LIFE Project Number

LIFE14 CCM/IT/000905

Final Report

Covering the project activities from 01/09/2015 to 31/08/2019

Reporting Date

<28/11/2019>

LIFE PROJECT NAME or Acronym

LIFE FoResMit

Data Project

Project location:	Italy: Toscana; Greece: Anatoliki Makedonia, Thraki
Project start date:	01/09/2015
Project end date:	31/08/2019
Total budget:	€ 1,480,568
EU contribution:	€ 879,264
(%) of eligible costs:	60

Data Beneficiary

Name Beneficiary:	Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria
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2. List of keywords and abbreviations

AHP = Analytic Hierarchy Process
BD = Bulk Density
BEF = Biomass Expansion Factor
C = carbon
CEC = cation exchange capacity
CH_4 = methane
CO_2 = carbon dioxide
CRU = Climate Research Unit
DBH = Diameter at Breast Height
DNA = DeoxyriboNucleic Acid
EGM = Environmental Gas Monitoring
ES = Ecosystem Service
FAS = Fixed Area Sampling
FoResMit = Recovery of degraded coniferous Forests for environmental sustainability Restoration and climate change Mitigation
GHG = green-house gas
GIS = Geographic Information System
GWP = Global Warming Potential
IRGA = Infra-Red Gan Analyzer
LIS = Line Intersect Sampling
MCDA = Multiple-Criteria Decision Analysis
N = nitrogen
NGO = non-governmental organization
N_2O = nitrous oxide
NPP = Net Primary Produtivity
PCR-DGGE = Polimerase Chain Reaction - Denaturing Gradient Gel Electrophoresis
PDSI = Palmer drought severity index
SPEI = Standardized Precipitation–Evapotranspiration Index
WBD = Wood Basal Density

3. Executive Summary

The general objective of the project was to apply innovative silvicultural practices for the restoration of peri-urban degraded coniferous forests in Italy (Monte Morello forest) and Greece (Xanthi forest), improving the ecological stability and climate change mitigation potential of these ecosystems. The project tested and verified in the field the effectiveness of thinning treatments in degraded coniferous forests in meeting climate change mitigation objectives. At the same time the project aimed at ensuring more resilient forest ecosystems and creating benefits for local population and human well-being.

A multidisciplinary approach was applied to define the impact of traditional and selective thinning treatments on vegetation structure, biomass increment, C accumulation in all relevant pools of vegetation and soil, and GHG fluxes (CO_2, CH_4 and N_2O), thus giving a complete picture of mitigation potential of management practices.

In detail, main deliverables and output includes:

- Detailed methodological protocols for: i) selection of monitoring plots and subplots; ii) measurements of above and belowground biomass and C stock; iii) litterfall and its components; iv) forest floor C and N stock and its fractionation in relevant pools; v) deadwood volume (comparing two different silvicultural treatments), C and N stock and decomposition rates; vi) soil C and N stock and bulk density; vii) GHG fluxes (CO_2, CH_4 and N_2O) with static chambers from soil, litter and deadwood and GWP; viii) C credits and C sequestration estimation, considering vegetation, soil and fluxes.
- 3 years of monitoring from 2016 to 2018 produced a large amount of data from the two sites including: i) C stock in aboveground and belowground biomass, litter, deadwood and soil; ii) structure, resilience and stability of the forest stands; iii) budget of CO_2, CH_4 and N_2O fluxes; iv) GWP during thinning, one and two years after thinning; v) bioenergy production and fossil fuel substitution; vi) C sequestration potential in vegetation and soil; vii) years required to produce C credits.
- Local community's involvement in the decision-making process to define forest management guidelines able to consider social needs and request through i) consultation of 269 beneficiaries of the forest through questionnaire survey; ii) involvement of 34 organized groups through semi-structured interviews; iii) public meeting with the citizens. Overall, 17 events have been organized, with 653 participants involved in meetings and workshops, plus hundreds involved in general publics dedicated events. A simple and informative factsheet and 340 Layman's report were also distributed to the general public, besides direct communication in field and in public premises.
- Local authorities, managers, politicians and officials of public administration have been informed about the silvicultural approach and results. 4 workshops specifically designed to policy makers have been organized, 25 public entities and 27 forest-wood chain actors declared their interest in the replication of selective thinning in Italy and Greece. The new plan of Xanthi-Geraka-Kimmerion public forest cluster already included selective thinning and the Forest Service of Xanthi has already applied selective thinning in the first tree marking process in spring 2019. Forest Directorates of Eastern Macedonia and Thrace and 8 municipalities declared to include the FoResMit approach in their management plans. A Manual reporting all methodologies, results and general guidelines have been produced and distributed in 400 copies, besides direct communication in field and in public premises.

Thinning implementation on 8.65 and 8.03 ha for selective and traditional thinning, respectively (Task C) and data collection (Task D) did not present particular problems, except for site heterogeneities and spatial variability, which required attention in the phase of monitoring plots selection, thinning operations in Italy and Greece and data elaboration. Preliminary Actions (Task A) have been extended for 6 months to collect more data and select properly monitoring plots.

Besides activities planned in the proposal, more effort has been devoted to understanding processes and drivers of mechanisms involved in C cycling and therefore C sequestration. An in-depth study

involving soil, litter and deadwood was performed, including microbiological analyses also by means of DNA (Actions D1and D2). GIS analysis was also performed to expand results to larger areas (Action C2 and D2). These additional activities used the budget saved from other actions. Action D3 was anticipated to demonstrate how the silvicultural treatments could compensate the CO_2 emissions of a cultural event and perform a trade-off analysis among ecosystem services considering different benefits created by the treatments. C brokerage foreseen in Action D3 was not implemented as foreseen, but contacts established with Regione Marche and UNCEM Marche allowed to quantify the forest area to be thinned necessary to compensate 9,000 t of CO_2 emitted during the realization of the third lane of the Regione Marche freeway. Moreover, adopted solutions have been proposed at public (Nucleo Monitoraggio del C of CREA-PB) and private entities (Ethifor) involved in sustainable management and development and will continue after the end of the project.

Overall, LIFE FoResMit project demonstrated the applicability of thinning treatments based on positive selection to recover degraded coniferous forests. Referring to the expected results, at the end of the project, the following main objectives were achieved:

- demonstration of the three mitigation options of i) 8 % reduction of GHG emissions, ii) sequestration of 44.8 t CO_2 ha^{-1} y^{-1} and iii) substitution of fossil fuels for energy production with biological products saving 1936 t CO_2.
- 6 % increased net primary productivity of forest stands, 33 % decrease of unstable trees and increased resilience
- 19 % increase of soil C stock
- after an initial increase, 8 % reduction of CO_2 emissions and GWP from soil and 20% increase of CH_4 uptake
- 3468 MWh produced with removed woody biomass and fossil fuel substitution
- quantification of C credits (95 € ha^{-1} yr^{-1}), C sequestration (44.8 t CO_2 ha^{-1} y^{-1}) and timing to gain C credits (5 years)
- forest ecosystem services improved, considering trade-off and synergies among provisioning, regulating, supporting and cultural services.
- Guidelines and know-how of silvicultural practices effectiveness provided.

Overall, advantages of selective thinning cover several ecosystem services and are not exclusive of C sequestration recovery.

Table 1. Impact of selective thinning on ecosystem services after 2 years

Type of ecosystem service	Indicator	Impact of selective thinning
Provisioning	Trees productivity	6 % increase
	Bioenergy production	3468 MWh
Habitat	Structural diversity	10 % increase
	Decomposed deadwood	18.2 m^3 decrease
	Stability and resilience	33 % increase
Regulating	Carbon stock in vegetation	40 % decrease
	Carbon increment in vegetation	6 % increase
	Carbon increment in soil	19 % increase
	CO_2 emissions	8 % decrease
	CH_4 uptake	20 % increase
	N_2O emissions	No significant changes
Cultural	Aesthetic attractiveness	increase
	Recreation opportunities	increase

4. Introduction

Description of background, problems and objectives (as foreseen in the proposal)

– *Climate related problem/issue addressed*

Forest degradation, resulting in a loss of biomass or in a reduced production, occurs through damage to residual trees and soil from poor logging practices, log poaching, fuelwood collection, overgrazing, and anthropogenic fire. Forest degradation, implying a decrease in canopy cover and regeneration, as well as forest fragmentation, will affect the annual increment of C sequestration, reducing the potential of these forests to act as a sink or transforming them into a source of GHGs. C emissions from deforestation and forest degradation have been estimated to account for about 12-20% of global anthropogenic CO_2 emissions. Although deforestation is the main source, forest degradation contributes to atmospheric GHG emissions through decomposition of remaining plant material and soil C. These larger emissions are no more balanced by the C storage capacity in woody biomass and soil, due to unstable structural conditions of the degraded stands. Deforestation and forest degradation are important contributors to global GHG emissions, but if these processes are controlled, forests can significantly contribute to climate change mitigation. Therefore, the current forest degradation needs an innovative management plan aimed to support and facilitate all the functionalities of a peri-urban forest, in a context of climate change mitigation.

