, voluntary markets are more flexible, responsive and innovative than compliance markets. For this reason, voluntary markets have had an outsized impact in the creation of offset project blueprints, called methodologies.

Annual issuance levels and prices in the voluntary market have been more stable over time than in the Kyoto credits market. Voluntary credit prices (market values) in 2016 were on average €2.7tCO_2e. The modest average credit price is linked to the substantial oversupply that persists in the voluntary market. Prices in 2018 ranged from less than €0.10/t CO_2e to more than €60/t CO_2e, but roughly half of the voluntary credits were transacted at under €1/tCO_2e (World Bank, 2019).

This range in prices may be attributed to several factors, including: project costs, buyers' preferences (e.g. specific locations, project type, co-benefits, etc) and the type of transaction. For example, the price of wind offsets from Asia was on average equal to €0.64/t CO_2, while afforestation/reforestation offsets from Africa were transacted at an average of €6.2/t CO_2. During the period 2008-2018, about 90 agricultural projects issued in total 6.7MtCO_2e of carbon offsets (Ecosystem Marketplace, 2018). These projects were associated with modification of agricultural practices to reduce emissions (e.g. by switching to no-tillage, reducing fertilizers, etc.). During the same period, about 170 projects associated with forestry and land use issued in total 95.3MtCO_2e of carbon offsets from managing forests, soil, grassland and other land uses.

Some regions favor certain offset categories. For example, as shown in Figure 4, in Asia and non-EU European countries (Georgia, the Russian Federation, and Turkey) offsets originate mainly from renewable energy projects (11.8 MtCO_2e and 1.3 MtCO_2e), while offsets from Latin America and the Caribbean as well as Africa were mainly from forestry and land-use projects (4.1 MtCO_2e and 2.9 MtCO_2, respectively). Offsets from projects in North America (Canada and the United States) were mostly from methane projects (3.7 MtCO_2e), while a significant part of offsets from projects in Oceania came from forestry and land-use projects (274 KtCO_2e).

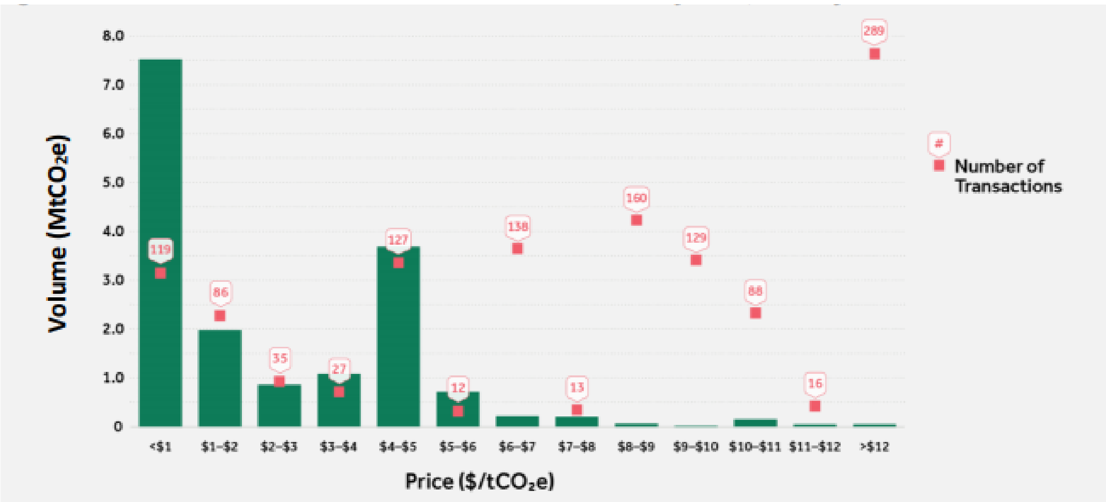

Figure 3: Volume of offsets sold and number of transactions by price, January-March 2018 (Ecosystem Marketplace, 2018)

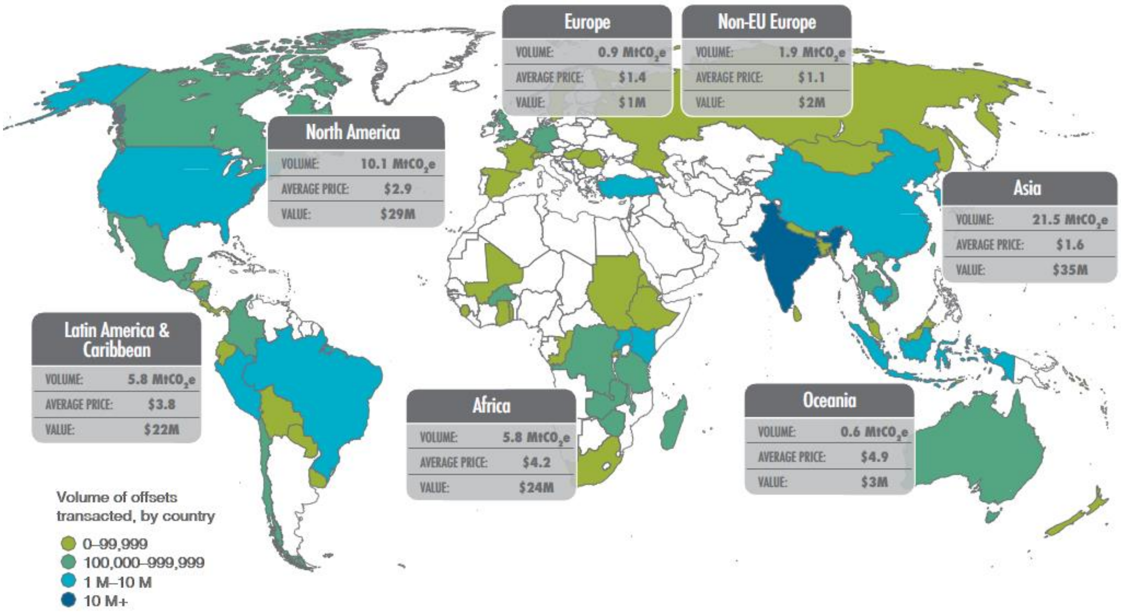

Figure 4: Voluntary carbon offset projects' values in different regions, 2016.

