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Climate Change

Deliverable C.1
Best Available Practices Guide for Tree-Crops Carbon Sequestration

LIFE CLIMATREE

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EXECUTIVE SUMMARY

In the context of present action was developed a concise methodology aiming to the accounting of TCs carbon sequestration with respect to their biological and cultivation characteristics. The cumulative results indicate that TCs in Greece, utilized as case study, accumulate annually an average of almost **4 t CO_2/ha**.

The detailed results of carbon removal potency, carbon emissions, and carbon sequestration estimates are presented in follow, complemented by an indication of the more significant findings (it must be noted though that the figures per land unit are given per 10 m^2, in order to be comparable with the carbon removal potentials per tree):

- Evergreen Intensive Category: This TC category presented a CO_2 removal potency of 4,54 kg per tree, which was almost doubled when the plantation density was accounted into 8,71 kg per 10 m^2. The inclusion of the TC's emission estimate of 3,25 kg of CO_2 per 10 m^2 resolute an annual balance of 5,47 kg of CO_2 per 10 m^2 (5.469 CO_2 kg/ha).
- Evergreen Extensive Category: This TC category presented a CO_2 removal potency of 5,66 kg per tree, which was reduced when the plantation density was accounted into 3,94 kg per 10 m^2. The inclusion of the TC's emission estimate of 1,72 kg of CO_2 per 10 m^2 resolute an annual balance of 2,22 kg of CO_2 per 10 m^2 (2.217 CO_2 kg/ha).
- Deciduous Intensive Category: This TC category presented a CO_2 removal potency of 1,55 kg per tree, which was more than doubled when the plantation density was accounted into 3,95 kg per 10 m^2. The inclusion of the TC's

emission estimate of 4,40 kg of CO_2 per 10 m^2 resolute an annual balance of -0,46 kg of CO_2 per 10 m^2 (-457 CO_2 kg/ha).

- Deciduous Intensive Category: This TC category presented a CO_2 removal potency of 8,78 kg per tree, which was increased when the plantation density was accounted into 11,29 kg per 10 m^2. The inclusion of the TC's emission estimate of 2,65 kg of CO_2 per 10 m^2 resolute an annual balance of 8,64 kg of CO_2 per 10 m^2 (8.639 CO_2 kg/ha).

The scientific team involved in the implementation of Action A.1 and the production of current report is composed by:

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1. Introduction

Mediterranean Sea consists the cradle of contemporary western civilization. Around its coasts the last 6.000 years have been thrived numerous civilizations, generating empires that perished on farmers labor. This constant pressure on crop demands drove the evolution of agriculture up to18th century, and the beginning of the Industrial Era. Up until then agriculture consisted the main productive sector of the economy, and its diversification was the fundamental assurance for food security. This necessity acting for millennia as driving force concluded to a fragmentized agricultural landscape that presents as a distinctive character the high proportion of agricultural land occupied by orchards. Indicatively, and according to Food and Agriculture Organization of United Nations statistics [1], the orchards, which consist the major part of permanent crops, occupy in general almost 6,5% of the North Mediterranean coast total area, and correspond to the 12% of the agricultural land, and to 20% of forests. These figures when narrowed down to the three countries participating in CLIMATREE are increased to 9% of the total area, corresponding to 17% of the agricultural land and more than 25% of forests.

As it is obvious from these figures the interest on the potentials of Orchards as Carbon Sinks has triggered the development of several research endeavors, since the introduction of this concept in the International scene. An extensive review of the relevant knowledge base was presented in the course of Action A.1, along with a novel approach for the inclusive assessment of orchards in National level. To enhance the proposed methodology's productivity we have already developed – through A.1 action – the attribution of all kind of orchards in four distinct clusters with regard their biological and agronomical individualities. For each of these clusters a representative crop – in terms of expansion/yield – is selected, and utilized as the case study for the relevant cluster's Land Use study. This study is performed within CLIMATREE's operational context and includes as core function the Carbon Life Cycle Assessment in (LCA) Tree Crops that is presented in Annex I, accompanied by the relevant Literature Review (Annex II), primary data collected in CLIMATREE's context (Annexes III & IV), and finally the update of the EcoSystem Services (ESS) Assessment (Annex V).

Present report summarizes the findings explicitly presented in the each time relevant annex, in a simplified but not simplistic approach. To facilitate the reader inquiries before the presentation of the findings an abstract key delineating the subject and the content of each Annex is given in follow:

- Annex I: This document aggregates all the formulas and assumptions considered for the calculations of the carbon removal potency, carbon emissions, and carbon sequestration estimates.
- Annex II: This document presents a focused research and policy documents review for the delineation of uncertainties of the calculation methodology.
- Annex III: This document presents the Survey methodology, documents, process and results that contributed to the calculation of the carbon emissions of all TC categories.
- Annex IV: This document presents the sampling methodology, data, process and results that contributed to the calculation of the carbon removal potency of all TC categories.
- Annex V: This document presents the methodology, process and results of all TC categories EcoSystem Services assessment.

The major challenge perceived through the action's implementation was to include in the operational context an additional to Carbon Sequestration factor, which is a prerequisite for the Orchards sustain and is no other than profitability. To accommodate this objective we had to improvise upon the well-established protocols of Carbon Footprint and Carbon LCA in order to include an indicator that could serve two masters; Carbon and Cash! As such indicator – specifically for Cash – may be considered the Crop Yield, which though is unrightfully excluded from the Carbon protocols. Considering two distinct facts presented by FAO in 2011 [2] we propose the inclusion of the Crop Yield as Carbon Indicator because of:

a) The field crop loss, which is accounted to 20% of the total yield, and which is accumulated in the Orchards Litterfal.

b) The losses through Value and Supply Chains, which cumulate to almost 27% of the total yield, and which are considered as Carbon Removal, since it is not consumed, and its fate relates to accredited management practices that assure long term storage.

More over this inclusion of the Crop Yield Index will also be utilized as a "correction factor" for the intensive cultivation measures, which are mostly directed towards crop than vegetative production.

Finally, in the course of Action implementation another aspect of orchards, focusing in the ESS approach was surfaced, namely the conception of the orchards - and more specifically the olive yards – as cultural assets that are also landscape structural elements. These common perceptions in the rural parts of Greece still utilize the olive tree as a substitute for land area unit. More over the heritable succession of olive yards concludes to the materialization of social bonds between land and family. Though significant the assessment of this aspect is only partially approached in the Annex V, and is excluded from further discussion since it only partially relates to the scopes and objectives of the action.

2. Best Available Practices

The concept of Best Available Practices is build upon a solid knowledge base of proven efficacy, within a given framework. Numerous previous endeavors have provided a relevant framework mostly for Soil Carbon Sequestration[1, 2] and Agricultural Carbon Sequestration[3, 4]. Therefore in the following lines a brief framework will be drawn for TCs Carbon Sequestration in order to facilitate the presentation of the present study's results.

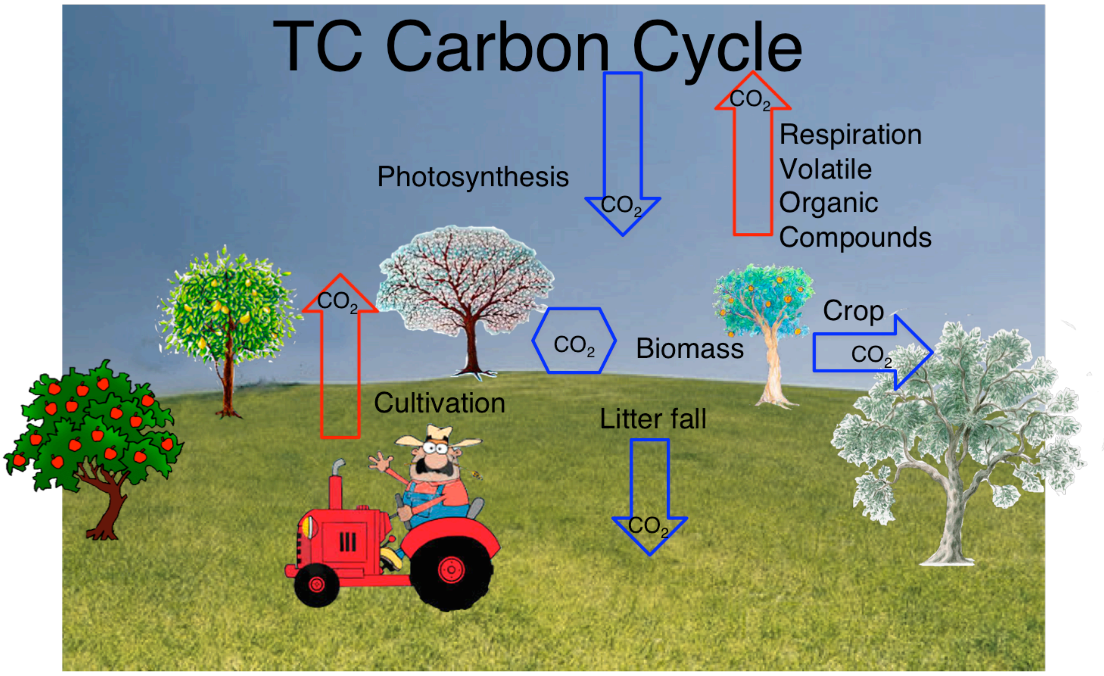

Figure 2.1: Orchard Annual Carbon Cycle Flows.

In this context the general perception of the Carbon Cycle in Orchards is depicted in **Figure 2.1**. In this image is clearly indicated that the ratio of photosynthesis is consumed either for respiration or for herbal tissue production. The

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[1] R. Lal. Soil carbon sequestration. SOLAW Background Thematic Report - TR04B. FAO

[2] Chicago Climate Exchange Offset Project Protocol.

[3] C. Ospina. 2016. Carbon Sequestration: Addressing Climate Change and Food Security through Sustainable Agriculture. The Climate Institute, Washington DC.

[4] Carbon Footprint of Five California Orchard Crops. Agricultural Sustainability Institute at UC Davis and California Climate and Agriculture Network (CalCAN). 2015.

later is considered the fundamental pump of carbon removal from the atmosphere. This pump feeds three pools of carbon; the living biomass, the crop, and the dead biomass (litterfal). On the other hand the main sources of Carbon Emissions are related to human activity in the form of direct and indirect emissions of Green House Gases (GHG). Those emissions are traced to either the machinery usage (direct emissions) or to GHG emissions from the applied agrochemicals (mostly Nitrogen Fertilizers). As extensively discussed in the relevant Annex I the emissions derived from the production of the productive means (e.g. machinery, agrochemicals, manure/compost, etc), are not included in the present approach in order to:

a) Avoid double counting during the integration of the present findings in the relevant National Inventory of GHG Emissions.
b) Avoid the inclusion of exogenous sources of Carbon (e.g. Manure and Compost) in the Carbon Sequestration potentials of the Orchard.

To assess the Carbon Sink potentials of Orchards three main clusters of factors were considered. The first cluster included the elements and factors that form the orchard and was integrated through Action A.1 in the operational framework of the study as the fundamental stratification of orchards in terms of biological and cultivation characters. Thus the two elements of **Orchard Structure** are cross – assessed through the Carbon Sink potentials estimation for each of the four Tree Crop (TC) Categories. The second cluster included the distinct potentials of **Carbon Removal** of each from the three main pools. In this chapter are discussed for each TC category the best available practices for the increase of Carbon Sequestration by Crop, Living and Dead Biomass. Finally, the third cluster involved the **Carbon Emissions** resulting from the application of different cultivation measures. Here the scope is inverted and subject of discussion is the decrease of Carbon emissions; both direct from fossil fuels , and indirect from fertilizers application and energy consumption. Therefore the best available practices of soil cultivation, irrigation, fertilization, crop and plant protection are reviewed against the structure of each TC category.

2.1. Orchard Structure

Orchards are composite systems, which stand metaphorically and literally between Humanity and Nature. They occupy mostly marginal lands standing in the edge of agricultural or urban areas, providing an unparalleled buffer zone for biodiversity conservation. Even though Orchards are artificial systems that are created, managed, and exploited by humans, they present a significant compliance with the local environmental and geophysical conditions. This compliance is established by the appropriate choice and combination of the two crucial elements that form the Orchard: **the kind of tree planted, and the method of cultivation**.

The farmer envisages this compliance in order to establish a profitable cultivation requiring minimum inputs and providing substantial revenue. Therefore each kind of TCs occupies a specific ecological zone, presenting compliance with climatic conditions, soil characters, and spatial conditions by choice. Even though these decisions limit the expansion of each TC, there are cases that this conditionality is poorly served. These cases regard the application of cultivation measures that will alleviate the unfavorable conditions, but also the hyper-intensive farms that are located in High Productivity Lands and present extremely high yields per hectare. Thus the sustainability of an Orchard is established upon a delicate balance between the TC's adaptation – depended on the TC physiology, and profitability - depended on the effectiveness of the cultivation inputs for increased yield.

These two fundamental elements and the between them combinations have been considered as the Orchards Stratification factors. Upon them are centered all the relevant experimental and field data, and consequently the results reflect upon their Carbon Sequestration Estimate (CSE). This last figure, – CSE – is accordingly presented for each element in follow.

2.1.1. Tree Physiology

The two principal categories reflected the fundamental biology of TC in terms of land cover. The first category included all the Deciduous TCs and the second the Evergreens. The calculation of the CSE for each was performed through the aggregation of the relevant figures for both intensive and extensive cultivation into an average, which is presented in **Figure 2.2**.

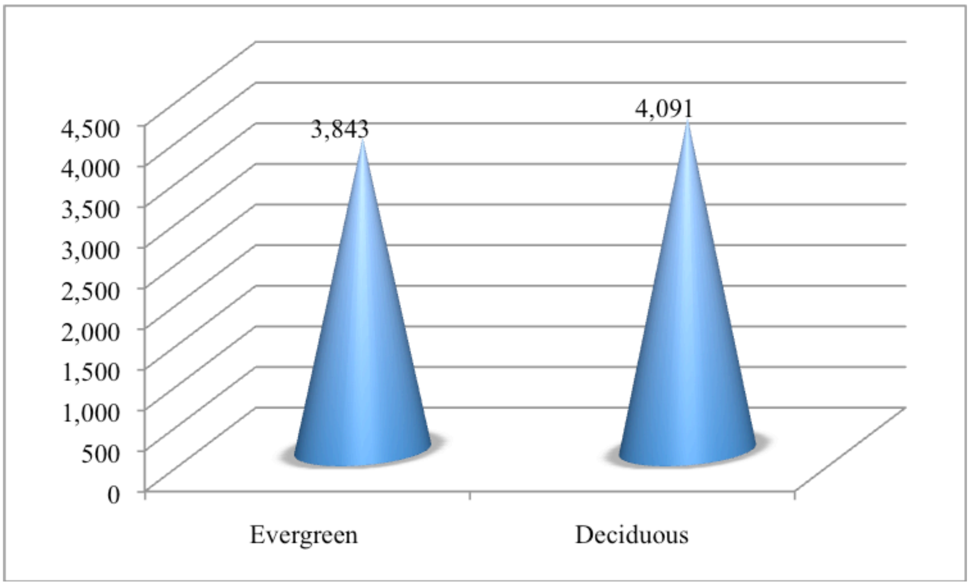

Figure 2.2: Orchard annual Carbon Dioxide Balance (Kg/ha) with respect to the biology of plants.

These derive from the data presented in **Tables 2.1 and 2.2**, originating from Annex I, and depicting the performance of Deciduous and Evergreen TCs respectively. The two categories along with their records are discussed shortly in follow, and extensively described and documented in Annexes I, III, and IV.

Deciduous TCs are mostly distributed within the Rosaceae Family with notable exceptions the dry nuts (Chestnut, Walnut, and Pistachio). Because of their biology these trees operate in Carbon Removal mode almost half the period of Evergreens, therefore it is safe to expect a significant lower CSE. This perception is alleviated by the also expected higher rate of litterfal, due to the drop of leaves, crops, and crop testa. More over considering the biology of Deciduous TC, and simultaneously studying their distribution is revealed prevalence in ecological zones with severe winters and frost periods, were evergreens do not thrive. Therefore even though deciduous TCs equal the evergreens in CSE, they must conform the best available choice in the relevant climatic zones.

Table 2.1: Evergreen TCs annual carbon flows and balance

TC	Carbon Emissions (Kg CO_2/ha)	Carbon Removal (Kg CO_2/ha)	Carbon Balance (Kg CO_2/ha)
Intessive	3244,00	8.713,14	3.469,14
Extensive	1713,18	3.940,68	2.217,50
Evergreen	**2.484**	**6.327**	**3.843**

Evergreen TCs are prominent through the Regions of consideration forming above the 70% of orchards. Prominent among them is the Olive seconded by the various Rutaceae crops belonging to the genus *Citrus* sp. The biology of these crops enables them to perform year round Carbon pumping from the atmosphere, nevertheless restrains their expansion to coastal frost-free areas for the Rutaceae, while Olive is expanded well into the mainland and up to moderate altitudes. The significant higher than Deciduous TC carbon removal potential that is recorded, is eased mostly by the reduced plantation densities, and to a lesser extent as a result of the lesser rate of Soil Carbon transfer as extensively discussed in Annex I.

Table 2.2: Deciduous TCs annual carbon flows and balance

TC	Carbon Emissions (Kg CO_2/ha)	Carbon Removal (Kg CO_2/ha)	Carbon Balance (Kg CO_2/ha)
Intessive	4.402,78	3.945,46	-457,32
Extensive	2.650,20	11.289,93	8.639,73
Deciduous	**3.526**	**7.618**	**4.091**

2.1.2. Cultivation Scheme

The two principal categories reflected the cultivation inputs of TC in terms of machinery usage and agrochemicals application. Intensive and Extensive stratification of TCs was performed through the methodology initially developed and applied through Action A.1. The ESS assessment performed in Action A.1, and included herein as Annex V, revealed the boundaries for the separation of the two clusters. Processing of the field data, presented in Annex IV, revealed an alternate situation. In specific several of the Apple and Peach farms initially considered of intensive culture proved extensive. Therefore the relevant data were transferred to the appropriate TC category, complementing thus the depiction of the deciduous extensive TCs. The calculation of the Carbon Sequestration Estimate for each Cultivation Scheme was performed through the aggregation of the relevant figures for both Evergreen and Deciduous TCs into an average that is presented in **Figure 2.3**.

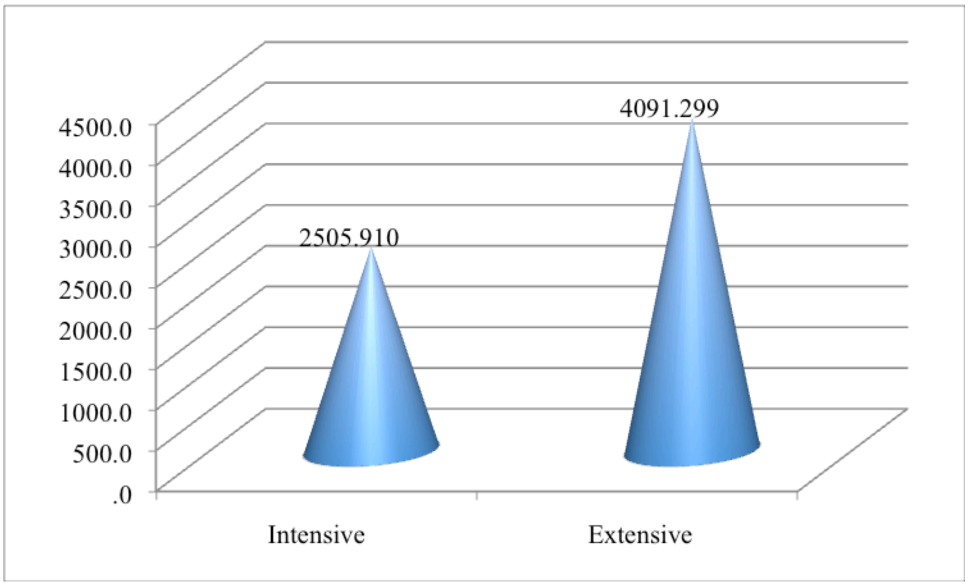

Figure 2.3: Orchard annual Carbon Dioxide Balance (Kg/ha) with respect to the cultivation scheme

These derive from the data presented in **Tables 2.3 and 2.4**, originating from Annex I, and depicting the performance of Intensive and Extensive TCs respectively. The two categories along with their records are discussed shortly in follow, and extensively described and documented in Annexes I, III, and IV.

Intensive Cultivation TCs are equally separated between Rosaceae and Rutaceae plant families. The detection of the conditionality for the development of the Intensive Cultivation characterization revealed the simultaneous performance of 3 out of the total 5 cultivation measures. The measures uniformly applied in these TCs were that of Irrigation, Fertilization, Pruning, and Plant Protection. In addition to them, Tillage was recorded mostly in the Evergreen TCs (Olive and Citrus sp.). The unifying character in this cluster is the increased Carbon Emissions as a result of the cultivation measures application. It is thus expected for these TCs to present a significantly decreased CSC against the corresponding Extensive Orchards. The inclusion though of the Crop in the carbon removal pools alleviate this effect, since with a rightful approach incorporates the financial sustainability prerequisite of increased yield per hectare. The emissions from these TCs derive from 12 interventions (Averge) annually the vast majority of which, regards plant protection measures. This cluster encompasses significant CSE because of the differentiated emissions depending the form of irrigation and mostly fertilization. Therefore even if Intensive TCs present a significantly lower CSE must remain as a viable recommendation for farmers that envisage increased revenue per land unit, but also considering the incorporation of best available practices extensively discussed in Annexes I and IV.

Table 2.3: Intensive Cultivation TCs annual carbon flows and balance

TC	Carbon Emissions (Kg CO2/ha)	Carbon Removal (Kg CO2/ha)	Carbon Balance (Kg CO2/ha)
Evergreen	3244,00	8.713,14	5.469,14
Deciduous	4.402,78	3.945,46	-457,32
Intensive	**3.823**	**6.329**	**2.506**

Extensive TCs prevail through the Regions of consideration forming almost the 80% of orchards. Prominent among them is the Olive seconded by the various deciduous dry nuts (Almond, Walnut, Chestnut). The cultivation measures uniformly applied in this cluster regard pruning, tillage, and to a lesser extend fertilization. The distinctive character of this cluster is the extended life span of the Orchards, which usually exceeds the 50 years. The significant higher than the Intensive TCs CSE that is observed, is eased by the reduced yields, and plantation densities, as extensively discussed in Annex I.

Table 2.4: Extensive Cultivation TCs annual carbon flows and balance

TC	Carbon Emissions (Kg CO2/ha)	Carbon Removal (Kg CO2/ha)	Carbon Balance (Kg CO2/ha)
Evergreen	2.650,02	11.289,93	2.217,49
Deciduous	1713,19	3.940,68	8.639,91
Extensive	**3.526**	**7.618**	**4.091**

2.2. Carbon Removal

Plants sole source for carbon uptake is the atmosphere. Though nutrients and water, mostly provided through soil, contribute to the growth of plants, all biomass production translates in atmospheric carbon consumption through photosynthesis. Therefore plants consist the prominent sustainable consumer of atmospheric carbon, which is utilized for plant respiration and biomass production. Forests have long been recognized as a carbon sink land use and numerous efforts have resulted to the IPCC protocol for the estimation of their carbon sink performance. The fundamental assumption for the inclusion of forest biomass production in the National GHG inventories is the long term storage of the organic carbon. This is accredited for the living biomass with the retention of land use, while dead biomass like leaves, twigs, trunks, and fruits, are all considered litterfal contributing with 36,7% of their biomass to the Soil Carbon Pool.

This prerequisite for long term storage of the atmospheric carbon removal by TCs, was positioned in the center of the present approach. Therefore each of the two prominent outputs that assure carbon long term storage were assessed against both the tree physiology and cultivation scheme, and specific conditions and management practices were recognized for improved performance of carbon removal. In addition to these two established carbon pools a third was recognized for TCs that also accommodate the fundamental prerequisite of long term carbon storage; The crop, and in specific the percent of crop that is not consumed.

In this context the present results regard three main pools of long term carbon storage by TCs: the Crop that includes the harvested product percent that is not consumed, the Biomass that includes the living tissues of the TCs, and the Litterfal that includes the fallen leaves, the pruning, the crop-loss, and the crop coatings. The relevant figures presented in **Figure 2.4** for each TC category refer to the Carbon Removal potentials per year and hectare and are derived from the relevant figures for Crop, Biomass, and Litterfal Carbon subjected to long term storage that are presented and shortly discussed in follow. It must be noted that the explicit methodology of estimation is presented in Annex I, while the relevant primary data can be found mostly in Annex III, and partially in Annex IV.

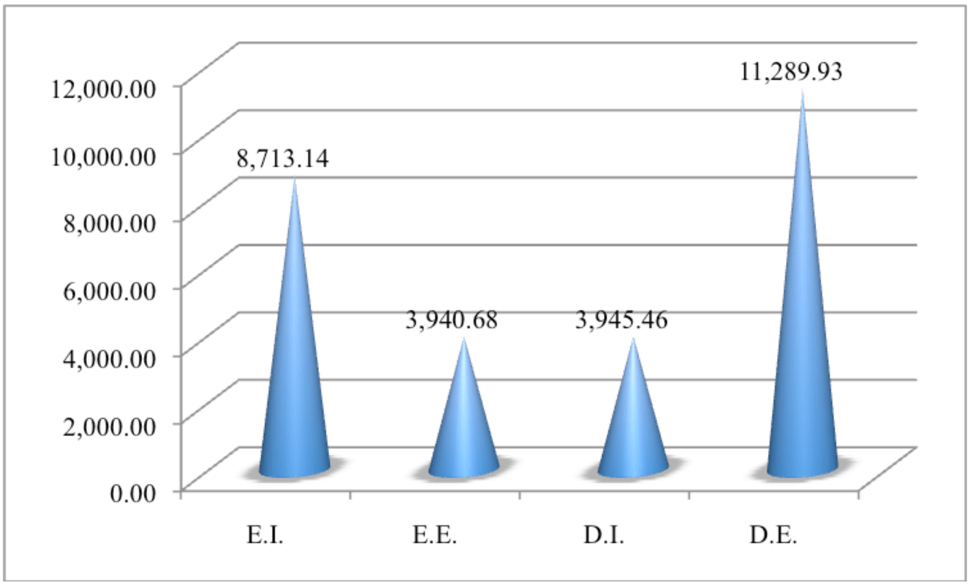

Figure 2.4: TCs Average annual Carbon Capture Estimate (in CO_2 Kg/ha)

2.2.1. Crop

The inclusion of a distinct crop fragment, which is that not consumed, consists a novelty of the CLIMATREE's approach. This direction was facilitated through the revision of the IPCC fundamental assumption that all Crop is, or will be eventually consumed, therefore emitted in the atmosphere. This revision was made possible through the combinatorial consideration of two documents; The FAO 2011 report on pre- and post- harvest loses of agricultural products, and the EU Policy on Waste Management and Circular Economy. The first document provided a clear and concise estimate on the percentages of annual fruit production that are lost in field, which is included in litterfal, and through the supply and value chains, that both account an average 27% of the annual production in EU. This percent is included in the Crop Pool Category, because the management of it is subjected to EU regulatory obligations that assure the long term storage of the organic matter. Because of the novelty of the approach we chose to present also herein the fundamental arguments and methodology of the Crop Carbon Content estimation.

Accounting of the annual crop production was easy through the retrieval of the annual national statistics for each country but that was it! This was the only easy step towards the definition of the carbon stored in each crop. The consequent step towards the carbon content estimation of fruits and nuts should be established upon the each fruits content of metabolites. Unfortunately these metabolites belong to vast diversity of chemical structures that their carbon content estimation requires differentiated coefficients. As standards for the metabolic products content of each representative TC were considered the USDA relevant fact-sheets, which were amended in relation with missing data (e.g. stone and seed metabolites) by experimental figures. For each class of metabolites (e.g. oils, sugars, proteins, etc) a dedicated coefficient was developed and the results of the carbon content estimation for each TC are given in

Table 2.5: Crop contribution to the Orchards' annual Carbon Sequestration Estimate.

TC	Plantation Density	Yield (Kg/tree, dry)	Biomass Sequestration (Kg/tree, dry)	C Sequestration (Kg/tree)	C Sequestration (Kg/ha)	CO_2 Sequestration (Kg/ha)
E.I.	524	23,50	6,35	0,12	64,10	**234,86**
E.E.	190	21,90	5,91	0,89	169,40	**620,67**
D.I.	695	7,70	2,08	0,03	23,98	**87,87**
D.E.	351	15,00	4,05	2,41	844,60	**3.094,60**

As it is obvious from these results the dry nuts form a differentiated and concise class of crops that greatly contribute to Orchard's carbon sequestration, while other similarly grouped classes are the stone and seeds baring Rosaceae, the Citrus sp. Fruits, and the Oil Crops, each presenting a gradient increase of CSE contribution.

But the main reason for inclusion of Crops in the herein approach cannot be subjected to a best available practice recommendation, since it could lead to food loss. What though could be subject of consideration is the more realistic estimation of the total amount of carbon that is permanently stored, and more importantly how it is stored or further utilized. In this context, and also considering the necessity for adaptation of the present approach into existing EU policies and Instruments are presented in follow the proposed approaches towards a well-documented inclusive estimate. The proposed approach is established on the Agricultural Industries TCs by-products, which are also subjected to management obligations.

Certification of Crop's Carbon Long Term Storage

A factory certification, provided to the farmer upon the crop deliverance, stating the quantity and management of the delivered crop by-products, which will assure long-term carbon fate.

Among the potential management choices available for application to agro-industrial by-products and wastes, in the following box are presented in line of preference the best available practices.

Preferential Agro-Industrial Waste Management Practices

1. Raw Material recovery (e.g. Wood, Oils, Fibers, Sugars, etc)
2. Energy Recovery (e.g. wood, biofuel, biogas etc)
3. Safe Subteranean Storage

2.2.2. Biomass

This Carbon pool includes the sum of the living plant tissues biomass. The estimation of the figures presented in **Table 2.6**, was based upon sampling extensively presented in Annex IV. This figure presented intriguing diversity between the TC up to the level of tree. When this figure was considered in Tree Unit the evergreens presented a significantly higher from the deciduous potency for C sequestration.

Table 2.6: Biomass contribution to the Orchards' annual Carbon Sequestration Estimate.

TC	Plantation Density	Biomass (Kg/tree, dry)				Sequestration (Kg/tree, dry)	C Sequestration (Kg/tree)	C Sequestration (Kg/ha)	CO_2 Sequestration (Kg/ha)
		shots	trunk	root	pruning				
E.I.	524	7,90	2,60	1,50	3,18	6,71	3,35	1.757,74	**6.440,36**
E.E.	190	8,60	2,40	1,24	4,50	5,88	2,94	558,97	**2.048,06**
D.I.	695	3,73	1,29	0,70	2,41	1,39	0,70	483,78	**1.772,58**
D.E.	351	6,80	1,34	0,73	2,80	3,50	1,75	614,95	**2.253,16**

This figure presented intriguing diversity between the TC up to the level of tree. When this figure was considered in Tree Unit the evergreens presented a significantly higher from the deciduous potency for C sequestration, doubled in between the best performing groups, namely Ev. Int. Vs Dec. Ex., and quadrupled in between the lesser performing groups, namely Ev. Ex. Vs Dec. Int.

Nevertheless the final performance per hectare is revealed that is mostly related to the plantation density. The Evergreen Intensive TC category through an average plantation density managed to retain its premium position referring to plant C sequestration potential while the Evergreen Extensive TC, through their notoriously low plantation density retracted two positions. The Deciduous Extensive TC that also exhibited an intermediate plantation density climbed to the second position, while the Deciduous Intensive TC, even though presented an increased plantation density did

Best Available Practices for TC Biomass Carbon Sequestration

1. Intermediate Plantation Density (above 300 and below 550 plants per hectare)
2. Prunning Manipulation (Low Intensity, Wood recovery, Grinding)
3. Biomass management beyond TC's life span (Wood recovery)

not manage to recover from the significantly low Biomass accumulation that this cultivation scheme implies.

2.2.3. Litterfal

This carbon pool is the more composite of the three. It includes the percent of Crop falling in the field, the leaves, the pruning leftovers, and especially for the dry nuts the seed coatings that also remain in the field after harvesting. In **Table 2.7** are presented the outcomes of the projections performed in Annex 1 mostly established upon the primary data of Annex IV, and partially to Annex III.