– *Outline the solution to be demonstrated / verified by the project*

The practice of thinning in Italy was cutting from below and with low to moderate intensity. However, with interventions of low intensity directed to the dominated plants alone, the structure of the forest is not positively affected; in practice, only the plants that over time would have disappeared due to natural mortality (self-thinning) are thinned. Interventions of this nature, besides not having a positive impact on the vigour of the forest, in practice represent only an element of disturbance which cannot be justified at crop level.

To reconcile the advantages of thinning from above with the easiness and replicability of the intervention, which contains as much as possible the costs of hammering, a method of thinning from above has been developed as simple and effective as possible: "selective thinning". The project tested and verified in two demonstration areas in Italy and Greece the effectiveness of this management option considering vegetation structure, biomass increment, C accumulation in all relevant pools of vegetation and soil, and CO_2 and other GHG emissions, thus giving a complete picture of its mitigation potential.

– *Description of the technical / methodological solution*

To fulfil its objectives, the project has been arranged into the following actions:

Preparatory actions to classify and characterize the two sites in Italy and Greece from a vegetation, climatic and pedological point of view. Target species/ecosystem types and test areas have been identified. The preparatory actions have been primarily used to validate the selection of the test areas, depending on vegetation and soil characterization. The methodological details of the Actions have been set out (e.g. sampling protocols) to ensure soundness to the aims of the project and comparability of results between the two sites.

Implementation actions have been devoted to the application of silvicultural treatments for the forest restoration and productivity increase. Different silvicultural treatments have been compared to demonstrate that innovative thinning has the best performance: 1) traditional thinning; 2) innovative selective thinning; 3) control plot without treatments. Harvested raw materials have been converted into electrical/heat energy as substitute of fossil fuels.

Monitoring actions have measured all C and N pools in above and belowground biomass, litter, dead wood and soil (IPCC 2003) and their temporal variations. Net primary productivity and C accumulation in soil after thinning treatments will be assessed. GHG fluxes from soil and dead-wood material have been quantified. C sequestration potential and GWP in the short and medium-term have been estimated. Performance indicators have been monitored and measured.

– *Expected results and climate action related benefits*

- demonstration of the three mitigation options of i) reduction/prevention of emissions, ii) sequestration – enhancing uptake of C and iii) substitution of fossil fuels for energy production with biological products.

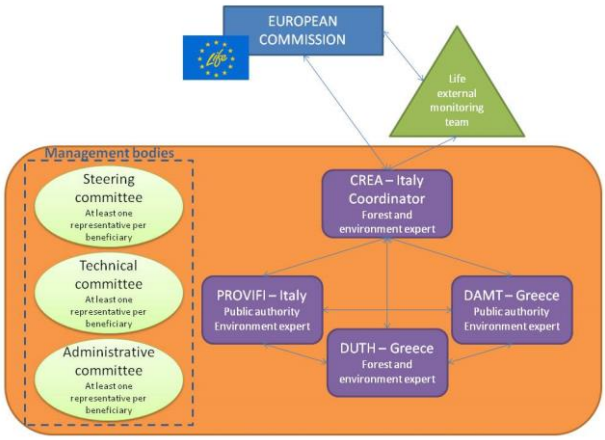
- increased net primary production of forest ecosystem, due to the removal of non-growing or dead trees and the higher growth rates of remained vegetation. An increment of productivity up to 40 – 60 % was expected;
- an initial increase of GHG emissions was expected, followed by a stabilization towards a reduction after thinning treatment;
- reduction of heterotrophic respiration of decomposable deadwood material, with a consequent reduction of CO_2 emissions in the range of 5-15 % per year was expected in the medium-long term;
- only minor changes in N_2O and CH_4 emissions were expected;
- the decrease of standing biomass due to harvesting will be counterbalanced by the energy cogeneration of wood material as fossil fuels substitution option. We expect a neutral balance from living plants and a positive balance from dead trees, corresponding to 40 % of forest biomass;
- carbon credits deriving from the thinning intervention will be quantified;
- selective thinning and harvesting to reduce tree densities and remove deadwood material will reduce the probability and intensities of fires.

Expected longer term results (as anticipated at the start of the project)

The project supports the implementation of regional and local policy instruments for sustainable land use with a specific focus on sustainable forest management and silvicultural options oriented to the restoration of peri-urban pine forests to reduce GHG emissions to the atmosphere, taking into account the ecological stability of the stands and the other relevant forest functions. The project will contribute to identify more appropriate mitigation strategies that have become closely connected to sustainable forest resources management, especially in peri-urban areas, including reduced emissions from forest degradation, enhanced sequestration rate in restored stands and provisioning of substantial co-benefits in terms of society's needs for energy, increasing the use of forest-derived biomass to substitute fossil fuels. Moreover, the project proposes a full account of changes of C pools in vegetation and soil and GHG emissions derived from management of degraded pine forest, thus contributing significantly in data availability and mitigation measures and improving the knowledge base for the development, assessment, monitoring, evaluation and implementation of effective climate change mitigation actions and measures and to enhance the capacity to apply that knowledge in practice.

5. Administrative part

The project management structure is very simple, with 4 beneficiaries and 3 committees (steering, technical and administrative), as reported below:



Steering Committee:
CREA: A. Lagomarsino, U. Chiavetta, A. Paletto
PROVIFI: L. Ermini
DUTH: K. Radoglou
DAMT: P. Mouchtaridis
Technical Committee:
CREA: A. Lagomarsino, I. De Meo
PROVIFI: L. Gheri
DUTH: E. Milios
DAMT: M. Triadafillidou
Administrative Committee:
CREA: M. Aglietti
PROVIFI: S. Pappalardo
DUTH: K. Kitikidou
DAMT: F. Doukalianou

CREA: Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, participate with two research Centers: Agriculture and Environment (Firenze) and Forest and Wood (Arezzo and Trento). The two Centers cover research activities on soil ecosystem functions and their conservation, and sustainable management of the forest environment.
PROVIFI: Città Metropolitana di Firenze is the territorial entity acting in development sectors, such as planning, managing infrastructure for mobility, environmental policies.
DUTh: Democritus University of Thrace participate with the Department of Forestry and Management of the Environment and Natural Resources (FMENR) carrying out research on the development, improvement, protection and management of forests, forest lands and the natural environment.
DAMT: Decentralized Administration of Thrace is responsible for the protection, exploitation and growth of forest resources aiming at the cover of needs of country in timber and other products and services of forest.
During all project phase, the FoResMit project has benefited from close collaboration between all beneficiaries and has maintained close contact through different media (e-mail, telephone, meetings, etc.). The management of the project was carried out in compliance with what was established in the proposal, with all partners acting in compliance with the Grant and Partnership Agreements. No significant deviations occurred.
The FoResMit management process maintained a permanent flow of action with the aim of achieving the objectives set. The specific management activities carried out were:

- Preparation of the Partnership Agreement;
- Organization of Coordination meetings;
- Organization of Monitoring meetings;
- Phone and Skype meetings between beneficiaries in order to plan and monitor the project technical activities, scientific and technical reports, dissemination;
- Continuous contact between all project beneficiaries for monitoring project activities;
- Preparation of material for meetings and dissemination events;
- General actions and activities for the coordination of the project;
- Management of the financial aspects of the project;
- Monthly (three-monthly in 2019) reports to the LIFE external team monitor on the evolution of the project.

AMENDMENTS were related to changes in the Form A2 and FC, on the legal address and representative of CREA (Letter Amendment Nr. 2 to Grant Agreement).

6. Technical part (maximum 25 pages)

6.1 Technical progress, per Action

Action A1 Climatic characterization and vegetation survey

Foreseen start date: 01/09/2015 Actual start date:01/09/2015
Foreseen end date: 31/12/2015 Actual end date:30/06/2016

Climatic characterization

All forecasted activities were carried out, using datasets from the Climate Research Unit (CRU), University of East Anglia, UK. Monte Morello climate is typically Mediterranean. A significant reduction of winter-early spring precipitation of about 20 % occurred during the last thirty years. Moreover, during the summer season a significant drought period appeared. Xanthi forest climate is semi wet Mediterranean with tendency to dry and it is characterized by mild and rainy winters, relatively warm and dry summers. The xerothermic period begins in the middle of June until the end of September. A significant decrease in rainfall was observed in the last decade that is estimated at around 25%, whereas in the study period the reduction increased at 50%.