European-headquartered organizations reported transacting 39.2 $MtCO_2e$ of voluntary carbon offsets in 2015 at an average price of €3.2/tonCO_2e. European-based forest carbon offsets comprised a much smaller subset of total transactions reported, with eight organizations reporting 285 $KtCO_2e$ offsets sold at an average price equal to €15.6/ton, (Hamrick and Brotto, 2017). Giving the fact that forest carbon offsets are quite close to the kind of CO_2 mitigation action from planting and/or better management practices of tree-crops we can use this price as an optimistic (upper limit value) proxy value of CO_2 sequestration, which corresponds to a voluntary market-based approach. However, due to the great uncertainty of prices in the voluntary market we also decided to use a lower limit value equal to the average price of C offsets in Europe (€3.2/ton). In other words, unlike the compliance market, voluntary market-based estimates of the CO_2 sequestration values, are much more uncertain and therefore a wider range of prices should be taken into consideration.

2.2 Estimating the monetary value of carbon sequestration based on the avoided damage costs

2.2.1 Integrated Assessment Models (IAMs)

Integrated Assessment Models (IAMs) of climate and the economy are mainly used in order to estimate the SCC based on the damage costs resulting from greenhouse gas emissions over a period of 100, 200 years or longer. Future climate damage is usually discounted to a current SCC value using a social discount rate. This discount rate has a large impact on the SCC value and choosing its value is an issue of high debate, as it depends on, expectations of future economic growth and ethical viewpoints about weighting welfare levels between different generations.

The most widely known IAMs are DICE, FUND[2] and PAGE[3], which can be considered reduced form models that simplify the complicated interplay between climate and the economy. According to Nordhaus (2011), these three models can be named "policy optimizing and top down climate-economy models". A similar feature of these models is that they have the ability to be combined in an integrated model, climate change, economic growth, and the effects of climate change on the economy. These models calculate how the greenhouse gas emissions result in changes in the atmospheric greenhouse gas concentrations, how these concentrations cause global warming, and how these changes in temperature cause economic damage. The monetary damage that results over time is discounted to arrive at present values. As carbon sequestration is

[2] The FUND model calculates climate change damage under the assumption of economic growth (Tol, 1999, 2002). The effects of temperature changes on the economy are then calculated using damage functions for eight economic and social sectors: agriculture, forestry, water, energy, sea level rise, ecosystems, health and extreme weather.
[3] The PAGE model calculates the effects of climate change under specific assumptions about economic growth. In this model, the damage that the associated temperature rise causes is included in economic and non-economic categories as well as the consequences of catastrophe risks for eight different regions (Hope, 2006; Stern, 2007a).

going to reduce these GHGs' concentrations, the value of 1 ton of CO_2 sequestered by tree crops in a given year can be considered as equal to the avoided damage cost of this ton. In this report, the focus is to assess the CO_2 values on the short and mid-term, e.g. on a 10-year period. Therefore, we are going to use the IAM's estimates for the until the end of the 4th phase (i.e. until 2030), for which the effects of discounting and uncertainty are less influential on CO_2 values.

Nordhaus (2007) used the DICE model for the empirical analysis. This model has been revised since then aiming inter alia, at taking into consideration the most updated climatic data, the ongoing decarbonization rates and the most recent assessment reports of the Intergovernmental Panel on Climate Change (IPCC). In this work, we are going to use the DICE-2016R version (Nordhaus, 2017), which assumes a decarbonization rate equal to -1.5%/year and a discount rate equal to 4.25%[4]. Based on this model, the SCC under the current (baseline) climate policy is €34.3per ton of CO_2 for emissions in 2020, and €47.5 in 2030 with the value rising at 3% per year. Under an optimized path this cost is slightly lower (€33.7 per ton in 2020 and €47.1 per ton in 2030).

Taking into consideration the results of the standard DICE model, we conclude that these results are completely different from those in the Stern Review. The Stern Review estimates that the current social cost of carbon in the uncontrolled regime is €244 per ton of CO_2 in 2020 and €298 per ton of CO_2 in 2030. The major reason for the Stern Review's high social cost of carbon is the low discount rate used. All the above estimates as well as the DICE-2016R estimates of the SCC with different discount rates on goods are shown in Table 1. We can easily understand that taking into account a large variety of assumptions makes it possible to obtain various carbon sequestration values. In this work we are using the baseline scenario of Nordhaus (2016), according to which the mean value for the 2020-2030 period is equal to €40.9 per ton of CO_2.

[4] Differences among the SCC values between the DICE and the other models (e.g. FUND and PAGE) can be attributed to the fact that there are different assumptions, such as those about emissions' reduction scenarios, (exogenous) economics growth patterns, and discount rates. Tol (2012) also noted that SCC is dependent on assumptions, such as the parameter of risk aversion and inequality aversion, as well as assumptions regarding various scenarios of climate, population growth, vulnerability to climate change and technological development.