Table 2.7: Litterfal contribution to the Orchards' annual Carbon Sequestration Estimate.

TC	Plantation Density	Biomass Sequestartion (Kg/tree, dry)				C Sequestartion (Kg/tree)					Sequestartion (Kg/ha)	Sequestartion (Kg/ha)
		litterfal				litterfal				Total		
		Crop	Leaves	Prun.	Coat.	Crop	Leaves	Prun.	Coat.			
E.I.	524	4,70	2,12	3,18	0,00	0,09	0,39	0,58	0,00	1,06	556,20	**2.037**
E.E	190	4,38	1,86	4,50	0,00	0,66	0,34	0,83	0,00	1,83	347,15	**1.271**
D.I.	695	1,54	1,91	2,41	0,00	0,03	0,35	0,44	0,00	0,82	569,06	**2.085**
DE	351	3,00	2,57	2,80	10,10	1,78	0,47	0,51	1,85	4,62	1.621,77	**5.942**

These previous results indicate that the Deciduous Extensive TCs present a significant premium when the litterfal Carbon sequestration is considered mostly because of the seed coating of the dry nuts, which form a distinct and unique source among the other TC categories. Otherwise the performance of this TC category almost equals the one from Evergreen Extensive TC. The intensive TCs present also an almost uniform performance that equals almost the half of the extensive TCs. Again as in Biomass sequestration the plantation density performs an adjusting operation alleviating both Intensive TCs, above the Evergreen Extensive.

In this category a major challenge is located in the manipulation of pruning. While the farmers collect most of the large branches as wood fuel, the remaining are rarely further processed. The suggestion of the following best available practices includes measures that could be applied in order to increase the penetrability of the Litterfal carbon to the soil carbon stocks.

Best Available Practices for TC Litterfal Carbon Sequestration

4. Intermediate to high Plantation Density (above 300 plants per hectare)
5. Pruning Manipulation (Wood recovery, Grinding)
6. Crop Loss management (Grinding)
7. Fallen Leaves management (Grinding)
8. Seed coatings management (Grinding)

2.3. Carbon Emissions

While plants accumulate and store atmospheric carbon in significant quantities; Farmers – the other significant half of orchards – consume fuels, energy, and agrochemicals that conclude to GHG emissions. This third cluster involving the Orchard Carbon Emissions results from the study of the different cultivation measures applied within each TC category. Two major variants were chosen, and were appropriately correlated in order to define the Orchard Carbon Emission Indicator. From these two variants, the first related to direct carbon emissions resulting from the operation of machinery consuming fossil fuels. The second variant is related to indirect GHG emissions that are corrected in Carbon Emissions Equivalents. These indirect emissions are mostly related to agrochemicals application; primarily from nitrogen fertilizers, and to energy consumption; mostly from irrigation. Both variants additively express the annual Carbon Emissions Estimate of orchards that is depicted in **Figure 2.5** for each of the TC categories.

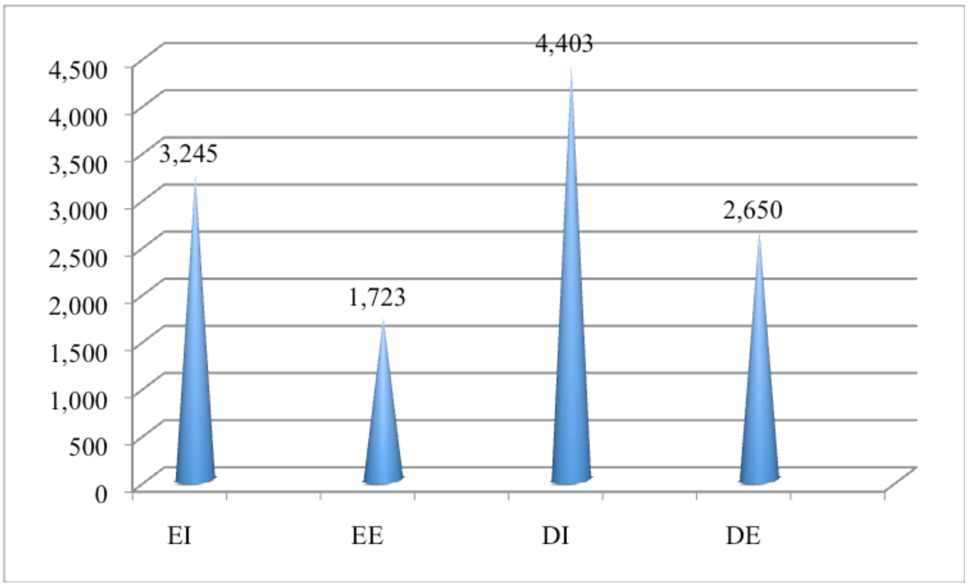

Figure 2.5: Annual TCs Carbon Emissions (in CO_2 Kg/ha)

A fundamental assumption for the calculation of the relevant figures relates to the emissions for the production of productive means, namely machinery, manure/compost, and agrochemicals. All these emissions are rightfully calculated in Crop Carbon LCA in order to provide a concise and inclusive assessment of the crop's environmental performance. But present scope was rather focused to land than crop as subject of assessment, and further more it is meant to integrate within the Emissions Trading System, therefore the inclusion of the relevant emissions, would conclude to double counting, according to IPCC protocols. More over the inclusion of these emissions would require the accounting of the relevant emissions from manure/compost, which consist an exogenous stabilized carbon source for the orchard and therefore their inclusion, considering also the large application volume per hectare, would jeopardize the credibility of the results in orchard biomass productivity. Therefore the estimates presented herein regard only the emissions occurring in farm level. In the same manner are also excluded the nursery emissions which regard a different land use, which may be located outside the regional or even national boundaries.

In this context and as previously stated the scope within the study of this cluster of variables is the decrease of Carbon emissions. This decrease, though not directly related, may be facilitated through the incorporation of Renewable Energy Resources both in National and Farm level. Therefore before the detailed discussion on each source of emissions and the relevant indication of the best available practices a list of more general recommendations could regard the energy and fuels mixture in both Farm and National levels:

General Recommendations

1. Enhance the incorporation of electricity in Farm Level
2. Foster the transition to RER in Farm Level
3. Reverse to «cleaner» fuels technology (e.g. gas) in Farm Level

Beside these general recommendations each of the 5 cultivation measures, namely soil cultivation, irrigation, fertilization, crop and plant protection are reviewed against the structure of each TC category. In the following chapters the contribution of each cultivation measure in the relevant TC's Carbon Emission is presented broken down to direct fuel emissions and indirect emissions. It must be noted that the explicit methodology of estimation is presented in Annex I, while the relevant primary data can be found mostly in Annex IV, and only for Pruning quantities in Annex III.

2.3.1. Soil Cultivation

Soil Cultivation was scaled in three major interventions with respect to the depth of tillage in the soil: a) Surface, b) Top Layer, c) Sub Layer. In this context numerous cultivation practices regarding weed control and/or green manuring were included herein. The analysis of the data collected through the field survey is summarized in **Table 2.8**, and briefly discussed in follow.

Table 2.8: TCs fuel consumption and carbon emissions as a result of soil cultivation

TC	Machinery Operation (h/ha)	Consumption (L/ha)	Carbon Emissions (Kg CO_2/ha)	Carbon Emissions % of Total
EI	2,75	11,54	30,93	6,15%
EE	1,68	6,75	18,08	3,59%
DI	0	0,00	0,00	0,00%
DE	3,26	32,87	88,10	6,99%

Soil cultivation has been generally depreciated as a cultivation measure and modern orchards have almost eliminated related practices as indicated by the only one farmer among the 25 of DI TC whom performed tillage, practically translating to zero emissions for this TC category. Both Evergreen TC categories presented significantly lower than the DE fuel consumption. Nevertheless, when this amount was compared against the sum of diesel fuel emissions it was revealed that soil cultivation contributes almost the same in EI and DE TCs and slightly less in the EE.

In this context the generally accepted negative impacts of Tillage on Soil erosion, soil fauna and flora diversity, and fertility argue in favor of the abolishment of this cultivation measure. Nevertheless, since herein are also included cultivation measures relating to the management of the Orchards under-canopy vegetation there are specific needs to be covered that do not allow the total eradication of the relative emissions. For these last cases the general recommendation focuses in the environmental parameters that favor them:

Best Soil Cultivation Practices

1. No Tillage
2. Soil Surface cultivation measures distributed within Fall and/or Spring

2.3.2. Irrigation

In the Mediterranean basin the long hot dry summers dictate the additional supply of water in Orchards in order to produce a decent and financially sustainable yield. This cultivation measure, depending on the technology implicated concludes to both direct and indirect carbon emissions. Besides the power source that gives to the water the required energy, there are also different applications methods that contribute to the diversification of the resulted carbon emissions amount. The prominent application method involves drip network, while also abundant are sprinklers, both in a grid or moving, while quite scarce is natural flow irrigation. The methodology for the calculation and the relative breakdown of each from the above-mentioned variables is presented and discussed in Annex III. Nevertheless a brief presentation of the break down between fuel and agrochemicals/energy emissions can be preformed herein through the respective **Tables 2.9** and **2.10**.

Table 2.9: TCs fuel consumption and carbon emissions as a result of irrigation

TC	Machinery Operation (h/ha)	Consumption (L/ha)	Carbon Emissions	
			(Kg CO_2/ha)	% of Total
EI	12,45	52,27	140,08	27,88%
EE	23,86	95,80	256,74	50,96%
DI	53,61	413,85	1.109,12	70,99%
DE	26,67	268,93	720,73	57,22%

Irrigation is the most significant contributor to all TC categories, with the exception of EI TCs the case of which will be further discussed. More specifically in the two extensive TC categories contributes more than 50% of the overall fuel emission, while in the DI exceeds the 70%. The reason behind the improved performance of the EI TC category, may be partially explained by the figures of **Table 2.10**.

As it is obvious from the comparison of Fuel and Energy emissions the reason for the EI lower than the other TCs Fuel emissions is explained by their higher Energy emissions. Nevertheless, this observation is partially reflected also into the overall EI TC carbon emissions, which is almost half of the DE TC category. The reasons for this differentiation may be retracted by several perceptions. To begin with the EI TC category is constituted mostly by *Citrus* sp plants and occupy flat, lowland, preferably frost free areas, therefore decreasing the machineries operational demands.

Table 2.10: TCs energy consumption and carbon emissions as a result of irrigation.

TC	Consumption (KWh/ha)	Carbon Emissions	
		(Kg CO2/ha)	% of Total
EI	185,00	166,50	5,13%
EE	30,00	27,00	1,57%
DI	163,00	146,70	3,33%
DE	113,00	101,70	2,74%

More over EI TCs have been grown for centuries in this areas therefore concluding to the development of crucial agricultural infrastructures in the form of electrical and primary irrigation grids, enabling thus the development of electricity as major energy input on the side of Fuels. Beside this differentiation, which is served through the General Recommendation 1 of the present chapter, there is also the variance between the application technologies. These escalate their operational demands in either fuel or energy on the following order: 1) natural flow, which has as prerequisite the steadily available through summer provision of significant water quantities; 2) Moving sprinkler, which has as prerequisite flat terrain; 3) Network sprinklers; 4) Drip grid, the last two sharing the fact that they do no require any particular operation conditionality.

Best Irrigation Practices

1. Natural Flow, depended on water sources
2. Moving Sprinkler, depended on terrain slope.
3. Sprinkler Network.

2.3.3. Pruning

Pruning is a cultivation measure uniformly applied through all TCs mostly by hand. The occasional use of chainsaws, which by the by is also a uniformly owned piece of equipment, is restricted to renewal pruning, and the consequent clean-up of the trunk and branch into fuel wood. Therefore pruning is efficiently applied within all TC's with respect to fuel and energy consumption.

Subject of further consideration within this cultivation measure may be considered the introduction of a fuel consumption machine in the form of Grinders (Πέτρο βοήθεια!!). The operation of this machinery may alleviate the carbon input but this increase must be checked against the benefits of Litterfal increased penetrability into the Soil Carbon pool.

Best Pruning Practices

1. By Hand.

2.3.4. Fertilization

2.3.4. Fertilization

Fertilization is also uniformly applied through out all 4 TC categories, though to a significant lesser extend in the EE. Carbon emissions derived from fertilization derive from two major sources: a) fuel consumption, and b) Nitrates (N_20) emission. Both sources are affected by the application methodology. These last factor presents respectively three distinct variances: 1) Solid, which regards the use of solid fertilizers; 2) Spray, which corresponds to the application of foliar fertilizers; 3) Irrigation, which involves the use of diluted fertilizers. The methodology for the calculation and the relative breakdown of each from the above-mentioned variables is presented and discussed in Annex III. Nevertheless a brief presentation of the break down between fuel and agrochemicals emissions can be preformed herein through the respective **Tables 2.11** and **2.12**.

Table 2.11: TCs fuel consumption and carbon emissions as a result of fertilization

TC	Machinery Operation (h/ha)	Consumption (L/ha)	Carbon Emissions	
			(Kg CO_2/ha)	% of Total
EI	2.01	8,44	22,62	4,50%
EE	1,26	5,05	13,53	2,69%
DI	3,25	25,09	67,24	4,30%
DE	2,65	26,72	71,61	5,69%

As clearly indicated in Table 2.11 the Fuel derived emissions do not participate significantly in the Orchards overall Fuel emissions. It must be noted though that among the methods of application the preferable is through Irrigation since the relevant Fuel emissions have already been accounted in the Irrigation accounting. Nevertheless, a different picture is drawn when the agrochemical emissions are included in the background.

Table 2.12: TCs agrochemicals consumption and carbon emissions as a result of fertilization.

TC	Consumption (Kg/ha)	Nitrate emissions (Kg/ha)	Carbon Emissions	
			(Kg CO2/ha)	% of Total
EI	625,00	7,81	2.328,13	85,81%
EE	316,00	3,95	1.177,10	97,77%
DI	516,00	6,45	1.922,10	92,90%
DE	284,00	3,55	1.057,90	91,20%

As it is obvious from the figures of **Table 2.12** nitrate emissions derived from the fertilizer application are the prominent source of Orchards indirect emissions. Among the methods of application Solid and Irrigation present the same Fuel and Agrochemical emissions coefficients. The Solid fertilizer application though requires more volume per hectare and is susceptible to various environmental factors, among which the more significant are Temperature and Humidity. On the other hand Spray fertilization emissions are half of Solid and almost 1/3 of Irrigation. A limitation that should be considered relates to the requirement for the existence of dedicated equipment; fortunately this equipment is already available since it is the same that is used for plant protection spraying.

Best Fertilization Practices

1. Spray of Foliar Fertilizers.

2.3.5. Plant Protection

Plant protection measures are usually referring to the application of plant and crop protection agents in the form of Herbicides, Pesticides, and Fungicides. Although this general description is fitting most of the cases in the EI TC includes one more significant intervention: that of frost protection. This source of emissions relates to both direct fuel emissions and indirect energy emissions. The methodology for the calculation and the relative breakdown of each from the above-mentioned variables is presented and discussed in Annex III. Nevertheless a brief presentation of the break down between fuel and energy emissions can be preformed herein through the respective **Tables 2.13** and **2.14**.

Table 2.13: TCs fuel consumption and carbon emissions as a result of plant protection.

TC	**Machinery Operation**	**Consumption**	**Carbon Emissions**	
	(h/ha)	**(L/ha)**	**(Kg CO_2/ha)**	**% of Total**
EI	27,45	115,24	308,84	61,46%
EE	20,02	80,39	215,45	42,76%
DI	18,66	144,05	386,05	24,71%
DE	14,03	141,47	379,14	30,10%

The figures of the previous table indicate that the fuel consumption is the major source of EI TC carbon emissions

Table 2.14: TCs energy consumption and carbon emissions as a result of plant protection.

TC	Consumption (KWh/ha)	Carbon Emissions	
		(Kg CO2/ha)	% of Total
EI	243,00	218,70	6,74%
EE	0,00	0,00	0,00%
DI	0,00	0,00	0,00%
DE	0,00	0,00	0,00%

3. Conclusions

The so far provided evidence by the study confirms the initial planning, as the TC clusters selected present a significantly differentiated CSE profile. More over their performance, which is presented in **Figure 3.1**, is structured upon an inclusive methodology that encompasses the relevant international standards. The performed analysis was conducted upon each TC's Carbon Sequestration Potency (e.g. Carbon Removal), and Carbon Emissions estimate. All figures calculation is established upon primary data (Field Sampling & Survey) well documented, and international standards and protocols, rightfully incorporated in the CLIMATREE's Operational context.

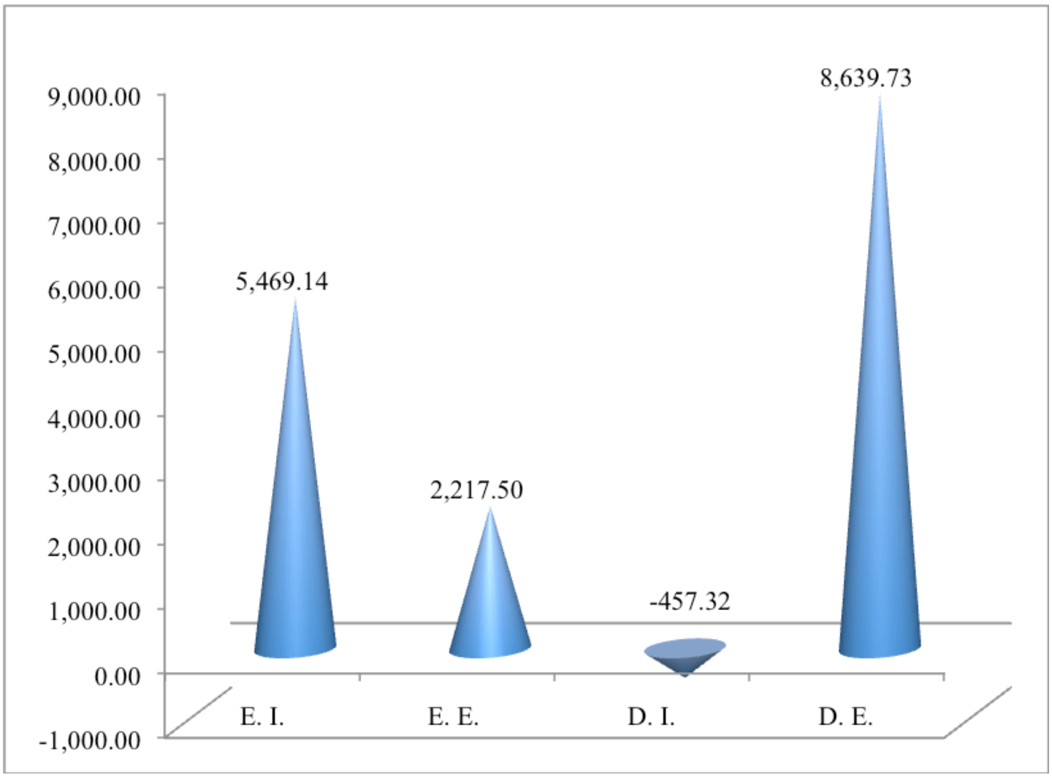

Figure 3.1: Annual TCs Carbon Balance (in CO_2 Kg/ha)

The CSE performance peaks for the Deciduous Extensive TCs, while deeps in the Deciduous Intensive TCs, a fact that argue in favor of the Deciduous TCs management potentials on their Carbon Sequestration Capacity. Evergreens performance also reveled significant aspects of orchards carbon sequestration. Here the reverse performance of the Intensive TCs against the Extensive, indicated by the figures presented in **Table 3.1**, lead to the indication of various crucial parameters.

Table 3.1:

TC	Carbon Emissions (Kg CO2/ha)	Carbon Removal (Kg CO2/ha)	Carbon Balance (Kg CO2/ha)
E. I.	3.244,00	8.713,14	5.469,14
E. E.	1.723,19	3.940,68	2.217,50
D. I.	4.402,78	3.945,46	-457,32
D. E.	2.650,20	11.289,93	8.639,73

1. Plantation Density: The two best performing TCs, D.E. and E.I. present respectively plantation densities of 351 and 524 trees per hectare, while the E.E. 190, and D.I. 651. This fact indicates the area between these two margins as a “fertile land” for the further development of Orchard Carbon Sequestration Performance.
2. Fertilization Practice: The facts herein reveled that Indirect Nitrate emissions from fertilization conform the major contributor to orchards emissions escalating from 43% of all emissions in the D.I. cluster, to 57% in the D.E., 68% in the E.E., and 72% in the E.I. Minimization of Nitrate emissions is found to be best served through spray application of foliage fertilizers, mostly because of their small application scale, and the significantly reduced nitrates emissions (almost 0,6% against 1,6% of drip application, and IPCC’s standard 1,25%).
3. Energy Mixture: The fact that the E.E. TCs even though present an unfavorable profile of indirect carbon emissions perform effectively overall is partially explained: a) by the plantation density that suggest a sustainable spatial distribution of plants; and b) by the establishment of electricity in the

Orchards Energy Mixture accounting to 72% of Fuels emissions. This performance also highlights as second major contributor to TCs carbon emissions these derived from fuel. As best available practice towards the minimization of this factor was recognized the conversion to electricity. Future perspectives on this scope suggest the conversion from diesel to more "clean" technologies (e.g. Gas, Hydrogen, etc).

Though the present report indicates significant findings also suggests points of specific interest that should be further pursued. From a methodological point of view the here presented primary data and results should be integrated with the accompanying reference data, enabling thus an inclusive account of carbon balance in additional ecological zones, and cultivation practices. More over the here stated general recommendations should be further delineated and expanded with the inclusion of socio-economic parameters, in order to feet within broader EU policies (e.g. CAP). Finally, the here provided Ecosystems Services Assessment accomplished early on the project timeline within A.1 Action should be further updated through the survey data collected, in order to provide policy makers with a cleaner and inclusive image of the TC's value(s).

Annex I

Variables affecting carbon sequestration: definition & enumeration methodology

1. Introduction

This study is performed within CLIMATREE's operational context and includes as core function the Carbon Life Cycle Assessment in (LCA) Tree Crops that can be perceived as a complex task, which depending the objective can be approached through differentiated directions.

An inclusive account of these approaches was provided in 2014 by Cerutti et all. [3], whom in a detailed and comprehensive review on this topic discussing the specific focus on almost 20 previous studies, and concluding to a proposed inclusive framework for the application of LCA in orchards. They recognised that modern food production is very diverse with high levels of specialisation and complexity. These features inevitably reflect on methods in the application of LCA to food products and agro-systems. System boundaries, functional units, allocation procedures and several other aspects contribute to there being substantial differentiation in the structure of LCA applications in fruit production systems, leading to significantly different results. Indeed, although scientific literature on the topic is recent and not particularly extensive, there are already many different ways of conducting LCAs in orchards.

The authors of this critical review were aiming to propose a framework for selecting the best parameters for an LCA application in fruit production systems according to the objective of the study. This has been achieved by reviewing the scientific and technical literature on the topic. In particular papers from international journals and conference proceedings have been considered and the review has covered all main aspects for conducting an LCA in fruit production systems. The particular characteristics considered were objectives, system boundaries, the product considered, the functional unit, data origin and the environmental impact assessment method used. A substantial part of the paper is devoted to the modelling of the orchard, as this is key to a reliable application of any impact assessment approach. Rather than merely describing the theoretical model, this paper presents concrete recommendations about how to build the orchard system for LCA application avoiding over or under-estimations of the different orchard stages.

Even though they proposed a solid framework compatible with the contemporary standards [4-5], **they also indirectly highlighted the week point on the presently prevailing approaches when the Land Use Carbon Footprint is the subject of the study, which is the choice of the fruit product mass as functional unit** in all but one case.

The study of the literature on LCA applications in the food sector, revealed nine objectives, which were found to be the most common purposes of LCAs in the fruit sector. These objectives were:

1) to profile the environmental burden of a fruit product, in which a specific production system is evaluated and results are related tothe case study without any intention of generalising;
2) to identify the environmental hotspots in production systems performance considering the different field operations and stages of the system;
3) to describe management strategies to improve environmental performance, a focus usually applied after objective 2 in order to give practical suggestions after the evaluations;
4) to compare the environmental burden of different food products on a common functional unit, e.g. a specific unit of nutrient content;
5) to compare different farming practices, e.g. organic and conventional;
6) to compare different environmental assessment methods such as LCA, ecological footprint analysis and water footprint in the same case study;
7) to profile the environmental burden of production in a given area by applying the LCA evaluation to a statistical database on farms in that specific area;
8) to evaluate the environmental properties of a supply chain, usually with the focus on differences in environmental impact for long and short distances between production and consumption sites; and
9) to assess a preliminary study for statistical investigations. In this case the LCA results were used with the outcomes of other indicators to develop complex indices

In concern with the general aspects of the cases studied it was recognised that the mainstream research on the LCA applied to fruit production systems and it was also assumed that in coming years, there will be more research for the environmental evaluation of fruit commercialisation. **This assumption excludes the Land Use as a formidable objective, and even though an inclusive and detailed account is provided for the application of LCA in the fruit sector the suggestions of this**

fundamental reference, and consequently the elaborated research advances is of low interest for the application of LCA under an Orchard Land Use perspective.

The only case among the 19 studies reviewed that presented a land area based functional unit was that of Mouron et al. [6] regarding the management influence on environmental impacts in an apple production system on Swiss fruit farms through the combinatorial LCA and statistical risk assessment. Even though the previously mentioned work establishes a formidable background for the development of the presently proposed methodology, and will be further and more elaborative presented in follow, Cerutti et al. review [4], provided significant inputs in relation with the following issues:

- <u>The nursery subsystem:</u>

In the literature reviewed, little importance is given to the nursery. Just three studies assess the environmental impacts of the nursery as a stage within the whole production system. Although in some perennial plantation systems its relative contribution may be negligible (Yusoff and Hansen, 2007), the nursery stage may play an important role for plants that need special protection in the early stages, such as specific growth substrates (Ingram, 2012) or plastics for greenhouses (Russo and Scarascia-Mugnozza, 2005). Due to all the nursery-related impacts, the application of an environmental indicator to the full production year only will probably underestimate the real environmental impact to a varying degree (in the studies reviewed here by about 30%, depending on the fruit considered and the assessment method) (Fig. 3). As the environmental impacts of the nursery stage are allocated per plant grafted or planted in the orchard, there is a strong relationship between the density of the plantation and the relative impact of the nursery (Cerutti et al., 2013). Although this relationship can be readily observed in comparative studies, owing to the small number of LCA studies on fruit that include the nursery stage, no significant correlation with the fruit species and the proportion of total impacts can as yet be identified. Therefore adopting a fraction of field production impacts considering the theoretical duration and plant capacity of the nursery study as a proxy is a risky approach that should be avoided when reliable data or reference case studies are available. The only way of making up for the lack of knowledge is to increase the number of studies including the nursery stage and to include nursery average impacts in LCA databases and tools, as is already done for other inputs such as fertilisers and pesticides.

More over, and most significantly, **the nursery GHG emissions are only indirectly related to the Orchard Land Use, since the nurseries occupy different ground that in most cases is located outside the regional boundaries of the orchard.** Therefore the inclusion of the related emissions in the orchard LCA is inappropriate as is also the inclusion of the emissions resulting during the production stage of the agricultural inputs and machinery utilized during the orchard cultivation. **This last exclusion that will be further discussed in the relevant chapter, relates to the prerequisite of IPCC 2006 guidelines to avoid double counting through the different carbon stock and GHG emission pools.**

- Orchard Modelling:

For the purposes of efficient modelling of an orchard system, it is necessary to take into account two aspects:

- Orchards are biological systems.

As for all other food production systems, the variability and unpredictability of living systems must be taken into account. Unlike industrial production, where the amount of commercial product is known and given as a reliable function of the inputs supplied, biological systems can have variable yields, depending on environmental conditions (biotic and abiotic). The strong dependence of biological production systems on weather conditions is also expressed as variations in the quantity of agricultural inputs needed to maintain production at the desired level. For example, in years with very high spring temperatures, the risk of pest attacks increases dramatically, with a consequent increase in agrochemical use (Sansavini et al., 2012) which affects both the impact on production and the impact on input losses (leaching for instance).

- Orchards are perennial systems.

Unlike field crops, the life cycle of which is completed in under a year, fruit systems involve plants with very variable duration (10e30 years) depending on the crop and management practice. The long cropping cycle of orchards means that there are processes that occur once over the entire life cycle (e.g. during orchard establishment and disposal) and other processes that are repeated a number of times depending on the length of the cycle (e.g. pruning and fertilisation). Furthermore, most temperate fruit cultures reach maturity in two to four years after the orchard is established. Before that age, the yield may be significantly lower (or even zero) because the plants are still too young. This may significantly affect the average yield and has to be

considered. Furthermore, the yield variability between years may be very high. For example, McLaren et al. (2010) reported that the highest yield for green kiwifruit over a period of six years was 31% greater than the lowest.
A detailed model of the fruit production system may take into account these two aspects by dividing the system into different stages (Fig. 1). This modelling approach was originally proposed by Milà I Canals et al., 2006 and later validated by Cerutti et al. (2010) and Cerutti et al., 2011. Six main stages have been considered in particular: (1) the nursery phase for producing rootstocks, scions and whips ready to plant, (2) planting and field preparation for the orchard, (3) the early low production phase due to the system's immaturity, (4) full production, (5) the low production phase due to plant senescence, and (6) the removal and disposal of plants. It should be noted that the final two stages are theoretical and are seldom found in commercial orchards in Europe since fruit growers replace the orchards at the end of stage 4 for economic reasons. Considering this model, stages 1, 2 and 6 do not have output in commercial production, but may contribute to generating the product's environmental impacts. Stages 3, 4 and 5 are those in which fruit is produced and the annual output quantity may vary from year to year. Although it is very difficult to find data for production as a function of orchard age, it is recommended that average production data (measured or modelled) be used for each of stages 3-5 (Fig. 1).

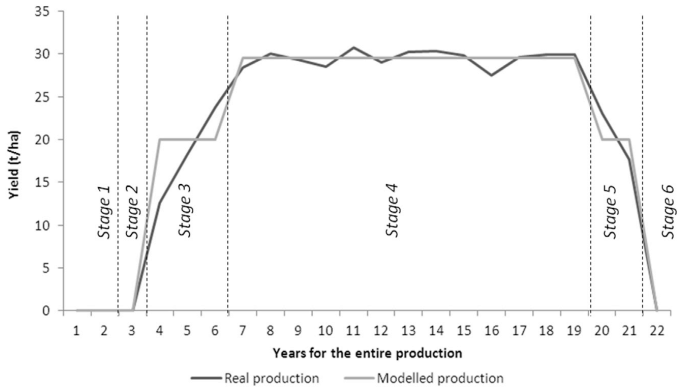

Fig. 1. Graphical representation of real and modelled production throughout the entire life of an apple orchard in Cuneo province, northern Italy, divided into six stages of production. Adapted from Cerutti et al. (2011)

Although the curve of Figure 1 is quite representative in terms of increments and stages, the year span correlates only for intensively cultivated orchards, which in the Mediterranean area constitute only a small fraction of the Orchards expansion. To cope with this discrepancy we have incorporated in the clustering scheme of A.1 action the relevant for each cluster life span. In specific in all but rare cases of the extensively cultivated orchards the life span exceeds the 50 years and in some cases (e.g. Olive, Almond etc) is accounted to centuries if not millennia, therefore constituting the Stages 5 and 6 obsolete under the present context.

More over Stage 1, as previously discussed, is irrelevant with CLIMATREE's objective and therefore will not be considered under the present context. On the other hand stages 2 and 3 relate to the orchards establishment and will be considered under the Land Use Change calculation scheme of IPCC 2006 guidelines.

Finally, the Figure 1 represents only the production increments and not the related orchard biomass figures, which present similarities but also discrepancies with the slopes of Figure 1. An indicative slope for living biomass escalation is provided in Figure 2.