	Monte Morello (IT)	**Xanthi (GR)**
Climate (1980-2014)		
Min – Mean – Max T (°C)	9.3 – 13.3 – 17.9	8.5 – 13.3 – 18.0
Precipitation (mm)	876	526
Palmer drought severity index (PDSI)	-0.53	-0.73
Standardized Precipitation–Evapotranspiration Index (SPEI)	-0.04	-0.12

Other data have been reported with the progress report in the deliverable A.1b Climatic and vegetation characterization of selected monitoring plots.

Vegetation characterization

All forecasted activities were carried out: a) delimitation of the 2 intervention areas and the 18 monitoring plots (9 for each site, with 3 replicates for each treatment); b) for all tree with diameter at breast height (DBH) > 3 cm the following attributes have been measured: species, DBH, total height, crown depth, crown projections, number of living whorls, minimum mensuration, crown vigour; c) forest type classification according the European Environmental Agency forest types nomenclature system; d) historical analysis of forest management; e) parameters of forest degradation.

Monte Morello forest has been planted during 1910-1980 years. The overall composition is typical of a coniferous plantation, more than 80% of biomass is characterized by pines (*Pinus nigra* e *Pinus brutia*) and cypress (*Cupressus sempervirens* e *Cupressus arizonica*) species. Moreover, an additional 10% of *Quercus cerris* is present. In terms of frequency, the overall composition resulted in a *Fraxinus Ornus* relative predominance in the understory layer.

Xanthi forest is a part of Xanhti –Gerakas – Kimerion public forest. The planting activities began in 1936 and took place periodically up to 2007. In the reforestations *Pinus brutia* was mainly planted. *Pinus maritima, Pinus pinea, Cupressus* spp. and *Pinus nigra*, as some broadleaves like *Robinia pseudoacacia* have also been used. There is an understory of broadleaves (*Quercus* spp., *Carpinus orientalis* etc.).

	Monte Morello (IT)	**Xanthi (GR)**
Stand characteristics (pre-thinning)		

Vegetation type	Plantations of site-native species (EEA-EFTs code: 6.14.1)	
Stand age (years)	55-65	50-60
Mean tree density (tree ha^{-1})	980	2626
Basal area (m^2 ha^{-1})	62.9	38.8
Mean height (m)	17.1	10.7
Unstable trees (%)	67	42

Details have been reported with the progress report in the deliverable A.1b Climatic and vegetation characterization of selected monitoring plots and in the deliverable A.1a List and localization of selected monitoring plots, where maps are available.

Action A2 Pedological survey

Foreseen start date: 01/09/2015 Actual start date:01/09/2015
Foreseen end date: 31/03/2016 Actual end date:30/06/2016

The pedological survey allowed to validate the selection of test areas to reduce biases due to soil heterogeneity and, in particular, the absence of initial differences among treatments has been checked. The results provided the following information: a) geological and pedological classification of the areas from existing thematic maps; b) soil profiles description; c) physico-chemical characterization at 0-10 and 10-30 cm depth, including texture classification, fertility class and percentage of inorganic N forms; d) analyses of soil organic C and N pools at 0-10 and 10-30 cm depth.

Monte Morello has a calcareous flysch (turbidites) substratum, constituted by alternating limestones, marly limestones ("alberese") marls, claystones and, subordinately, sandstones. The soil typologies are Calcaric Cambisols and Cambic Calcisols, the thermometric regime is mesic and the moisture regime is udic. The soils present a loam or clay loam texture, showed moderately alkaline reaction, usually high and very high carbonate content. Depth was very variable, ranging from less than 50 cm to more than 100 cm. Soil organic matter content of the site was typical of a Mediterranean forest site, with a clear vertical distribution of total N and total organic C.

The geological formation of the Xanthi's periurban forest is part of the Rodopi's mountain formation, consisting mostly by metamorphic rocks, Gneisses and Para-gneisses. The soils are deep more than 60cm), approximately 10cm in depth well drained. The soil type is Cambisols with a moderately acidic pH (5.6) and a low content of carbonates (6.2%). Soils had a sandy clay to sandy clay loam texture, with average values of sand and clay of 60% and 17.5% respectively. Soil organic matter content of the study site showed a clear vertical distribution of total N and total organic C.

Three more months respect to what foreseen were needed to complete the Action, because of high field variability and laboratory work underestimation.

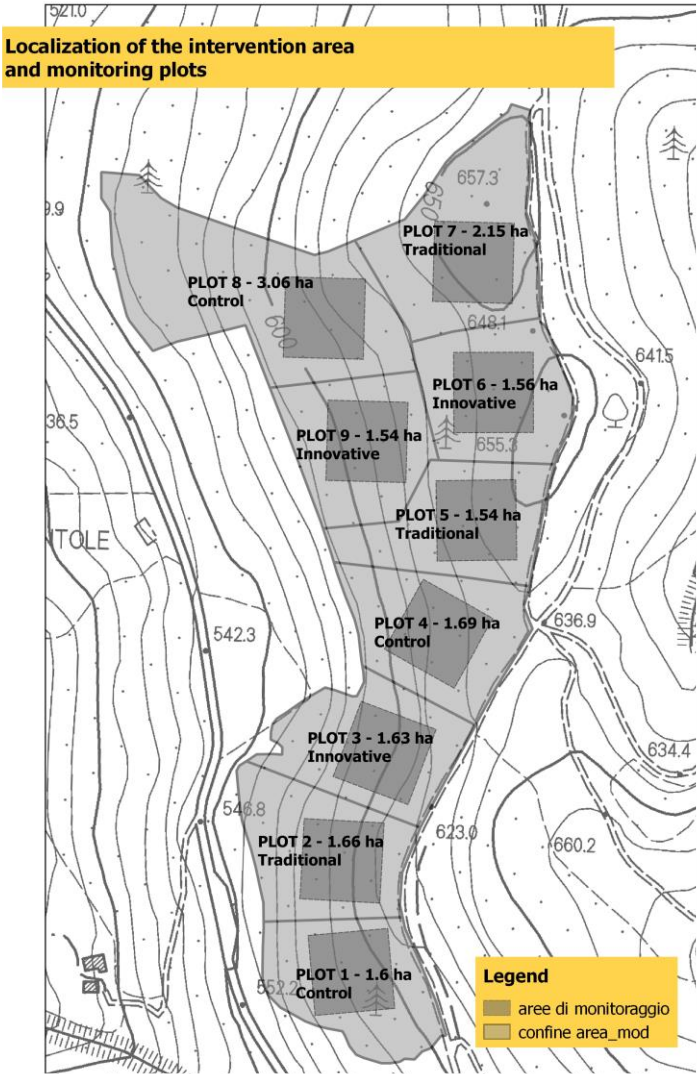
Details have been reported with the progress report in the deliverable A.2a Soil profiles description and pedological classification of monitoring plots and A.2b Physico-chemical characterization of monitoring plots.

	Monte Morello (IT)	**Xanthi (GR)**
Soil characterization (pre-thinning)		
Soil type	Calcaric Cambisols and Cambic Calcisols	Cambisols
pH – Carbonates (%)	8.1 – 8.2	5.6 – 6.2
Sand (%) – Clay (%)	38.4 – 27.1	60.0 – 17.5
Total Organic C (kg m^{-2})	5.5	3.3
Soil Organic Matter (kg m^{-2})	9.5	5.7

Total nitrogen (kg m^{-2})	0.39	0.48
Labile Organic C (kg m^{-2})	0.17	0.03

Action C1 Realization of thinning intervention in Italy

Foreseen start date: 01/01/2016 Actual start date:01/11/2015
Foreseen end date: 31/12/2016 Actual end date:31/12/2016



9 demonstration plots were selected in Monte Morello forest and randomly assigned, considering three replicates, to each of the silvicultural treatment applied: Control (no silvicultural interventional), Traditional (Thinning from below) and Selective (Selective thinning).

PROVIFI and CREA performed the following activities: i) a map of the applied silvicultural treatment areas 1:10.000; ii) all field measurements which were necessary for treatment implementation; iii) tender for operations was assigned to be concluded in 90 days.

Cutting activities have been performed between 03/08/2016 and 30/11/2016, according to the following schedule:

- August 3rd 2016 to October 31st 2016: i) survey and check of the work progress; ii) harvesting, iii) forest roads and paths preparation for yarding; iv) yarding operations
- October 31st 2016 to November 24th 2016: i) due to the weather conditions time extension was needed to complete the previous operations
- November 24th 2016 to November 30th 2016: wood-chipping operations

A series of administrative work by PROVIFI was needed: one month was needed to technically and legally validate the field activities until the end of December 2016; additionally, 20 working days were needed to check other administrative circumstances mandatory to authorize the payment by the PROVIFI as a public body.