Table 1: Global SCC by different assumptions. (adapted from Nordhaus, 2016)

Scenario	Assumption	2020	2030
Base parameters	Baseline	34.3	47.5
	Optimal controls	33.7	47.1
The Stern Review discounting	Uncalibrated	244.2	298.3
Alternative discount rates	2.5%	128.8	151.4
	3%	80.3	96.5
	4%	37.6	47.0
	5%	20.8	26.8

2.2.2 Stated preference methods

As already mentioned, another method that can be used to estimate the value of CO_2 sequestration is the WTP for this ecosystem service, which as in the case of IAMs, is associated with the avoided damage cost (i.e. it estimates the individual and social benefits of avoiding the future impacts/costs of climate change). The relevant literature includes opinion polls regarding concerns related to climate change and stated preference valuation methods which have focused on the value of carbon sequestration by different agricultural and forestry activities (Shrestha and Alavalapati, 2004; Brey et al., 2007; Glenk and Colombo,2011, Rodriguez-Entrena et al., 2012). However there is very limited literature on this kind of valuation of carbon sequestration, particularly around the mitigation role of tree-crops.

Concerning the estimates obtained from those studies, we can see that the annual WTP for a reduction of one ton of CO_2 was found equal to: (a) €17 in the study of Rodriguez-Entrena (2012), which focused on the sequestration potential of olive trees in Andalusia (Spain), (b) €37 in the study of Brey et al. (2007) examining the benefits of an afforestation program in Catalonia (Spain), (c) €45.5 for the case of a forest management program implemented in Scotland (Glenk and Colombo, 2011). These estimates were obtained from payment vehicles mainly associated with taxes (i.e. compulsory payments). In this context, CLIMATREE designed a survey study to elucidate the economic value of CO_2 sequestration, being an ecosystemic service, by tree cultivations in the conditions of Southern Europe. To make respondents familiar with the setting of the payment vehicle we used a market-based tool, such as a certification/ecolabel, which is directly associated with a food/nutritional product. In this context, a questionnaire survey was conducted to explore the consumers' preferences and values concerning the ecosystem service of carbon sequestration and storage provided by tree crops and specifically by olive trees. In particular, a hypothetical scenario was developed requesting participants'/consumers' willingness to pay (WTP) for eco-certified olive oil (associated with olive grove management practices that can increase the per hectare carbon sink performance). The method and results will be analytically presented in the D.2 Deliverable of this project. However, it is worth mentioning that the marginal value of sequestering a ton of CO_2 was found equal to 212.5€/tCO_2 (i.e. close to the Stern Review scenario but quite larger than the other value estimates). Remarkably this value it is worth mentioned that responders rather perceive agricultural product under evaluation which is directly linked to the area cultivated and its yield. The CO_2 sequestration emerges as an ecosystem service, which, however is hardly quantified in tons of CO_2 sequestrated but rather as a positive contribution to climate change avoidance. As a result, the interpretation of the findings can be used to link agricultural product(s) and cultivation area(s) as the unit providing the ecosystem service.

Table 2: Marginal carbon sequestration values (€/tCO_2) based on different methods/approaches

Category	Method	CO_2 sequestration value estimate (per ton of CO_2)
Avoided in other sectors ETS	Global average nominal prices on January 15, 2020[a]	€24.2 [21.90, 26.58]
Avoided in other sectors VOLUNTARY CARBON MARKETS	(a) Average price of Offsets Transacted in Europe (b) Average price of Forestry and Land use Offsets Transacted in Europe	(a) €3.2/ton (b) €15.6/ton
Avoided damage costs SCC	DICE-2016R baseline model Average value for the 2020-2030 period (Nordhaus ,2016)	€40.9 [€34.3, €47.5]
Avoided damage costs WTP	Survey of LIFE-CLIMATREE (analytically presented in D2 report)	212.5€

3. Estimating the per hectare sequestration value of tree crops

In order to examine the possibility of implementing any future agri-environmental policy that would be able to incorporate LULUCF activities into greenhouse gas reduction options (e.g. in the EU-ETS) it is necessary to convert the values of Table 2 (i.e. the marginal value of sequestering a ton of CO_2) into a per-hectare basis. In this framework, for each tree-crop examined in the LIFE CLIMATREE project we are going calculate: (a) its per hectare sequestration value at a baseline scenario (i.e. under the current cultivation practices, (b) the potential value added of CO_2 sequestration when using best cultivation practices (in terms of climate change mitigation), and (c) the sum of [a] and [b] which corresponds to the per hectare sequestration value for a best case (i.e. best practices) scenario. Then these results will be integrated into a GIS environment to map the spatial variation of these outcomes in each NUT3 region of the study area (Greece, Italy and Spain).

In the first step of this procedure, we used the results of the CO_2 calculation algorithm (as estimated in the Deliverable of Action C.4) to estimate the crop-specific annual sequestration potential of the selected tree-crops. The main assumption made here is that we used the ARC_{area_i}, i.e. the annual CO_2 removal potential for a specific tree crop *i* (cultivated) area, equal to one hectare (the removal potential is thus expressed in tCO_2/ha/year)[5]. These estimates were obtained from two different scenarios: (a) a baseline scenario based on current farming practices ($ARCbase_{area\_i}$) and (b) an optimal scenario ($ARCopt_{area\_i}$), which takes into consideration the application of a combination of best practices for CO_2 storage[6]. Subtracting the second estimate from the first one represents the sequestration potential, which entirely due to the application of best practices:

$$[CO_2 \text{ sequestration potential induced by best practices}]_{area,\, i} = ARCopt_{area\_i} - ARCbase_{area\_i} \quad [1]$$

The above mentioned estimates for each tree-crop is presented in the first three rows of Tables 3-7.