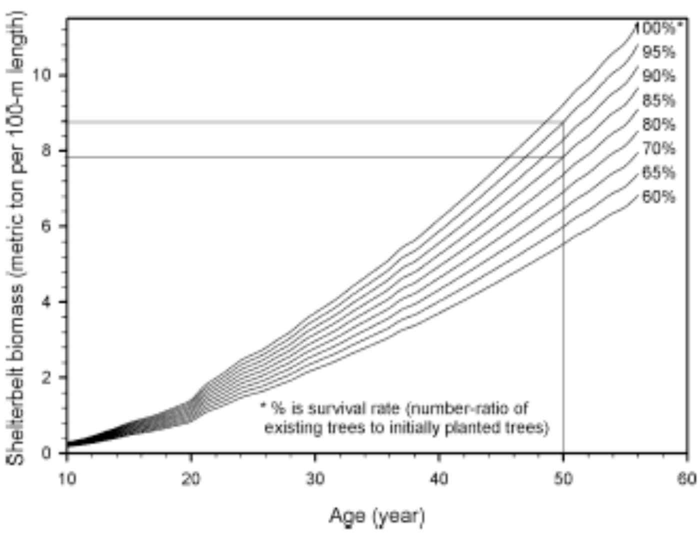

Fig. 2 – Above-ground woody biomass of a single-row Russian-olive shelterbelt at different ages in Philips County, Montana, USA (spacing in a row is 2m and soil is Telstad-Joplin loam).

- Functional Unit:

The functional unit helps quantify the productive output of the orchard in order to allow a comparison of different production systems. Fruits and fruit products may be of different quality and have different nutrient and economic values, and thus it may be difficult to find a useful functional unit. In most cases, however, there is not much debate about the definition of a functional unit (e.g. 1 kg of product). Furthermore, the use of a mass-based or a land-based functional unit reflects the perspective addressed by the particular study: the former is used in a product-orientated expression of agricultural production and the latter in a land-orientated expression (Hayashi, 2013). Furthermore, the land-based functional unit represents the land-management function of agriculture.

Land use-based functional units where the environmental impacts are related to the management of 1 ha of orchard. A land-based and currency-based functional unit is used in just one of the studies reviewed (Mouron et al., 2006b). The land use-based functional unit, such as 1 ha of orchard, is not frequently used in LCA, partly because land use is not a service and does not provide a productive function, even if land suitable for fruit production is often rare. In fact, it makes more sense to consider land use to be an environmental impact in an LCA. However, land use is an integrated line of thinking in an agronomic setting and can produce interesting results. In general, converting resource consumption or environmental impacts to units of land use allows the impacts of cultivating a certain area to be evaluated. This parameter is also called a farm’s impact intensity (Mouron et al., 2006b). The land use-based functional unit in fruit production is complementary to the mass-based functional unit because they give different results and both should be used. Indeed, when considering impacts per unit area alone, low input-output systems will have a better ranking for decreased impacts at a regional level. From a life cycle perspective, however, they create a need for additional land use to produce a quantity of products similar to the high input-output systems, leading to additional impacts (van der Werf et al., 2007).

2. Definition of Variables affecting Carbon Sequestration

2.1. Variables of Carbon Removal

Plant biomass constitutes a significant carbon stock in many ecosystems. Biomass is present in both aboveground and below-ground parts of annual and perennial plants. The methods focus on stock changes in biomass associated with woody plants and trees, which can accumulate large amounts of carbon (up to hundreds of tonnes per ha) over their lifespan.

Perennial crops include trees and shrubs as orchards, vineyards and except where these lands meet the criteria for categorisation as Forest Land. The amount of carbon stored in and emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables that are aggregated in the relevant strata of Equation 2.1.

Activity data in this section refer to estimates of land areas of growing stock and harvested land with perennial woody crops. They are regarded as strata within the total cropland area (to keep land-use data consistent) and are disaggregated depending on the conditionality of growth and loss factors. Examples of Cropland subcategories are given in the following Box.

EQUATION 2.1

ANNUAL CARBON STOCK CHANGES OF ORCHARD LAND-USE AS A SUM OF CHANGES IN ALL STRATA

$$\Delta C_{LUi} = \Delta C_{DI} + \Delta C_{DE} + \Delta C_{EI} + \Delta C_{EE}$$

Where:

ΔC_{OLUi} = carbon stock changes for orchard land-use

Subscripts denote the following strata:

DI = Deciduous Intensive Tree Crops

DE = Deciduous Extensive Tree Crops

EI = Evergreen Intensive Tree Crops

EE = Evergreen Extensive Tree Crops

The Variables considered within each Stratum derive directly from the general IPCC guidelines [7], which have been accumulated in the Generic Equation 2.2. Though in this equation that clearly indicates the sum of the variables considered as carbon stock, in which are definitely included the harvested products, from the general guidelines on AFOLU the later have been omitted. In the following lines will be provided arguments towards the inclusion of the TC Harvested products in the Generic Equation 2.2.

The issue of the TC HFP inclusion in the Orchards LCA under present perspective is of crucial importance and relates mostly to the related emissions by HFP once they move in another pool of GHG emissions. The fate of HFP in Europe, and the world, has been extensively studied by Gustavsson et al. [7] in the context of the "Global Food Losses and Food Waste - extent, causes and prevention"- FAO report of 2011, and is briefly presented in the following Table 1.

Table 1: Waste percentages used for fruits & vegetables in Europe, references can be found in Annex 1 Waste percentages of food losses and waste.

Agricultural Production	Postharvest Handling & Storage	Processing & Packaging	Distribution	Consumption
20%	5%	2%	Fresh 10%	Fresh 19%
			Processed 2%	Processed 15%

These figures suggest that a significant portion of the HFP is never consumed and is forwarded directly to another pool of GHG, namely either Landfills or husbandry, already accounted in the National GHG inventories. More specifically the figures of the Table 1 are translated in the Equation 2.3 terminology as in follow and are shortly presented in Table 2, as percentages of the Gross Annual HFP production.

- Agricultural Production Wastes: These wastes occur before the harvest and therefore can be considered as factors contributing to $\mathbf{\Delta C_{LI}}$
- All other Wastes: These wastes occur after the harvest and therefore can be indisputably considered as Carbon Sink Tissues.

While the Table 2 Figures suggest that almost 50% of HFP may be considered as carbon sink tissue, in direct compliance with the Orchard living Biomass, this is not the case for Olive Harvested Products in specific, and the Oil Crops in general, in which the sum of the HFP should be included in the equation.

Table 2: Waste percentages of fruits in Europe and their translation in IPCC nomenclature and accounting with respect to Gross Annual HFP (The Distribution and Consumption Figures presented as averages).

Agricultural Production	Postharvest Handling & Storage	Processing & Packaging	Distribution	Consumption
ΔC_{LI}	**ΔC_{HFP}**			
0,2 * HFP	0,05 * HFP	0,02 * (0,95 * HFP)	0,06 * (0,931 * HFP)	0,17 * (0,87514 * HFP)
20%	5%	1,9%	5,58%	14,87%
Total of HFP				
20%	**27,36%**			

Perennial woody vegetation in orchards, vineyards, and agroforestry systems can store significant carbon in long-lived biomass, the amount depending on species type and cultivar, density, growth rates, and harvesting and pruning practices. Carbon stocks in soils can be significant and changes in stocks can occur in conjunction with soil properties and management practices, including crop type, tillage, drainage, residue management and organic amendments. Burning of crop residue produces significant non-CO_2 greenhouse gases and the calculation methods are provided. In this respect the relevant Carbon Pools for Cropland under 2006 IPCC Guidelines are:

- Biomass
    - Above Ground Biomass
    - Below Ground Biomass
- Dead Organic Mater
    - Deadwood
    - Litter
- Soil Organic Mater
- Harvested Fruit Products

EQUATION 2.2

ANNUAL CARBON STOCK CHANGES FOR A STRATUM OF A LAND-USE CATEGORY AS A SUM OF CHANGES IN ALL POOLS

$$\Delta C_{LUi} = \Delta C_B + \Delta C_D + \Delta C_S + \Delta C_H$$

Where:

ΔC_{OLUi} = carbon stock changes for orchard land-use strata

Subscripts denote the following carbon pools:

B = biomass (Above and Below Ground)

D = deadwood and litter

S = soils

H = Harvested Fruit Products**.**

2.1.1. Biomass

Carbon can be stored in the biomass of croplands that contain perennial woody vegetation including, but not limited to, monocultures such as coffee, oil palm, coconut, rubber plantations, fruit and nut orchards, and poly-cultures such as agro-forestry systems (IPCC).

Within the present context In the Biomass pool of carbon removal is considered the annual axial and radical growth of plant tissues that remain in the tree.

2.1.2. Deadwood and Litter

The plant tissues that for whatever reason are removed from the tree are accounted within the present biomass pool. Here are included the fruit loss, the leaves, and the pruning.

Since these tissues have a limited decomposition period that does not expand over a long period they cannot be perceived as a long-term storage carbon pool. Nevertheless, these tissues after their decomposition conclude to an increase of the Soil Carbon, which in turn is considered as long-term carbon storage pool.

2.1.3. Soils

Soils constitute a distinct carbon pool, and moreover they comprise an identified ecosystem closely related but also independent from the land use. This carbon pool presents respiration of its own, originating from soil fauna biodiversity, and accepts carbon from various sources. In order to delineate the contribution of TC in this carbon pool, only the carbon removed from the atmosphere through the orchard photosynthesis is accounted within the present study’s context.

In this context this carbon pool will be considered the final destination of the litterfal and deadwood and therefore, will not be included in the accounting of TC carbon balance.

An additional argument towards this decision can be perceived through the consideration of the various inputs to carbon soil among which the most prominent in orchards are the organic fertilizers (Compost and Manure) and Green Manure. The carbon these inputs contribute into soil carbon are not removed from the atmosphere as a result of tree photosynthesis and therefore their inclusion would jeopardise the credibility of the orchards carbon removal potentials.

2.1.4. Harvested Fruit Products

This carbon pool is accounted only in the context of the not consumed harvested fruit products. This amount is estimated along the supply and value chain and its consideration as a long-term carbon storage pool is established upon the organic wastes management prerequisites dictated by the Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, in which subject of distinct consideration are the issues of incineration, composting, biomethanisation of municipal and non-hazardous waste.

More precisely, measures have been foreseen in order to reduce the production of methane gas from landfills, inter alia, in order to reduce global warming, through the reduction of the landfill of biodegradable waste and the requirements to introduce landfill gas control. The measures taken to reduce the landfill of biodegradable waste should also aim at encouraging the separate collection of biodegradable waste, sorting in general, recovery and recycling. It must be noted that as biodegradable waste is defined any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.

Member States are required to set up a national strategy for the implementation of the reduction of biodegradable waste going to landfills, which include measures to achieve the recycling, composting, biogas production or materials/energy recovery, therefore assuring the long-term storage of the carbon contained therein.

2.2. Variables of Carbon Emissions

The life cycle inventories of emissions and used resources methodology were taken from Mouron et al. (2006).

Direct field emissions of ammonia, nitrous oxide, methane, phosphorus, nitrate and heavy metals were calculated by models with situation dependent parameters (Nemecek, 2003). Consequently the system included all activities in the orchards.

Not considered activities were those of the transport of the products to the farm and transport of materials from the farm to the orchards as well as those at the wholesaler and retailer such as sorting, storing and packaging of the fruits. The allocation of the inputs to the orchards was clearly defined by the farmer's survey presented in Annex III. Post harvest activities in the orchards that were linked to the next harvest were included in the LCA for the next season. For each orchard and each year a separate LCA was performed. Impacts from the manufacturing of the following inputs were not taken into account in the LCA:

- Tractors and equipment, including their transport and maintenance.
- Buildings, required for shelter of tractors, equipment and materials.
- Energy carriers, which were diesel for machinery and electricity for lighting the buildings.
- Pesticides.
- Mineral fertilizers including their transport; no liquid or solid manure was applied.
- Tree nursing, including inputs for planting and 3 years of establishing of the orchards.
- Constructions for hail protection.
- Water for irrigation.
- Application of compost.

Two functional units (FU) were used to enumerate the environmental impacts of the TC emissions.

2.2.1. Direct CO_2 emissions

The cultivation Inputs results were focussed around Questions 17 and 18 responses of the relevant Questionnaire template. These questions paired with the relevant orchard area provided the fundamental figures of Fuel, Energy, and Agrochemicals consumption per hectare, which were of indispensable value for the accounting of CO_2 emissions.

Further more the incorporation of the Annex II table 3.3.2 to the stated forms of cultivation measures along with primary data of the questionnaires made possible the attribution of specific machinery operation hours per hectare and cultivation measure for the diesel consumption.

Gasoline consumption could not be delineated within cultivation measures, as it was more sporadically mentioned, and could only be attributed to the operation of hand held equipment (e.g. chainsaws, string trimmers etc).

2.2.2. Indirect CO_2 emissions

In a relevant manner the average electricity consumption per hectare was uniformly correlated with irrigation since the only electricity powered machinery is the irrigation pump. A notable exception regards the Evergreen Intensive TCs, in which the frost protection, applied through irrigation sprinklers, heating or combination of them was also a significant consumer of electricity.

Indirect GHG emissions in the form of CO_2 equivalent emissions were calculated against the average consumption of Nitrogen fertilizer per hectare. Further delineation within different application forms was not feasible at the present time since in most cases it was detected a nominal deviation from the unit scale considering the volume and/or weight of application within each fertilization application form.

3. Methodology of LCA

3.1 Objective

In CLIMATREE perspective the objective of the Carbon LCA is described as the calculation of the Land Use Carbon Balance of the Mediterranean orchard agrosystems within a National perspective.

3.2 Functional Unit

This ambitious target dictates the utilization of a functional unit that will present cumulatively the following characteristics: a) readily available time series of data; b) yearly update of the data set; c) consistency through out the three countries. Therefore, the functional unit selected was the Land Area of one (1) hectare of Tree Crop.

In addition to this primary functional unit a secondary was also utilized in order to facilitate the calculation of the annual biomass production. This functional unit is defined as the biological unit of TC the Tree. This secondary functional unit is consequently alleviated to the primary through the incorporation of the typical for each TC category plantation density. The pursuit towards the achievement of CLIMATREE's objectives indicated a number of crucial knowledge gaps regarding the issues of:

a. the presence of a unitary sampling dataset covering all 5 relevant crops

To resolve this gap we provided a limited time (1 year so far) dataset including 5 indicative samples per crop, including all of the required data for the methodology implementation.

b. the stoichiometric adjustments for the calculation of fruit carbon content

To resolve this gap we utilized previous reports on each relevant fruit's content, including sougars, fats, protein, and fibers, in order to construct a more accurate coefficient for each fruit.

c. the availability of cultivation inputs datasets for all 5 relevant crops.

To resolve this gap we designed a field survey aiming to delineate – and complement – the National Standards for machinery usage per hectare, orchard, and cultivation measure.

As it is obvious so far at the heart of the present action's beat is the production of a solid methodology enabling the cumulative accounting in National level of Carbon Balance of the orchards land use. This approach aims to offer policy makers with arguments towards the establishment of orchards as a distinct category of Land Use. Besides the previously discussed aspect of Carbon Balance calculation, and its repercussions on the Green House Gas exchange Ecosystem Service, an inclusive approach was performed against the provision of all kind of ESs for all four clusters of orchards indicating a crucial knowledge gap on orchards biodiversity. As a part of the present action's field survey was also included a biodiversity questionnaire in order to provide a more clear image on Orchards Land Use significance from various perspectives.

3.3 Boundaries

The geographical boundary of the LCA is defined by the Cradle-to-Gate approach, in regard with the land use.

The chronological approach of the LCA is expanded over the TCs life span. This translates to first year that of the plantation's establishment, and to last year as that of the plantation's destruction.

Further more the incorporation of the IPPC protocol dictating the accounting of the change in biomass is only estimated for perennial woody crops. The change in carbon in cropland biomass (ΔC_{CCB}) is estimated from the annual rates of biomass gain and loss. Therefore the chronological boundary of the herein developed methodology is defined as the calendar year.

3.4 Data Origin

3.4.1. Sampling for dry matter coefficient definition

3.4.2. Field survey for agronomic characters

3.4.3. Literature review

3.5 Enumeration of Variables affecting Carbon Sequestration

3.5.1. Variables of Carbon Removal

I. Biomass

The default methodology for estimating carbon stock changes in woody biomass is provided in Chapter 2, Section 2.2.1 of the IPCC guidelines. This section elaborates this methodology with respect to estimating changes in carbon stocks in biomass in Cropland Remaining Cropland, which is the case considered in the present study. The whole methodology is structured upon the TC Biomass per Hectare Estimation (B_{TC}), which is given by the following equation and is applicable to each TC category:

$$B_{TC}=D_P*B_T$$

B_T: Plant Annual biomass production
D_P: Plantation Density

The plant annual biomass production (B_T) is accounted on the basis of the following formula:

$$B_T=B_W+B_R+(B_S-a*B_L)$$

B_W: Annual wood biomass production
B_R: Annual root biomass production
B_S: Annual shots biomass production
a: Leaves annual loss coefficient (a deciduous=1, a evergreen=0,3)
B_L: Annual leaves biomass production

Finally in order to conclude to the annual per Hectare change of carbon stocks in cropland biomass (ΔC_{CCB}) is utilized the TC Biomass per Hectare figure (B_{TC}) in the following equation:

$$\mathbf{\Delta C_{CCB} = b*B_{TC}}$$

b: Carbon Content Coefficient of wood (estimated on the basis of the woody tissue content of cellulose, semi-cellulose and lignin to 0,5)

II. Harvested Fruit Production

IPCC guidelines do not incorporate the accounting of the carbon captured in the Harvested Fruit Production. For reasons explicitly described previously the herein developed methodology incorporates the percent of the harvested fruit production that is not consumed and is treated like waste in the supply and value chains. The Annual Biomass of Harvested Fruit Production not Consumed per Hectare and Year (B_{HF}) is derived from the following equation:

$$B_{HF}=B_F*L_A$$

B_F: Fruit Yield per Hectare

L_A: 0,2736 Coefficient reflecting the Annual Loses in Supply & Value chains.

The estimation of the carbon content of this Biomass is structured upon each fruit composition. This composition was retrieved from the literature review of Annex II and incorporates the fundamental metabolites presented in the following table.

Primary Metabolites Content of Representative Fruits (all Figures in %, * Given as Difference, ** The figures regard only to the edible portion of the fruit/nut)

Fruit	NDB Nr.	Water	C-H*	Fat	Protein	Sugars	Ash/total Minerals	Total
Peach**	09236	88,87	1,15	0,25	0,91	8,39	0,43	98,85
Almond**	12061	4,41	18,4	49,93	21,15	4,35	1,76	81,6
Olive**	09195	75,28	5,69	15,32	1,03	0,54	2,14	94,31
Apple	09003	85,56	3,49	0,17	0,26	10,39	0,13	96,51
Orange	09205	86,75	2,58	0,12	0,94	9,35	0,26	97,42

It must be noted that since the relative figures are given for fresh fruits the relevant national statistics can be readily utilized for the provision of the Fruit Yield per Hectare. This figure consequently is the key element for the estimation of the Annual Fruit Carbon per Hectare change (ΔC_F) according to the following equation:

$$\mathbf{\Delta C_F=(B_{HF}*F_{hc}*P_{hc})+((B_{HF}*F_{su}*P_{su})+(B_{HF}*F_{pro}*P_{pro})+(B_{HF}*F_{fat}*P_{fat})}$$

F_{hc}: Carbon Content Coefficient of Hydrocarbons (C_nH_{2n+2}))

$=(12*n)/[(12*n)+(2*n)+2]=$**0,85**

F_{pro}: Carbon Content Coefficient of Protein $[(C_nH_{2n+1}))C_2H_4O_2N]_x$

=(12*7)/[(12*7)+(14*1)+(16*2)+(14*1)]=**0,58**

F_{fat}: Carbon Content Coefficient of Fats $(C_nH_{2n}O_2)$ =

$[12*18]/[(12*18)+(36*1)+(16*2)]^{-1}$=**0,76**

F_{su}: Carbon Content Coefficient of Sugars $[(C_6H_{10}O_5)_n]$ =

[6*12]/[(6*12)+(10*1)+(16*5)]=**0,44**

P_x: Percentage of the respective metabolite (H/C, sugars, protein, fat) in fruit's weight

III. Litter

IPCC guidelines in Chapter 2, on the Generic Methodologies Applicable to Multiple Land-Use Categories indicates that Tier 2 methods should be used for the estimation of carbon stock changes in litter carbon pools (Equation 2.17). Within the present context the Gain-Loss Method (Equation 2.18) that track inputs and outputs per year and hectare is utilized. These estimates are established on the field measurements of Annex IV. In this context the Annual Litter Biomass per Hectare Biomass (B_{TL}) for each of the TC categories is estimated through the following equation:

$$B_{TL}=B_L*D_P$$

B_L: Annual Litter biomass

D_P: Plantation Density

The Annual Litter Biomass (B_L) is estimated according to the following equation, which is established upon the experimental figures presented in Annex IV.

$$B_L=B_P+B_{FNH}+(a*B_L)+B_{FS}$$

B_P: Annual pruning biomass

B_{FNH}: Annual Fruit Not Harvested biomass = $0,2*B_F$

a: Leaves annual loss coefficient (a deciduous=1, a evergreen=0,3)

B_L: Annual leaves biomass production

B_{FS}: Annual Fruit Septa biomass

The Carbon Content of Litter (C_L) is estimated with the utilization of the following formula:

$$C_L=(B_P*b)+C_{FNH}+(a*b*B_L)+(B_{FS}*b)$$

a: Leaves annual loss coefficient (a deciduous=1, a evergreen=0,3)

b: Carbon Content Coefficient of wood (estimated on the basis of the woody tissue content of cellulose, semi-cellulose and lignin to 0,5)

C_{FNH}: Carbon Content of Fruit not harvested calculated as for fruit harvested (See previous heading)

Finally the annual change in Carbon Stocks per Year and hectare (ΔC_L) due to litter is given by the concluding equation:

$$\mathbf{\Delta C_L= C_L*c}$$

c: Carbon fraction of litter stored in Soil Carbon coefficient = 0.367

3.5.2. Variables of Carbon Emissions

Cultivation Measures in modern agriculture incorporate the extensive use of machinery and/or electricity, which readily translate in fuel and energy consumption. Cultivation Measures Carbon emissions may be summarised according to the following equation:

$$C_{CM} = C_F + C_E + C_D$$

C_F: Carbon emissions from Fuel consumption

C_E: Carbon emissions from Energy consumption

C_D: Carbon emissions from Diverse sources

I. Fuel Consumption

Fuel Consumption translates to machinery operation, which is utilized for various purposes. The generic equation for the calculation of C_F is:

$$C_F = M_C * H_O * A_{TC}$$

M_C: Machinery Coefficient of carbon emissions per hour

H_O: Hours of Operation per Hectare

A_{TC}: Area of TC in Hectares

The Machinery Coefficient of carbon emissions per hour (M_C), will be extracted from the relevant National legislation, considering the relevant EU legislation.

Machinery operation is dictated by general national guidelines aiming to provide a solid technical measure for the CAP implementation. In Greece the following table indicates the relevant time rates per hectare and measure:

Cultivation Measure	**Hour of machinery operation per hectare**
Tillage (Summer ± 20 cm)	3,5
Tillage (Autumn ± 20 cm)	3,0
Tillage (± 40 cm)	4,0
Tillage (+ 10 cm)	2,0
Tillage (-10 cm), Spraying, Fertilizing, Mixing, Leveling, Irrigation	1,5

II. Energy Consumption

Energy Consumption translates to emissions of GHG during the production of electricity, which is greatly depended upon the Fuel mixture in National Level. The generic equation for the calculation of C_E is:

$$C_E = [(E_{C1} * P_{S1}) + \ldots + (E_{C4} * P_{S4})] * K_H * A_{TC}$$

E_C: Energy Coefficient of carbon emissions

P_S: Percentage of energy Source in National Mixture (1: Fossil Fuel, 2: Gas, 3: Nuclear, 4: Renewable Sources)

K_H: KWH consumption per Hectare

A_{TC}: Area of TC in Hectares

III. Agrochemicals Consumption

These emissions arise as consequence of distinct cultivation measures; the *in situ* burning of pruning; and the *in situ* GHG emissions of manure. The generic equation for the calculation of C_D per Hectare is:

$$C_D = [(C_P * G_B) * D_P + (W_C * E_C)] * A_{TC}$$

C_P: Carbon content of pruning

G_B: Grade of Burning

D_P: Plantation Density in Plants per Hectare

W_C: Weight of Organic Fertilizer per Hectare

E_C: Equivalent of CO_2 emissions per Kg

A_{TC}: Area of TC in Hectares

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Annex II

Review report on Variables affecting carbon sequestration

1. Introduction

The variables considered for the calculation of Tree Crop Carbon Life Cycle, were distributed among three major clusters. The first cluster defined was the biological, which incorporated the fundamental thresholds of tree growth, life span, the carbon content of herbal tissues, and the photosynthesis period. The second cluster considered was the agronomical, which included as major parameters the structure and form of the plantation, and the cultivation measures applied. The third cluster defined was the socio-economical, which included the prerequisites of financial and social feasibility for all the variables considered.

Within this context the variables of all three clusters were diverged in two clades. The first clade regarded the variables contributing to the definition of the amount of carbon captured by the Tree-Crop (TC) incorporating as main variable the annual production of organic matter per hectare. The second clade regarded the variables contributing to the delineation of the amount of carbon emissions by the Tree-Crop. Within this second clade as cumulative variables were considered the annual consumptions of fuels and energy per hectare.

Present report is aiming to summarize the knowledge base upon these variables and their consequent branches as extensively described in Annex I that elaborated on their definition & enumeration methodology. As the specific targets of literature review have already been indicated in this previous report, here will be presented the review approach, the main data bases, the literature search methodology, and of course the results of the review complemented with enumerated input for incorporation in Annex I equations.

2. Methods and Sources

The review sources and methodology utilized as fundamental background the Technical report on Tree-Crop Categorization (Deliverable A1), which established:

- A solid clustering scheme of TC depended upon their biological and agronomical characters.
- An assessment methodology for the delineation of the Eco-System Services (ESS) provision by each TC.
- An Inclusive Indicator Set for the ESS provision assessment of the four major clusters of TCs.
- An informative summary of the advances on TCs ESS research endeavours.

2.1. Methods

The current review methodology presents a two-fold approach, with each approach aiming at different target. The first approach related to the pursuit of the research advances on the specific Regulatory ESS functions that were highlighted in Deliverable A1:

- Biotic Support: ***Biodiversity*** in Number of birds per Hectare.
- Abiotic Support: ***Soil Carbon Sequestration*** in Tones of CO_2 per Hectare and Year.
- Flows Support: ***Carbon Footprint*** in Tones of CO_2 per Hectare and Year.

In this context the Key words used in data mining included as first term the Keyword ***Orchard***, followed by the relevant function description (e.g. Orchard + Biodiversity, Orchard + Soil Carbon Sequestration, Orchard + Carbon Footprint). Here will be presented the retrieved results on ***Carbon Footprint***, further limited through Geographical philtres in order to present conformity with CLIMATREE's implementation area. The rest of the results are correlated to Annex V and will be cordially presented therein.

The second approach related to the retrieval of research updates on the delineation of case-specific data (e.g. the primary metabolites content of fruits, the net annual production of organic matter per hectare and TC, etc) and utilised as secondary keyword the botanical and common nomenclature of the representative for each cluster TC:

- ***Olea europaea* – Olive**
- ***Amygdalus communis* – Almond**
- ***Malus sylvestris* – Apple**
- ***Citrus sinensis* – Orange**
- ***Prunus persica* – Peach**

The primary keyword was retrieved after the detected in Annex I key characters of Carbon Flows in TC:

- Carbon Removal
  - **Annual Biomass Production.**
  - **Primary metabolites fruit content.**
- Carbon Emissions
  - **National Energy Mixture**
  - **Hours of machinery operation per cultivation measure and hectare**
  - **Fuel and agrochemicals consumption related carbon emissions**

While the first approach was aiming to update the present operational framework, providing to the action's objective a sound scientific background, the second approach was most focused, aiming to delineate specific accounting bottlenecks of the carbon sequestration enumeration methodology recognised in Annex I.

In this context the performed search was focussed on legislative sources and the relevant regulatory frameworks.

2.2. Sources

Within the previous context two main sources were considered for the retrieval of the relevant data: a) scientific data-bases, and b) Legislation and Policy Recommendation documents.

2.2.1. Scientific Data Bases

As main source was utilized Scopus data base, which includes nearly 36,377 titles (22,794 active titles and 13,583 Inactive titles) from approximately 11,678 publishers, of which 34,346 are peer-reviewed journals in top level subject fields Life Sciences, Social Sciences, Physical Sciences and Health Sciences. It covers three types of sources Book Series, Journals, Trade Journals. All journals covered in the Scopus database, regardless of who they are published under, are reviewed each year to ensure high-quality standards are maintained. Searches in Scopus also incorporate searches of patent databases.

In addition to Scopus, Google Scholar was also utilized as a secondary source when the results from Scopus search were insufficient. Google Scholar is a freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines. The Google Scholar index includes most peer-reviewed online academic journals and books, conference papers, theses and dissertations, preprints, abstracts, technical reports, and other scholarly literature, including court opinions and patents. While Google does not publish the size of Google Scholar's database, third-party researchers estimated it to contain roughly 160 million documents as of May 2014 and an earlier statistical estimate published in PLOS ONE using a Mark and recapture method estimated approximately 80-90% coverage of all articles published in English with an estimate of 100 million.

2.2.2. Legislation and Policy Documents

Within these source are included diverse pools of data retrieval that include: a) International Policy Guidelines and Legislation, b) National Legislation and Directives, c) Regional Policy Implementation Documents.

International Pool of search included two main sources the first of which is the Intergovernmental Panel on Climate Change (IPCC), which is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP), and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC. The IPCC reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. As an intergovernmental body, membership of the IPCC is open to all member countries of the United Nations (UN) and WMO. Currently 195 countries are Members of the IPCC. Governments participate in the review process and the plenary Sessions, where main decisions about the IPCC work programme are taken and reports are accepted, adopted and approved. Thousands of scientists from all over the world contribute to the work of the IPCC. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. IPCC aims to reflect a range of views and expertise. Because of its scientific and intergovernmental nature, the IPCC embodies a unique opportunity to provide rigorous and balanced scientific information to decision makers. By endorsing the IPCC reports, governments acknowledge the authority of their scientific content. The work of the organization is therefore policy-relevant and yet policy-neutral, never policy-prescriptive.

The second International Source is defined as the Directorate-General for Climate Action (DG CLIMA), which leads the European Commission's efforts to fight climate change at EU and international level. Its mission includes the tasks to formulate and implement climate policies and strategies, take a leading role in international negotiations on climate, implement the EU's Emissions Trading System (EU ETS), monitor national emissions by EU member countries, promote low-carbon technologies & adaptation measures. Towards this mission DG CLIMA formulates and implements cost-effective policies for the EU to meet its climate targets for 2020, 2030 and beyond, while also ensures climate change is taken into account in all other EU policies and that adaptation measures will reduce the EU's vulnerability to the impacts of climate change. More over in DG CLIMA work load are included the international negotiations on climate change and ozone-depleting substances, with non-EU countries, the implementation of the EU's Emissions Trading System (EU ETS) and the promotion of its linkage with other carbon trading systems aiming to the build up of a global carbon trading market, the monitoring of how EU member countries are implementing their national targets in sectors outside the EU ETS, and the promotion of the development of low-carbon technologies and adaptation measures by creating regulatory frameworks to guide the deployment of these technologies and by providing financial support.

3. Results & Discussion

3.1. Orchards Carbon Footprint

The relevant query in Scopus utilizing as Key-Words ***Orchard*** + ***Carbon Footprint*** returned 29 scientific papers [1-29]. All of these papers were critically considered starting from the earlier entry, which was dated to 2010 indicating thus the novelty of the relevant research subject.

This first endeavour by Muller et al. [29] to investigate the Orchards Carbon Footprint was focussed on the more severe of the cultivation inputs, the Pesticides. In this work a tool was developed for assessing the environmental impact of pesticides used for producing a specific product. This paper introduced the concept of the pesticide footprint (PFP), which fills this gap by estimating the total loss of pesticides, and their respective impact on humans and ecosystems, per product unit in a life-cycle framework. The impact assessment considers how these losses affect humans through the consumption of the product containing residues, and ecosystems through the exposure to residues in the environment. The PFP includes the production of the pesticide, its application in the orchard, and the final disposal of waste.