Biometrical parameters and structure indices have been measured before (2015), immediately after thinning (2016) and two years after thinning (2018). Main results are summarized in the following table, reporting the percentage variation with respect to Control:

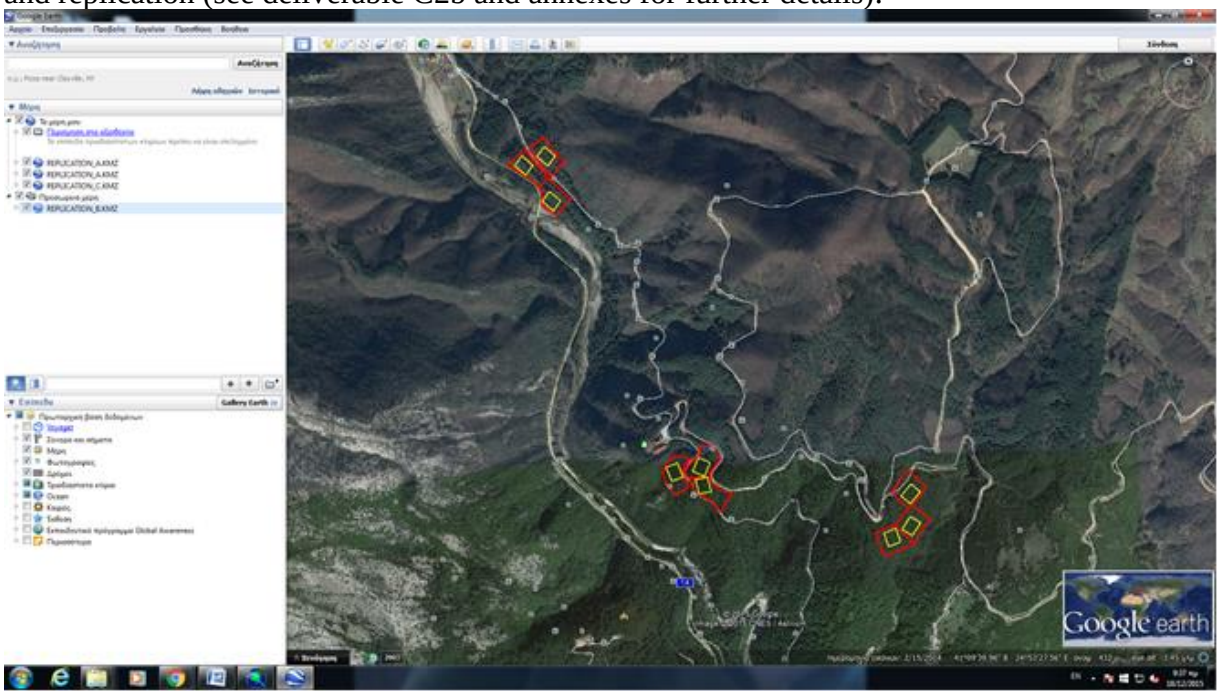
	Traditional thinning	Selective thinning
Trees (number)	-35 %	-42%
Basal area (m^2)	-25 %	-40%
Biomass increment (%)	+6%	+6%
Radial increment (%)	+35%	**+60%**
Unstable trees (number)	-11%	**-33%**

Mean stability (%)	+0,3%	**+4%**
Structural heterogeneity (%)	-	+10

Action C2 Realization of thinning intervention in Greece

Foreseen start date: 01/01/2016 Actual start date:01/01/2016
Foreseen end date: 31/12/2016 Actual end date:31/12/2016

9 demonstration plots of 1.1 ha each were selected in Xanthi forest and randomly assigned, considering three replicates, to each of the silvicultural treatment applied: Control (no silvicultural interventional), Traditional (Thinning from below) and Selective (Selective thinning). Map in GIS environment collecting geographic dataset (spatial data) and various database (attribute data), creating feature classes and datasets for each area, was developed and used for data spatialization and replication (see deliverable C2b and annexes for further details):



Cutting activities have been performed in September 2016. DAMT was in charge with all procedures and permissions for cutting.

The following variables have been measured: i) DBH of each tree; ii) total height (*h*) and bole height (h_b) of the trees with $h \geq 1.3$ cm, with Haglöf Vertex laser hypsometer; iii) form height (*fh*) of the trees with $d \geq 15$ cm, with Bitterlich's Spiegel relaskop; iv) social rank and health (visual assessment).

Biometrical parameters and structure indices have been measured before (2015), immediately after thinning (2016) and two years after thinning (2018). Main results are summarized in the following table, reporting the percentage variation with respect to Control:

	Traditional thinning	Selective thinning
Trees (number)	-21%	-29%
Basal area (m^2)	-21%	-40%
Biomass increase (%)	3%	4%
Basal area increase (%)	3%	5%
Unstable trees (%)	-0.4%	-5.3%
Conifer volume (m^3)	-18.8%	-28.1%
Broadleaves volume (m^3)	-7.6%	-33.4%

Action D1 Monitoring and quantification of C pools in vegetation and soil

Foreseen start date:	01/01/2016	Actual start date:	01/10/2015
Foreseen end date:	30/06/2019	Actual end date:	30/06/2019

Above and belowground biomass

Trees biomass was monitored before (2015) and two years after the treatments (2018) by measuring: DBH, total height (H), species and position of all the trees with DBH > 3 cm. Aboveground biomass was estimated through species-specific biomass expansion factors (BEF) and wood basal density coefficients (WBD) which convert wood volume to biomass dry weight (see deliverable D1). Belowground biomass was derived from aboveground biomass using root/shoots conversion factors experimentally tested for different species (see deliverable D1). Biomass was converted to C stock using a 0.5 coefficient. Data were used for C credits and C sequestration calculation in Action D3. For further details see Deliverable D1. A new measurement is foreseen in 2021, 5 years after thinning and 3 years after the end of the project.

MONTE MORELLO: at stand level, after two years from treatment, the observed yearly relative increment was 6% of both traditional and selective thinning.

XANTHI: at stand level there was a statistically significant increase of aboveground biomass in selective thinning after two years from treatment. The increase in traditional thinning was not statistically significant.

	2015	2016	2018	Increment
		Mg C ha^{-1}		Mg C ha^{-1} y^{-1}
			Monte Morello	
Control	212.2	212.2	221.6	9.4
Traditional	223.2	172.3	192.8	20.5
Selective	168.6	110.5	123.7	13.2
			Xanthi	
Control	317.2	330.5	357.0	13.3
Traditional	213.2	226.3	252.6	13.2
Selective	165.9	176.7	198.1	10.8

Deadwood

The field measurements on lying deadwood are conducted using two methods: FAS (Fixed Area Sampling) and LIS (Line Intersect Sampling). Lying deadwood on the soil (logs), standing dead trees (snags) and stumps were measured in the 36 monitoring plots:

	Lying deadwood	**Standing dead trees**	**Stumps**	**Total**
Monte Morello (m^3 ha^{-1})				
Decay class 1	2.90	4.48	0.00	7.38
Decay class 2	15.05	4.82	0.07	19.94
Decay class 3	32.37	4.48	0.70	37.55
Decay class 4	8.51	0.12	0.40	9.03
Decay class 5	1.09	0.02	0.07	1.18
Total	***59.91***	***13.92***	***1.25***	***75.08***
Xanthi (m^3 ha^{-1})				
Decay class 1	0.91	0.21	0.89	2.01
Decay class 2	0.52	0.99	0.49	1.99
Decay class 3	0.69	0.43	0.79	1.91
Decay class 4	0.69	0.00	0.38	1.07
Decay class 5	0.30	0.00	1.94	2.23
Total	***3.11***	***1.63***	***4.48***	***9.21***

For further details see deliverable D1.

Litter

Litterfall was collected seasonally through 72 traps and the main litter components (conifers vs. broadleaves: pine needles, deciduous leaves, twigs and branches with diameter < 4.5 cm, reproductive structures and bark) have been separated. Forest floor litter was collected once a year (2015, 2016, 2017 and 2018) and separated into three representative fractions: L - fresh or almost undecomposed litter; F - medium to strongly fragmented material with many mycelia and thin roots; H - completely decomposed amorphous material.

BOTH SITES: Compared to the un-thinned plots, under selective thinning coniferous litterfall fraction decreased, while deciduous litterfall fraction increased, in line with the project objective favouring native broadleaved species. Thinning basically increased litter biomass in all horizons immediately after thinning, whereas two years after thinning a reduction of litter was observed, which was more evident in selective thinning.