[5] This estimate includes the removal potential dyu to the production of fruit biomass

[6] We used a scenario in which the following best practices were used together for each tree-crop: (a) use of fertigation, (b) use of ground cover plants of the Leguminosae family, (c) electricity needs are exclusively covered by renewable energy sources.

In the next step of the analysis, we converted the annual sequestration potential of each crop (expressed in tCO_2/ha/year) into monetary values for the associated ecosystem service. For this purpose, we used the results of Table 2 - i.e. the carbon sequestration values (CO_{2_seq}Value) across the *j* different valuation approaches - as follows:

$$[\textit{Baseline economic value of } CO_2seq_{area\_i,j}] = ARCbase_{area,i} * CO_{2\_seq}Value_j \quad [2]$$

$$[\textit{Optimal economic value of } CO_2seq_{area\_i,j}] = ARCopt_{area,i} * CO_{2\_seq}Value_j \quad [3]$$

$$[\textit{Value added of } CO_2seq_{area\_i,j} \textit{ due to best practices}] = [3]-[2] \quad [4]$$

By using these formulas (Eq. 2-4) we are able to estimate: (a) the per hectare economic value of CO_2 sequestration for each tree-crop in both scenarios, as well as (b) the value-added of using the best practices (also expressed in €/ha). The last three rows of Tables 3-7 present the monetary value estimates for each tree-crop (olive trees, almond trees, orange trees, peach trees and apple trees). From these outcomes we can conclude that the selection of the marginal CO_2 sequestration value (from table 2) is very important regarding the determination of the final value. Besides, the different interpretation of these values can be crucial in designing alternative policy incentives and measures for future agri-environmental strategies/reforms. It should be also noticed that despite the fact that economic values are quite different among the selected crops (for any given marginal value of CO_2 sequestration)[7], the value-added of the best practices are not so diverse[8].

Table 3: Economic value of CO2 sequestration per hectare for olive trees

Estimates \ Method	ETS[1]	Voluntary market[2]	SCC[3]	WTP
CO_2 seq (baseline scenario) in CO_2/ha	4.203			
CO_2 seq (best practices) in CO_2/ha	4.946			
Additional sequestration induced by best practices	0.743			
Economic value per hectare (baseline) in €/ha	101.87	65.56	171.89	893.08
Economic value per hectare (best practices) in €/ha	119.88	77.15	202.28	1050.96
Value added of additional sequestration induced by best practices in €/ha	18.01	11.59	30.39	157.88

[1] The mean value (24.2€/ton) was used
[2] The upper value (15.6 €/ton) was used
[3] The mean value (40.9€/ton) was used
[4] The price estimate of 212.5€/ton was used

[7] For example the economic value of CO_2 sequestration provided by a hectare of almond-trees is: (a) almost 6 times higher than the value provided by a hectare of apple-trees under the baseline scenario, or (b) 4 times higher than the value provided by a hectare of apple-trees under the optimal scenario.

[8] For example, when using the EU-ETS value estimates, this range extends from 18€/ha/year to 24.6€/ha/year.

Table 4: Economic value of CO2 sequestration per hectare for almond trees

Estimates \ Method	ETS[1]	Voluntary market[2]	SCC[3]	WTP
CO_2 seq (baseline scenario) in CO_2/ha	9.033			
CO_2 seq (best practices) in CO_2/ha	9.996			
Additional sequestration induced by best practices	0.963			
Economic value per hectare (baseline) in €/ha	218.97	140.92	369.46	1919.58
Economic value per hectare (best practices) in €/ha	242.31	155.94	408.85	2124.21
Value added of additional sequestration induced by best practices in €/ha	23.34	15.02	39.39	204.64

[1] The mean value (24.2€/ton) was used
[2] The upper value (15.6 €/ton) was used
[3] The mean value (40.9€/ton) was used
[4] The price estimate of 212.5€/ton was used

Table 5: Economic value of CO2 sequestration per hectare for orange trees

Estimates \ Method	ETS[1]	Voluntary market[2]	SCC[3]	WTP
CO_2 seq (baseline scenario) in CO_2/ha	5.660			
CO_2 seq (best practices) in CO_2/ha	6.672			
Additional sequestration induced by best practices	1.012			
Economic value per hectare (baseline) in €/ha	137.20	88.30	231.49	1202.75
Economic value per hectare (best practices) in €/ha	161.73	104.08	272.88	1417.78
Value added of additional sequestration induced by best practices in €/ha	24.53	15.02	41.39	215.03

[1] The mean value (24.2€/ton) was used
[2] The upper value (15.6 €/ton) was used
[3] The mean value (40.9€/ton) was used
[4] The price estimate of 212.5€/ton was used

Table 6: Economic value of CO2 sequestration per hectare for peach trees

Estimates \ Method	ETS[1]	Voluntary market[2]	SCC[3]	WTP
CO_2 seq (baseline scenario) in CO_2/ha	7.274			
CO_2 seq (best practices) in CO_2/ha	8.287			
Additional sequestration induced by best practices	1.013			
Economic value per hectare (baseline) in €/ha	176.31	113.47	297.49	1545.66
Economic value per hectare (best practices) in €/ha	200.87	129.28	338.93	1760.97
Value added of additional sequestration induced by best practices in €/ha	24.56	15.81	41.44	215.31

[1] The mean value (24.2€/ton) was used
[2] The upper value (15.6 €/ton) was used
[3] The mean value (40.9€/ton) was used
[4] The price estimate of 212.5€/ton was used