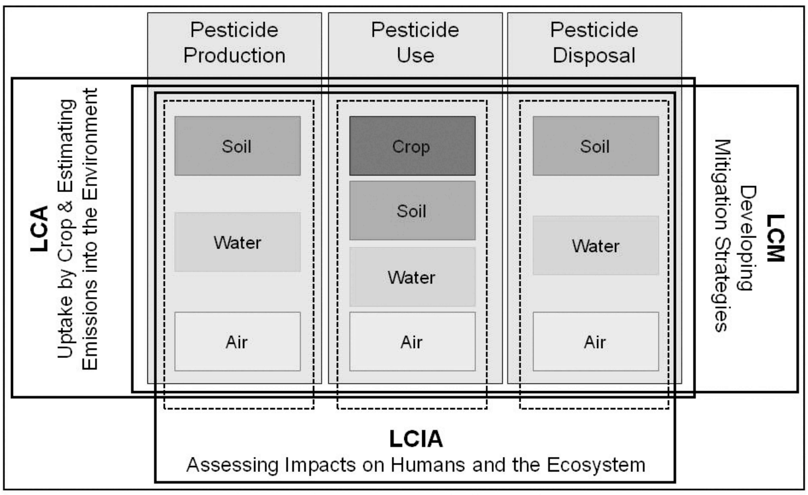


Fig. 1: Conceptual scheme of a product-related pesticide footprint (Muller et al. 2010).

Page [28] soon after this first approach recognised that Carbon footprint can be perceived as an indicator of greenhouse gas emissions and global warming, and introduced a modelling approach on carbon footprints based on life cycle assessment in order to evaluate the net contribution of greenhouse gases to the atmosphere from orchard production systems over one growing year. This net balance approach considered the sources and sinks of carbon and therefore provided a better reflection of an orchard system's net contribution to climate change, but did not incorporate in the accounting the crop yield. Carbon footprinting of organic kiwifruit and apple production systems in New Zealand indicated that the studied systems had a net sequestration from **2.4 to 5 t of CO_2/ha/year** and therefore can be potentially considered as carbon sinks under the Kyoto Protocol.

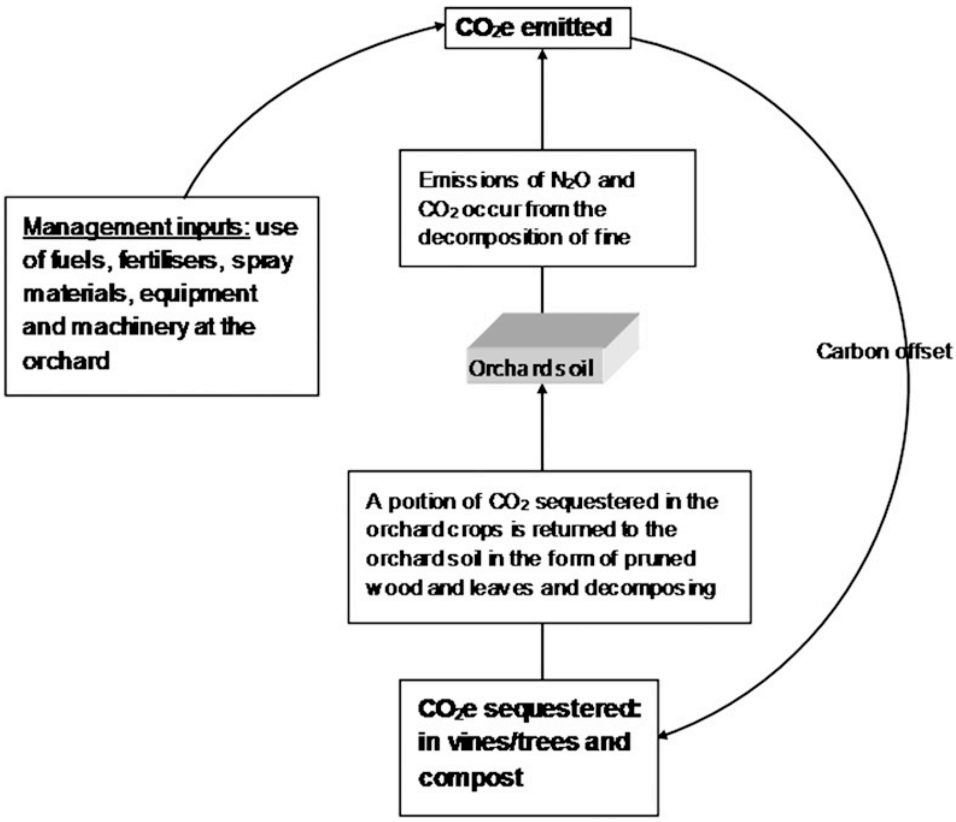


Fig. 2: Carbon cycle of an orchard system for carbon footprinting (Page, 2011).

In the same time perceptions on the Orchards Management framework were facing a significant shift recognised and highlighted by Palmer [27]. The long pursued target to improve the efficiency of carbon acquisition and distribution to the fruit for each hectare of orchard land, primarily by the choice of rootstocks, training systems, tree quality, light use efficiency, harvest index have featured prominently to the study and comparison of different systems of production for perennial fruit crops. While issues of sustainability, which initially focused on issues such as Integrated Fruit Production (IFP) to reduce chemical pesticide use and on occasions mechanisation to improve economic sustainability have also been considered, currently there is a necessity to look at not only the whole system within the orchard (trees, soil, understorey, windbreaks) but also the energy costs and carbon footprint of the relevant production systems - the orchard system in a much wider dimension.

While Blanke's paper [26], was a mismatch focusing in Apple market figures and trends in China, the 2011 references concluded with a CLIMATREE's partner research approach. In specific, Xiloyannis et al. [25] discussed some key issues of sustainable kiwifruit production by addressing a number of orchard practices with the multiple objectives of improving fruit quality, increasing soil fertility and minimising the environmental impacts of kiwifruit production. Increasing soil-carbon inputs by recycling prunings and covercrop biomass and by the application of composts all contribute to the build-up of soil carbon. These practices also enhance soil-water retention and fertility and fruit yield and quality. In conclusion, they recognised the need for an improved methodology for assessment of the carbon footprint of orchards including aspects of orchard management, though with a focus towards the improvement of soil carbon inputs.

A year later the research focus of Lu et al. [24] provided valuable insights towards the understanding of **Soil Respiration in Orchards**, an issue of high importance due to the lack of adequate knowledge according to IPCC guidelines. In this study, soil respiration under a tree intercropping system, an orchard and an agricultural land in north China were quantified during the growing season of March-November 2010. In the tree intercropping system, eight-year-old walnut (Juglans regia L.) was intercropped with an annual wheat (Triticum aestivum L.) - mung bean (Vigna radiata L.) rotation. During the study period, the **overall soil respiration rate** was 1.89, **1.63** and 2.05 μmol m^2 s^{-1} for the walnut intercropping, **walnut orchard** and cropland systems, respectively. **Thus, there was a reduction in soil respiration when the cropland was converted to walnut intercropping and walnut orchard in north China.** The higher soil CO_2 emission in the cropland result from the higher soil organic carbon and soil temperature. The van't Hoff model described the soil respiration as a function of soil temperature in the walnut intercropping system with R 2 > 0.78. Moreover, the temperature sensitivity of soil respiration (Q 10) was determined in the walnut intercropping system. The Q 10 values were similar in the walnut intercropping system and walnut orchard at 2.33 and 2.28, respectively, and significantly greater than for cropland (1.59). The result suggests that the walnut intercropping system had a higher sensitivity of soil respiration to temperature change than agricultural land. These results suggest that Orchard intercropping could be practiced above conventional agriculture and produced less soil CO_2 emissions.

In 2013 Alsina et al. [23] elaborated their study over the **Nitrogen and Methane emissions as a result of Nitrogen Fertilization** in an Almond Orchard. They recognised that Nitrogen fertilizer applied to soil is the primary source of the greenhouse gas (GHG) nitrous oxide (N_2O). The assessment of N_2O emissions, or net fluxes of the GHG methane (CH_4), are lacking for upland, arid agricultural ecosystems worldwide. In California, where rates of application for nitrogen (N) can exceed 300 kg per hectare for N-intensive fruit and nut crops (> 2 million acres), liquid N fertilizers applied through microirrigation systems (fertigation) represent the predominant method of N fertilization. Little information is available for how these concentrated and spatially discrete N solution applications influence N_2O emissions and net CH_4 fluxes (the sum of methanogenic and methanotrophic activity). In this study we examined soil N_2O-N emissions and net CH_4 fluxes for drip and stationary microsprinklers, two of the most widely used fertigation emitters, in an almond orchard where 235.5 kg N/ha were applied during the season of measurement (2009-2010). We accomplished this by modeling the spatial patterns of N_2O and CH_4 at the scale of meters and centimeters using simple mathematical approaches. For two applications of 33.6 kg/ha and three applications of 56.1 kg/ha targeted to the phenologic stages with highest tree N demand, the spatial patterns of N_2O fluxes were similar to the emitter water distribution pattern and independent of temperature and fertilizer N form applied. Net CH_4 fluxes were extremely low and there was no discernible spatial pattern, but areas kept dry (driveways between tree rows) generally consumed CH_4 while it was produced in the microirrigation wet-up area. The N_2O-N emissions for fertigation events at the scale of days, and over a season, were significantly higher from the drip irrigated orchard (1.6 6 0.7 kg N_2O-N ha-1yr-1) than a microsprinkler irrigated orchard (0.6 6 0.3 kg N_2O-N ha-1 yr-1). N_2O emissions and net CH_4 fluxes were only significantly correlated with soil water filled pore space and not with mineral-N. The correlation was much better for N_2O emissions. Our results greatly improve our ability to scale N_2O production to the orchard level, and provide growers with a tool for lowering almond orchard carbon and nitrogen footprints.

During the same year Blanke [22] elaborated on another crucial aspect affecting Carbon Footprint of Orchards; **the GHG emissions as a result of the Thinning cultivation measure**. Carbon footprinting of thinning in fruit orchards is based on fossil fuel consumption, converted into greenhouse gas emission (GHG) and expressed as CO_2 equivalents, which comprises carbon dioxide (CO_2 ; factor 1), methane (CH_4 ; factor 25) and nitrous oxides (N_2O; factor 298), according to PAS 2050: Oct 2011 and PAS 2050-1 (hort). Flower thinning with ATS foliar nitrogen fertiliser emitted 25-37 kg CO_2e /ha per treatment (without associated N_2O emissions), while fruitlet thinning with 6-BA emitted ca. 13 kg CO_2e /ha, Brevis 18.5 (single application) or 34 (double application) kg CO_2e /ha and lime sulfur in organic orchards 27-42 kg CO_2e /ha. Mechanical thinning with the Bonner machine at 6 km/h at 360 rpm produced 27.9 kg CO_2e /ha emissions, while manual fruitlet thinning after June drop had a carbon footprint of only 3.1 kg CO_2e /ha, since manual labour does not utilize fossil fuel.

The first reference from 2014 was recognised as a mismatch, since Balas [21] work related to the virtues of Greenhouses using energy derived from Renewable Energy Resources. The second reference though, also from Blanke [20], elaborated further on the implications of the recently established standard PAS 2050-1 by the British Standards Institution (or BSI), which is the national standards body of the United Kingdom. The PAS 2050-1(2012) was released in 2012 as the standard for orchard systems viz. horticulture after a year of public consultation and expert meetings under the hospice of Productschap Tuinbouw in Amsterdam and BSI in London. The PAS 2050-1(2012) was accompanied by five pilot projects in New

Zealand, Spain, Netherlands, Germany and the UK, including fruit crops such as Citrus orange (for juice), strawberry, kiwi, pear and apple. The PAS 2050-1 (2012) was developed as a “business to business” (B2B) or “from cradle to gate” standard, which implies a life cycle assessment (LCA) from the supply of the nursery tree to the farm gate, clarification of previously uncertain issues such as

1) provision for carbon sequestration, land use change (LUC) and an option for biogenic carbon (i.e., the carbon stored in the products);

2) allocation on a physical basis (gravimetrical or volumetric) rather than on an economic basis

3) number of harvest seasons required and inclusion of juvenile tree phase and

4) allocation of nitrogen fertiliser application as a major source of nitric oxides and greenhouse gas emissions (GHG) in orchard carbon footprints.

Also in 2014, a Cradle to Grave approach on Extra Virgin Olive Oil (EVOO) Carbon Footprint was presented by Rinaldi et al. [19]. In this study, olive orchard cultivation, EVOO extraction, bottling, packaging, storage at -18. °C and distribution in the main importing countries were studied from a life cycle assessment perspective, with the main objective of identifying the processes with the largest environmental impacts. The selected functional unit was 1 L of EVOO, packaged for distribution. Inventory data was gathered mainly through both direct communication using questionnaires and direct measurements. To determine the CF the ISO/TS 14067:2013 was followed while the EF was evaluated according to ISO standards 14040 and 14044. Even though this study’s objective was far from the current objectives an inclusive inventory of fuel consumptions and the related GHG emissions from the cultivation measures in the Olive yard was provided in the context of the study.

Table 1: Inventory data for olive trees cultivation per 1 ha of cultivated area (Rinaldi et al. 2014)

Material and energy inputs	Unit	Amount	Data source
Mowing			
Diesel	kg	17.48	Measured data
Fertilizing			
Diesel	kg	11.66	Measured data
Urea (as N)	kg	28.12	Measured data
Boric acid	kg	0.37E−03	Measured data
LDPE (package)	kg	3.3E−03	Assumption
HDPE (package)	kg	0.09E−03	Assumption
Fertilizers transport (lorry 16–32 t; 214 km)	tkm	1.78	Measured data
Emissions from fertilizing			
CO2 (from urea application)	kg	0.58	(IPCC, 2006)
N2O (from urea application)	kg	44.83	(IPCC, 2006)
Pest and disease control			
Diesel	kg	22.71	Measured data
Water	m3	3.00	Measured data
Coprantol	kg	0.72	Measured data
Rogor	kg	0.41	Measured data
Pirecap	kg	0.02	Measured data
Suprafos	kg	0.21	Measured data
Coccitox	kg	0.19	Measured data
LDPE (packaging)	kg	0.02	Assumption
HDPE (packaging)	kg	0.13	Assumption
Chemicals transport (van b3.5 t; 300 km)	tkm	0.15	Measured data
Pruning			
Diesel	kg	53.28	Measured data
Harvesting			
Diesel	kg	50.57	Measured data
Olives transport to mill			
Diesel	kg	17.41	Measured data

The following year, 2015, a boost was observed in the number of relevant publications that reached a total of nine papers, almost equalling the scientific production of the previous 5 years. Among these papers only three were found irrelevant: the paper of Blanke [12], which was related to a post-conference excursion report; the papers of Xiloyannis et al. [13] and Holmes et al. [14], which investigated the dynamics of Orchards CFP in the Soil Carbon Pool.

Tozzini et al. [18] elaborated on carbon sequestration estimates for Michigan orchards. Using the apple carbon balance model (Lakso et al., 2001) they estimated tree carbon assimilation and sequestration and the carbon footprint for both apple and cherry, and described **lifetime dry matter accumulation for both apple and cherry and relate it to trunk cross-sectional area (TCSA).** Total biomass in the perennial structure of trees was measured from trees excavated and trunk circumference was measured for each tree, 45 cm aboveground. The study was conducted on 27 apple trees and 20 'cherry trees. Fresh weight of recoverable roots, trunks, and branches was recorded in the field after excavation. Subsamples of roots and aboveground wood from different ages of the canopy were collected, weighted, and dried to constant weight at 60°C. The calculated percentage of dry weight (approximately 62% for both species) was used to estimate dry biomass weight of excavated trees. **Trees total dry weight (kg) was found to be linearly correlated with TCSA in apple and cherry**. Similar regression equations can be applied selectively to aboveground trees dry biomass and root dry biomass. On the sampled trunk sections, they measured cross sectional area growth according to growth rings and used it to estimate annual dry biomass sequestered by single trees. Mean annual dry biomass sequestered was **4.5 kg/tree in 30 years old cherry trees and varied from 1.1 to 2.7 kg/tree in apple trees**, where the variability may be explained by the different age, rootstocks, and cultivars of the trees employed.

During the same year CLIMATREE's partners contributed further to the knowledge base of Orchards Carbon Footprint through the paper of Fiore et al. [17]. This study utilized the most recent and recognised standards for carbon footprint (CFP) ISO 14067:2013 incorporating thus the required inclusion of land based emissions (CO_2 fluxes from soil organic carbon change and field emissions from fertilization) into greenhouse gas accounting. These two categories of emissions are often disregarded from CFP studies of fruit products. In the present paper a simple methodology to include land-based emissions into **greenhouse gas (GHG) accounting of fruit product from perennial crops** is tested on a case study, and the results compared to experimental measurement from literature in order to evaluate its point of strength and weakness; this methodology is based on IPCC guidelines for national GHG inventories (IPCC, 2006). All fossil (anthropogenic) and biogenic emissions arising from all agricultural operations during orchard life cycle have been accounted according ISO 14067:2013. Fertilization resulted to be the most impacting agricultural operation, together with the production of materials constituting the irrigation pipe system and its supporting structure (metal and cement poles, wire). The most innovative aspect of the tested methodology consists in considering the sink role of soil in fruit orchards managed according to sustainable agronomical practices (increasing of internal and external carbon input to soil). Comparison with measurements data from literature revealed that the simple methodology tested can be improved in order to improve the accuracy of the estimates according to pedoclimatic conditions and crop specificities. **Even though valuable, these contributions were rather focussed in Crop than the orchards CFP, and therefore of limited applicability under the present objective.**

On the contrary Muller et al. [16] approached the subject of Orchard CFP under a broader perspective, best described as Eco-efficiency, assessing the sustainability of orchards through the quantification of environmental impacts and resource consumption. Their study aimed to identify sustainable kiwifruit production, by considering orchards' environmental and economic performance through the survey of 40 orchards with different cultivars and management (integrated v. BioGro certified organic). Assessment of environmental performance was restricted to greenhouse gas emissions (carbon footprint of the orchard phase). Carbon footprints for the cultivars and management systems were comparable. **An intriguing approach of this study was related to the choice of functional unit, which expanded over both Land Area and Volume of Production**. Their analysis revealed that **fertilizer use and the N-associated emissions as hot spots for greenhouse gas emissions**. This result though is greatly attributed in the background system of fertilizer production, packaging, storage and transport, **therefore not directly correlated to the Orchard Land Use**. **In this respect their finding that the integrated system present insignificantly higher than the organic system GHG emissions is debateable**. Nevertheless this study successfully demonstrated that the metric of eco-efficiency can enhance product differentiation for customers and can also assist orchardists to find the most sustainable management system. However, the volatility of commodity markets and changing consumer preferences remain challenges.

The assessment of the fertilization method of Green Manure impacts in Peach Orchards CFP was the subject of the study presented by Wang et al. [15]. Their focus related to the long-term effects of green manure on carbon storage in fruit orchards, an important issue for carbon footprinting according to PAS 2050-1. Thus, for assessing carbon sequestration, the carbon distribution in the vegetation, litter and soil within the same nectarine orchard was compared with three management practices such as sloping plot without conservation measures, a terraced plot without conservation measures, and a terraced plot with green manure of Arachis pintoi 'Amarillo' as mulch, with the following results:

(a) carbon storages of fruit tree and litter in the nectarine orchard ranged from 13.0 to 14.7 t carbon ha^{-1} , and 0.54 to 0.59 kg carbon per plant, respectively. No significant difference was found between different treatments. However, the carbon storage from A. pintoi increased to 5.12 t carbon ha^{-1} in the T 3 treatment.

(b) Soil organic carbon (SOC) and soil organic carbon density (SOC D) in T 3 treatment significantly increased compared with T 1 and T 2 treatments, and decreased with the increase of soil depth. A significant difference was observed between every soil layers in T 3 treatment.

(c) During the 13 years after orchard establishment, the soil organic carbon sources influenced the $\delta\ ^{13}C$ distribution with depth and carbon originate. The upper soil layer SOC turnover in T 3 treatment was 1.59 and 1.41 times greater than those of T 1 and T 2 treatments, respectively, indicating that terraced nectarine orchard with A. pintoi as green manure could rapidly sequester SOC in subtropical China.

Even though as most of the studies considered under the present context, this also addresses the CFP under an inclusive framework not focused on the Orchard Land Use, presents also significant contributions for CLIMATREE's objectives in the form of the following Figure.

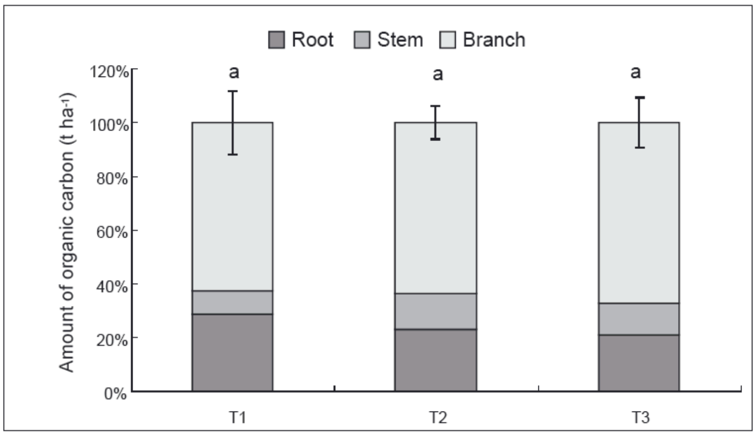


Fig. 3: Amount of Carbon in Nectarine fruit tree vegetation under different management practices (Wang et al., 2015).

The paper of Kendal et al. [11] introduced a novel approach on Energy Use and GHG emissions of Almond orchards, though it was also focused on the crop implicating as functional unit the Volume of Product, and therefore their results are of limited value under the present objectives. Their comprehensive, multiyear, life cycle-based model included orchard establishment and removal; field operations and inputs; emissions from orchard soils; and transport and utilization of co-products. These processes were analyzed to yield a life cycle inventory of energy use, greenhouse gas (GHG) emissions, criteria air pollutants, and direct water use from field to factory gate. Results show that 1 kilogram (kg) of raw almonds and associated co-products of hulls, shells, and woody biomass require 35 megajoules (MJ) of energy and result in 1.6 kg carbon dioxide equivalent (CO 2 -eq) of GHG emissions. Nitrogen fertilizer and irrigation water are the dominant causes of both energy use and GHG emissions. **Co-product credits play an important role in estimating the life cycle environmental impacts attributable to almonds alone**; using displacement methods results in net energy and emissions of 29 MJ and 0.9 kg CO_2 -eq/kg. **The largest sources of credits are from orchard biomass and shells used in electricity generation, which are modeled as displacing average California electricity.** Using economic allocation methods produces significantly different results; 1 kg of almonds is responsible for 33 MJ of energy and 1.5 kg CO_2 -eq emissions.

The conclusive reference of 2015, presented by Maris et al. [10] was related to the effects of irrigation, nitrogen application, and a nitrification inhibitor on nitrous oxide, carbon dioxide and methane emissions from an olive orchard, and therefore of crucial importance under CLIMATREE's objectives. The comparison of nitrous oxide, carbon dioxide and methane associated with the application of N fertiliser through fertigation was conducted through a field study in a high tree density

Arbequina olive orchard. Drip irrigation combined with nitrogen (N) fertigation wass applied in order to save water and improve nutrient efficiency. Nitrification inhibitors reduce greenhouse gas emissions. Subsurface drip irrigation markedly reduced Nitrate emissions compared with surface drip irrigation. Fertiliser application significantly increased Nitrate emissions. Denitrification was the main source of Nitrate losses (calculated as emission factor) ranging from -0.03 to 0.14% of the N applied, were lower than the IPCC (2007) values. The Nitrate losses were the largest, equivalent to 1.80% of the N applied, from the drip irrigation treatment which resulted in water filled pore space > 60% most of the time (high moisture). Nitrogen fertilisation significantly reduced carbon dioxide emissions in 2011, but only for the subsurface drip irrigation strategies in 2012. The olive orchard acted as a net methane sink for all the treatments. Applying a nitrification inhibitor (DMPP), the cumulative Nitrate emissions were significantly reduced with respect to the control. The DMPP also inhibited carbon dioxide emissions and significantly increased methane oxidation. Considering global warming potential, greenhouse gas intensity, cumulative nitrate emissions and oil production, it can be concluded that applying N through DMPP drip irrigation treatment was the best option combining productivity with keeping greenhouse gas emissions under control.

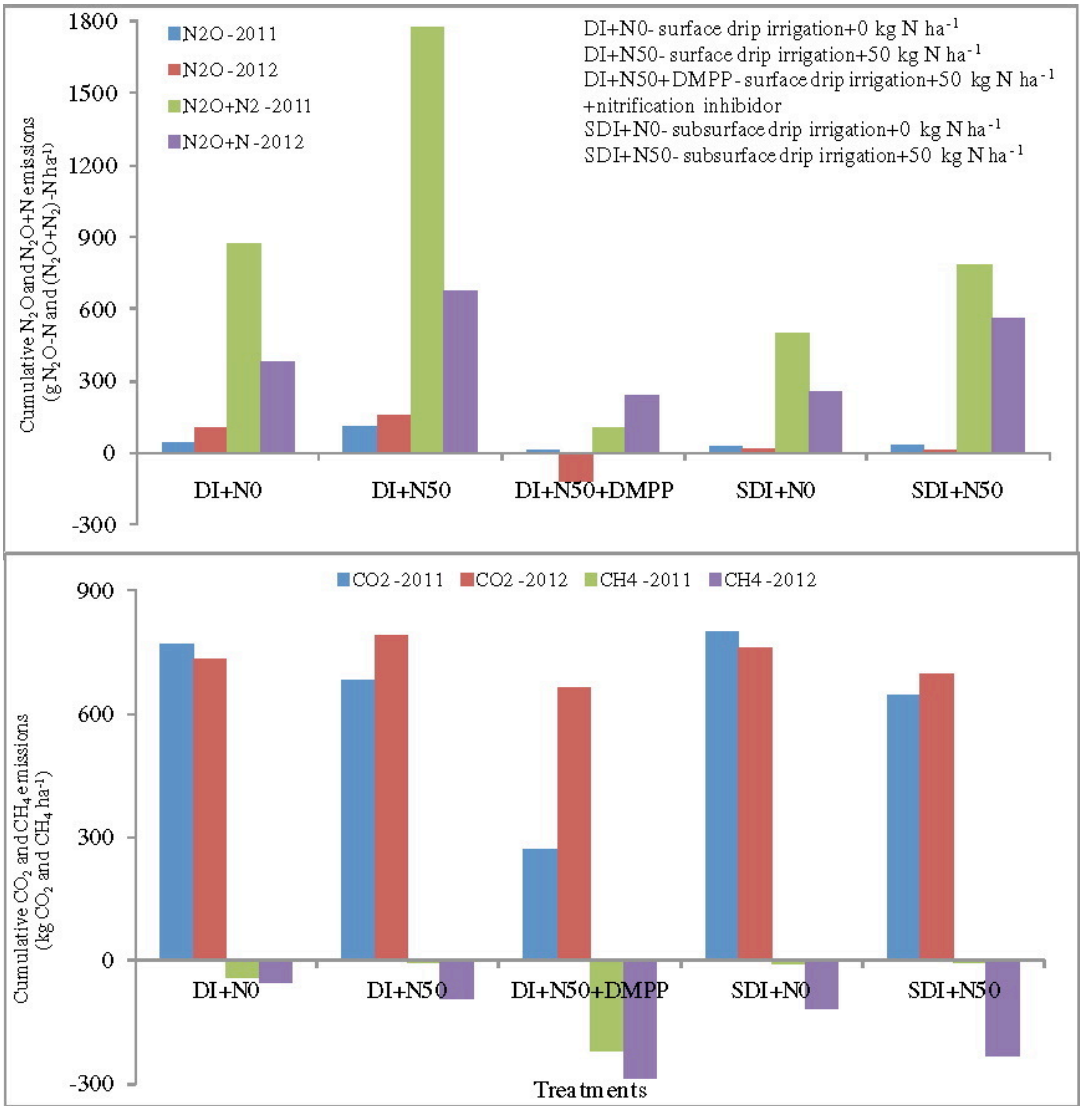


Fig. 4: Amount of Nitrogen and Carbon emissions in Olive Orchard under different fertilization practices (Maris et al., 2015).

The following year, 2016, the trend on Orchards CFP studies was confirmed through the detection of 8 more references. Among these papers half were found irrelevant: the paper of Clothier [3], which was investigating orchards as a natural capital supplying valuable ecosystem services; the paper of Gentile et al. [5] that focused on the quantification of the potential contribution of soil carbon to orchard carbon footprints; the paper of Muller et al. [6] that was almost identical with that of

Holmes et al. [14]; and the paper of Mowat [7], which presented a market oriented assessment of the environmental impact of the New Zealand kiwifruit value chain.

Cordes et al. [9] evaluated the carbon footprint of Chilean organic blueberry production, through a cradle-to-farm gate approach. This study obtained a resource use inventory and assessed the carbon footprint (CF) of organic blueberry (Vaccinium corymbosum) production in the main cultivation area of Chile in order to identify CF key factors and to provide improvement measures. The method used in this study follows the ISO 14040 framework and the main recommendations in the PAS 2050 guide as well as its specification for horticultural products PAS 2050-1. Agricultural factors such as fertilizers, pesticides, fossil fuels, electricity, materials, machinery, and direct land use change (LUC) were included. Only three orchards present direct LUC. The direct LUC associated with the conversion from annual crops to perennial crops is a key factor in the greenhouse gas removals from the orchards. When accounting for direct LUC, the CF of organic blueberry production in the studied orchards ranges from removals of −0.94 to emissions of 0.61 kg CO_2 -e/kg blueberry. CF excluding LUC ranges from 0.27 to 0.69 kg CO_2 -e/kg blueberry. The variability in the results of the orchards suggests that the production practices have important effects on the CF. The factors with the greatest contribution to the greenhouse emissions are organic fertilizers followed by energy use causing, on average, 50 and 43 % of total emissions, respectively. The CF of the organic blueberry orchards under study decreases significantly when taking into account removals related to LUC. The results highlight the importance of reporting separately the greenhouse gas (GHG) emissions from LUC. The CF of blueberry production could be reduced by optimizing fertilizer application, using cover crops and replacing inefficient tractors and large irrigation pumps. The identification of improvement measures would be a useful guide for changing grower practices.

Another study presented by Yan et al. [8] delegated the farm and product carbon footprints of China's fruit production, through the life cycle inventory investigation of representative orchards of five major fruits. This study aimed to characterize the carbon footprints of China's fruit production and to figure out the key greenhouse gas emissions to cut with improved orchard management. **Yearly input data of materials and energy in a full life cycle from material production to fruit harvest** were obtained via field visits to orchards of five typical fruit types from selected areas of China. Carbon footprint (CF) was assessed with quantifying the greenhouse gas emissions associated with the individual inputs. Farm and product CFs were respectively predicted in terms of land use and of fresh fruit yield. Additionally, product CFs scaled by fruit nutrition value (vitamin C (Vc) content) and by the economic benefit from fruit production were also evaluated. **The estimated farm CF ranged from 2.9 to 12.8 t CO_2 -eq ha −1 across the surveyed orchards**, whereas the product CF ranged from 0.07 to 0.7 kg CO_2 -eq kg $^{-1}$ fruit. While the mean product CFs of orange and pear were significantly lower than those of apple, banana, and peach, the nutrition-scaled CF of orange (0.5 kg CO_2 -eq g $^{-1}$ Vc on average) was significantly lower than others (3.0–5.9 kg CO_2 -eq g $^{-1}$ Vc). The income-scaled CF of orange and pear (1.20 and 1.01 kg CO_2 -eq USD $^{-1}$, respectively) was higher than apple, banana, and peach (0.87~0.39 kg CO_2 -eq USD $^{-1}$). Among the inputs, synthetic nitrogen fertilizer contributed by over 50 % to the total greenhouse gas (GHG) emissions, varying among the fruit types. There were some tradeoffs in product CFs between fruit nutrition value and fruit growers' income. Low carbon production and consumption policy and marketing mechanism should be developed to cut down carbon emissions from fruit production sector, with balancing the nutrition value, producer's income, and climate change mitigation.