Litter biomass before and after thinning for Monte Morello and Xanthi forests:

	2015	**2016**	**2017**	**2018**
		Mg C ha^{-1}		
		Monte Morello		
Control	9.0	9.2	11.8	9.1
Traditional	8.1	14.7	12.0	10.3
Selective	9.8	11.8	12.1	7.3
		Xanthi		
Control	1.1	1.2	1.2	1.2
Traditional	1.2	1.7	1.3	1.3
Selective	1.0	1.8	1.7	1.7

Soil

Soil was collected once a year (2015, 2016, 2017 and 2018) from the same position as forest floor litter at depth of 0-10 and 10-30 cm within each plot. Further, undisturbed soil samples were collected for soil bulk density (BD) measurement, to calculate soil organic C stock for each depth. Data were used for C credits and C sequestration calculation in Action D3. A new measurement campaign is foreseen in 2021, 5 years after thinning and 3 years after the end of the project.

MONTE MORELLO: The effect of thinning on soil C stock became evident two years after treatments, with an increase of 29 and 33 % in Traditional and Selective treatments, respectively. Overall, 32.0 and 35.6 t CO_2 ha^{-1} y^{-1} were sequestered into soil up to 30 cm depth with traditional and selective thinning, respectively.

XANTHI: The effect of thinning on soil carbon stock two years after thinning was an increase of 5 % in both traditional and selective treatments. Overall, 16.5 and 16.9 t CO_2 ha^{-1} y^{-1} were sequestered into soil up to 30 cm depth in traditional and selective thinning, respectively.

	2015	2016	2017	2018
		Mg C ha^{-1}		
		Monte Morello		
Control	99	148	119	100
Traditional	102	133	105	129
Selective	104	161	131	134
		Xanthi		
Control	66	74	73	72
Traditional	64	83	86	88
Selective	57	91	93	95

Action D2: Monitoring and quantification of GHG emissions and Global Warming Potential

Foreseen start date:	01/01/2016	Actual start date:	01/01/2016
Foreseen end date:	30/06/2019	Actual end date:	30/06/2019

The effect of thinning treatments on GHG exchanges was mediated by abiotic (temperature and moisture) and biotic drivers, mainly litterfall and C and N content of both forest floor and mineral soil. Short-term effects of thinning on CO_2 emissions were dependent on the timing of logging operations and organic matter inputs and for this reason were higher at Monte Morello than Xanthi, where the impact of thinning was lighter. The difference in duration and type of cutting were the most evident factors influencing GHG emissions, leading to almost 7 Mg CO_{2eq} ha^{-1} emitted more in Monte Morello (during three months) than Xanthi forest (during one month). After the end of silvicultural operations, the increase was reduced sharply and a decrease of GHG emissions was evident, in both sites. CO_2 was largely the most important gas contributing to GWP. Both sites were net CH_4 sink and CH_4 uptake increased significantly with selective thinning (+ 20 % on average). N_2O fluxes were characterized by low emissions with seasonal peaks independent of treatments.

MONTE MORELLO: gas collection had been performed once or twice a month from February 2016 until December 2018, for a total of 46 sampling events. CO_2 emissions followed a typical pattern driven by soil temperature, with the lowest values during winter. During the three months of thinning a peak of emissions was observed, 6.2 kg CO_2 ha^{-1} more than control plots. GWP followed CO_2 trend, with a short-term increase and without significant differences due to thinning after two years. In the second year, selective thinning saved 1.6 Mg CO_2 ha^{-1} with respect to Control.

XANTHI: gas collection had been performed twice a month from September 2016 until December 2018, for a total of 52 sampling events. Two years after thinning implementation, thinning was able to affect significantly CO_2 fluxes variation, with mean annual CO_2 emissions lower at selective compared to control. Mean GWP from all three GHGs (CO_2 + CH_4 + N_2O) is 74667 ± 2555 kg CO_{2eq} per ha per year, ranking among treatments in the order control > traditional > selective. A comparison of GWP among thinning treatments showed that the selective thinning was able to reduce CO_2 emissions by 2.9 Mg CO_{2eq} per ha with control as reference during the two years after thinning.

Considering both sites, during the 2nd year after silvicultural operations, selective thinning saved 2.4 Mg CO_{2eq} ha^{-1} y^{-1} with respect to control, on average. The reduction of CO_2 emissions was possibly related to an indirect effect of both soil heterotrophic and autotrophic respiration and soil environmental factors alteration caused by thinning.

	Monte Morello		Xanthi	
	Absolute change	% effect	Absolute change	% effect
CO_2 (kg C ha^{-1} y^{-1})	-883	-8	-416	-4
CH_4 uptake (kg C $ha^{-1}y^{-1}$)	0.36	+20	0.38	+21
N_2O (kg N $ha^{-1}y^{-1}$)	-0.03	-6	0.15	+39
GWP (Mg CO_{2eq} ha^{-1} y^{-1})	-3.3	-8	-1.5	-4

For further details see Deliverable D2.

With respect to the performance indicators and expected results reported in the proposal we found these differences related to the overall amount of GHG fluxes (higher for CO_2 emissions and lower for CH_4 uptake), whereas the impact remained about the same in terms of percentage.

GHG	Unit of measure	EXPECTED State-of-play at the end of the project period	ACTUAL State-of-play at the end of the project period	EXPECTED Impact at project level	ACTUAL Impact at project level
CO_2	Mg ha^{-1} y^{-1}	16.7	38.8	-3.3	-2.7
N_2O	kg ha^{-1} y^{-1}	1.35	3.3	0.0	-0.2
CH_4	kg ha^{-1} y^{-1}	-70	-13.6	-30	-2.3

Action D3 Governance of the project results in the carbon voluntary market

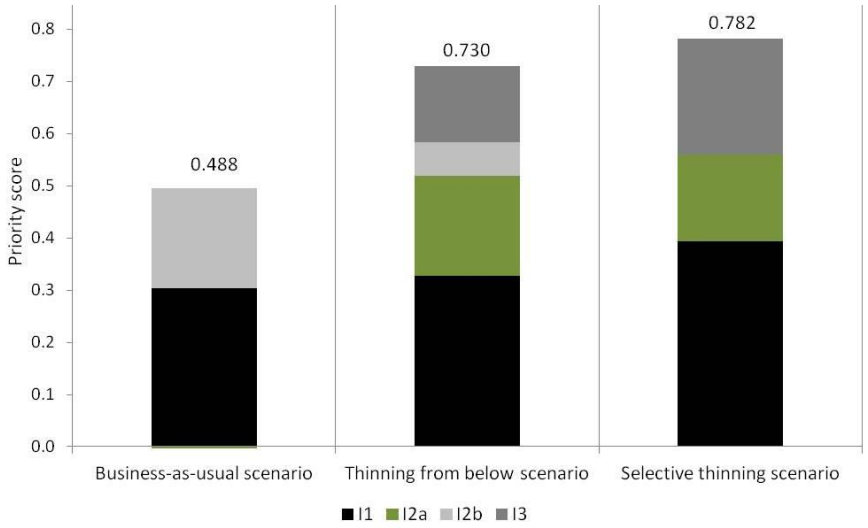
Foreseen start date: 01/01/2018 Actual start date:01/01/2016
Foreseen end date: 30/06/2019 Actual end date: 31/07/2019

To quantify C credits (CCs) generation, changes in C-stock – considering aboveground and belowground biomass, deadwood – and in C-sequestration (vegetation – soil – GHGs) were calculated (see table). After the selective thinning the C-stock decreases of 220 tCO_2 ha^{-1} (95% of changes are in above-ground biomass and 5% in deadwood). This decrease prevented CCs generation in the short term and C credit brokerage foreseen in the proposal. Moreover, small areas under thinning are not enough to generate marketable CCs and we did not implement C credit brokerage. In order to generate marketable CCs is necessary to apply the silvicultural treatments on the entire Monte Morello forest. However, C sequestration increased in vegetation and soil the two years after thinning, which has had the effect of transforming the forest into a net sink of CO_2, fulfilling its function of climate change mitigation. Contacts established with Regione Marche and UNCEM Marche demonstrated how to compensate CO_2 emitted during the realization of the third lane of the Regione Marche freeway through selective thinning on at least 400 ha. Summing the C-sequestration capacity of above- below-ground biomass and soil, and subtracting the C lost due to the soil emissions, the recovering time of the C-stock lost as result of silvicultural treatments and the economic benefits (Carbon Credits) were calculated considering the current price of 1 CC (approximately 2.1 € for tCO_2 - *Voluntary Carbon Markets Insights* 2018).