Table 7: Economic value of CO2 sequestration per hectare for apple trees

Estimates \ Method	ETS[1]	Voluntary market[2]	SCC[3]	WTP
CO_2 seq (baseline scenario) in CO_2/ha	1.442			
CO_2 seq (best practices) in CO_2/ha	2.448			
Additional sequestration induced by best practices	1.006			
Economic value per hectare (baseline) in €/ha	34.95	22.49	58.98	306.41
Economic value per hectare (best practices) in €/ha	59.34	38.19	100.12	520.18
Value added of additional sequestration induced by best practices in €/ha	24.39	15.70	41.14	213.77

[1] The mean value (24.2€/ton) was used
[2] The upper value (15.6 €/ton) was used
[3] The mean value (40.9€/ton) was used
[4] The price estimate of 212.5€/ton was used

Then, we imported our results into a GIS environment in order to estimate the average and aggregate regional values (corresponding to the NUTS3 level) of the ecosystem service under consideration. Specifically, in each NUTS3 region of Greece, Italy and Spain we used the current data on cultivated areas (tree crops) together with the economic estimates for each tree-crop (as shown in Tables 3-7). Based on these data we tried first to calculate the average economic value of CO_2 sequestration, which is currently provided (i.e. under the baseline scenario) by a representative area with tree-crops, in each NUT3 region (expressed in €/ha). It should be mentioned that for the sake of simplicity, we used a single-value estimate (i.e. the EU-ETS market value). Besides, spatial variation remains invariant upon the marginal value of CO_2 sequestration.

Figure 5 presents the spatial variation (ranging from 34€/ha/year up to 165€/ha/year) of the per hectare economic value of CO_2 sequestration in all three countries. Following the same procedure, but using now the value-added estimates of adopting the best practices (last rows of Tables 3-7), results to a new map (Figure 6). This map represents the spatial variation of the average additional value (per hectare of tree-crop areas) that can be created within a NUTS3 region, by adopting the best practices.

To determine the aggregate economic value (i.e. the aggregate positive externality) of tree-crops with respect to their carbon sequestration potential, we multiplied the per-hectare economic value of each tree-crop with its total cultivated area: (a) in each region, as well as (b) in each country. The regional results are illustrated in Figure 7, which shows the aggregate value of CO_2 sequestration, while Figure 8, depicts the aggregate value-added (per region) of adopting the best practices. Finally, Table 8 illustrates the aggregate value of CO_2 sequestration - derived from each tree-crop - at the national level, while Table 9 also summarizes the aggregate (at the national level) economic value-added of CO_2 sequestration that each tree-crop may contribute by following the best practices.

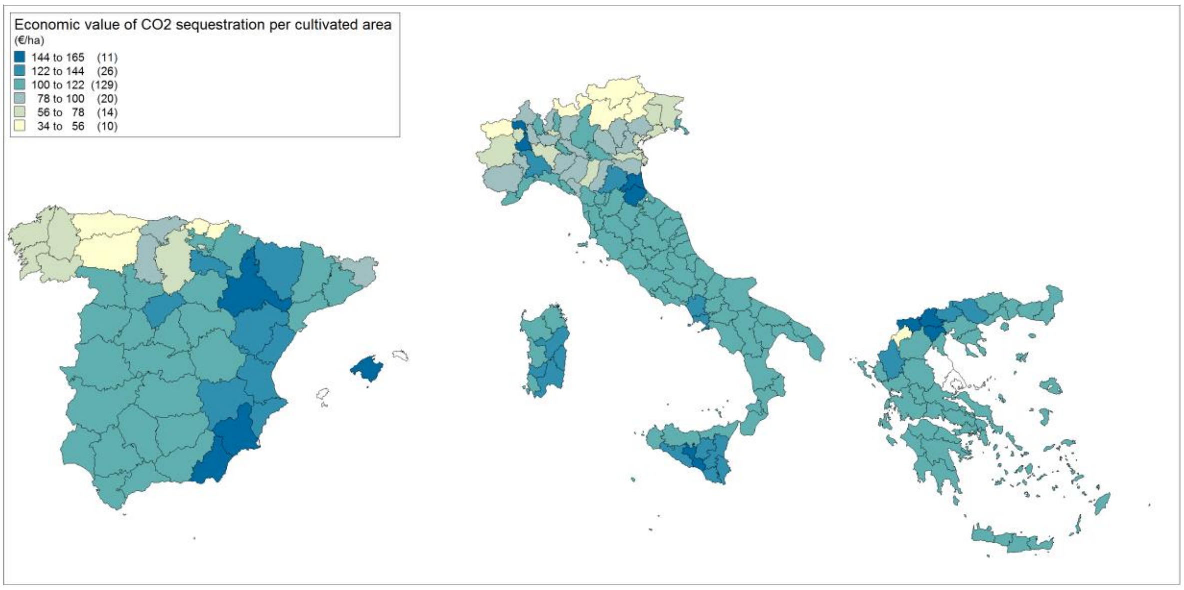

Figure 5. Spatial variation of the per hectare economic value of CO_2 sequestration (€/ha) for the selected tree-crops (NUTS3 scale): baseline scenario