CLIMATREE's partners contributed greatly to a most relevant reference that elaborated on the improvement of the accounting of field emissions in the carbon footprint of agricultural products, through a comparison of default IPCC methods with readily available medium-effort modeling approaches. Peter et al. [4] working on the estimation of greenhouse gas (GHG) field emissions from fertilization and soil carbon changes recognised them as challenges associated with calculating the carbon footprint (CFP) of agricultural products. At the regional level, the IPCC Guidelines for National Greenhouse Gas Inventories (2006a) Tier 1 approach, based on default emission factors, insufficiently accounts for emission variability resulting from pedo-climatic conditions or management practices. However, Tier 2 and 3 approaches are usually considered too complex to be practicable. In this paper different readily available medium-effort methods are evaluated in relation to their potency to improve the accuracy of GHG emission estimates. The data implicated originated from four case studies—two wheat crops in Germany and two peach orchards in Italy—to test the performance of Tier 1, 2, and 3 methodologies and compare the estimated results with available field measurements. The methodologies selected at Tier 2 and Tier 3 level are characterized by simple implementation and data collection, for which only a medium level of effort for stakeholders is required. The Tier 2 method consists of calculating direct and indirect N 2 O, emissions from fertilization with a multivariate empirical model which accounts for pedo-climatic and crop management conditions. The Tier 3 method entails simulation of soil carbon stock change using the Rothamsted carbon model. Results and discussion: Relevant differences were found among the tested methodologies: in all case studies, the Tier 1 approach exceeded the

Tier 2 estimations for fertilizer-induced emissions (up to +50 %) and the measurements. **Using this higher Tier approach reduced the estimated CFP calculation of annual crops by 4 and 21 % and that of the perennial crop by 7 %.** Removals related to positive soil carbon change calculated using the Tier 1 approach also exceeded the Tier 3 calculations for the studied annual crops (up to +90 %) but considerably underrated the Tier 3 estimations and measurements for perennial crops (−75 %). In this case, the impact of the selected Tier method on the final CFP results was even more relevant: an increase of 194 and 88 % for the studied annual crops and a decrease of 67 % for the perennial crop case study. The use of higher Tiers for the estimation of land-based emissions is strongly recommended to improve the accuracy of the CFP results. The suggested medium-effort methods tested in this study represent a good compromise between complexity reduction and accuracy improvement and can be considered reliable for the assessment of GHG mitigation potentials. **Even though this study is of crucial importance in relation with the validity and credibility of the method of choice for the estimation of Orchards GHG emissions fails to incorporate, and consequently investigate, the fundamental IPCC methodology for Carbon capture, which recognises as a distinct category the harvested products**.

CLIMATREE's beneficiaries elaborated also on the potential effect of sustainable production systems on carbon and water footprint in fruit tree orchards. Xylogiannis et al. [2] recognising Climate Change impacts to agriculture proceeede in the analysis of water and carbon resource use at a farm scale that could contribute to design practices with no (or minimum) impact on the environment. Carbon footprint (CF) and water footprint (WF) are being used to indicate the impacts of the C and W use by production systems. This paper reports the effects of sustainable orchard management practices (e.g., notillage, retention of pruning residues, compost application, guided irrigation) on CF and WF in fruit tree orchards. Results show that CF decreases in a sustainably managed orchard (-0.79 kg CO_2 per kg fruits) compared to locally conventional managed orchard fields (0.14 kg CO_2 per kg fruits), and is acting as a sink for carbon. The WF analysis shows that the sustainable practices contributed to the ~40% reduction of the blue water component use, associated with a corresponding increase of the green water component use. Hence, the good practices adopted may represent a local (farm scale) tool for mitigation of a global problem.

Finally in 2017 Rebolledo-Leiva et al. [1] presented a joint carbon footprint assessment and data envelopment analysis for the reduction of greenhouse gas emissions in agriculture production. Operations management tools are critical in the process of evaluating and implementing action towards a low carbon production. Currently, a sustainable production implies both an efficient resource use and the obligation to meet targets for reducing greenhouse gas (GHG) emissions. The carbon footprint (CF) tool allows estimating the overall amount of GHG emissions associated with a product or activity throughout its life cycle. In this paper, was proposed a four-step method for a joint use of CF assessment and Data Envelopment Analysis (DEA). Following the eco-efficiency definition, which is the delivery of goods using fewer resources and with decreasing environmental impact, an output oriented DEA model is proposed in order to maximize production and reduce CF, taking into account simultaneously the economic and ecological perspectives. In another step, this study established targets for the contributing CF factors in order to achieve CF reduction. The proposed method was applied to assess the eco-efficiency of five organic blueberry orchards throughout three growing seasons. The results show that this method is a practical tool for determining eco-efficiency and reducing GHG emissions.

3.2. Carbon Removal Clade

3.2.1. Primary metabolites fruit content.

The necessity for delineation of this subject is derived by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2. In specific while the carbon fraction of dry matter (CF) comprises a fundamental coefficient applied through out the equations of chapter 2 is delineated with a default value of 0.37 {corresponding to tonne C (tonne d.m.)$^{-1}$} only for litter, which is the general assumption for wood that is a mixture of Cellulose and Semi-Cellulose.

The inclusion on the calculations of the TC harvested products though present a discrit discrepancy with this assumption since fruits and nuts contain much more than Cellulose. In this respect the specific content of the representative fruits was defined as a subject of interest under the CLIMATREE's operational context, and was delineated through the United States Department of Agriculture, Agricultural Research Service, National Nutrient Database for Standard Reference Release 28 [30], as presented in Table 2.

Table 2: Primary Metabolites Content of Representative Fruits (all Figures in %, * Given as Difference, ** The figures regard only to the edible portion of the fruit/nut)

Fruit	NDB Nr.	Water	C-H*	Fat	Protein	Sugars	Ash/total Minerals	Total
Peach**	09236	88,87	1,15	0,25	0,91	8,39	0,43	98,85
Almond**	12061	4,41	18,4	49,93	21,15	4,35	1,76	81,6
Olive**	09195	75,28	5,69	15,32	1,03	0,54	2,14	94,31
Apple	09003	85,56	3,49	0,17	0,26	10,39	0,13	96,51
Orange	09205	86,75	2,58	0,12	0,94	9,35	0,26	97,42

The figures of Table 2 complemented by the relevant figures of the seeds of Olive and Peach and seed pericarps of Almond, Olive, and Peach will be utilized in conjunction with the stoichiometric coefficients described in Annex I for the estimation of the C content of the harvested crops.

3.2.2. Annual Biomass Production.

The initial research in Scopus for Olive Orchards returned more than 1.300 references, which when filtered with Biomass term were narrowed to 122. From them a critical review further indicated 4 [31-35] that will be utilized as basic references for the Olive Orchards Annual Biomass production estimation. In the same context the initial search figures for Almond Orchards were 600, and after refinement 46, from which 7 [36-42] were considered as fundamental references. Peach Orchard figures were respectively 1.629, and 88, from which after a short review 8 [43-51] were included as basic references. Orange Orchards respectively returned 1.016 and after refinement 73 results from which 6 [52-57] were included in the present review. Finally, Apple orchards search returned 5.847 and 302 results. These were further refined through a geographical allocation to 44 from which, after a short review, 8 [58-65] were selected and included in the relevant depository.

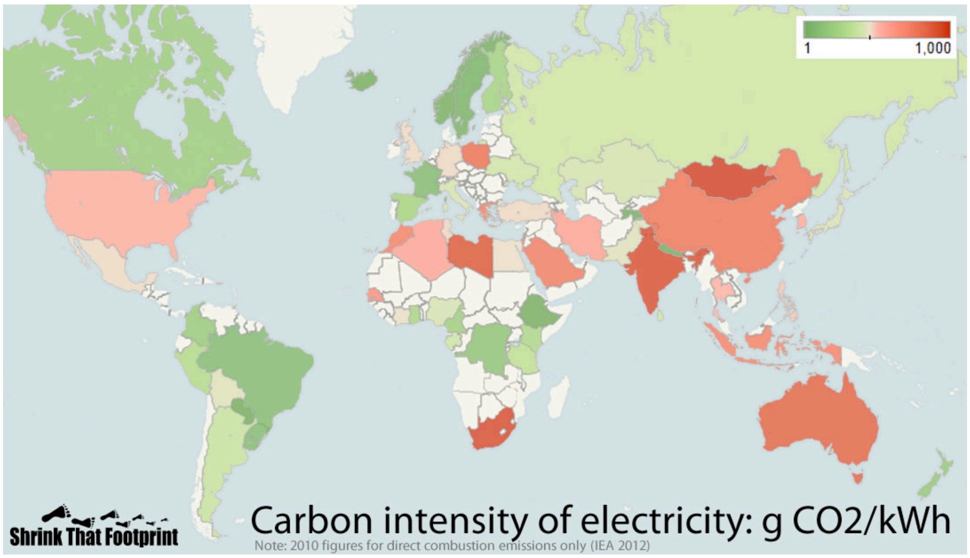
The integration of these fundamental references in CLIMATREE's context is fundamental for the structuring of a sound and widely applicable protocol expanding over broader geographic areas. In this context the further assessment of these references was deemed more appropriate to conclude in aggregated figures for biomass production among the four TC categories. The potential inclusion of these aggregated figures in the present Action's context would be premature and partially contradictory to the prescribed objective of the Action to provide the project with a real life approach established on actual data derived from field samplings and surveys.

3.3. Carbon Emissions Clade

3.3.1. National Energy Mixture

The facts on the national energy mixture and the related CO_2 emissions is under continuous change as Renewable Energy Resources are incorporated in the national grid. More over present status in the Energy sector of Greece is rather liquid since there is an on-going privatisation of the main electricity provider.

The carbon intensity of electricity varies greatly depending on fuel source. Shrink That Footprint is a resource for squeezing more life out of less carbon. They are an independent research group that provides information to people interested in reducing their climate impact. Their core focus is understanding, calculating and reducing carbon footprints. As a rough guide the electricity produced from coal has a carbon intensity of about 1,000g CO_2/kWh, oil is 800g CO_2/kWh, natural gas is around 500g CO_2/kWh, while nuclear, hydro, wind and solar are all less than 50 g CO_2/kWh. The carbon intensity of grid electricity is determined by the fuel mix used in generation. In this source using figures from the IEA was produced a map to show just how different the carbon intensity of electricity is around the world.



The relevant figures in indicate that Greece's average emissions are 0,9 g CO_2/kWh.

3.3.2. Hours of machinery operation per cultivation measure and hectare

Ability to predict tractor fuel consumption is very useful for budgeting and management. The objective of this factsheet is to develop relationships using field measurements and Nebraska Tractor Test Laboratory results to estimate tractor fuel consumption. Using these equations, farmers can estimate and compare the fuel consumption for different operating and loading conditions.

Depending on the type of fuel and the amount of time a tractor or machine is used, fuel and lubricant costs will usually represent at least 16 percent to over 45 percent of the total machine costs. Thus, fuel consumption plays a significant role in the selection and management of tractors and equipment used in agriculture. Currently, most budget models use a simplified methods for estimating fuel consumption. Better estimates representing actual field operations are needed to compare machinery management strategies.

The worth of a tractor is assessed based on work output and the cost associated with completing the task. Drawbar power is defined by pull (or draft) and travel speed. An ideal tractor would convert all fuel energy into useful work at the drawbar. However, due to power losses, not all fuel energy is converted into useful work.

Efficient operation of farm tractors may depend on: (1) maximizing the fuel efficiency of the engine and the mechanical efficiency of the drivetrain, (2) maximizing tractive efficiency of the traction devices, and (3) selecting an optimum travel speed for a given tractor-implement system. This factsheet focuses on methods to estimate and improve fuel efficiency of a diesel power unit. The sum of the above mentioned task has been excessively studied and presented [66].

Nevertheless, the necessity for an inclusive account of the related issue was approach through the regulatory framework of Greece. In specific and in the context of the Regional working document on Agricultural Inputs and Indicators the following operation hours were incorporated in the accounting methodology of Annex I:

Cultivation Measure	Operation (h/ha)
Tillage (Summer ± 20 cm)	3,5
Tillage (Autumn ± 20 cm)	3,0
Tillage (± 40 cm)	4,0
Tillage (+ 10 cm)	2,0
Tillage (-10 cm), Spraying, Fertilizing, Mixing, Leveling, Irrigation	1,5

3.3.3. Fuel and agrochemicals consumption related carbon emissions

Grisso et al. [66] did not incorporated a cumulative coefficient for the estimation of carbon dioxide emissions relating to the operation of agricultural machinery. Therefore an additional web search revealed the relevant standards from the U.S. Energy Department (https://www.eia.gov/tools/faqs/faq.php?id=73&t=11) that were defined as **2,68 kg CO_2 per L of Diesel, and 2,31 kg CO_2 per L of Gasoline.**

In relevance with the indirect emissions generated by the fertilizers **the IPCC standard of 1,25 % of the applied N fertilizer weight** was considered the base line for the accounting of the related nitrate emissions. In a similar manner the conclusion to carbon dioxide equivalent emissions was performed in full compliance with the IPCC protocol through the incorporation of the **N_2O to CO_2 coefficient multiplier of 298.**

4. Conclusions

All bottleneck of the Annex I calculations were successfully resolved through the incorporation either state of the art research results, and/or sufficiently established international standards.

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Annex III

Field report on Variables affecting carbon sequestration

1. Introduction

The present report originally is prescribed in the project's outcomes in order to delineate the variables affecting carbon emissions as a result of the cultivation measures applied in the orchards. Though the initial targeting of the related tasks is retained and fully served through action implementation, an additional target was added in the task's operational context; the delineation of the biodiversity presence within the four orchards clusters.

Therefore the appropriate methodology for the relevant data acquisition should be able to cohere with the aforementioned bilateral approach. As such was selected the structured questionnaire survey. The survey's objectives are presented in the following introductory lines followed by the detailed methodological approach, while the results remain pending and will be completed according to the action's schedule. As supplements A, B, and C, are attached the Participation Form (A) and the Biodiversity (B) and Cultivation (C) Questionnaires.

The first objective of the survey relates to the Orchard Land Use originated carbon emissions. As the main source of emissions have been defined the cultivation measures, for which a carbon emissions calculation algorithm is explicitly described in Annex I, and the fundamental figures required for this calculation include:

a. Machinery Emissions: The relative targets for definition and enumeration are the:
    I. Kind of machinery used for each cultivation measure, in order to delineate the kind and quantity of fuel used, per hour of operation.
    II. Hours of yearly operation per machinery, in order to calculate the annual fuel consumption and the related GHG's emissions in CO_2 equivalents.
b. Energy Consumption Emissions: The relative targets for definition and enumeration are the:
    I. Kind of machinery used for each cultivation measure, in order to delineate the kind and quantity of energy consumption, per hour of operation.

II. Hours of yearly operation per machinery, in order to calculate the annual energy consumption and the related GHG's emissions in CO_2 equivalents.

c. Other Emissions: The relative targets for definition and enumeration are the pruning handling originated carbon emissions:

   I. Kind of pruning, in order to delineate the kind and quantity of herbal tissues removed from the Orchard.

   II. Pruning's manipulation definition in order to conclude to the fate of the herbal tissues (e.g. whether they remain in the orchard, or removed), and the related GHG's emissions in CO_2 equivalents.

The survey's second objective regards the biodiversity occurrence in the Orchards. The pursued data under this objective include the definition of total number of species within the three macroscopic Kingdoms of life. A complementary target of the survey is the delineation of common perceptions on biodiversity among the targeted population, namely the orchard farmers. The data retracted by the Biodiversity Questionnaire are distributed among the 5 representative crops and relate to:

a. Fauna Records: The relative targets for definition and enumeration are:

   I. *Taxa* Number, of Mammals, Reptiles, Birds, and Insects Classes, crosschecked by,

   II. *Taxa* Number of Families distribution into the respective Class.

b. Flora Records: The relative targets for definition and enumeration are:

   I. *Taxa* Number, of Annuals, Perennials, Shrubs and Trees, crosschecked by,

   II. *Taxa* Number of Families distribution into the respective plant category.

c. Fungi Records: The relative targets for definition and enumeration are:

   I. *Taxa* Number of macroscopic visible mushrooms distribution into representative families of the Agaricomycetes Class.

Beside these two distinct cluster of objectives the survey is also aiming to serve as a direct communication approach of CLIMATREE to its end users; the orchard farmers. More over through the questionnaires are obtained crucial metadata on the distinct data input (e.g. Plantation Density, and equipment and machinery description in Cultivation Inputs Questionnaire, and Frequency along with yearly distribution of primary observations in the Biodiversity Questionnaire). Finally, the participants in the survey farmers will be regularly updated on the CLIMATREE's progress, materialising thus a direct line of communication between them.

2. Survey Methodology

2.1 Research Approach

The fundamental research approach incorporates the unassisted answering of the questionnaires by the farmers. For this purpose the structured questionnaires of the survey are conformed as a list of questions that are both open ended and close ended, depending on the question's framework and form. The open ended question, in which possible responses are not supplied in advance, regard to the definition of the observation status by the farmers and the short description of their fields. The close-ended questions provide a set of responses or options from which the farmer indicates his/her choice. These sets of questions concerns factual issues, with a limited range of responses, and are aiming to the information extraction from the target group.

2.2 Target Groups and Sample Size Definition

The Type of Sampling applied to the study will be cluster-sampling scheme over the agricultural population, with focus on each of the five representative crops, the producers of which will form the relative clusters.

As focal points for cluster formation in the cases of Orange, Peach, and Apple, has been considered key juice industry facilities and arrangements have been performed in order CHB S.A. to embrace CLIMATREE's objective. Thus Survey's Questionnaires will be accompanying the crop deliverances procedure promoting the participation of all farmers. Further more the crops industrial utilization assures conformity of the crops environment and cultivation practices with the intensive character of the respective tree-crop clusters. This collaboration encompasses distinct geographical allocation in a Regional scale:

- Orange orchards are located in the Region of Peloponnese, Greece.
- Peach orchards are located in the Region of West Macedonia, Greece.
- Apple orchards are located in the Region of Thessaly, Greece.

The other two clusters of Almond and Olive will be pursued through the implication of relative Cooperatives and/or producers groups. The later will be oriented towards the organic producers since their cultivation practices are more related to the extensive character of the tree crop categories.

The sample size step of reliability will be 25 responders in each cluster, which is a valid number of participation in agronomical surveys. The targeted sample size on the other hand will be 50 responders per representative tree-crop, enabling thus an increased validity of the acquired data. All responders will be contacted in person by authorized, trained personnel of the collaborating organization in the cases of Orange, Peach, and Apple, while in the cases of Olive and Almond the first approach and the Questionnaires introduction will be assisted by AUA personnel.

2.3 Questionnaires Structure

The Questionnaire is structured upon three main components:

- Participation Form (Supplement A): Here are included two text bodies; the first briefly explains CLIMATREE concept, and the second consists by a Non-Disclosure Agreement Statement between the participant and the Agricultural University of Athens, on the personal data the participants provides in his responses. The concluding part of this component regards fields for the participant's personal data and sign.
- Biodiversity Questionnaire (Supplement B): Here are included 5 main sub-components: the first regards the definition of crucial orchard metadata, and is presented as heading of the Questionnaire; the second regards the observation status of the responders and includes Questions 1 to 3; the third relates to the observation records of Fauna through Questions 4 to 10; the fourth regards the observation records of Flora by Questions 11 to 17; the fifth relates to the observation records of Fungi through Questions 18 to 21.
- Cultivation Inputs Questionnaire (Supplement C): Here are included 5 main sub-components: the first regards the definition of crucial orchard metadata, and is presented as heading of the Questionnaire; the second regards the machinery inventory of the responders and includes Questions 1 to 5; the third relates to the definition of the cultivation measures applied in the Orchard through Questions 6 to 12; the fourth regards the records of agrochemical usage by Questions 13 to 16; the fifth relates to the annual consumptions and cost of Fuel, Energy, and Agrochemicals through Questions 17 and 18.

2.4 Questions Formation

The following logical framework between the data required for the application of Annex I methodology and the Questionnaire structuring was utilized for the phrasing of the Questions:

Biodiversity Questionnaire (Supplement B):

The data retracted by the Biodiversity Questionnaire are distributed among the 5 representative crops and relate to:

a. Metadata on Plantation Density, Regional Allocation of the Orchards, and Average Farm Size through Sub-Component 1 (Heading).
b. Metadata on Observation Status of the responder through Sub-Component 2, relating to Season and Frequency of Visits (Question 1), Duration of Visits (Question 2), and Time of Visits (Question 3).
c. Fauna Records: The relative data retracted include a building confidence section including the verification of sighting (Question 4), the Frequency of sighting (Question 5), and the attribution of the sighted animal in the relevant Class (Question 6). The last question directs the responder to Questions 7 to 10, were is delineated respectively the:
    I. *Taxa* Number, of Mammals (Question 7), Birds (Question 8), Reptiles (Question 9), and Insects (Birds (Question 10) Classes, crosschecked by,
    II. *Taxa* Number of Families distribution into the respective Class.
d. Flora Records: The relative data retracted include a building confidence section including the verification of sighting (Question 11), the Frequency of sighting (Question 12), and the attribution of the sighted plant in the relevant categories (Question 13). The last question directs the responder to Questions 14 to 17, were is delineated respectively the:
    I. *Taxa* Number, of Mammals (Question 7), Birds (Question 8), Reptiles (Question 9), and Insects (Birds (Question 10) Classes, crosschecked by,
    II. *Taxa* Number of Annuals (Question 14), Perennials (Question 15), Shrubs (Question 16), and Trees (Question 17), crosschecked by,
    III. *Taxa* Number of Families distribution into the respective plant category.
e. Fungi Records: The relative data retracted include a building confidence section including the verification of sighting (Question 18), the Frequency

of sighting (Question 19), and the season of sighting (Question 20). In the last question is delineated the:

I. *Taxa* Number of macroscopic visible mushrooms distribution into representative families of the Agaricomycetes Class (Question 21).

<u>Cultivation Inputs Questionnaire (Supplement C):</u>

The data retracted by the Biodiversity Questionnaire are distributed among the 5 representative crops and relate to:

a. Metadata on Plantation distance form the residence and the market Sub-Component 1 (Heading).
b. Machinery Emissions: The relative data are obtained through Sub-Components II and III:
   I. The machinery used for each cultivation measure, is derived by Sub-Component II and relates to: Kind (Question 1); and Age, HP, and Fuel per Kind of Machinery (Questions 2 to 5).
   II. Hours of yearly operation per machinery, is derived by Sub-Component III and relate to the: Identification of the cultivation measures applied in the orchard along with their annual frequency (Question 6); Definition of the tillage applications (intensity, total area, annual number in Question 7); Definition of fertilization (intensity, total area, annual number, form of application, and kind of fertilizer in Question 8); Definition of irrigation (intensity, total area, annual number, form of application, and duration per application in Question 9); Definition of pruning (intensity, total area, annual number, form of application, in Question 10); Definition of frost protection (intensity, total area, annual number, form of application, fuel/energy source, and duration per application in Question 11).
c. Energy Consumption Emissions: The relative data are obtained through Sub-Components II and III:
   I. The machinery used for each cultivation measure, is derived by Sub-Component II and relate to: Kind (Question 1); and Age, KW, and Fuel per Kind of Machinery (Questions 4 and 5).
   II. Hours of yearly operation per machinery, is derived by Sub-Component III and relate to: Identification of the cultivation measures applied in the orchard along with their annual frequency (Question 6); Definition of

fertilization (intensity, total area, annual number, form of application, and kind of fertilizer in Question 8); Definition of irrigation (intensity, total area, annual number, form of application, and duration per application in Question 9); Definition of pruning (intensity, total area, annual number, form of application, in Question 10); Definition of frost protection (intensity, total area, annual number, form of application, fuel/energy source, and duration per application in Question 11); Other Cultivation Measures (Open Answer in Question 12)

d. Other Emissions: The relative data are obtained through Sub-Components III Question 10.
e. Agrochemicals Consumption: The relative data are obtained through Sub-Components IV, and relate to the enumeration of indicators relating to observed biodiversity in the relative orchards and the draw of conclusions on unfavourable impacts of the orchards cultivation to the natural environment. These data regard the: Identification of the agrochemicals applied in the orchard along with their annual frequency (Question 13); Definition of herbicide usage (Volume, total area, annual number, form of application, and duration of application in Question 14); Definition of pesticide usage (Volume, total area, annual number, form of application, and duration of application in Question 15); Other Agrochemicals Usage (Open Answer in Question 16)
f. Fuel and Energy Consumption and Cost:

2.5 Questionnaires Filling

Since the method selected for the questionnaires administration is that of self-completion, there is no need for dedicated interviewers. Even though such a role is absent there is another key role that of the Introducer of the questionnaires. This role will be performed by the Reception Quality Control personnel of the collaborating industries, which is of Academic education and with an already establish routine of communication with the respondents, part of which will be the Questionnaires handing, and introduction.

2.6 Questionnaires Proofing

This task will be performed through a combinatorial application of:

a. Data cross fit (e.g. Fuel Consumption vs Hours of machinery operation).
b. Confirmation contact with the responders.

2.7 Data Processing

After the fieldwork, data from the questionnaires will be processed, analyzed, and presented in the form of a report. The process involves the following activities:

<u>Questionnaires Data Process</u>

i. Checking and Editing of Questionnaires was performed upon arrival to AUA. AUA personnel routinely edited the questionnaires to correct errors, omissions, or logical inconsistencies in filling them. Before the data process, a complete re-check and editing were performed in order to clean the data.

ii. Categorization of responses, was performed according to the fundamental representative TC. Thus five cluster of data were compiled, namely for Olive, Orange, Peach, Apple, and Almond.

iii. Data Coding, which involves the transcription of the questionnaires data in numeric values in a spreadsheet. The relative excel files are attached as ***Supplement D***

<u>Data Analysis</u>

i. Data proofing, as previously described.

ii. Data fitting, during which, the questionnaires of the Five Crops, were attributed among the Four TC categories. Thus were formed the relative excel files are attached as ***Supplement E***

iii. Data editing performed in the previous files relating to missing values (e.g. ha in a cultivation measure spreadsheet), and incorrectly reported volumes (e.g. grams instead of kg).

iv. Data analyses during which, were calculated averages, percentages, proportions and ratios, of the various data labels.

Data Presentation & Interpretation

Two basic approaches are involved in the presentation and interpretation of data from structured questionnaires. The analysis of close-ended questions, which are more or less quantitative, involves:

i. First summarizing the information in a tabular or statistical form, and
ii. Describing in words or text the information presented.

The presentation will be descriptive for the Biodiversity Questionnaire, and analytical for the Input Questionnaire. Simple statistical procedures that are used in most studies include calculating averages, percentages, proportions and ratios.

The last stage of the data presentation is interpretation. It involves explaining the underlying reasons for the findings, and drawing implications from them. The discussion can highlight the significance of the main findings by contrasting them with other studies on the subject. Based on the findings and discussion, recommendations for further action can be made. This may involve the introduction of interventions or the suggestion of best available practices identified through the survey.

3. Results & Discussion

3.1 Participation Results

The originally prescribed target of 50 Questionnaires per kind of TC was achieved with respect to received questionnaires. The initial screening of the received questionnaires revealed numerous lacking the Declaration forms that were discarded. The relative figures are given in follow for each TC category along with the relative average agronomical characters of each TC and a small discussion on the initial stages of data analyses. Before the detailed presentation though, a significant detail must be mentioned that relates to the Data fitting process.

In specific the Almond questionnaires a typical representative of the Deciduous Extensive TCs were of unacceptably low volume (3 completed questionnaires). To overcome this obstacle during data fitting the Apple and Peach Questionnaires that had reached this level (29 and 34 respectively) were pre-assessed against the kind and number of cultivation measures and were further divided among the Deciduous Intensive and Extensive TC categories. The relative figures for Apple are 13 orchards categorized as Extensive and 16 as Intensive, and for Peach 9 and 25 respectively. The relevant spreadsheets of TC categories are presented in Supplement E.

3.1.1. Evergreen Extensive TCs

In total 64 questionnaires regarding olive yards were received. Among them 17 did not included the Declaration Form there fore were discarded. Data Coding of the remaining 47 Questionnaires revealed 6 more that did not included essential data (e. g. Area of orchards), or had no response to more than three quarters of the Questions, which were not included in the final spreadsheet of Supplement E.

A data analysis was performed in the included 41 questionnaires originating from all around Greece. The initial results on the Evergreen Intensive Orchard agronomical characters indicate an average plantation density of **190 trees per hectare,** though extremities like 50 to 10 trees per hectare did occurred.

Cross fitting of the results within this TC category was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 4,02 L consumption of fuel per hour of operation was checked against literature data and found within a marginal deviation.

3.1.2. Evergreen Intensive TCs

In total 72 questionnaires regarding orange orchards were received. Among them 21 did not included the Declaration Form there fore were discarded. Data Coding of the remaining 51 Questionnaires revealed 3 more that did not included essential data (e. g. Area of orchards), or had no response to more than three quarters of the Questions, which were not included in the final spreadsheet of Supplement E.
Cross fitting of the results within this TC category was performed through targeted verification of declarations through phone contact.
A data analysis was performed in the included 48 questionnaires originating from the Region of Peloponnese. The initial results on the Evergreen Extensive Orchard agronomical characters indicate an average plantation density of **524 trees per hectare,** with no extremities occurring.

3.1.3. Deciduous Extensive TCs

This TC category is of combinatorial nature. The questionnaires included herein belong to various crops; in specific 3 regard almonds, 9 regard peaches, and 13 correspond to apples. In total 29 questionnaires regarding the present TC category were subjected to proofing. Cross fitting was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 10,08 L consumption of fuel per hour of operation was checked against literature data and found within full compliance. The final spreadsheet of the present TC category is included in Supplement E.
A data analysis was performed in the included 29 questionnaires originating mostly from the Regions of W. and C. Macedonia. The initial results on the Deciduous Extensive Orchard agronomical characters indicate an average plantation density of **351 trees per hectare,** with no extremities occurring.

3.1.4. Deciduous Intensive TCs

This TC category is of combinatorial nature. The questionnaires included herein belong to peaches, represented by 23 Orchards and apples by 16 orchards. In total 29 questionnaires regarding the present TC category were subjected to proofing. Cross fitting was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 7,72 L consumption of fuel per hour of operation was checked against literature data and found within full compliance. The final spreadsheet of the present TC category is included in Supplement E.

A data analysis was performed in the included 29 questionnaires originating mostly from the Regions of W. and C. Macedonia. The initial results on the Deciduous Extensive Orchard agronomical characters indicate an average plantation density of **695 trees per hectare,** though 2 extremities reporting tens of thousands trees per hectare did occurred, but were omitted from the herein result as they affected unevenly the average.

3.2 Biodiversity Results

This part of the survey is rather focussed on the biodiversity records and their comparative presentation and discussion of all TCs within the respective Life Kingdom results. The fundamental philosophy of this section of the survey presented a binary scope: first to detect the farmers perception on biodiversity, and consequently to enumerate the occurrence of biodiversity through sightings accounting by the farmers. The Biodiversity Questionnaire, presented in Supplement B, also served two masters. The initial sheet clarified the field visits details, which are presented in **Table 3.2**, and are of crucial importance for the definition of the farmers sighting “window”. **These results, combined with the average distances from the farm to the residence and market, may contribute further to the allocation of the fuels consumed for transportation and cultivation measures, thus further delineating the farm’s fuel consumption.**

Table 3.2: Duration and annual frequency within the seasonal and daily distribution of field visits (D: daily, W: weekly, M: monthly, Mrn: morning, Nn: noon, Af: afternoon).

TC	Sp			Su			Fa			Wi			Duration (h)			Time		
	D	W	M	D	W	M	D	W	M	D	W	M	3-	3-6	6+	Mrn	Nn	Af
EI	31%	64%	28%	28%	49%	46%	51%	64%	5%	62%	54%	8%	77%	41%	5%	95%	13%	56%
EE	26%	46%	28%	33%	36%	31%	33%	46%	21%	23%	33%	33%	62%	26%	18%	95%	5%	26%
DI	66%	32%	2%	83%	15%	2%	32%	59%	10%	2%	34%	63%	46%	46%	7%	59%	5%	39%
DE	64%	36%	0%	92%	8%	0%	32%	68%	0%	12%	36%	52%	20%	76%	4%	96%	4%	36%

Beyond this previously defined time frame of the observations, which resolute so far the dominance of morning visits in all but the DI, TCs, that mostly last up to six hours. The seasonal distribution of the daily visits indicates a correlation with the biology of the crops; the evergreen orchards visits were located mostly in Fall and Winter, and the deciduous orchards mostly in Spring and Summer.