	Baseline scenario	**After TT scenario**	**After ST scenario**
Time for the C-stock recovering (yr)		3	5
Potential annual economic benefits from the sale of CCs (€ ha^{-1} yr^{-1})	-	108.8	94.9
Global economic benefits from the sale of CCs on the whole Monte Morello complex (1,035 ha) (€ yr^{-1})	-	112,608	98,222

Action D3 was anticipated and the following activities were performed: i) demonstration of how the silvicultural treatments could compensate the CO_2 emissions of a cultural event ii) trade off analyses among ecosystem services considering different benefits created by the treatments; iii) assessment of economic value of ecosystem services, including C sequestration; iv) forest wood-chain analysis and circular bioeconomy approach; v) investigation of visitors' demands and perceptions on peri-urban forests to include into management plans; vi) dissemination of a demonstrative document to SMEs and public entities involved or interested in C credits market.
Multi-Criteria Decision Analysis (MCDA) was used instead of SWOT (Strenght, Weakness, Opportunity and Threat) analysis in order to provide more detailed quantitative information concerning ecosystem services supply. The results of MCDA (reported in detail in Deliverable D4) were used to compare and to identify a ranking of importance of ecosystem services provided by traditional and selective thinning considering the following indicators:

- I_1 for the current economic importance of recreational benefits [€ ha^{-1} yr^{-1}];
- I_{2a} for the C-stock removed by thinning [tCO_2 ha^{-1}], and I_{2b} for the C-sequestration in above/below-ground biomass and soil [tCO_2 ha^{-1} yr^{-1}];
- I_3 calculated as the average annual income from the sale of wood products [€ ha^{-1} yr^{-1}].



The results show that the optimum forest management solution is the selective thinning followed by the traditional one. The results show that both types of thinning have a positive effect on all three indicators increasing the biophysical and economic benefits for the local community, but the selective thinning provides the best performance. Only applying the selective thinning is possible to increase the number of visitors (+29%) and, consequently, the site attractiveness. Besides, in the "Selective thinning scenario" the wood volume collected is 40% higher than in "Thinning from below scenario".

Deliverables on "Quantification of the carbon credit number considering the changes in the different carbon pools" and "Identification of key points leading to best practices and lessons learned in the carbon credit governance" were merged together and presented in one deliverable (Deliverable D3).

Awareness of the stakeholders involved in the project was reached through social events (653 participants) and groups targeted interviews (34).

Awareness among local population was reached through interviews and websites (see deliveral E5 for further details), social activities (2 public events and 5 seminars for the general public) and questionnaire survey to 269 recreationists visiting the Monte Morello area (see deliveral E8 for further details).

The CCs calculation will be repeated 5 years after thinning (2021), using outputs from Actions D1 and D2 and their generation will be used for publications and C credits governance in collaboration with public and private entities. FoResMit has been included in the surveys of Nucleo Monitoraggio del C (CREA-PB) and Rete rurale Nazionale and has been inserted in the database of Ethifor company for potential use of C credits calculation and results in the future.

Action D4 Monitoring of technical-socio-economic assessment of the LIFE FoResMit project

Foreseen start date: 01/01/2019 Actual start date: 01/01/2019
Foreseen end date: 31/08/2019 Actual end date: 31/08/2019

Action D4 assessed how selective thinning implemented with the LIFE FoResMit procedures comply with quality standards and is socio-economically viable, mainly increasing the social awareness and acceptance of the benefits of protecting the environment. Technical, social and economic viability and impact of FoResMit approach were evaluated.

Technical assessment

The forest-wood chain in Monte Morello was analyzed considering four main steps: felling, harvesting; chipping and wood transport (from forest to biomass plant or wood processing enterprise). For each step the material flows – the wood assortments derived by silvicultural treatments (traditional and selective thinning) and the CO_2 produced by forestry actions – have been estimated, as summarized in the following table:

Step	Workers	Working time [h]	Average productivity [t h^{-1}]	Fuel consumption [l]	CO_2 emissions [kg CO_2 t^{-1}]
Felling	2-4	756	1.6	454 gasoline	0.86
Harvesting	2-4	504	2.4	2318 diesel	5.1
Chipping	2	120	10.1	2400 diesel	5.2
Transport	Truck	-	20.0	210 diesel	0.46
Total					11.62

The use of the woodchip for heat production, compared to the use of natural gas and heating oil, allows to save, respectively, 207 and 278 gCO_2 kWh^{-1}. Further details are reported in Deliverable D4.

Social assessment

The local community's involvement in the decision-making process was carried on in three main steps: 1) Consultation of beneficiaries of the forest through questionnaire survey; 2) Involvement of organized groups though semi-structured interviews and 3) Public meeting with the citizens.

The recreational activities were assessed through the administration of a semi-structured questionnaire to a sample of 201 visitors (75% of 269 visitors contacted) of the Monte Morello forest. The questionnaire focused on people's preferences towards ecosystem services provided and visual-aesthetic impacts of the two silvicultural treatments applied (thinning from below and selective thinning).

Changes in the recreational opportunities in Monte Morello forest in the three forest management scenarios are summarized in the following table:

Scenario	Baseline	Thinning from below	Selective thinning
Priority score (AHP)	0.2093	0.2873	0.5034
Annual number of visitors	18,475	19,916	23,908
Recreational economic benefits (€ ha^{-1} yr^{-1})	179.2	193.2	231.9

The results highlighted a preference for selective thinning. Further details are reported in Deliverable D4.

Economic assessment

Four indicators have been defined in order to assess the efficiency of forest wood-chain and the economic impact considering the core principle of circular economy (4R framework – Reduce, Reuse, Recycle, and Recover) and then evaluated by a Multi-Criteria Decision Analysis (MCDA) comparing 4 different forest strategy options defined considering the silvicultural treatments applied and the potential wood products, as reported in the table:

Forest strategy options	Reduce [€ ha^{-1}]	Reuse [y]	Recycle [%]	Recover [kg CO_2 m^{-3}]
Traditional thinning + woodchips	337.8	0.5	0.3	-626.9
Selective thinning + woodchips	515.8	0.5	0.2	-626.4
Traditional thinning + packaging and poles	1,124.8	11.6	0.0	-373.2
Selective thinning + packaging and poles	1,667.3	8.9	0.0	-378.7

The results show that the current forest management strategy did not optimize the productive function because the wood harvested is totally allocated for bioenergy production. The economic value and the lifespan of wood products can be increased by means of the wood harvested valorization.

Action E.1 Project website

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/12/2015 Actual end date: 31/12/2015

During October 2015 the web site www.lifeFoResMit.com and the project Facebook page (https://it-it.facebook.com/pages/category/Community/Life-Foresmit-987204574678617/) were published, and they are network-accessible in English, Italian and Greek language. The site was periodically updated and it contains, in its public areas, all the documents produced during the project's activities, in particular: Visit counter; Link to other LIFE+ projects; Link to each beneficiary website; Results update; News update; Coming up; Reserved area; Link with the Facebook page for event booking/registration. Moreover, the partners added information about the project and dissemination activities to their corresponding corporate web sites and created a link to the web site created by CREA. Link to other projects are easily accessible. The technical deliverables and informative materials were uploaded on the website.
The project web site and Facebook page created are clearly and visibly marked with LIFE logo. Until August 2019 the website visitors were 803,820 and the Facebook friends 303. Other details regarding website indicators are reported in the deliverable E1.

Action E.2 LIFE+ information boards

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/12/2015 Actual end date:31/12/2017

During the first period of the FoResMit project CREA created the structure of the project Notice Board and produced 8 FoResMit Notice Boards, which were sent to all partners and displayed in visible spots and accessible places to the public on the partners' premises.
At each site 2 notice boards are permanently installed, plus other 6 smaller boards identifying the type of treatment. The notice boards report in an easy and synthetic way the rationale of the project, the methodological approach and figures of what is permanently visible in the forests.

Action E.3 Layman's report

Foreseen start date: 01/03/2019 Actual start date: 01/03/2019
Foreseen end date: 31/08/2019 Actual end date: 31/08/2019

At the end of the project CREA produced 600 FoResMit Layman's report in English, Italian and Greek already distributed at the meeting "*La foresta di Monte Morello: gestire una risorsa ed i suoi benefici. La parola ai cittadini*" on 19 March 2019 and at the final meeting in Florence on 14 May 2019 (340 copies distributed) and available on the website. Layman's reports have been also sent by mail at FoResMit stakeholders, as reported in the Deliverable E4 (Report on diffusion activity).