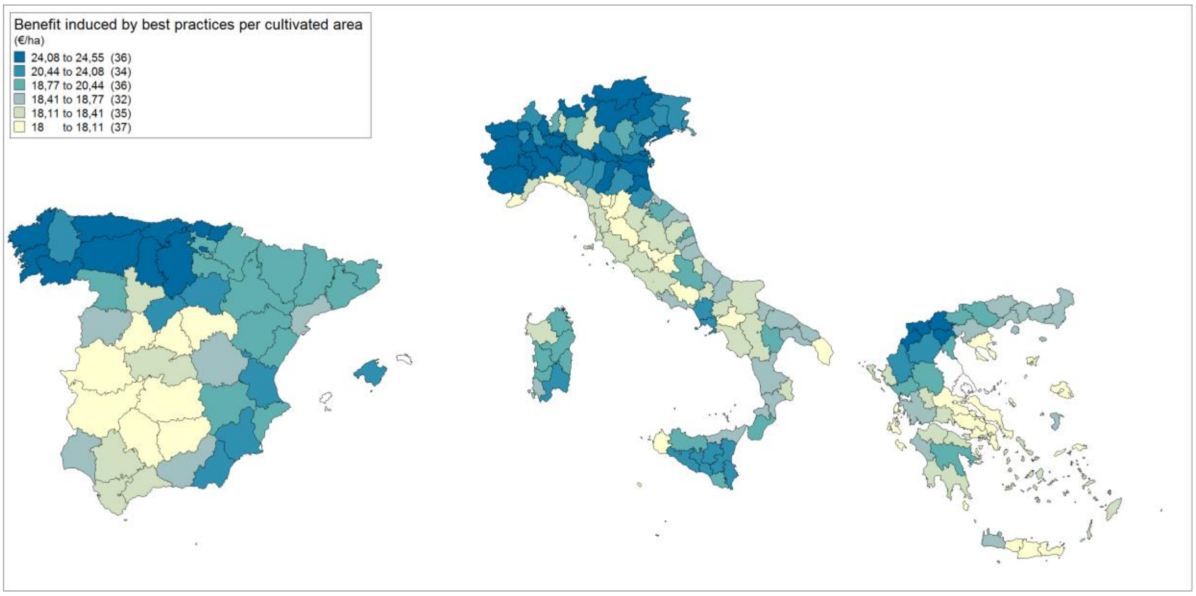

Figure 6. Spatial variation of the added sequestration value/benefit (€/ha) induced by best practices (NUTS3 scale)

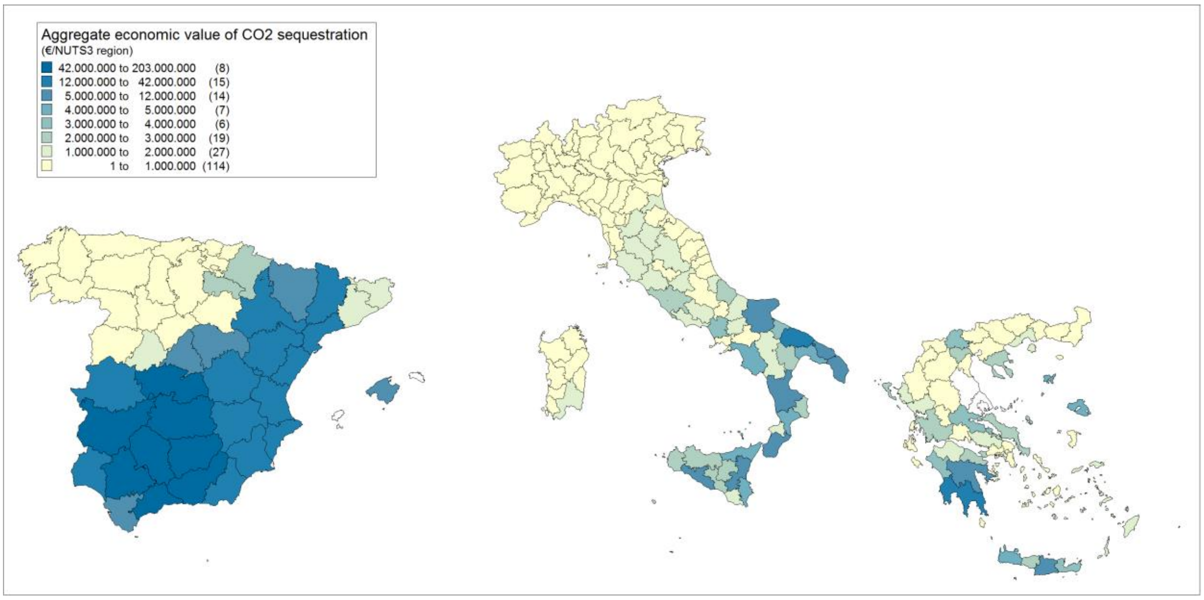

Figure 7. Spatial variation of the aggregate (regional) economic value of CO_2 sequestration (€/NUTS3 region)