The structuring of the biodiversity sighting questions incorporated both visual and common linguistic descriptions. This binary definition worked well since the completion rate of the Biodiversity far exceeds that of the Cultivation Input questionnaires. The major categories of Biodiversity incorporated the three macroscopic Kingdoms of Life. Within each Kingdom were established artificial (not systematic) and easily recognizable clusters in order to enhance the understanding of the farmers.

In this respect within the Animal Kingdom four clusters were formed: a) Mammals, further distinguished in relation to their feeding habits to Carnivores, Herbivores, and Omnivores; b) Birds, further distinguished in Raptors, Migratory birds, Seabirds, Domestic and Indigenous; c) Reptiles, including the categories of Snakes, Lizards, and Turtles; d) Insects, further delineated to Beetles, Flies, Bees, Grasshoppers, and Butterflies.

Similarly, within the Plants Kingdom were formed also four clusters, with respect to growth patterns: a) Annuals, in which 8 categories were included separated by the form of their flowers; b) Perennial Herbaceous, which incorporated 3 main categories; c) Shrubs (woody), further distinguished also with respect to their flower form; d) Trees, separated in Conifers, Evergreen Broadleaved and Deciduous.

Finally, the Mushrooms were delineated in four major categories related to their carposomas: a) Grilled, e.g. Agaricus sp.; b) Sponged like, e.g. Boletus sp.; c) Solid, e.g. Tuber sp.; d) Sphaerical, e.g. Lycoperdon sp.

The presentation of the results is performed through an Average per hectare Sighting indicator, which depicts the relevant biodiversity occurrence with respect to the area of observation.

3.2.1. Fauna

The animal sightings as expected were rather scarce occurring in most of the TC categories once in every five or more visits. A notable exception indicating the value of the respective TC as shelter providers regards the Evergreen Extensive TCs, in which almost 1/3 of the farmers declared that he comes to visual contact with animals every time he visits his fields.

Another notable remark relates to the data presented in Table 3.2 from which is indicated the season that daily visits prevail and therefore certain assumptions maybe drawn on the reported animal sightings. In specific, the Evergreen TCs that present a daily visit pattern within Fall and Winter, and which have been reported to comprise valuable wild life shelters, will be further upgraded under the consideration that these seasons present a minimum activity peak for birds, reptiles, and insects. On the other hand the comparable figures reported for the Deciduous crops maybe explained by the season of the observations that facilitates animal activities.

Table 3.2.1: Animal sighting frequency, total number, and average per ha.

TC	Frequency			Mammals	Birds	Reptiles	Insects
	Every Time	Once in 5 - Vis.	Once in 5 + Vis.				
EI	8%	44%	47%	54	84	93	126
	Sighting per ha:			**0,99**	**1,54**	**1,70**	**2,30**
EE	27%	54%	19%	119	161	123	268
	Sighting per ha:			**1,17**	**1,59**	**1,21**	**2,64**
DI	9%	50%	41%	60	119	119	197
	Sighting per ha:			**0,93**	**1,84**	**1,84**	**3,05**
DE	0%	63%	37%	29	39	61	65
	Sighting per ha:			**0,52**	**0,69**	**1,09**	**1,16**

In relation to the efficacy of the orchards as wild life shelters, keeping in mind the previous conclusions on the season of observations, both evergreen TC categories outperform the relative Deciduous. This finding may be explained by the biology of the trees, since the evergreen provide a year round land cover that protects animals from the elements and provides also protection against the predators.

3.2.2. Flora

Plant sightings are more closely related to the agricultural practices performed within the orchards boundaries. More over the year round land cover provided by the evergreen TCs has also an effect to the below canopy vegetation since it blocks a significant amount of sunlight, but also offers a protective environment, increasing the temperature in the cold months and offering humidity during the hot dry season.

The result on plant sighting frequencies was rather uniform indicating their landlocked nature. In specific in all TCs the sightings were reported to occur either in each visit, or every 5 or less visits, with notable exceptions the two Deciduous TC categories, in which a small percent of sightings occurred once in every 5 or more visits.

Table 3.2.2: Plant sighting frequency, total number, and average per ha.

TC	Frequency Every Time	 Once in 5 - Vis.	 Once in 5 + Vis.	Annual	Perenial	Bush	Trees
EI	64%	36%	0%	115	42	50	25
	Sighting per ha:			**2,10**	**0,77**	**0,91**	**0,46**
EE	68%	32%	0%	252	89	85	89
	Sighting per ha:			**2,39**	**0,85**	**0,81**	**0,85**
DI	50%	45%	5%	184	47	34	8
	Sighting per ha:			**2,58**	**0,66**	**0,48**	**0,11**
DE	77%	14%	9%	52	14	21	18
	Sighting per ha:			**0,77**	**0,21**	**0,31**	**0,27**

As also for the animals the season of observation plays a vital role in the sightings reported. But in the present case there is also another significant variant, the ecological zone of the orchards. In specific Evergreen orchards occupy lowlands, where the limiting factor for vegetation is the hot dry weather occurring mostly during summer, while Deciduous orchards occupy high landlocked grounds, were the limiting factor is the fierce cold during the winter months.

Taking in consideration this facts is easy to understand that the prevailing agricultural practices that affect the ground vegetation may be defined as tillage and herbicide application. The first of these cultivation measures is applied mostly in the Extensive orchards explaining thus the limited reported average sightings in DE orchards. More over in the deciduous TCs, in which most of the activity is concentrated during the Spring and Summer months there is a necessity for a clear ground in order to facilitate the frequent and safe visits of the farmers.

3.2.3. Fungi

Mushroom occurrence in orchards is more closely related to the steady provision of Dead Organic Matter, as this is the fundamental substrate for their feeding and development. Also essential for their appearance is the occurrence of high humidity that mostly occurs during the transition seasons of Spring and Fall.

Within previous context can be easily explained the reported sighting frequencies, which escalate from the Evergreens to the Deciduous crops, mostly as a result of the steady annual supply of literfal in the form of trees foliage.

The seasonal distribution of the sightings is also explained by the additional prerequisite conditionality for high humidity, indicating as prevailing seasons of observation Spring and Fall. Again here the ecological zone of the evergreen TC suggest a significant sighting occurrence in the winter months during which the temperature is more mild and a significant amount of precipitation is located.

Table 3.2.3: Mushroom sighting frequency, seasonal distribution, total number, and average per ha.

TC	Frequency			Season				Mushrooms
	Every Time	Once in 5 - Vis.	Once in 5 + Vis.	Sp	Su	F	W	
EI	8%	46%	46%	0%	0%	66%	34%	58
Sighting per ha:								**1,30**
EE	8%	31%	62%	12%	3%	55%	30%	73
Sighting per ha:								**0,97**
DI	15%	58%	35%	15%	0%	79%	45%	68
Sighting per ha:								**1,04**
DE	43%	35%	22%	17%	0%	61%	22%	58
Sighting per ha:								**0,81**

On the other hand the Deciduous orchards prevailing seasons of daily visits (Spring and Summer) explains the slightly decreased average sightings per hectare.

3.3 Cultivation Inputs Results

The cultivation Inputs results were focussed around Questions 17 and 18 responses of the relevant Questionnaire template. These questions paired with the relevant orchard area provided the fundamental figures of Fuel, Energy, and Agrochemicals consumption per hectare, which were of indispensable value for the accounting of CO_2 emissions.

Further more the incorporation of the Annex II table 3.3.2 to the stated forms of cultivation measures along with primary data of the questionnaires made possible the attribution of specific machinery operation hours per hectare and cultivation measure for the diesel consumption.

Gasoline consumption could not be delineated within cultivation measures, as it was more sporadically mentioned, and could only be attributed to the operation of hand held equipment (e.g. chainsaws, string trimmers etc).

In a relevant manner the average electricity consumption per hectare was uniformly correlated with irrigation since the only electricity powered machinery is the irrigation pump. A notable exception regards the Evergreen Intensive TCs, in which the frost protection, applied through irrigation sprinklers, heating or combination of them was also a significant consumer of electricity.

Indirect GHG emissions in the form of CO_2 equivalent emissions were calculated against the average consumption of Nitrogen fertilizer per hectare. Further delineation within different application forms was not feasible at the present time since in most cases it was detected a nominal deviation from the unit scale considering the volume and/or weight of application within each fertilization application form.

3.3.1. Evergreen Extensive TCs

Extensively cultivated evergreen orchards present an unequal cultivation inputs profile, which is mostly centred on Diesel and Fertilizers. Even though unequal this profile, presented in Table 3.3.1.1, indicates that this TC category presents the more sustained inputs.

Table 3.3.1.1: Fuel, Energy and Agrochemical Consumption of Evergreen Extensive TCs (D: diesel, G: gasoline, F: fertilizer, E: electricity)

Fuel	Consumption (L/ha)	Source	Consumption per ha
D	188,00	F	316 Kg
G	6,60	E	30 KWh

These figures unique among all TCs indicate a very narrow penetration of alternative options for the farmers. In specific, both fuel and energy resources can be narrowed down to Diesel, while Fertilization occurs mostly in the form of solid Fertilizer application.

A significant disadvantage of the EE TC is the small penetration of Electricity in the Orchards energy mixture. This can be easily explained by the performed cultivation measures that are presented in the following Table 3.3.1.2.

Table 3.3.1.2: Hours of Machinery operation per Hectare and Cultivation measure in Evergreen Extensive TCs.

Machinery	Tillage	Fertilization	Irrigation	Plant Protection	Total	Fuel Consumption (L/h)
h/ha	1,68	1,26	23,86	20,02	46,82	4,02
% of Total	3,59%	2,69%	50,96%	42,76%	100%	

The distribution of fuel consumption within the EE TCs cultivation measures indicates as dominant contributors of Carbon emissions the Irrigation and Plant Protection measures among which is almost equally divided above 90% of the machinery operation. On the other hand the form of this cultivation measures reflects low fuel consumption per hour of operation since they do not require an excessive power generation.

Cross fitting of the results within this TC category was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 4,02 L consumption of fuel per hour of operation was checked against literature data and found within a marginal deviation. It must be noted that this low consumption may be attributed to the prevailing of irrigation as the major contributor in machinery operation. This cultivation measure does not require the movement of the tractor and therefore concludes to the observed minimum fuel consumption per hectare.

3.3.2. Evergreen Intensive TCs

Intensively cultivated evergreen orchards present an equal cultivation inputs profile, which is mostly centred on Electricity and Fertilizers. Even though equal this profile, presented in Table 3.3.2.1, indicates that this TC category presents the more balanced inputs.

Table 3.3.2.1: Fuel, Energy and Agrochemical Consumption of Evergreen Intensive TCs (D: diesel, G: gasoline, F: fertilizer, E: electricity).

Fuel	Consumption (L/ha)	Source	Consumption per ha
D	187,50	F	625 Kg
G	12,50	E	428 KWh

These figures unique among all TCs indicate a very wide penetration of alternative options for the farmers. In specific, both fuel and energy resources may be considered as equal contributors in the EI TCs energy mixture, while Fertilization occurs mostly in the form of solid Fertilizer application.

A significant advantage of the EI TC is the implication of Electricity in the Orchards energy mixture. This fact along softens the impacts of the performed frost protection measures on carbon emissions. More over the expansion of the electricity utilization in the irrigation also contributes to the observed low among TCs of diesel consumption. The distribution of the machinery operation and the consequent diesel consumption distribution among the performed cultivation measures are presented in the following Table 3.3.2.2.

Table 3.3.2.2: Hours of Machinery operation per Hectare and Cultivation measure in Evergreen Intensive TCs..

Machinery	Tillage	Fertilization	Irrigation	Plant Protection	Total	Fuel Consumption (L/h)
h/ha	2,75	2,01	12,45	27,45	44,66	4,20
% of Total	6,16%	4,50%	27,88%	61,46%	100%	

The distribution of fuel consumption within the EI TCs cultivation measures indicates as dominant contributors of Carbon emissions the Irrigation and Plant Protection measures which combinatory comprise almost 90% of the machinery operation. Even though the sum of these two cultivation measures is paired with the EE TCs, the distribution within them is quite different. Here the dominant role in machinery operation is allocated to plant protection measures mostly in the form of Spraying. The form of this cultivation measures reflects a low fuel consumption per hour of operation since they do not require an excessive power generation.

Cross fitting of the results within this TC category was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 4,2 L consumption of fuel per hour of operation was checked against literature data and found within a marginal deviation.

3.3.3. Deciduous Extensive TCs

Extensively cultivated deciduous orchards present also an equally distributed cultivation inputs profile, which is mostly centred on Diesel and Fertilizers, with Electricity and Gasoline to follow close. Even though equilibrated this profile, presented in Table 3.3.3.1, indicates that this TC category presents the more balanced inputs among all TC categories.

Table 3.3.3.1: Fuel, Energy and Agrochemical Consumption of Deciduous Extensive TCs (D: diesel, G: gasoline, F: fertilizer, E: electricity).

Fuel	Consumption (L/ha)	Source	Consumption per ha
D	470,00	F	284 Kg
G	100,00	E	113 KWh

These figures indicate the more balanced energy mixture profile. In specific, both fuel and energy resources can be narrowed down to Diesel and Electricity, while Fertilization occurs mostly in the form of solid Fertilizer application, but also in the form of foliage application.

The observed increased consumption of Gasoline cannot be attributed to any cultivation measure and maybe correlated with the transfer of product to the farmer markets, and/or to the transport from and to the residence of the farmers.

A significant advantage of the DE TC is the balanced form of the Orchards energy mixture. This can be easily explained by the performed cultivation measures that are presented in the following Table 3.3.3.2.

Table 3.3.3.2: Hours of Machinery operation per Hectare and Cultivation measure in Deciduous Extensive TCs..

Machinery	Tillage	Fertilization	Irrigation	Plant Protection	Total	Fuel Consumption (L/h)
h/ha	3,26	2,65	26,67	14,03	46,61	10,08
% of Total	6,99%	5,69%	57,22%	30,10%	100%	

The distribution of fuel consumption within the DE TCs cultivation measures indicates as dominant contributors of Carbon emissions the Irrigation and Plant Protection measures which combinatory comprise almost 90% of the machinery operation. Even though the sum of these two cultivation measures is paired with the Evergreen TCs, the distribution within them is quite different. Here the dominant role in machinery operation is allocated to irrigation measures. The significant contribution though of tillage in machinery operation reflects high fuel consumption per hour of operation since they do require an excessive power generation.

Cross fitting of the results within this TC category was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 10,08 L consumption of fuel per hour of operation was checked and found fitting against literature data.

3.3.4. Deciduous Intensive TCs

Intensively cultivated deciduous orchards present also an equal cultivation inputs profile, which is mostly centred on Diesel and Fertilizers, with Electricity and Gasoline to follow close. Even though equal this profile, presented in Table 3.3.4.1, indicates that this TC category presents the more excessive inputs.

Table 3.3.4.1: Fuel, Energy and Agrochemical Consumption of Deciduous Intensive TCs (D: diesel, G: gasoline, F: fertilizer, E: electricity).

Fuel	Consumption (L/ha)	Source	Consumption per ha
D	583,00	F	516 Kg
G	334,00	E	163 KWh

These figures unique among all TCs indicate the DI as the most demanding in fuel consumption. In specific, both Diesel and Gasoline consumption are the highest reported among all TCs, as also fertilizer application which, though was seconded to this of the EI TCs.

The observed increased consumption of Gasoline cannot be attributed to any cultivation measure and maybe correlated with the transfer of product to the farmer markets, and/or to the transport from and to the residence of the farmers.

A significant disadvantage of the DI TC is the small penetration of Electricity in the Orchards energy mixture, when compared against the excessive fuel consumption. This can be easily explained by the performed cultivation measures that are presented in the following Table 3.3.4.2.

Table 3.3.4.2: Hours of Machinery operation per Hectare and Cultivation measure in Deciduous Intensive TCs..

Machinery	Tillage	Fertilization	Irrigation	Plant Protection	Total	Fuel Consumption (L/h)
h/ha	0	3,25	53,61	18,66	75,52	7,72
% of Total	0,00%	4,30%	70,99%	24,71%	100%	

The distribution of fuel consumption within the DI TCs cultivation measures indicates as dominant contributors of Carbon emissions the Irrigation and Plant Protection measures which combinatory comprise almost 95% of the machinery operation. Even though the sum of these two cultivation measures is paired with the Evergreen TCs, the distribution within them is quite different. Here the dominant role in machinery operation is allocated to irrigation measures, which translates in low fuel consumption per hour of operation since they do not require an excessive power generation.

Cross fitting of the results within this TC category was performed against the total diesel fuel consumption per hectare, paired with the total diesel machinery hours of operation. The relative figure of 10,08 L consumption of fuel per hour of operation was checked and found fitting against literature data.

4. Supplements

Supplement A

CLIMATREE's Survey Participation Form

LIFE+ CLIMATREE Field Survey

LIFE+ CLIMATREE is an EU co-funded project aiming to Climate Change Mitigation. The approach chosen towards this objective targets the orchards crop land, allas TreeCrops (TC), which are perceived as potential Carbon Shinks.

The establishment of TC as Carbon Deposits is a complexed and nefarious task since it includes innovative perspectives, requiring the development of case specific methodologies, which in turn must be transformed in user-friendly e-tools, and succesfully communicated to the policy makers. Even though this goal seems unreachable, is of crucial importance for the Mediterranean primary sector structuring, because almost half of the crop land there is covered with orchards.

The recognition of TC as CCM agents, also enhancing the Ecosystems Services provision, may provide National authorities with arguments on their GHG accounting and monitoring efficacy, while will also advocate to the multifunctional role of rural areas depending of course upon their custodians - Farmers - motivation. In the course of establishing TC as Carbon Deposits, the fundamental task regards the accounting of Carbon Balance within the TC perimeter.

In order to perform this task the provision of realistic figures on the cultivation inputs by the custodian/farmers consist the most impregnable foundation. Please give 5 minutes of your valuable time in order to foster your plantations future perspectives.

DISCLAIMER

The undersigned, declares that present document and any information transmitted with it are confidential and intended solely for the use of the Agricultural University of Athens to which they are addressed. Agricultural University of Athens will not re-transmit it, disclose its contents, or reveal any personal data contained herein. Agricultural University of Athens may use and/or publication of processed data, taking consideration of my previous statement.

Name:

Telephone: E-mail:

Date:

Sign

Supplement B

CLIMATREE's Biodiversity Questionnaire

Orchards Biodiversity Survey

Tree Crop: Orange	Date:………………………………………………………….
Total Area:……………………………	Region:……………………………………………………….
Number of Fields:……….……………	Plantation Density (plants/1000m^2):…………………………

Observation Status

1. How often do you visit your fields?

a. Spring:	Daily:………..	Weekly:………	Monthly:…….
b. Summer:	Daily:………..	Weekly:………	Monthly:…….
c. Autumn:	Daily:………..	Weekly:………	Monthly:…….
d. Winter:	Daily:………..	Weekly:………	Monthly:…….

2. How long lasts an average visit?

a. 1 to 3 hours	☐
b. 3 to 6 hours	☐
c. more than 6 hours	☐

3. What time of the day do you visit your fields?

a. Morning	☐
b. Noon	☐
c. Afternoon	☐

Fauna Records

4. Have you noticed the presence of animals in your fields during your visit?

a. Yes	☐
b. No	☐

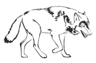
5. If Yes, how often?

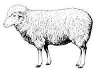
a. Each Time	☐
b. Some Times (1 sight every 5 visits)	☐
c. Rarely (1 sight every 5 or more visits)	☐

6. If Yes, what kind of Animal?

a. Mammal	☐
b. Bird	☐
c. Reptile	☐
d. Insect	☐
e. Other (please specify)	☐

7. Mammals sighted are:


a. Carnivore — Number of Species:


b. Herbivore — Number of Species:


c. Omnivore — Number of Species:

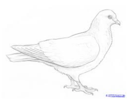
d. Other (please specify) — Number of Species:

8. Birds sighted are:


a. Raptors — Number of Species:


b. Migratory — Number of Species:

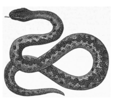

c. Seabirds — Number of Species:

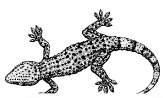

d. Domestic — Number of Species:


e. Indigenous — Number of Species:

f. Other (please specify) — Number of Species:

9. Reptiles sighted are:

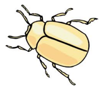

a. Snakes — Number of Species:


b. Lizards — Number of Species:


c. Turtles — Number of Species:

d. Other (please specify) — Number of Species:

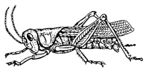
10. Insects sighted are:



a. Beetles ☐ Number of Species:

b. Flies ☐ Number of Species:

c. Bees ☐ Number of Species:



d. Grasshoppers ☐ Number of Species:

e. Butterflies ☐ Number of Species:

f. Other (please specify) ☐ Number of Species:

Flora Records

11. Have you noticed the presence of plants in your fields during your visit?

a. Yes ☐

b. No ☐

12. If Yes, how often?

a. Each Time ☐

b. Some Times (1 sight every 5 visits) ☐

c. Rarely (1 sight every 5 or more visits) ☐

13. If Yes, what kind of plant?

a. Annual ☐

b. Perennial ☐

c. Bush ☐

d. Tree ☐

e. Other (please specify) ☐

14. Annual plants sighted are:


a. Grasses ☐ Number of Species:

b. Flowering

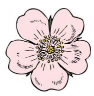

i. Daisy ☐ Number of Species:


ii. Umbels ☐ Number of Species:


iii. Tubes ☐ Number of Species:


iv. Cross ☐ Number of Species:

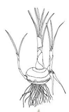

v. Insect ☐ Number of Species:


vi. Rose ☐ Number of Species:


vii. Bell ☐ Number of Species:

viii. Other ☐ Number of Species:

15. Perennial plants sighted are:

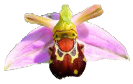
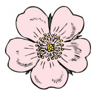
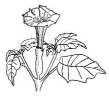

a. Bulbous ☐ Number of Species:


b. Herbaceous ☐ Number of Species:


c. Woody ☐ Number of Species:

d. Other ☐ Number of Species:

16. Shrubs sighted flowers are:

	a. Daisy	☐	Number of Species:
	b. Umbels	☐	Number of Species:
	c. Tubes	☐	Number of Species:
	d. Cross	☐	Number of Species:
	e. Insect	☐	Number of Species:
	f. Rose	☐	Number of Species:
	g. Bell	☐	Number of Species:
	h. Other	☐	

17. Trees sighted are:

	a. Evergreen		
	i. Conifer	☐	Number of Species:
	ii. Broadleaf	☐	Number of Species:
	b. Deciduous	☐	Number of Species:
	c. Other	☐	Number of Species:

Fungal Records

18. Have you noticed the presence of mushrooms in your fields during your visit?

a. Yes ☐

b. No ☐

19. If Yes, how often?

a. Each Time ☐

b. Some Times (1 sight every 5 visits) ☐

c. Rarely (1 sight every 5 or more visits) ☐

20. Mushroom sighting is in:

a. Autumn ☐

b. Winter ☐

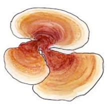
c. Spring ☐

d. Summer ☐

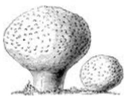
21. Mushroom sighted are:

a. Grilled ☐ Number of Species:

b. Porous ☐ Number of Species:



c. Solid ☐ Number of Species:



d. Globose ☐ Number of Species:

e. Other (please specify) ☐ Number of Species:

Supplement C

CLIMATREE’s Cultivation Measures Questionnaire

Orchards Inputs Survey

Tree Crop: Orange

Average Distance of Fields from Home (in km):__________________

Average Distance of Fields from Market (in km):__________________

Equipment Status

1. What kind of Equipment do you use for Orange Cultivation

	Yes	No	Number
a. Tractor			
b. Truck			
c. Pump			
d. Chainsaw			
e. Other			

2. Your tractor is:

	Age (Years)	HorsePower (HP)	Fuel (Gasoline/Petrol)
a. Tractor 1			
b. Tractor 2			
c. Tractor 3			

3. Your Truck is:

	Age (Years)	HorsePower (HP)	Fuel (Gasoline/Petrol)
a. Tractor 1			
b. Tractor 2			
c. Tractor 3			

4. Your Pump is:

	Age (Years)	Pressure (inches)	Fuel (Gas/Pet/Electricity)
a. Pump 1			
b. Pump 2			
c. Pump 3			

5. Your Chainsaw/Other is:

	Age (iYears)	HorsePower (HP)	Fuel (Gas/Pet/Electricity)
a. Chainsaw 1			
b. Chainsaw 2			
c. ________ 1			
d. ________ 2			

Cultivation Measures

6. In Orange Cultivation I practice:

	Yes	No	Applications Yearly (Number)
a. Tillage			
b. Fertilization			
c. Irrigation			
d. Pruning			
e. Heating			
f. Other			

7. Tillage applications are:

	Depth (cm)	Area (ha)	Applications Yearly (Number)
a. Tillage 1			
b. Tillage 2			
c. Tillage 3			

8. Fertilization applications are:

	Vol (Kg/ha)	Area (ha)	Form (Org/Chem)	App (S/I/L)	Annual (Nr)
a. Fertilization 1					
b. Fertilization 2					
c. Fertilization 3					

9. Irrigation applications are:

	Vol (Kg/ha)	Area (ha)	Form (D/S/C)	Dur/ion (h)	Annual (Nr)
a. Irrigation 1					
b. Irrigation 2					
c. Irrigation 3					

10. Pruning applications are:

	Int/ty (S/L/)	Area (ha)	Form (H/M)	Annual (Nr)
a. Pruning 1				
b. Pruning 2				
c. Pruning 3				

11.Heating applications are:

	Duration (h)	Area (ha)	Form (H/W/N)	Fuel (G/P/E)	Annual (Nr)
a. Heating 1					
b. Heating 2					
c. Heating 3					

12. Other applications are:

Describe shortly

a. ________

b. ________

c. ________

Agrochemicals Usage

13. What kind of Agrochemicals do you use in Orange Cultivation

	Yes	No	Annual (Nr)
a. Herbicides			
b. Pesticides			
c. Other			

14. Herbicides are:

	Vol (Kg/ha)	Area (ha)	Application (I/L/S)	Dur (h/ha)	Annual (Nr)
a. Herbicide 1					
b. Herbicide 2					
c. Herbicide 3					

15. Pesticides are:

	Vol (Kg/ha)	Area (ha)	Application (I/L/S)	Dur (h/ha)	Annual (Nr)
a. Pesticide 1					
b. Pesticide 2					
c. Pesticide 3					

16. Other Agrochemicals are:

Describe shortly

a. __________

b. __________

c. __________

d. __________

e. __________

Yearly Consumption

17. Power Supply

	Quantity (m^3 - L)	Value (€)
a. Gas		
b. Gasoline		
c. Petrol		
d. Electricity		

18. Agrochemicals

	Quantity (Kg)	Value (€)
a. Fertilizer Ch		
b. Fertilizer Or		
c. Pesticide		
ci. _________		
cii. ________		
ciii. _______		
d. Herbicide		
di. _________		
dii. ________		
diii. _______		
e. Other		
ei.__________		
eii._________		
eiii. ________		

Annex IV

Measurement of Variables affecting carbon sequestration

1. Introduction

One of the most significant tasks of the developed methodology is the enumeration of annual gross biomass production of the plantations. The here-included works were designed to provide all the relevant data in a concise and uniform data set, presenting minimum deviations as a result of experimental errors derived mostly by:

a. Humans carrying the tasks,
b. Differentiated methodological approaches of previous studies,
c. Alteration of climatic zones within previous studied crops.

The major limitation on the enumeration of annual biomass production is that it should be reflected upon the LCA's functional unit, which has been defined as one hectare of land. This prerequisite counteracts with the nature of the desired figure, which can be easily measured on the biological unit of tree. The approach followed towards the resolution of this inconsistency is presented in Figure 1, and shortly discussed in follow.

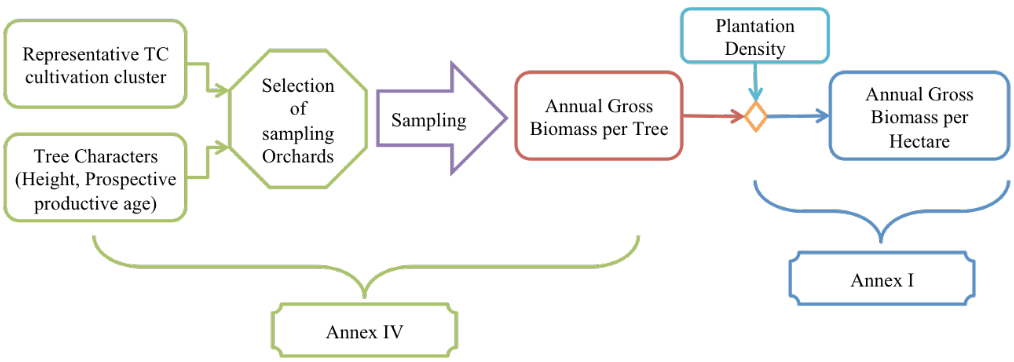


Figure 1: Annex IV tasks semantic diagram

The followed approach presented as starting point the definition of the each representative crop's cluster, which in turn provided the description of the desirable sampling pools in the terms of tree size and plantations prospective lifespan. Once this crucial information was available Orchards presenting the desirable characteristics were screened and the 3 most representative plants for each of the 5 representative tree crops was selected for sampling. Once the sampling was complete, according to the methodology described in follow, the sample figures were upgraded to figures per tree.

The consequent step of the Figure 1 relating to the correlation of the annual biomass produced per tree to the LCA's functional unit of land area, is performed through the methodology described in Annex I, implicating the average plantation density of the cultivation cluster of interest.

2. Methodology

2.1. Sampling Pools

Malus sylvestris: The sampled orchard was located in the premises of AUA, with a plantation density of 350 trees/hectare. The three trees sampled were of:

Apple 1:

a. Height: 4,5 m
b. Age: 25
c. Cultivar:

Apple 2:

a. Height: 5 m
b. Age: 25
c. Cultivar:

Apple 3:

a. Height: 5,5 m
b. Age: 25
c. Cultivar:

Amygdalus communis: The sampled orchard was located in the premises of AUA, with a plantation density of 300 trees/hectare. The three trees sampled were of:

Almond 1:

a. Height: 5,5 m
b. Age: 15
c. Cultivar:

Almond 2:

a. Height: 6 m
b. Age: 24
c. Cultivar:

Almond 3:

a. Height: 5,5 m

b. Age: 67
c. Cultivar:

Olea europaea: The sampled orchard was located in the premises of AUA, with a plantation density of 300 trees/hectare. The three trees sampled were of:

Olive 1:

a. Height: 3,5 m
b. Age: 145
c. Cultivar: Koroneiki

Olive 2:

a. Height: 4 m
b. Age: 74
c. Cultivar: Lianolia

Olive 3:

a. Height: 5 m
b. Age: 67
c. Cultivar: Kalamon

Prunus persica: The sampled orchard was located in the premises of AUA, with a plantation density of 600 trees/hectare. The three trees sampled were of:

Peach 1:

a. Height: 2,5 m
b. Age: 12
c. Cultivar:

Peach 2:

a. Height: 2 m
b. Age: 15
c. Cultivar:

Peach 3:

a. Height: 3 m
b. Age: 17
c. Cultivar:

Citrus sinensis: The sampled orchard was located in the premises of AUA, with a plantation density of 400 trees/hectare. The three trees sampled were of:

Orange 1:

a. Height: 2,5 m
b. Age: 25
c. Cultivar:

Orange 2:

d. Height: 3 m
e. Age: 25
f. Cultivar:

Orange 3:

d. Height: 3 m
e. Age: 25
f. Cultivar:

2.2. Sampling Protocol

From each sampling point three samples were collected from various heights and orientations depicting the extremes and the average of the produced herbal tissues. In specific samples were consisted by:

a. Fruit: A constant 10% of each tree's total crop was sampled after harvesting; the final sample was dried according to the protocol of § 2.3.
b. Axial Growth:
    a. Annual shots with leaves: A constant 10% of each tree's total vegetation was sampled in the end of the vegetative season (Sep to Nov 2016) after through marking of each tree's annual shots (Mar-Apr 2016); the final sample was dried according to the protocol of § 2.3.
    b. Annual roots: A constant 10% of each tree's total rootlet was sampled in the end of the vegetative season (Sep to Nov 2017) after through marking of each tree's annual roots during transplantation (Mar-Apr 2017); the final sample was dried according to the protocol of § 2.3.
c. Radical Growth:
    a. Trunk and branches: A constant 1% of each tree's total wood tissue was sampled in the beginning of the vegetative season (Mar to Apr

2016), to provide a reference figure, which will be correlated by sampling in the beginning of the next vegetative season (Mar-Apr 2017); the final sample was dried according to the protocol of § 2.3.

b. Root: A constant 10% of each tree's total root tissue was sampled in the beginning of the vegetative season (Mar-Apr 2017), to provide a reference figure, which will be correlated by sampling in the end of the vegetative season (Sep-Oct 2017); the final sample was dried according to the protocol of § 2.3.

d. Pruning: A constant 100% of each tree's total vegetation was sampled in the end of the pruning (Mar-Apr 2016); the final sample was dried according to the protocol of § 2.3.