Action E.4 Diffusion material preparation

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

During the project, all partners prepared various dissemination materials to be used in fairs, conferences, newsletters, in particular:

- Logo definition and design performed. A FoResMit logo was created for the project, to be shown on all dissemination documents of the project;
- 14,400 FoResMit brochures in English and Italian

- 61 posters (42 posters put in Florence area municipalities)
- 5 rolls-up
- 150 children books
- 650 usb flashes, 200 keyrings, 200 block-notes, 350 small notebooks, 500 small information packages, 250 folders, 900 pens, 800 pencils, 100 magnets, 100 brooches, 50 bags, 20 t-shirts, 20 k-ways and 20 huts for a total of 4,320 FoResMit gadgets. The larger amount of gadgets produced was necessary to cover the high participation at organized events.

Diffusion materials have been distributed in 20 workshops and events organized by the project (see Deliverable of Action E8), 28 events and fairs (see Deliverable of Action E10) and 14 Networking events (see Deliverable of Action E6), as reported in detail in the Deliverable E4 (Report on diffusion activity). The material will be continuously distributed to the future events or as electronic material.

Action E.5 Press and media release

Foreseen start date:	01/09/2015	Actual start date: 01/09/2015
Foreseen end date:	31/08/2019	Actual end date:31/08/2019

During the project, FoResMit produced:

- 26 general articles on national and International media, such as: Georgofili info; Sherwood; Corriere fiorentino; Ricerca Forestale; Dendronatura; Gazzetta Ambiente; Urbanistica Informazioni; Forest@; Italia Forestale e Montana; TuttoSesto; video interviews available on YouTube (https://www.youtube.com/watch?v=xMjLdoZ5BSE&list=PLQEtCH8MlAC4DAp8YBf-4qtmS1mYFxtEo&index=3.) and SestoTV (https://www.youtube.com/watch?v=X8rIUPiqli0); website of Italian Ministry of the Environment and Protection of the Territory and the Sea (https://www.minambiente.it/pagina/life-foresmit-centro-di-ricerca-l-agrobiologia-e-la-pedologia-di-firenze); report of Rete Rurale Nazionale (https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/19231) and European Forest Institute (http://www.fao.org/fileadmin/user_upload/mountain_partnership/docs/efi_tr_101_2017_tognetti_etal.pdf).
- 11 technical/scientific publications on peer reviewed national and international journals: Annals of Forest Research; Urban Forestry & Urban Greening; Journal of Sustainable Forestry; Forests; Annuals of Silvicultural Research; Forest Systems; Science of the Total Environment; Forest Science; Environmental quality;
- 8 theses of University of Firenze, Roma and Trento.

Details are reported in deliverables E5 (General articles published and Technical/Scientific articles published) and documents are reported as annexes. All articles are also in the project website.
The documents are detailed in the dedicated deliverables of Action E5: i) General articles published and ii) Scientific and technical articles published, which are sent as annex of this Final Report.

Action E.6 Networking

Foreseen start date:	01/09/2015	Actual start date: 01/09/2015
Foreseen end date:	31/08/2019	Actual end date:31/08/2019

During the project, all the beneficiaries activated networks stimulating an international exchange of ideas among consortia that have been working in the past or present on similar topics (9 LIFE projects, see deliverable E6 for further details).
In addition, FoResMit participated and/or organized 11 networking events (see deliverable E6 for further details).

Moreover, FoResMit project was involved in the activities of the following COST actions, presenting project results in 3 meetings (see deliverable E6 for further details):

- Orchestrating forest-related policy analysis in Europe (ORCHESTRA) FPS COST Action FP1207
- Linking belowground biodiversity and ecosystem function in European forests (BioLink) COST Action FP1305.

The networking was useful to implement several field activities comparable in different project's areas and joint dissemination activities, producing several outputs reported in deliverables E6.

Action E.7 LIFE FoResMit manual

Foreseen start date: 01/01/2019 Actual start date: 01/01/2019
Foreseen end date: 31/08/2019 Actual end date: 31/08/2019

At the end of the project CREA produced 600 FoResMit manual in English, Italian and Greek already distributed at Italian final workshop in Florence on 14 May 2019 and available on website, distributing 400 copies, as reported in Deliverable D4 (Report on diffusion activity).

Action E.8 Demonstration workshop, seminars, conferences and other events

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

During the project 2 international meetings, 3 technical workshops, 6 seminars, and 2 public events for citizen awareness and involvement were organized and defined in Italy and Greece, for a total of 653 participants. Details of the events are reported in the Deliverable E8 (Report on organization of workshops, seminars and events).

Contacts with National and International associations have been taken during the project duration and will continue after the project end, as detailed in the Deliverable E8.

4 demo tracks were prepared, 2 for each field site, indicated by explicative notice boards (figures are reported in deliverable E8).

The report on events organized by FoResMit is detailed in the dedicated deliverable Report on organisation of workshops, seminars and events. Differently to what foreseen in the proposal, the participation in workshops, seminars and events is detailed at Action E10 and the dedicated deliverable (Deliverable Action E8: Report on participation of workshops, seminars and events) is merged with the Deliverable Action E10: Report on participation in fairs and other events at Project End.

Action E.9 Dissemination to Institutions and policy makers

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

FoResMit beneficiaries activated several contacts with Policy Makers, Technicians and Officials of Institutions for discussing about project activities and results in order to activate a review of forest normative issues dedicated to forest management and thinning interventions and to define and fix important technical procedures for future replicability of FoResMit activities.

- Tuscany Region (dr. Elisabetta Gravano and Alessandro Varallo)
- NGOs interested in forest resilience and stability (Agriambiente, local associations)
- Sesto Fiorentino Municipality (Dr. Silvia Bicchi, Enio Bruschi).
- General Secretary of Decentralized Adm. Macedonia & Thrace (Dr. Nikitas Fragkiskakis)
- The Deputy Minister of the Environment & Energy (Mr. John Tsironis)
- Corpo Forestale dello Stato (dr. Stefano Ignesti)
- The Deputy Minister of the Environment & Energy (Mr. Sokratis Famelos)
- Ministry of Environment, MATTM and Italian NCP (Federico Benvenuti)
- Rete Rurale Nazionale (dr. Alessandro Monteleone)
- CREA-PB, Nucleo Monitoraggio del Carbonio (dr. Saverio Maluccio)

Four specific workshops specifically dedicated to Institutions and policy makers, politicians and officials of public administration at local and regional scale were organized (in addition to those reported in Action E8) and reported in the Deliverable of Action E9.
Results of Action E9 highlighted the absence of constraints on adopting Selective thinning in forest management plans either in Italy or in Greece, where the new management study of Xanthi-Geraka-Kimmerion public forest already applied selective thinning. It was agreed that the selective thinning in black pine forests will not be the subject of a specific new forest norm, but rather will be implemented by the current regional legislation. After project end this activity will continue to adopt Selective thinning in other areas, as reported and certified in the After-LIFE plan.

Action E.10 International fairs and other events

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

The FoResMit beneficiaries have disseminated the project activities objectives and preliminary results participating at 8 fairs and 27 events, in addition to those reported as networking and detailed in Action E6). Main fairs and events are reported in the Deliverable Action E10.
Each of the 27 workshops and meetings produced also an abstract, which is printed in the book of abstracts of each event and is available also as press release (available as annex to Action E10 deliverable). Deliverable of Action E10 (Report on participation in fairs and other events at Project Mid-term) was merged with the Deliverable Action E8 (Report on participation of workshops, seminars and events).

Action E.11 Digital supports for international diffusion

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

During the mid-term period of the project, CREA prepared a preliminary project video to be used in project events.
In the final period of the project, other 2 videos have been prepared in English, Italian and Greek with support of external expert company. The videos have been published on the project website (http://lifeforesmit.com/it/i-nostri-video/), have been produced in 500 DVD copies distributed at Italian final workshop in Florence on 14 May 2019 (200 copies) and sent by mail by means of direct contacts.
The results of the activities carried out in Action E.11 are detailed in the dedicated Deliverable Action E11: Three-lingual video and Deliverable Action E11: Three-lingual informative DVD, which are sent as annex of this Final Report.

Action E.12 After-LIFE Communication Plan

Foreseen start date: 01/06/2019 Actual start date: 01/06/2019
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

CREA, with the support of all the project beneficiaries, has prepared the FoResMit After-LIFE communication plan attached to this Final Report as Deliverable.
We identified 63 stakeholders interested in future activities related to forest management, replicability, carbon credits, dissemination, recreation and teaching activities.