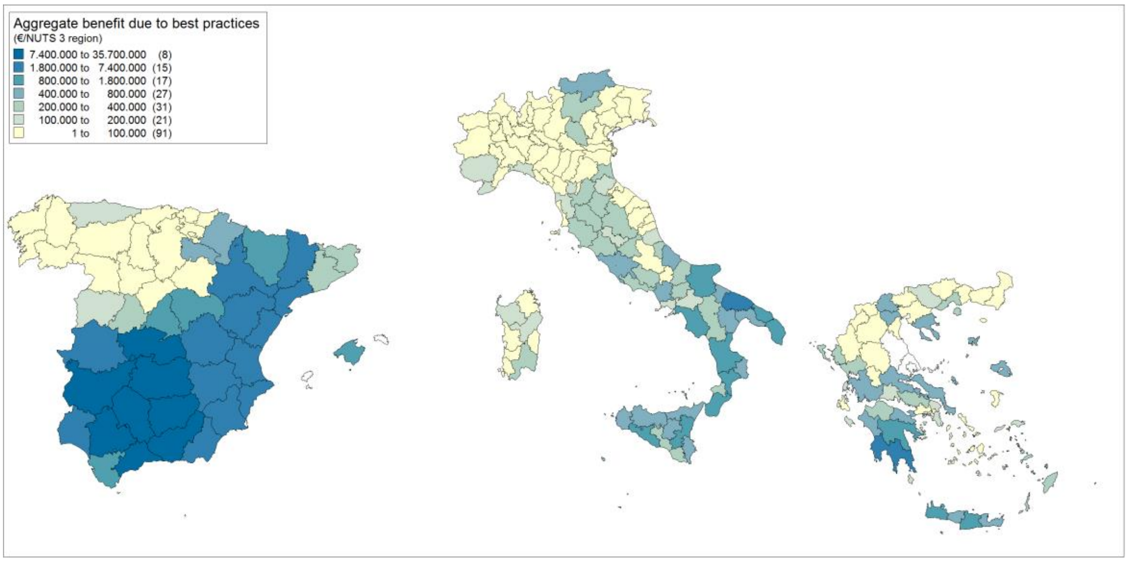

Figure 8. Spatial variation of the aggregate (regional) benefit of CO_2 sequestration (€/NUTS3 region) induced by best practices

Table 8: Aggregate economic value at the national level (positive externality under the baseline scenario) of tree-crops' CO_2 sequestration

	Greece		Spain		Italy		Whole region	
Cultivation	Ha	10^6 €	Ha	10^6 €	Ha	10^6 €	Ha	10^6 €
Olive trees	782,821	79.75	7,965,013	811.4	1,128,634	114.97	9,876,468	1,006.12
Almond trees	7,278	1.59	501,916	109.9	58,155	12.73	567,349	124.23
Orange trees	33,863	4.65	137,032	18.80	84,421	11.58	255,315	35.03
Peach trees	37,449	6.60	46,416	8.18	68,226	12.03	152,091	26.82
Apple trees	7,594	0.27	31,855	1.11	52,362	1.83	91,811	3.21
TOTAL	869,005	92.85	8,682,232	949.40	1,391,798	153.15	10,943,034	1,195.40

Table 9: Aggregate economic value-added of CO_2 sequestration that can be created at the national level by adopting the best practices

	Greece		Spain		Italy		Whole region	
Cultivation	Ha	10^6 €	Ha	10^6 €	Ha	10^6 €	Ha	10^6 €
Olive trees	782,821	14.10	7,965,013	143.45	1,128,634	20.33	9,876,468	177.88
Almond trees	7,278	0.17	501,916	11.71	58,155	1.36	567,349	13.24
Orange trees	33,863	0.83	137,032	3.36	84,421	2.07	255,315	6.26
Peach trees	37,449	0.93	46,416	1.14	68,226	1.68	152,091	3.74
Apple trees	7,594	0.19	31,855	0.78	52,362	1.28	91,811	2.24
TOTAL	869,005	16.20	8,682,232	160.44	1,391,798	26.71	10,943,034	203.35

4. Policy implications and policy measures

Not recognizing tree-crops carbon sequestration in the CO2 emission accountability in the medium term implies that the EU underestimates the GHG abatement potential of the agricultural sector. Accordingly, policymakers are not applying the GHG emission reduction commitment in a socially cost-effective manner. Therefore, it is necessary to reinforce the role that agriculture can play in contributing to the EU climate and energy targets included in the Europe 2020 Agenda (Rodríguez-Entrena et al. 2014).

So far, the substantial potential of carbon sequestration by agricultural practices has been given insufficient policy support in the EU level. Proper design and management of tree-crop practices can make them effective carbon sinks, which would be beneficial both for farmers and for society as they could be cost effective substitutes, for far more expensive alternative abatement options (Aertsens et al., 2013).

Society assigns a higher value to reducing CO2 (20 Euros per ton of reduction) than to the abatement cost of CO2 emissions by industry and energy sectors. Therefore, any relevant LULUCF mitigation strategy could have sufficient support to compensate for emissions in other sectors.

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5. Tracing Policy Instruments to enhance the Mitigation Potentials

This section of the report will trace a framework with financial instruments that could support the exploitation of the mitigation potentials of tree cultivations. The absorption and sequestration of CO_2 is an essential ecosystem service that can be linked with direct and indirect economic incentives. Currently, CO_2 absorption is not supported by an essential financial support to those stakeholders providing it. This is a typical situation of a positive externality whose importance prescribe the development of a comprehensive system of actual payment. Such a payment creates financial incentives to the farmers to provide this service and more important drives farmers behavior towards increasing concern over climate as puts of their business. A clear link between agriculture and climate actions is established and hence agricultural activities are becoming an essential climate tool, as far as tree cultivation are concerned.

The present report considers two types of financial incentives. Direct payment with the context of the Common Agricultural Policy and the exploitation of innovative financial frameworks such as the voluntary CO_2 offsetting markets.

5.1 Direct economic incentives

The CO_2 sequestration from tree crop cultivations emerges a substantial ecosystem service which however evades existing markets and therefore receives no payment. CO_2 sequestration is a positive externality. The need for an effective mitigation policy in the agricultural sector necessitates the development of a comprehensive system of payments to support the CO_2 sequestrations. Such a system can be designed within the context of the forthcoming new CAP.

This report delineates the principles of a system of direct incentives that supports the mitigation potentials of tree cultivations. The objective is to support the "additional" mitigation potentials arising from actions that increase CO_2 sequestrations beyond that occurring under the current standard cultivation practices. The achievement of additional CO_2 sequestration will be linked with direct economic incentives.