2.3. Dry Weight Measurement Protocol

The tissue moisture content may be expressed by weight as the ratio of the mass of water present to the dry to the dry weight of the tissue sample, or by volume as ratio of volume of water to the total volume of the tissue sample. To determine any of these ratios for a particular tissue sample, the water mass must be determined by drying the tissue to constant weight and measuring the tissue sample mass after and before drying. The water mass (or weight) is the difference between the weights of the wet and oven dry samples. The criterion for a dry tissue sample is the sample that has been dried to constant weight in oven at temperature between 100 – 110 ^{o}C (105 ^{o}C is typical). It should be noticed that this temperature range has been based on water boiling temperature and does not consider the tissue physical and chemical characteristics.

$$Dry\ Matter\ (\%) = [Final\ Net\ Dry\ Weight\ (g) / Initial\ Net\ Fresh\ Weight (g)] * 100\%$$

3. Results

The detailed results of the sampling are presented in Supplement A. The processed results are presented consequently in Table 1 as averages per tree crop category.

Table 1: Biomass Accumulation per year and tree crop category in Greece

TC	Biomass (Kg/tree, dry)				
	crop	shots	trunk	root	prunings
E.I.	23,50	7,90	2,60	1,50	3,18
E.E.	21,90	8,60	2,40	1,24	4,50
D.I.	7,70	3,73	1,29	0,70	2,41
D.E.	15,00	6,80	1,34	0,73	2,80

The relative figures for Italy and Spain were provided from the corresponding beneficiaries on the basis of either previous experimental efforts or literature surveys, and are presented consequently as Tables 2 and 3.

Table 2: Biomass Accumulation per year and tree crop category in Italy

		Vegetation (leaves)		**Root (annual production)**		**Pruning material**		**Yield**		**Cover crops**		**Thinning**	
	p ha^{-1}	**t d.m. ha^{-1}**											
Olive 1	150	1.54	(0.08)	0.32	(0.04)	2.81	(0.17)	2.07	(0.11)	0.37	(0.02)	n.a.	n.a.
Olive 2	330	1.47	(0.07)	0.50	(0.04)	2.20	(0.13)	7.24	(0.38)	soil tilled	n.a.	n.a.	n.a.
Apple*	3,333	2.36	(0.14)	1.90	(0.10)	2.36	(0.13)	9.19	(0.50)	1.09	(0.06)	n.a.	n.a.
Orange	660	3.00**	(0.17)	1.80	(0.06)	1.53	(0.09)	2.03	(0.10)	0.25	(0.01)	n.a.	n.a.
Peach	454 - 800	2.96**	(0.18)	1.41	(0.52)	1.40	(0.08)	3.04	(0.16)	1.58	(0.09)	0.24	(0.06)
Almond	278	1.85	(0.10)	0.38	(0.02)	1.34	(0.08)	1.20	(0.06)	n.a.	n.a.	n.a.	n.a.

Table 3: Biomass Accumulation per year and tree crop category in Spain

Spacing (m2)	**Age**	**Total Seasonal Net CO2 fixation**	**Comments**	**Yield**	**Pruning weight**	
6x3	mature orchard >20 years old	3855 kg/CO2 Ha Year	Determined by Eddy Covariance in citrus orchard	43,5 Tones/ha	14,6 kg/tree fresh weight	
5x4	Intermediate orchard 6 years old			37,4 Tone/ha	10,7 kg/tree fresh weight	5,6 kg/tree dry weight
4x2	Young orchard 2 years old			0,123 Tones/ha	0,895 kg/tree fresh	0,431 kg/tree dry

					weight	weight
4x2	Young orchard 3 years old			4,75 Tones/ha	1,2 kg/tree fresh weight	0,567 kg/tree dry weight
4x2	Young orchard 2 years old			0,432 Tones/ha	0,104 kg/tree fresh weight	0,045 kg/tree dry weight

As it is obvious the correlation of the provided figures is not feasible within the C.1 Action context, and this is why the Action was designed this way. The complete experimental data set acquired from Greece will be utilized for the present action Purposes and the infiltration of the relevant data will be subject of the consequent actions aiming to integrate the here developed methodology into an International environment.

4. Supplements

Annex V

Significance of Variables affecting carbon sequestration

Ecosystem Services Functions

Preface

The present assessment, originally foreseen as a distinct outcome of the Action's C.1 beginning, was deemed far too valuable for the TC's sound categorization and therefore was performed and delivered as part of Action A.1 deliverable. To maintain though consistency with project proposal is also presented accordingly in C.1 Deliverable. In the following lines are presented the summarized findings, and in the following chapters the methodological approach and the results of the assessment.

Before the detailed review on the assessment of each ESs function we performed a study on the potentials for the cumulative integration of each tree-crop category with respect to their ESs provision. This study was based on existing literature data and concluded to the definition of two coefficients:

A. Everegreen vs Deciduous TCs: Considering as baseline the Deciduous TC, the Evergreen TC present a Regulation ESs coefficient of 2, and Provision ESs coefficient of 0,5.

B. Intensive vs Extensive Cultivation Method: The Integrated ESs coefficient for intensive TCs, considering as baseline the relevant extensive (Traditional, Organic, etc), was defined to 0,25.

Consequently, for each of the homologous groups of ESs functions was performed a detailed review on the respective assessment protocols, and a preliminary set of indicators was chosen in order to validate the proposed methodology as follows:

A. Provision TC Services: As cumulative indicator was chosen the average yield in tonnes per hectare, which can provide substantial evidence for the contribution of TC in Food and Biomass Provision Services.

B. Regulation TC Services:

   a. Biotic Support: For this function was chosen the number of birds per Hectare, which was calculated by Rodríguez-Entrena et al. (2012), for olive groves to present averages of 10 *taxa* ha^{-1}.
   b. Abiotic Support: as indicator was chosen the Soil Erosion respectively. This indicator was calculated by Rodríguez-Entrena et al. (2012), for olive groves to present an average 10 t soil $ha^{-1}year^{-1}$
   c. Flows Support: as indicator was chosen the Soil Carbon Sequestration. These indicators was calculated by Rodríguez-Entrena et al. (2012), for olive groves to present an average of 2,5 tCO_2 $ha^{-1}year^{-1}$.

C. Cultural TC Services: The proposed indicator is the total area of Orchards in hectares.

The cumulative results of TCs ESs assessment according to the developed methodology are summarized in the following table:

Ecosystems Services	**ES Function**	**Grade**	**Performance**
Regulation	Biotic support	13,13	5,14
	Abiotic support	18,75	7,35
	Flows support	4,69	1,60
Provision	Nutrition	11,25	2,69
	Biomass		
Cultural	Stewardship/ Diversity	8.356.337,63	1,12

The performance indicator was constructed in order to integrate the grade per hectare indicator to the sum of the TCs area and is defined by the following equation:

P= Grade per Hectare* (TC category hectares/TC total hectares).

Previous results concerning TC categorization provided an innovative and inclusive framework for both the continuation of CLIMATREE's implementation but also for the Assessment of their respective ESs.

In the same manner the methodology developed for the ESs assessment congregated the available knowledge of the field while simultaneously recognized crucial knowledge gaps that must be addressed in the course of CLIMATREE's implementation.

Both results are significant for project implementation because they provide a uniform and scientifically sound background for the cumulative interpretation of project's results into Policy priorities and measures, while they are also expected to enhance the project's results transferability and replicability in different environments and geographical scales.

1. Introduction

Ecosystem services are the bridge between nature and society, and are essential elements for the community's well being. Ecosystem Services (ES) are generally considered as a cumulative figure enabling humanity to access both the tangible and intangible value of Nature. Several classifications of ESs are available, but the most comprehensive work has been done by the Millennium Ecosystem Assessment (MEA), which classifies ESs in four categories:

1. provisioning services: include all the biomass produced by ecosystems and directly used by human such as food, water, timber, and fiber;
2. regulating services: sustain the functioning of the ecosystems, regulating important elements like climate, floods, diseases, wastes, and water quality;
3. supporting services: are necessary to support all other ESs, such as soil formation, photosynthesis, and nutrient or water cycling;
4. cultural services: provide recreational, aesthetic, and spiritual benefits, and affect all intangible values derived from the contact with nature.

This classification, despite is clarity, does not provide guidance to an efficient economic evaluation of ESs which needs to pinpoint the "final good" enjoyed by the people that directly affects their well-being. The attention to "final good" was originally proposed by Fisher et al. and implies that all the intermediate processes and services (like supporting services) that constitute the "back-office" provider of the overall ESs cannot be considered in the economic analysis. An attempt to improve the economic evaluation of ESs has been done by the UK government, which in 2011, published the first UK National Ecosystem Assessment. This classification disentangles ecosystem process/intermediate services and final services to improve the economic evaluation of ESs (Pedone et al., 2014).

However the significance of ESs is of high priority for the integrated impact assessment (IA) of policies in the European Commission takes place in an environmentof competing problem frames, contested policy objectives and a multitude of interested actors. Diehl et al. (2016) elaborated on the potential value of integrating the ecosystem services concept for improving the consideration of environmental benefits and values during framing and appraisal of new policies at European level. This approach was based on a workshop conducted with experts encompassing their disciplinary fields to the science–policy interface. A review of recent literature and impact assessment reports from policy science and ecosystem services research allowed for a two-way contemplation. The potential integration of concepts was analysed for conceptual, technical, ethical and pragmatic aspects. It was found that indicator sets applied in the impact assessment reports follow a much less formalised structure than the reports or the procedure. An integration of the ecosystem services concept would enhance the requisite variety of indicators used, and thus contribute to the overall goal for sustainable development. Potentials for improving IA lie particularly in the up- and downscaling of benefits and values, policy relevant comparative studies and the prospective possibilities for innovation in indicator development. Based on this rationale of improving requisite variety for future decision making, the emphasis lies on a further development of the ESS concept along two pathways of operationalisation: the translation of the concept for a comprehensive approach at a higher level of abstraction (soft application),and the application of the concept for providing aggregated, quantitative and unit-based information at different steps of an IA (hard application).

Sornoyi (2016) framing the quantification of environmental sustainability recognised that recent concepts have mostly focused on narrative economic and societal aspects rather than quantitative ones. Many key sustainability indicators also lack a consistent definition of sustainability, have perspectives that are too short-term, and are unable to model the dynamics of complex environmental utilization which can then result in inappropriate projection of long-term sustainability and/or sustainability indication. The proposed generalized quantitative framework of environmental sustainability requires that

1. environmental capacities and utilization rates are identified,
2. their complex temporal dynamics are:
    a. quantitatively modelled or estimated
    b. while also adjusting for uncertainties, and finally,
3. using one of three options, determining which cumulative utilization pathways can be sustained for a (usually well-defined) period of time.

On the other hand decision-making on resource managements received worldwide attention in the past decades given the urgent need to preserve ecosystems and find a sustainable balance between long-term and short-term benefit and costs of human activities. However, a management decision can cause undesirable consequences if it lacks understanding of the complex nature of ecosystems, which lead to the multi-functionality of land systems. A land system does not provide only one function but combinations of a variety of overlapping functions, each of which provides different ecosystem goods and services to society (Lee and Lautebach, 2016).

Land systems thus have a potential to provide multiple ecosystem services. Due to functional trade-offs and synergies among the different components of this multi-functionality within the land, a decision potentially influences which services people can get or lose at the same time. Therefore, a comprehensive understanding of the multi-functional land system and of the different ES derived from it is crucial in natural resource management to avoid undesired and often unaware trade-offs and to enhance synergies among ES (ibid.).

Croplands and pastures occupy approximately 40% of the Earth's terrestrial surface, making them the largest land use types on the planet. Agricultural expansion and intensification result in loss of biodiversity and reduction of the variety and levels of ecosystem services (Barral et al., 2015), which are benefits that people obtain from ecosystems (MEA, 2005). Converting land for agricultural use leaves some provisioning ES unaffected and improves other provisioning ES (e.g., food and fiber), while at the same time it is considered as a factor reducing land available to supply other supporting, regulating and cultural ES.

A significantly different character though was recently proved for orchards, which represent a rather unique category of cropland with respect in the ESs deliverance. The example establishing this differentiation is developed around the city of Aksu, situated at the northern fringe of the Taklimakan Desert in northwest China, which is exposed to severe periodic dust and sand storms. In 1986, local authorities decided to establish a peri-urban shelterbelt plantation, the so-called Kökyar Protection Forest, with the aim of reducing dust and sand storm impacts on Aksu City by the regulating ecosystem services provided by the plantation. It was realised as a patchwork of poplar shelterbelts and orchards. The total area of the plantation reached 3800 ha in 2005. The Kökyar Protection Forest since then has been used as a case study to answer the following question: *under which institutional frameworks and to which financial conditions can peri-urban shelterbelts be established and maintained?* While the endeavour of planting the shelterbelt was made possible by the annual mass mobilisation of Aksu citizens, based on the Chinese regulation of the "National Compulsory Afforestation Campaigns", the task of the shelterbelt permanent maintenance, is facilitated by leasing orchard plots to private fruit farmers. From the perspective of the local economy, annual farming net benefits generated by Kökyar fruit farmers more than compensate for annual government grants for maintenance, resulting in an average overall monetary net benefit (Missall et al. 2015).

Another aspect of world scale importance concerns the tropics, where large areas are transformed into simplified ecosystems characterised by altered tree species composition and diversity. Human activities in these landscapes have a strong effect on the land cover and exert a selective force on tree species and functional traits, hereby potentially shaping the distribution of ecosystem services in the landscape. Koen et al. (2015) assessed how the land use determines tree species assemblages, their associated traits and potential ecosystem services, which was studied for 589 systematically sampled locations in the Afromontane highlands of Taita Hills (SE Kenya). Several tree traits were non-random distributed in the human-dominated landscape. For instance, on croplands (70% of the sampled locations) belonged 66.5% of the observed species to the exotic tree species group. This group was characterised by significantly larger seeds and fruits, corresponding with the abundance of many fruit trees. Also three functional traits (i.e. economic function, nitrogen fixation and agroforestry potential) were clearly associated with this group. The cloud forest tree species group and small-leaved indigenous group were significantly more present on woodes sites and homesteads (~42%). However, no functional traits were unique for both indigenous groups, implying that farmers may exchange them by exotics, which could be catalysed by the loss of local knowledge about indigenous tree resources and benefits.

A few years earlier Almagir et al. (2009) provided crucial proofs for the conformity of ESs provision through different land uses, which included orchards and rain forest in Australia. The Wet Tropics Australia, is environmentally and biologically diverse, and supplies numer-ous ecosystem services. It contributes to the community well-being of this region, Australian nationaleconomy and global climate change mitigation efforts. However, the ecosystem services in the regionhave rarely been assessed undermining strategic landscape planning to sustain their future flow. In thisstudy, we attempted to: (i) assess the quantity of five regulating ecosystem services – global climateregulation, air quality regulation, erosion regulation, nutrient regulation, and cyclone protection, andthree provisioning ecosystem services – habitat provision, energy provision and timber provision acrossrainforests, sclerophyll forests and rehabilitated plantation forests; (ii) evaluate the variation of supplyof those regulating and provisioning ecosystem services across environmental gradients, such as rain-fall, temperature, and elevation; (iii) show the relationships among those ecosystem services; and (iv)identify the hotspots of single and multiple ecosystem services supply across the landscape. The resultsshowed that rainforests possess a very high capacity to supply single and multiple ecosystem services,and the hotspots for most of the regulating and provisioning ecosystem services are found in upland rain-forest followed by lowland rainforest, and upland sclerophyll forest. Elevation, rainfall and temperaturegradients along with forest structure are the main determinant factors for the quantity of ecosystem ser-vices supplied across the three forest types. The correlation among ecosystem services may be positive ornegative depending on the ecosystem service category and vegetation type. The rehabilitated plantationforests may provide some ecosystem services comparable to the rainforest.

Even though orchards are considered as valuable potential natural assets their contribution to ESs provision has not yet be approached in general. The presented in the previous chapter framework for the categorisation of Tree-Crops (TC) is utilized in follow in order to provide safe estimates on the ESs provided by each TC category. Each category is built to consist by groupings of TC with similar botanical, biological, and cultivation characters, increasing thus the homogeneity of each group with the respective indicative TC. Present endeavour aspires to partly unveil the potentials of the Mediterranean orchards as ESs providers. This formidable targeting is escalated through a detailed review of the methodologies and the indicators implied previously for the enumeration of a distinct ES covering all 19 ESs considered in the MEA. Consequently are reviewed separately the case studies for the indicative TC from each one of the 4 TC categories and the cumulative assessment is presented and discussed accordingly.

2. Methods

2.1. Methological Approach

Within the previously developed context lies a key challenge that CLIMATREE projects faces now: considering simultaneously multiple ES and their potential consequences rather than focusing only on a few services in isolation. The concept of multi-functionality has been originally developed at the landscape scale (Bolliger et al., 2011; Mastrangelo et al.,2014). However, it can be transferred to larger scales at which parts of the multi-functionality present at the landscape scale might be hidden due to aggregation effects. Likewise, the concept can be applied at smaller scales but one has to keep in mind that some functions might diminish at small scales such as functions that lead to:

- water regulation,
- seed dispersal,
- pollination and
- pest control that connect different parts of the landscape.

Therefore, interactions across multiple scales are important to be considered in decision-making (Willemen et al., 2012; Dick et al., 2014). The global research community endeavours to elaborate the concept of ES both in theory and practice to preserve multiple ES (MA,2005; Carpenter et al., 2009). The Millennium Ecosystem Assess-ment (MA, 2005) has raised the awareness of the importance of identifying multiple ES and their interactions (Raudsepp-Hearneet al., 2010; Willemen et al., 2012). The number of publication has risen rapidly in last decades on this issue (Bennett et al., 2009).Bennett et al. (2009) stressed the importance of understanding direct and indirect relationships among multiple ES. Recent studies focusing on multiple ES have taken several perspectives using various methodological approaches. The concept of “bundles” of ES has been commonly applied in the assessment of provisioning multiple ES in a landscape (e.g. Raudsepp-Hearne et al., 2010;Martín-López et al., 2013).

This approach tries to identify groups of ES that co-occur repeatedly in landscapes showing patterns of the provision of ES derived from the different land use and land cover types (Raudsepp-Hearne et al., 2010; Turner et al., 2014). It is frequently based on a GIS analysis at the landscape or the regional scale (O’Farrell et al., 2010; Nemec and Raudsepp-Hearne, 2012). Often complementary statistical or descriptive analyses have been used to identify the bundles. Another research line tends to focus on ecosystem processes and functions that underpin ES (Dickie et al.,2011; Lavorel et al., 2011).

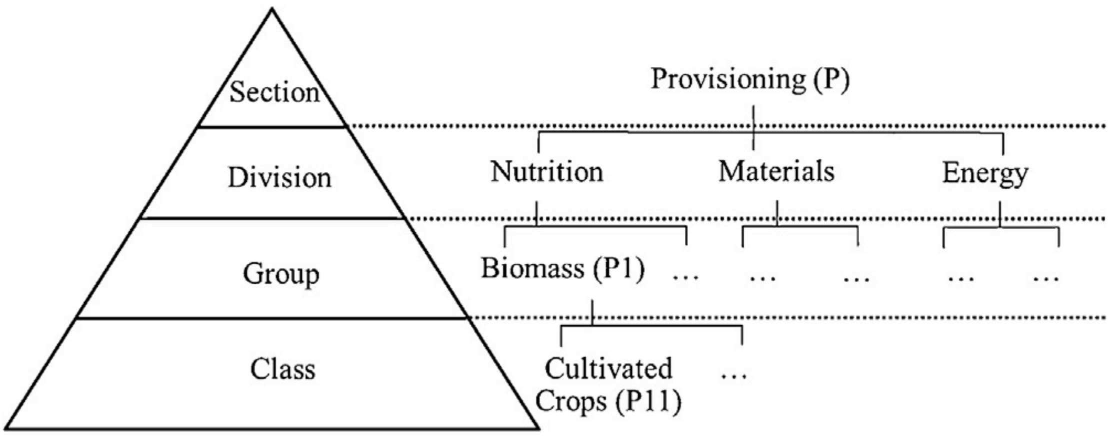


Fig. 1. The CICES nested hierarchy structure (left) and example of provisioningsection and ES code in brackets (adapted from Haines-Young and Potschin (2013)).

The relationships among multiple ES are either identified by statistical analysis of field data or by the analysis of the output process models such as the Lund-Potsdam-

Jena General Ecosystem Simulator (LPJ-GUESS) (Smith et al., 2001) or the Soil Water Assessment Tool (SWAT) (Arnold et al., 1999). Lautenbach et al. (2013) for example analyzed the relationships between bio-energy crop and food production, water regulation and water quality regulation using SWAT together with an optimization approach. Relationships of ES pairs can be categorized into ‘trade-off’, ‘synergy’, and ‘no-effect’. The term ‘trade-off’ in ES research has been used when one service responds negatively to a change of another service (MA, 2005). An attempt to maximize the provision of a single service will lead to sub-optimal results if the increase of one service happens directly or indirectly at the cost of another service (Holling, 1996; Rodríguez et al., 2006; Haase et al., 2012). When both services change positively in the same direction, the relationship between two ES is defined as synergistic (Haase et al., 2012); this is also called a ‘win–win’ relationship (Howe et al., 2014). When there is no interaction or no influence between two ES, this is defined as a ‘no-effect’ relationship. The relationship between a pair of ES can differ across different scales and across different socio-ecological systems (Kremen,2005; Hein et al., 2006; Bennett et al., 2009). An example for this is the “externality” of a decision on a certain service as pointed out by Rodríguez et al. (2006): a decision that seems to influence ES positively for a specific region might cause substantial trade-offs in areas nearby or faraway (e.g. ‘off-site effects’ (Seppelt et al.,2011) and ‘telecoupling’ (Liu et al., 2013; Liu and Yang, 2013)).

If the effects of this decision are viewed at a larger scale including all those negatively influenced areas, the relationship between ES might be characterized by a trade-off. Cimon-Morin et al. (2013) showed in their review study that the relationship between biodiversity and ES changes with scale and region. The relationship between carbon storage and habitat was, for example, described mainly as synergistic at the global scale, but at a finer scale regions of high biodiversity and high carbon storage might be disjunct leading to a trade-off relationship. Furthermore, the relationship can change in different land systems. Land systems are defined by the terrestrial components of environmental systems such as vegetation and soil type, as well as human-environment interactions such as land use intensity, socio-economic factors (Oliver et al., 2004; Dearing et al., 2010;Václavík et al., 2013; Verburg et al., 2013). A decision on increasing a service can affect the other services differently in different land systems. For example, West et al. (2010) showed differences in a trade-off relationship between carbon sequestration and food provisioning among regions with different land systems. Given the increasing interests on relationships between ES in literature, two recent review studies (Mouchet et al., 2014;Howe et al., 2014) addressed aspects of relationships between ES. Mouchet et al. (2014) provided a methodological guideline for assessing trade-offs between ES, whereas Howe et al. (2014) analyzed relationships between ES with a focus of beneficiaries and users.

However, neither of the two studies analyzed pair-wise relationships between ES, which is a first step to investigate relationships among multiple ES (Chan et al., 2006; Raudsepp-Hearneet al., 2010; Jopke et al., 2014). Kandziora et al. (2013) provided a matrix of pair-wise relationships between ES on a conceptual level, but the relationships between ES have not been studied so far based on case study results. In this study, we aim at quantifying pair-wise relationships based on a quantitative review of relationships between ES based on the published literature. As the aforementioned literature showed, the relationship between ES has been studied at various scales, indifferent land systems using various methodological approaches, which complicates the synthesis. We, therefore, addressed threekey hypotheses to investigate the relationships between ES: first, a dominant relationship between ES exists for each ES pair; second, this relationship is influenced by the scale at which the relationship had been studied as well as by the land system the case study took place; and third, this relationship is further affected by the method applied to characterize the relationship.

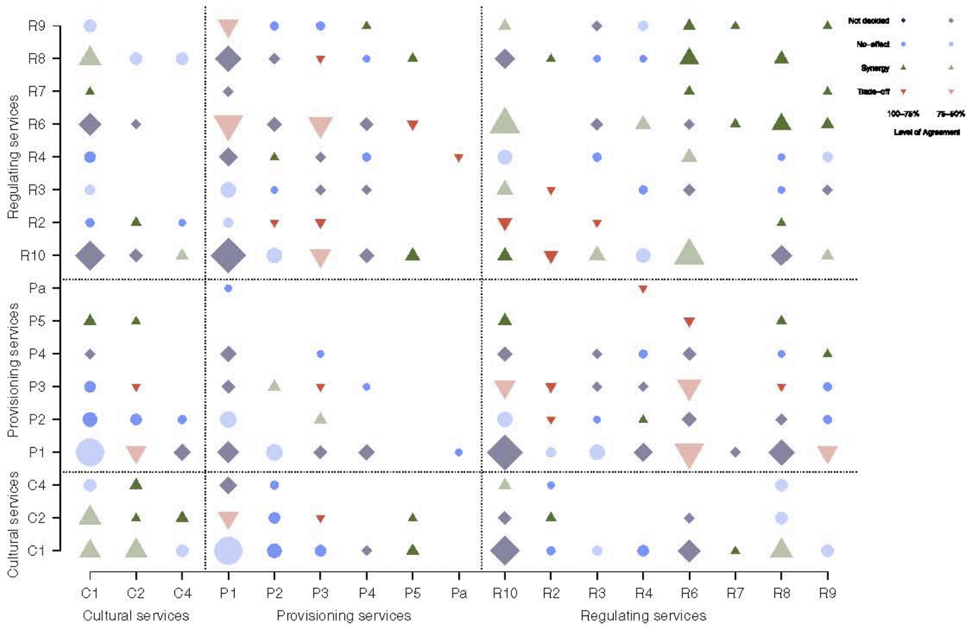


Fig. 2. Result from analysis of 67 case studies with 476 pairs of ecosystem services, showing the empirical pattern of relationships between them. X and Y axes represent theES classification code used in the analysis (See Table ST1). The size of the symbol indicates the square root scaled number of studies. The color intensity represents the level ofagreement. C: Cultural services, P: Provisioning services, R: Regulating services. C1: Physical and experiential interactions, C2: Intellectual and representative interactions, C4:Other cultural outputs, P1: Nutrition biomass, P2: Nutrition water (i.e. drinking purpose), P3: Materials biomass (e.g. for production and agricultural uses), P4: Material water(i.e. non-drinking purpose), P5: Biomass-based

energy sources, Pa: Renewable abiotic energy source, R10: Atmospheric composition and climate regulation, R2: Mediation byecosystems, R3: Mass flows, R4: Liquid flows, R6: Life cycle maintenance, habitat and gene pool protection, R7: Pest and disease control, R8: Soil formation and composition,R9: Water conditions. (Lee and Lautenbach, 2016)

Within the studied pairs and groups Cultural Services comprise a well-defined synergistic group while Regulating Services also present significant synergistic character among the distinct functions, and Provisioning Services correspond to the most diverse group with significant discrepancies. In detail:

- C: Cultural services, while all of them provide in general a No-Effect profile with other ESs they are recognised as synergistic between them. In precise:
    - C1: Physical and experiential interactions are identified as synergistic with Soil formation and composition (R8), Pest and disease control (R7), and Biomass-based energy sources (P5).
    - C2: Intellectual and representative interactions are identified as synergistic with Biomass-based energy sources (P5), and Mass flows (R3), and antagonistic to Nutrition biomass (P1), and Materials biomass (P3).
    - C4:Other cultural outputs, which have been identified to positively, interact only with Atmospheric composition and climate regulation (R10).

  In conclusion Cultural Services will be considered as a Unit for the present ESs assessment.

- P: Provisioning services present in general a rather independent profile among them, which is replicated in their relationships with Cultural Services, and is considerably diversified when they are considered against the Regulating Services, with which present a mostly antagonistic character. In precise:
  - P1: Nutrition biomass provision is considered antagonistic with Atmospheric composition and climate regulation (R10), Life cycle maintenance, habitat and gene pool protection (R6), and Intellectual and representative interactions (C2).
  - P2: Nutrition water (i.e. drinking purpose) provision is antagonistic to Mediation by ecosystems (R2), but synergistic with Liquid flows (R4), and Materials biomass (P3)
  - P3: Materials biomass (e.g. for production and agricultural uses) provision is antagonistic to Intellectual and representative interactions (C2), Soil formation and composition (R8), Life cycle maintenance, habitat and gene pool protection (R6), Mediation by ecosystems (R2), and Atmospheric composition and climate regulation (R10).
  - P4: Material water (i.e. non-drinking purpose) provision is considered synergistic only with Water conditions (R9).
  - P5: Biomass-based energy sources provision on the other hand are considered antagonistic to Life cycle maintenance, habitat and gene pool protection (R6) but synergistic with Soil formation and composition (R8), Atmospheric composition and climate regulation (R10), and Cultural Services (C2, C3).
  - Pa: Renewable abiotic energy source provision is considered antagonistic to Liquid flows (R4).

In conclusion for the here considered ESs will be constructed two major evaluation units these of Nutrition (Food and Water-P1 & P2) and Biomass (for raw materials and fuels-P3-P5 & Pa).

- R: Regulating services, which also include the supporting services of the MA (2005), consist a more or less homogenized group with significant synergistic effects among the here included ESs, as also with the Cultural Services. On the contrary, mostly antagonistic effects characterize the relation of the here-considered Regulating ESs, with the Provisioning Services.
    - R2: Mediation by ecosystems source provision is considered antagonistic to Atmospheric composition and climate regulation (R10), Mass flows (R3), Materials biomass (P3), and Nutrition water (P2), while synergistic character is established for the relations with Soil formation and composition (R8), and Intellectual and representative interactions (C2).
    - R3: Mass flows provision is considered synergistic to Atmospheric composition and climate regulation (R10, while antagonistic character is established for the relation with Mediation by Ecosystem Sources (R2).
    - R4: Liquid flows provision presents synergies with Nutrition water (P2), and Life cycle maintenance, habitat and gene pool protection (R6), and antagonism with Renewable abiotic energy source (Pa).
    - R6: Life cycle maintenance, habitat and gene pool protection is consider synergistic with almost all of the Regulation Services

Functions, while presents a significantly antagonistic character with most of the Provisioning Services, and a neutral for the Cultural.

- R7: Pest and disease control provision presents synergies with Water conditions (R9), Life cycle maintenance, habitat and gene pool protection (R6), and Other cultural outputs (C4).
- R8: Soil formation and composition provision presents mostly synergies with a plethora of Functions such as Life cycle maintenance, habitat and gene pool protection (R6), Mediation by Ecosystem Sources (R2), Biomass-based energy sources (P5) and Other cultural outputs (C4), and only one Trade-off with Materials biomass (P3).
- R9: Water conditions provision presents mostly synergies with a plethora of Functions such as Life cycle maintenance, habitat and gene pool protection (R6), Pest and disease control (R7), Biomass-based energy sources (P5), and only one Trade-off with Nutrition biomass (P1).
- R10: Atmospheric composition and climate regulation provision presents mostly synergies with a plethora of Functions such as Life cycle maintenance, habitat and gene pool protection (R6), Water conditions (R9), Mass flows (R3), Biomass-based energy sources (P5), and Physical and experiential interactions (C1), and only two Trade-offs with Mediation by ecosystems sources (R2) and Material biomass (P3).