Land use change with increasing tree cultivations.

A direct payment can be given to the plantation new land with tree crops. Abandoned land and other marginal land use areas can be used for planting perennial fruit trees. For these kinds of "projects" a direct payment can be given. The duration of the payment could last until the period that yields are achieved.

This period indicatively can last around 5 years. Although it is difficult and to some extent abstract to define a unified economic incentive, such an attempt is worth undertaken to serve the operational requirements and to initiate a fruitful discussion. In this context, we suggest the following schedule of incentives:

- 100€/acre when the optimum cultivation scenario is adopted[9]
- 70€/acre when the medium cultivation scenario is adopted
- 60€/acre when the modest mitigation scenario is adopted

To define these specific incentives the intensive development of the tree biomass during the first period of the cultivation has been taken into account. The intensive development of the biomass result in relatively high absorption of CO_2 from the atmosphere. This amount could be given to farmers regardless if other additional indirect payment they receive. Indirect payment concern voluntary CO_2 markets and eco labeling systems. After this initial period and as the cultivation offer yield, we suggest a system of direct payment that indicates further incentives to support CO_2 sequestration. Therefore, we suggest two classes of incentives: one for cultivation that participate in voluntary CO_2 offsetting systems or/and pro labeling system AND one for cultivation that donate participate in such an innovative system.

An indicative payment for cultivation that participate in voluntary markets and/or eco labeling system can be:

- 50€/acre for cultivation adopting the optimum cultivation method
- 30€/acre for cultivation that adopt the medium cultivation method
- 20€/acre for cultivation adopting the modest cultivation method

An indicative payment for those cultivations not participating in neither voluntary market nor eco labeling scheme could be as follow:

- 30€/acre for cultivation adopting the optimum cultivation method

[9] Those cultivation scenarios are described in the deliverables C5.

- 20€/acre for cultivation that adopt the medium cultivation method
- 10€/acre for cultivation adopting the modest cultivation method

5.2 Voluntary markets of CO_2 sequestration

Voluntary markets emerge as an innovative instrument that can essentially support the mitigation potentials of tree cultivations. The CO_2 sequestrations by tree groves can be the basis of a CO_2 offsetting project. "Emitters" can purchase the amount of CO_2 absorbed by orchards in order to offsetting their CO_2 emissions; this is particularly relevant when their CO_2 emissions cannot be reduced because of technical or economic obstacles. In this context, the CO_2 absorption by tree cultivations are offsetting emissions in other sectors. Farmers, then, sell their mitigation potentials and obtain an economic incentive to act in a climate friendly way. In fact, the CO_2 sequestration by the tree cultivation is an important ecosystem service that can gain an economic profit through CO_2 voluntary market. CO_2 voluntary markets have been expanding the recent years under the pressure for meaningful climate policies. The mitigation potential of orchards present certain comparative advances. They are related with the so-called co-benefits arising by the tree cultivations. Tree cultivations produce foods hence ensure the international target of food security as defined by UN sustainability objectives and other international forums. Furthermore, under proper management, tree cultivations support a number of additional ecosystemic services such as soil formation, desertification avoidance, proper water management. These ecosystem services co-exist with CO_2 sequestration and therefore all can be enhanced through a voluntary market which offer a supporting incentive to farmers being the major providers of these services.

The international standards for the creation of a CO_2 voluntary market set certain requirements. They are briefly delineated here in order to guide the development of such a project. A voluntary market concern exclusively "additional" CO_2 sequestration. This is to say that absorption under the current business as usual status cannot be part of an offsetting process. The requirement of "additionality" indicates that there exist two potentials for voluntary markets in the case of tree cultivations. First, the planting of new areas with crop trees and second the adoption of new, mitigation rich, cultivation practices as those defined by " report on policy suggestions for climate change mitigation policies".

In this respect the deliverables of CLIMATREE create the necessary knowhow for the assessment of the mitigation potentials of tree cultivations. The knowhow of CLIMATREE can support the development of an international standard for the evaluation of the "additional" CO_2 sequestrations that can be sold in a voluntary market.

The development of voluntary market is essentially a project of financial – agricultural – climate nexus. Such a project necessitates the following steps:

- design of a CO_2 sequestration project involving tree crop cultivations

- assessment of the CO_2 volume that can be sequestrated by the project accordingly to the relevant international standards. In this respect, CLIMATREE methodology establishes the basis for a specified standard concerning CO_2 sequestration by the cultivations
- certifying the CO_2 absorption
- creating a voluntary market where byers can purchase CO_2 offsets directly from farmers or from an intermediary stakeholder

It is worth mentioned that the development of a voluntary market does not preclude the direct payment enhancing the mitigation potentials of tree cultivations as delineated in the previous section of this report.

6. Conclusions

- The carbon sequestration values in real markets (ETS or voluntary markets) approximate **€20-€30/ per ton of CO2 equivalent.**

- These value estimates are much higher if they are estimated on the basis of society's benefits from reducing future damage costs (especially when a WTP valuation method is implemented)

- Carbon values in agriculture (and particularly in tree-crops sequestration potential) can be affected by:
  a) the targets of the emission reduction levels as defined by policy makers,
  b) the optimal levels of emissions' reduction while maintaining an economically sustainable agricultural production under different cultivation practices
  c) the societal welfare levels of emissions' reduction
  d) the valuation method

- Climate change mitigation by agriculture could be a promising avenue for policy as it could be financed by additional funds (e.g. by credits sold to the industry, aviation, etc).

- Future CAP could play an important role at implementing climate change mitigation activities (carbon sequestration cultivation practices) in agriculture

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