In conclusion from the 8 ESs functions considered herein three major groups will be structured for further evaluation:

A. Biodiversity Biotic Support (including R6, R7, and R8)

B. Environmental Support (Including R2, R9, and R10)

C. Flows Support (Including R3 and R4)

2.2. Geographical Scale

The previously described TC ESs Assessment methodology eventually comprises a tool that will focus on a distinct Land-Use, characterized as "*Orchard Land*", which comprises a significant percent of the Northern Mediterranean EU countries, as depicted in Table 1:

Table 1: Land Coverage by Tree Crops in CLIMATREE's implementation area

Country	**Area (Ha)**		
	Total	**Tree Crops**	**%**
Greece	13.195.700	1.812.178	13,73%
Italy	30.133.800	1.258.169	4,18%
Spain	50.599.000	4.397.967	8,69%
Total	**93.928.500**	**7.468.314**	**7,95%**

The three countries, Italy, Greece, and Spain, consist a virtual arch on the Northern Mediterranean area, depicted in Map 1, which includes the 3 from the four major peninsulas of the Mediterranean Sea.

Map 1: Geographical location of the CLIMATREE's implementation area.

All three countries share a common Climatological background and present the same distribution of their *Orchard Land*, which occupies mostly slopped marginal agricultural land, and partially to a lesser extend levelled high productivity agricultural land.

2.3. Strata Definition

Present document aims to develop a common operating framework among the three national environments, for the successful implementation of present action.

As basic criteria implied for the selection of the representative tree-crops are proposed the following:

1. Total Area of Cultivation, in Hectares
2. Average Tree-Crop Life-Span, in Years
3. Annual Crop Yield, in Tones per Hectare

In the action's description is indicated the generic cladogram of tree-crop categories, which includes two biological categories as the two first ranks:

1. Evergreen Trees
2. Deciduous Trees

In order for the assessment of these two primary categories is required a short description of the biological cycle for each tree.

The next level of categorization regards the cultivation methodology; this level can be duplicated, as it is possible for a given tree-crop to be cultivated with multiple and diverse cultivation methodologies within even the same Region. These two categories are of course artificial and will consist by assumptions on the overage inputs among the various tree-crops:

1. Intensive Cultivation;
2. Extensive Cultivation

A tree-crop will have to conform to certain elements of discrimination in order to be included in either category. The following proposed criteria should be further defined and thresholds to be set for this attribution:

a. Plantation Density and Tree Growth in Trees per Hectare, as depicted in the ACI Growth Indicator.
b. Years of prospective productive life of the Plantation, as depicted in the ACI Year Indicator.
c. Soil Cultivation Frequency and form of application, in implementation number per year and depth of tillage respectively, which participates in the formation of CII indicator.

d. Irrigation Frequency and Volume, in implementation number per year and tones per hectare respectively, which participates in the formation of CII indicator.

e. Agrochemicals Usage, in Kg per year and hectare, which participates in the formation of CII indicator.

The third level of the dendrogram of tree-crop categories regards the ecological area that each crop occupies. This categorization includes three options:

1. Coastal Zone
2. Midland Zone
3. Mountain Zone

These three categories were include in order to provide a more solid framework for Italy and Spain, as in Greece the first Categories are merged due to the proximity of the Sea to the high Mountains. Attribution of crops in those categories will be pursued through the implementation of two basic Criteria:

a. Elevation, in Meters can distinguish cases for all three categories; e.g. above 500 m of altitude: Mountain Zone, in between 500 and 100 m of altitude: Midland Zone, and below 100 m of altitude: Coastal Zone

Distance from the sea, in Km may distinguish crops of low elevation but with significant differentiation from the coastal zone. In the same manner this criterion could be utilized for tree-crops of higher elevation but with direct proximity to the sea.

2.3.1. Cultivation Intensity Analysis

The methodology implicated for the attribution of each crop cultivation intensity degree was established upon two main considerations. The first one regarded the analysis of the numan-oriented inputs in the form of cultivation measures. The second provides an additional criterium, depicting the impacts of cultivation measures upon the natural form of the tree.

Main objective of this two fold approach is to include all aspects of tree cultivation in the evaluation procedure, providing thus an integrated approach considering both the human inputs and the state of difference between the cultivated and natural tree. The ecological signifficance of each tree-crop with respect to the Ecosystems Sevices Approach conforms the cosequent step of tree-crop consideration and closes the loop of tree-crop cultivation total appraoch.

In both cases will be followed the same methodological approach, which will enumarate the degree of intensity for each and every one of the relevant cultivation measure and/or forms of growth. Consequently and based upon the previous enumaration a Cultivation Intensity Indicator (CII) will be generated for each cultivation measure, while a Agronomical Characters Indicator (ACI) will enumerate the deviation of each Tree-Crop plantation characters from the natural characters of the relevant Tree.

Cultivation Measures Intensity Analysis

Grading of the cultivation measure impacts intensity will be performed after carefull consideration of the following parameters:

- Number
- Frequency

- Intensity

For the enumaration of the Number (N) is utilized the 0 to 3 scale were 0 means the relevant cultivation measure is not applied, and 3 the maximum number of repetitions per year observed for the given measure:

N Indicator	***Number of cultivation measure annual repetitions.***
0	*Cultivation measure not applied*
1	*Total numbers of repeptitions (N) ≤ 33% of maximum observed*
2	*Total numbers of repeptition (N): 33% < N ≤ 66% of maximum observed.*
3	*Total numbers of repeptition (N) > 66% of maximum observed.*

The enumaration of Frequency (F) is similarly structured upon the following evaluation scale:

F Indicator	***Frequency of cultivation measure annual repetitions.***
0	*Cultivation measure not applied*
1	*Total weeks between repeptitions (F) > 66% of maximum observed*
2	*Total weeks between repeptition (F): 33% < F ≤ 66% of maximum observed.*
3	*Total weeks between repeptition (F) ≤ 33 % of maximum observed.*

Intensity (I) of each cultivation measure is also calculated within the same numerical range according to the folowing scale:

I Indicator	*Intesnity of cultivation measure.*
0	*Cultivation measure not applied*
1	*Average Intensity of repeptition (I) ≤ 33% of maximum observed*
2	*Average Intensity of repeptition (I): 33% < I ≤ 66% of maximum observed.*
3	*Average Intensity of repeptition (I) > 66% of maximum observed.*

The three previous indicator will be enumaretd for each tree crop and will be combined in order to provide the relevant Tree-Crop CIS, according to the following formulas:

Cultivation Measure Intensity:

Tree-Crop Cultivation Intensity:

$$\mathbf{CII = (CMI_1 + CMI_2 +...+CMI_v)^{-v}}$$

The final evaluation matrix is structured upon an xls spreadsheet that incorporates the fundmanetal algorithms of CII calculation and presents the following image:

Tree-Crop	**Irrigation**				**Tillage**				**Fertilization**				**Crop Protect.**				**CII**	
	N	**F**	**I**	**CMI_I**	**N**	**F**	**I**	**CMI_T**	**N**	**F**	**I**	**CMI_F**	**N**	**F**	**I**	**CMI_P**		
T-C min	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	**0**	min
T-C max	3	3	3	**27**	3	3	3	**27**	3	3	3	**27**	3	3	3	**27**	**27**	max
T-C 1	3	3	2	**18**	2	2	2	**8**	2	2	2	**8**	2	2	2	**8**	**10,5**	39%
T-C 2	1	1	1	**1**	1	1	1	**1**	1	1	1	**1**	1	1	1	**1**	**1**	4%
T-C 3	3	2	1	**6**	3	2	1	**6**	3	2	1	**6**	3	2	1	**6**	**6**	22%
T-C 4	2	2	2	**8**	2	2	2	**8**	3	3	3	**27**	3	3	3	**27**	**17,5**	65%

T-C 5	3	3	3	**27**	3	3	3	**27**	1	1	1	**1**	0	0	0	**0**	**13,75**	51%

2.2.1. Agronomical Characters Intensity Analysis

Grading of the agonomical characteristic intensity variation will be performed after carefull consideration of the following parameters:

- Form of Growth
- Prospective Age

For the enumaration of the Growth (G) is utilized the 0 to 3 scale were 0 means that tree growth under cultivation is equal or bigger than in Nature, and 3 corresponds to the maximum observed decrease in meters for the given crop:

G Indicator	*Height and Area Coverage of each Tree.*
0	*Height and coverage (G) ≥ Nature*
1	*Height and coverage (G) ≤ 33% of maximum observed decrease.*
2	*Height and coverage (G): 33% < G ≤ 66% of maximum observed decrease.*
3	*Height and coverage (G) > 66% of maximum observed decrease.*

Prospective Age is reflected through the Years indicator (Y) of each tree-crop, which is also calculated within the same numerical range according to the folowing scale:

Y Indicator	*Prospectice productive years of tree-crop.*
0	*Number of Years (Y) ≥ Nature*

1	*Number of Years (Y) ≤ 33% of maximum observed decrease.*
2	*Number of Years (Y): 33% < Y ≤ 66% of maximum observed decrease.*
3	*Number of Years (Y) > 66% of maximum observed decrease.*

The three previous indicator will be enumaretd for each tree crop and will be combined in order to provide the relevant Tree-Crop CIS, according to the following formulas:

Agronomical Intensity:

$$\mathbf{AI = G*Y}$$

Tree-Crop ACI:

$$\mathbf{ACI = (AI_1 + AI_2)^{-2}}$$

The final evaluation matrix is structured upon an xls spreadsheet that incorporates the fundmanetal algorithms of ACI calculation and presents the following image:

Tree-Crop	**Growth**			**Years**			**ACI**	
	N	**F**	**AI_G**	**N**	**F**	**AI_Y**		
T-C min	0	0	**0**	0	0	**0**	**0**	min
T-C max	3	3	**9**	3	3	**9**	**9**	max
T-C 1	3	3	**9**	2	2	**4**	**6,5**	72%
T-C 2	1	1	**1**	1	1	**1**	**1**	11%
T-C 3	3	2	**6**	3	2	**6**	**6**	67%

T-C 4	2	2	**4**	2	2	**4**	**4**	44%
T-C 5	3	3	**9**	0	0	**0**	**4,5**	50%

2.2.2. **Tree-Crop Cultivation Intensity Analysis**

The final evaluation on tree-crop cultivation categorization (TCC) will be performed with the application of the following formula, enumerating the TCC indicator:

<u>TCC Indicator:</u>

$$\mathbf{TCC = CII*CAI}$$

Finally, the TCC indicator is utilized for the attribution of each crop in one of the two respective categories, according to the following scale:

TCC value	Category
TCC ≥ 60	Intensive
TCC < 60	Extensive

3. Results

The previously described TC ESs Assessment methodology, is shortly summarized in the following Table 1 where are presented and described all of the variables under consideration.

Previews quantitative assessments of relationships between ES based on the published literature proved that: Dominance is an expressed character of the relationship between coupled ESs; This relationship is not influenced by the scale at which the relationship had been studied as well as by the land system; This relationship is further affected by the method applied to characterize the relationship.

Considering the later fact we concluded that the descriptive method selected for the present study present’s a higher probability to identify more trade-off relationships, in contrast with multi-variate statistics, which is more likely to identify ‘no-effect’ relationships. More over the selected methodology circumnavigates the lack of comprehensive information, which is required for well-informed policy decisions that do not ignore side-effects in multi-functional land-systems.

On the weighting of the TC ESs we utilized a conception developed originally by Vackar et al. (2016) for the comparison of protected and unprotected areas with natural baselines. Their results show that humans appropriate a considerable share of natural ecosystem productivity and carbon stocks, and significantly reduce natural biodiversity and ecosystem services. Human appropriation of net primary production reached more than 60% in total, humans reduced original biodiversity levels by 69%, and net carbon storage was considerably decreased by intensive types of land use. All three indicators significantly differed between protected areas and unprotected areas, suggesting that protected areas maintain higher biodiversity levels, store more carbon and are in total less influenced by human exploitation than average non-protected landscape. Furthermore, they delivered evidence that human appropriation of net primary production is negatively related both to biodiversity and ecosystem services indicated by mean species abundance and net carbon storage at the national level. In present study, this last conclusion was elaborated as indicator of anthropogenic pressures on ecosystems and biodiversity to compare the level of human influence within TC functional groups and natural areas. The actual state of TCs ecosystems is compared to a natural baseline that is intact with the prevailing natural habitat in the area of consideration. Our results contribute to the quantitative evidence of the impacts of anthropogenic transformation of natural ecosystems on the ecosystem condition based on the indicative yield per hectare transition rate between intensive and extensive crop systems.

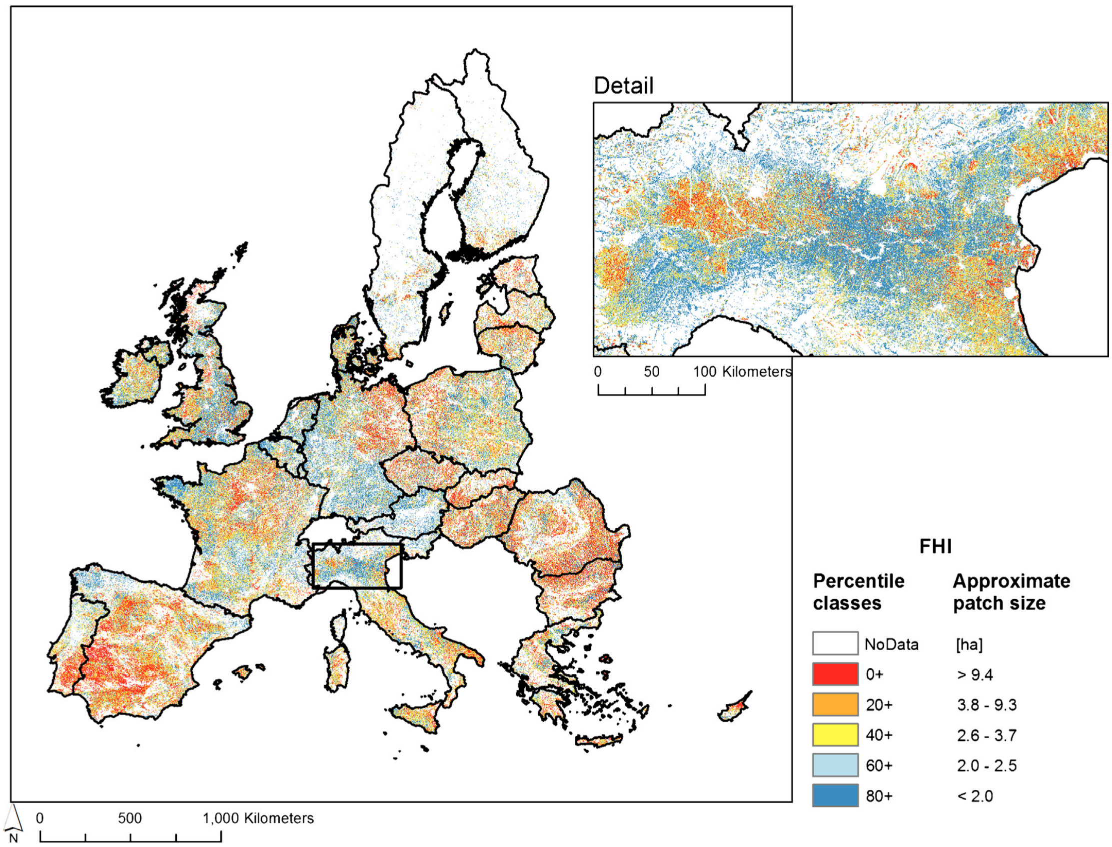
Table 1: Ecosytems Services Functions Vs the respective providers and functional units according to Petrosillo et al. (2010).

Ecosystems Service/Function		**Direct and intermediate ecosystem service providers (ESPs)/organization level**	**Functional units**
Regulation	Biotic support	Insects, birds, mammals and supporting landscape land use/land cover	Species, populations, communities, habitats, landscapes
	Abiotic support	Biogeochemical cycles, plants, micro-organisms, supporting landscape land use/cover	Biogeochemical cycles, populations, species, functional groups, landscapes
	Flows support	Leaf litter and soil invertebrates; soil micro-organisms; nitrogen-fixing plants; plant and animal production and supporting landscape land use/cover	Species, populations, functional groups, communities, habitats, landscapes
Provision	Nutrition	Plants and supporting landscape land use/land cover	Species, landscapes.
	Biomass	Plants, Landscape land use/cover, Leaf litter and soil invertebrates, soil micro-organisms, aquatic micro-organisms, aquatic invertebrates and supporting landscape land use/cover	Species, functional groups, habitats, landscapes
Cultural	Aesthetic	All biodiversity, landscape land use/cover	Species, populations, communities, habitats, landscapes

In the following lines are presented in abstract the fundamental assumptions for the deliverance of the respective results presented consequently in Chapters 3.3.1-4. In specific:

3.1.1. Everegreen vs Deciduous TCs

Mapping and assessment of ecosystem services in agricultural landscapes as required by the EU biodiversity policy need a better characterization of the given landscape typology according to its ecological and cultural values. Such need should be accommodated by a better discrimination of the landscape characteristics linked to the capacity of providing ecosystem services and socio-cultural benefits. Often, these key variables depend on the degree of farmland heterogeneity and landscape patterns. Weisteinner et al. (2016) employed segmentation and landscape metrics (edge density and image texture respectively), derived from a pan-European multi-temporal and multi-spectral remote sensing dataset, to generate a consistent European indicator of farmland heterogeneity, the Farmland Heterogeneity Indicator (FHI). In this study were mapped five degrees of FHI on a wall-to-wall basis (250 m spatial resolution) over European agricultural landscapes including natural grasslands. Image texture led to a clear improvement of the indicator compared to the pure application of Edge Density, in particular to a better detection of small patches. In addition to deriving a qualitative indicator this study attributed an approximate patch size to each class, allowing an indicative assessment of European field sizes. Based on CORINE land cover, was also identified pastures and heterogeneous land-cover classes as classes with the highest degree of FHI, while agro-forestry, olive groves and Fruit trees and berry plantations appeared less heterogeneous on average, which are depicted in Map 2. Further clarification on the typology of is established on the fundamental ecology of each TC, which affects crucial characters for the ESs expression. In specific Evergreen TCs present a yearly respiration and photosynthesis cycle with also year round land cover that enhances the provision of wildlife shelter services as also the provision of micro-climate regulation and hazard prevention services against threats like Soil Erosion and floods. On the other hand material flows in evergreen TCs are integrated within a two-year cycle while in deciduous TCs this task is performed in a yearly manner. In general and according to the previous fundamental assumptions Evergreen TCs present almost double the potential provision of Regulating ES of Deciduous TCs, while in respect to the Provisioning ESs this analogy is reversed especially with regard to the materials provision, and nutrient cycles, which accelerate as a result of the semester long vegetative cycle. Therefore considering as baseline the Deciduous TC, the Evergreen TC present a Regulation ESs coefficient of 2, and Provision ESs coefficient of 0,5.



Map 2: Farmland Heterogeneity Indicator (FHI) for Europe (EU27), Alternative AB. The detail shows the FHI for the agricultural area around the Po River in Northern Italy; Weisteinner et al. (2016).

3.1.2. Intensive vs Extensive Cultivation Method

The study of traditional agrarian systems can provide useful knowledge for improving the sustainability of present-day agriculture. Nonetheless, with the loss of traditional agro-ecosystems and the rationale that guides them, as has happened in Europe, an historical research approach can have a decisive role to play in recapturing this knowledge. The study of the evolution of a typical Mediterranean agro-ecosystem during the last 250 years by Casado and de Molina, (2009), is supporting the claim that high diversity and the internalization of energy flows and nutrient cycles found in traditional agriculture, are not only characteristics of the greatest sustainability of such systems, but are based in the need for additional land in production.

During the past and up to the middle of the 20th century, the territorial dependency of the agricultural metabolism based on solar energy obliged farmers to maintain very strict land use equilibrium, to begin with on a local scale and later on a regional scale A considerable amount of land had to remain "uncultivated" or be devoted to feed livestock. Over that time the system conserved wide spatial heterogeneity and great biological diversity. However, both small-scale and large-scale farmers shifted their focus towards growing crops with the highest market value and increasing the yield for each unit of surface area. This production focus required ever-increasing amounts of space for farming, shorter rotations, fewer varieties and types of crop and, of course, more water. Their productive efforts upset the balance of energy and nutrients in the agro-ecosystem, particularly with the introduction of fertilizers and labour from outside the system.

This process was further intensified over the course of the 20th century, forming an agricultural metabolism of a typically industrial character, highly dependent on external resources for its functioning and reproduction. The expansion of agriculture and of crops with the highest commercial value has lead to an increase in relationships of physical exchange, through the market and the importation of ever increasing quantities of materials and energy.

All this has shaped an ever more homogenous landscape with less biological diversity. Basic functions performed by the land in the past (production of fuels, food for livestock, basic foodstuffs etc). Production ("domestic extraction") in energy terms was 4.3 times greater, whilst the real amount of land appropriated just to provide the nutrients also increased by a factor of 4.2. So the increase in physical production of the agro-ecosystem over intensification has taken place at the same rate as land has been "imported" from elsewhere, simplifying the landscape and its biodiversity. This analogy is utilized for the calculation of the Integrated ESs coefficient for intensive TCs, considering as baseline the relevant extensive (Traditional, Organic, etc), which is 0,25.

3.1.3. Provision TC Services

TCs as a source of food has a substantial spill over that affects the Earth's ecosystems. This results in an 'ecological footprint' of food: negative environmental impacts per capita. The footprint depends on the dietary choice of types and amounts of food, on the non-consumed part of product flows and its fate ('waste' or 'reused'), on transport and processing along the value chain, on the environmental impacts of production per unit area, and on the area needed per unit product. Yield gaps indicate inefficiency in this last aspect: resource-use efficiency gaps for water and nutrients indicate that environmental impacts per unit area are higher than desirable. Ecological intensification aimed at simultaneously closing these two gaps requires process-level understanding and system-level quantification of current efficiency of the use of land and other production factors at multiple scales (field, farm, landscape, regional and global economy). Contrary to common opinion, yield and efficiency gaps are partially independent in the empirical evidence. Synergy in gap closure is possible in many contexts where efforts are made but are not automatic. With Good Agricultural Practice (GAP), enforceable in world trade to control hidden subsidies, there is scope for incremental improvement towards food systems that are efficient at global, yet sustainable at local, scales (Van Noordwijk & Brussaard 2014). Within this context the total yield per hectare incorporates most of the substantial information on the provision of the relative services by TC, and therefore an average yield in tonnes per hectare could provide substantial evidence for the contribution of TC in Food and Biomass Provision Services.

3.1.4. Regulation TC Services

Soil ecosystem functions are derived from plant, animal and microorganism communities and the nonliving environment interacting as a unit. Human activities have affected soil ecosystem functions and in many cases caused soil ecosystem collapse. Nikolaidis (2011) provided a synthesis of current knowledge of human impacts on soil ecosystems, with a special focus on knowledge gaps regarding soil ecosystem shifts and tipping points, using the island of Crete, Greece as an example. Soil ecosystem shifts are abrupt changes that occur at ''tipping points'' and have long-lasting effects on the landscape and both the biotic and abiotic structure of the soil. These shifts can occur due to climate change, land use change, fertilization, or above-ground biodiversity decline. The environmental pressures in the agricultural land of Crete, place the island very close to tipping points, and make it an ''ideal'' area for soil ecosystem shifts. Reversing the trend of the shift while using the soil ecosystem services, means that significantly more organic matter needs to be added to the soil compared to the amount added under set-aside conditions. Soil physical and chemical characteristics were studied explicitly by Miralles et al. (2009) with respect to the climatic and geomorphological factors in 68 sites of a mountain calcimorphic ecosystem in Southeastern Spain. Land use and vegetation were natural pine forest, evergreen oak forest, reforested pine forest of different ages, bush, juniper forest, and olive, almond and cereal crops under conventional tillage. This study utilized multivariate data treatments, and 17 soil variables were processed. Most characteristics were significantly correlated with total organic C (mean=28.5±4.6 g kg^{-1}), which demonstrates the central role of the organic matter in the functioning of the whole ecosystem. New soil quality descriptors consisting of ratios to soil organic carbon were obtained, informing about the specific activity (per C unit) or performance of the organic matter, independently of its total content. When soil data are directly processed by using principal component analysis, we found a set of high quality soils under natural and old reforested forests, where environmental services provided by soil depend on the high levels of quality descriptors related to organic carbon, e.g. cation exchange capacity (CEC), total porosity, or aggregate stability. When variables such as CEC, porosity and aggregate stability are calculated as ratios to the total organic carbon, a new classification pattern is obtained, allowing to detect soils with organic matter of high maturity which in general do not coincide with soils with high organic matter content. The results suggest the assessment of soil quality based on ratios informing on the organic matter performance should be emphasized as an alternative to direct descriptors based on the total organic carbon content. Based on those two fundamental conceptions as indicator for assessing both the TCs contribution to Flows and Abiotic Support was chosen the Soil Carbon Sequestration and the Soil Erosion respectively. These indicators were calculated by Rodríguez-Entrena et al. (2012), for olive groves to present averages of 2,5 tCO_2 $ha^{-1}year^{-1}$, and 10 t soil $ha^{-1}year^{-1}$.

Mediterranean landscapes comprise a complex mosaic of different habitats that vary in the diversity of their floral communities, pollinator communities and pollination services. Using the Greek Island of Lesvos as a model system, we assess the biodiversity value of six common habitats and measure ecosystemic 'health' using pollen grain deposition in three core flowering plants as a measure of pollination services. Three fire-driven habitats were assessed: freshly burnt areas, fully regenerated pine forests and intermediate age scrub; in addition we examined oak woodlands, actively managed olive groves and groves that had been abandoned from agriculture. Oak woodlands, pine forests and managed olive groves had the highest diversity of bees. The habitat characteristics responsible for structuring bee communities were: floral diversity, floral abundance, nectar energy availability and the variety of nectar resources present. Pollination services in two of our plant species, which were pollinated by a limited sub-set of the pollinator community, indicated that pollination levels were highest in the burnt and mature pine habitats. The third species, which was open to all flower visitors, indicated that oak woodlands had the highest levels of pollination from generalist species. Pollination was always more effective in managed olive groves than in abandoned groves. However, the two most common species of bee, the honeybee and a bumblebee, were not the primary pollinators within these habitats. We conclude that the three habitats of greatest overall value for plant-pollinator communities and provision of the healthiest pollination services are pine forests, oak woodland and managed olive groves. We indicate how the highest value habitats may be maintained in a complex landscape to safeguard and enhance pollination function within these habitats and potentially in adjoining agricultural areas. (Potts et al. 2006). Nevertheless pollination is a valuable service cannot be considered as a safe biodiversity indicator. For this function was chosen the number of birds per Hectare, which was calculated by Rodríguez-Entrena et al. (2012), for olive groves to present averages of 10 *taxa* ha^{-1}.

3.1.5. Cultural TC Services

Assessing the ways in which rural agrarian areas provide Cultural Ecosystem Services (CES) is proving difficult to achieve. Carvalho-Ribeiro et al. (2016) developed an innovative methodological approach named as Multi-Scale Indicator Framework (MSIF) for capturing the CES embedded into the rural agrarian areas. This framework reconciled a literature review with a trans disciplinary participatory workshop. Both of these sources revealed that societal preferences diverge upon judgemental criteria, which in turn relate to different visual concepts that can be drawn from analyzing attributes, elements, features and characteristics of rural areas. It concluded that it is possible to list a group of possible multi scale indicators for stewardship, diversity and aesthetics. This research carries major implications for policy at different levels of governance, as it makes possible to target and monitor policy instruments to the physical rural settings so that cultural dimensions are adequately considered.

Within this context the following set of indicators were promoted as more solid and of wide acceptance among the local populations:

<u>Stewardship:</u> Refers to the sense of order and care present in the landscape reflecting active and careful management (Ode Sang and Tveit, 2013). The proposed indicator

is Number of man-made structures with a function, which translates to total area of Orchards in hectares.

Diversity: Is defined as the richness and diversity of landscape elements and features noted for their proximity and location, as well as the grain size of the landscape (Tveit et al., 2006). The proposed indicator relates to Edges between agriculture and other land uses, which translates also to total area of Orchards in hectares as TCs in the Mediterranean region usually occupy either marginal land or comprise distinct thickets within arable land, contributing thus to the landscape diversification.

Aesthetics: Relates to landscape characteristics or features which are able to promote a feeling of liking or disliking (adapted from Gobster et al., 2007). No dominant indicator was favoured over this value enumeration; instead numerous subjective indicators were proposed: Sublime features e.g., mountains; Viewpoints; Variety of colors/smell; Landscape features providing coherence; Listed trees classified as monuments; Topographic variability; Time depth, time origin “old landscapes”. Therefore present category will be omitted from further evaluation.

Orchard Type	**Area (Ha)**	**Representative Taxon**	**Ecosystems Services**	**ES Function**	**Grade per He**	Grade Total
Deciduous Intensive	631651,86	*Malus sylvestris / Prunus persica*	Regulation	Biotic support	0,88	0,07
				Abiotic support	1,25	0,11
				Flows support	0,31	0,03
			Provision	Nutrition	1,50	0,13
				Biomass		
			Cultural		557.089,18	0,07
Deciduous Extensive	1444125,87	*Amygdalus communis*	Regulation	Biotic support	3,50	0,68
				Abiotic support	5,00	0,97
				Flows support	1,25	0,00
			Provision	Nutrition	6,00	0,68
				Biomass		
			Cultural		2.228.356,70	0,30
Evergreen Intensive	942757,68	*Citrus sinensis*	Regulation	Biotic support	1,75	0,22
				Abiotic support	2,50	0,32
				Flows support	0,63	0,08
			Provision	Nutrition	0,75	

Orchard Type	**Area (Ha)**	**Representative Taxon**	**Ecosystems Services**	**ES Function**	**Grade per He**	Grade Total
				Biomass		0,09
			Cultural		1.114.178,35	0,15
Evergreen Extensive	4456713,4	*Olea europaea*	Regulation	Biotic support	7,00	4,17
				Abiotic support	10,00	5,96
				Flows support	2,50	1,49
			Provision	Nutrition	3,00	1,79
				Biomass		
			Cultural		4.456.713,40	0,60
	7475248,81					

Ecosystems Services	**ES Function**	**Grade**	**Performance**
Regulation	Biotic support	13,13	5,14
	Abiotic support	18,75	7,35
	Flows support	4,69	1,60
Provision	Nutrition	11,25	2,69
	Biomass		
Cultural	Stewardship/ Diversity	8.356.337,63	1,12

4. Conclusions

The fundamental challenge in the elaborated study was focused towards the minimization of the inefficient and inappropriate impacts on provisioning of multiple ES by enhancing the understanding of multi-relationships between ES. Making this information more explicit and accessible is more likely to drive at more balanced conditions (Carpenter et al., 2009). In this study, we tried elaborate on relationships between ES by a synthesis of relationships between ES according to the established scientific literature and best available practices. Our results provide an overview of ES homologous groups assessment; those results reflect in a national level for a specific land use – namely orchards - of various biological and cultivation background. Those results equip the project with a practical tool towards the implementation of C.1 Action.

In specific, our results highlighted pairs of ES for which more input is needed from the scientific community. Those results were already utilized in the design of the project's implementation. To be more precise critical knowledge gaps that were identified relate to the availability of primary data on the following subjects of the 5 archetypal crops:

1. *Olea europaea*
2. *Amygdalus communis*
3. *Malus sylvestris*
4. *Citrus sinensis*
5. *Prunus persica*

A. Biomass:

- I. Annual Production per plant
    - α. Foliage

β. crop

γ. root

II. Stored in plant tissue

α. trank

β. root

III. Crop by products

α. Cuttings

β. Crop Residues

B. Cultivation:

I. Machinery

II. Human Labour

III. Agrochemicals

IV. Soil Cultivation

V. Irrigation

C. Biodiversity

I. Plants

II. Fungi

III. Insects

IV. Animals

The limited number of case studies and the uneven distribution across ES groups, scales and land system archetypes is a potential explanation for it. Therefore, we encompass those priorities in the course of the project's implementation in order to to come to a more complete picture on relationships between different ES. Being able to predict the direction of a relationship between ES as a function of scale and land system would be an important step for decision support and ecosystem management but it would be by no means the end of the end of the road.

Previous results concerning TC categorization provided an innovative and inclusive framework for both the continuation of CLIMATREE's implementation but also for the Assessment of their respective ESs.

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