Action F.1 Project management

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

The general management structure includes 4 beneficiaries and three committees (steering, technical and administrative.
Besides the committees, technical meeting on specific aspect of the project have been held via skype or phone calls among experts: i.e. vegetation survey and monitoring, GHGs fluxes

determination, soil and litter. The outputs of these contacts are visible in the large amount of publications involving different partners.
During all project phase, the 3 associated beneficiaries, PROVIFI, DUTH and DAMT participated in project management activities keeping in smooth contact with the project coordinator and the other beneficiaries. In this sense, they prepared and attended the project management meetings and collaborated with CREA in the preparation of this Final Report, as set out in the project proposal.
Information exchange within each Committee was done by regular e-mail exchanges. Frequent use of Skype was favored, particularly to solve technical issues related to methodologies in Action D1, D2 and D3, release of scientific articles, joint participation at meetings and workshops. Steering and Technical Committees had monthly or bi-monthly contacts via skype and met twice a year, during monitoring and progress meeting. Administrative Committee met before each report (once a year).
The following coordination and progress meetings were organized:

date	Location	Aims	Participants
8-9/10/2015	Florence (CREA)	Kick-off meeting and technical meeting	All beneficiaries, Monitor
4-8/04/2016	Xanthi (DUTh)	Technical meeting	CREA, DAMT, DUTh
6-7/02/2017	Florence (PROVIFI)	Technical meeting	All beneficiaries, Monitor
8-9/05/2018	Florence (CREA)	Progress meeting and coordination meeting	All beneficiaries, Monitor
8-9/11/2018	Xanthi (DUTh and DAMT)	Progress meeting and technical meeting	All beneficiaries, Monitor
3-4/04/2019	Orestiada (DUTh)	Coordination meeting	CREA, DAMT, DUTh
13/05/2019	Florence (CREA)	Coordination meeting	All beneficiaries

Action F.2 Monitoring

Foreseen start date: 01/09/2015 Actual start date: 01/09/2015
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

Competence and expertise of the various groups constituted a guarantee of technical quality and a multifunctional approach, while the presence of institutions and managers who paid attention to the economic sustainability of the interventions have guaranteed their overall economic soundness.
Monitoring tasks have been carried out for each action, in particular:

- CREA, as project coordinator, had continuous contacts with all project beneficiaries for monitoring project activities
- CREA, as coordinating beneficiary, prepared and sent a monthly indication of operative activities to be done to all the partners
- CREA, as coordinating beneficiary, every month sent a report to the monitor of LIFE's External Assistance Team on the progress of the project, which allowed him to follow-up of the FoResMit project.

During the FoResMit project a large amount of operations were performed in progressive steps: site characterization, monitoring plots selection, methodological protocols, implementation of thinning, monitoring of thinning effects. All phases involved several meetings. Project beneficiaries have carried out different meetings in order to organize, coordinate, monitor and develop the project.
Monitoring meetings with LIFE's External Assistance Team were organized:

date	Location	Aims	Participants
8-9/10/2015	Florence (CREA)	Kick-off meeting	All beneficiaries, Monitor
23/10/2015	Bruxelles	Kickoff meeting for	CREA

		LIFE14 projects	
12-13/04/2016	Xanthi (DUTh)	Progress meeting	All beneficiaries, Monitor
6-7/02/2017	Florence (PROVIFI)	Progress meeting	All beneficiaries, Monitor
8-9/05/2018	Florence (CREA)	Progress meeting	All beneficiaries, Monitor
8-9/11/2018	Xanthi (DUTh and DAMT)	Progress meeting	All beneficiaries, Monitor and EU officer
13/11/2019	Florence (CREA)	Final meeting	CREA, Monitor

Action F.3 Audit

Foreseen start date: 01/06/2019 Actual start date: 01/06/2019
Foreseen end date: 31/08/2019 Actual end date:31/08/2019

For beneficiaries for which the total contribution in the form of reimbursement of actual costs as referred to in Annex III is above EUR 750,000 the certificate on the financial statements and underlying accounts ("certificate on the financial statements") is not needed (amendment N° 3 to grant agreement LIFE14 CCM/IT/000905).

6.2 Main deviations, problems and corrective actions implemented

Overall, the project remained in line with objectives and the time schedule foreseen.
The following deviations occurred:

- The acronym of the legal name of the Coordinating beneficiary has changed by CRA to CREA maintaining the same name (Consiglio per la ricerca in Agricoltura e l'analisi dell'economia agraria), activities and characteristics. (Letter Amendment Nr. 2 to Grant Agreement).
- The form FC in the Grant Agreement of the FoResMit project presents a calculation error and has been corrected (Letter Amendment Nr. 2 to Grant Agreement)
- Action A1 was extended to June 2016, due to technical reason including the use of Terrestrial Laser Scanner for the vegetation survey, which required an extra time for the set up and calibration and further application in Xanthi site.
- Action A2 was extended to June 2016. The extension was required for practical reason regarding the opening of soil profiles within plots and laboratory analyses.
- Action C1 was anticipated to the end of 2015 in order to allow administrative procedures to be carried out in time by PROVIFI following the Italian legislation. Longer duration of thinning implied higher involvement of expert technicians.
- Action C2 required more field activities than expected and higher technician involvement.
- Action D1 was anticipated to September 2015 in order to have extra time to monitor deadwood biomass and C pool and complete the initial sampling before thinning intervention. Extra working days were needed to complete the measurements of vegetation parameters, to compare the methodologies for deadwood biomass measurement and to test the terrestrial laser scanner in Italy and Greece. Litterfall collection occurred seasonally instead of monthly, thus a reduced number of working days was needed. Forest floor was more in depth analysed in laboratory through microbiological and biochemical analyses. We dedicated more effort and more working days than foreseen on deadwood monitoring field mesocosms and performing laboratory analyses for microbial communities and enzymes.
- Action D2 required a larger amount of working days because: i) 20 % more samples (10368 samples) than foreseen were included in the monitoring to increase accuracy, ii) assessment of forest floor and deadwood contribution to emissions to include all processes (further 1656 samples), iii) two persons concurrently were required to measure fluxes in the forest, iv) a large amount of data required more time for elaboration than expected, v) more publications than foreseen were produced (45 instead of 30 foreseen). Higher involvement of permanent

personnel was required to fulfil these additional activities, together with students, trainees and non-employees' personnel. The cost of gas chromatographic determination per sample was reduced and partly covered with internal funding. The number of samples was increased with respect to those planned, working days increased. Extra monitoring for litter and deadwood contribution to GHGs emissions was performed.

- Action D3 was anticipated to January 2016 to include a cultural event in the municipality of Monte Morello forests (Sesto Fiorentino municipality) in collaboration with local administrators to quantify the C emissions and other environmental impacts of the "*Fiera di Primavera*". Credit brokerage was not implemented because: i) during the duration of the project C credits are still negative due to biomass removal with thinning and ii) small areas under thinning are not enough to generate marketable CCs. To solve this drawback, we calculated: i) C credits generation and the years estimated to achieve a C gain and ii) C sequestration potential considering vegetation, soil and gas exchanges. Other actions replaced C brokerage to obtain concrete results and will continue in the AFTER-LIFE period: i) commitment of UNCEM Marche and Regione Marche to compensate emissions during the realization of the third lane of the Marche freeway (see the letter of interest, the report and the presentation annexes); ii) contact with "Nucleo Monitoraggio del Carbonio" of CREA-PB that is the Italian reference for voluntary market of carbon and ecosystem service (questionnaire and inclusion in the database of projects) ; iii) demonstration of how the silvicultural treatments could compensate the CO_2 emissions of a cultural event (see publications of Gatti et al. (annexes at Deliverable E5); iv) contacts with SMEs (Carbonsink, Etifor) involved in C credits market to use FoReMit approach and inclusion in the database for future activities; v) assessment of economic value of ecosystem services, including C sequestration; vi) forest wood-chain analysis and circular bioeconomy approach. C credits calculation will be repeated 3 years after project end and C market implementation will occur on larger areas through the collaborations already established. Published documents were produced (see Deliverables of Action E5) and other are submitted (reported in the AfterLIFE document) or in preparation.
- Action E4 included the production of a children's book about peri-urban forest and climate change.
- Action E8 was improved with the organization of extra workshops by DAMT addressed to sensitize young population.
- Action F1 required changes due to CREA internal re-organization and consequent administrative changes: CRA-ABP became CREA-AA and administrative direction was moved to Bologna; CRA-SEL became CREA-FL and direction of Trento and Arezzo is in Arezzo. These changes have meant that the responsible for signatures of timesheet changed during years and is referred to the director or the office responsible, when available.

6.3 Evaluation of Project Implementation

The following table compares through quantitative and qualitative information the results achieved at the end of the FoResMit project against the objectives of the proposal:

Action	**Results foreseen**	**Results achieved**	**Evaluation**
A.1. Climatic characterization and vegetation survey	Walter & Lieth diagrams. Trends and frequencies analysis of the main climatic variables at monthly, seasonal and yearly scale. Complete quantification of the vegetation consistence and	Min, mean, max temperature and precipitations for both sites. PDSI and SPEI calculated. Vegetation type, stand	In line. 6 more months than expected were needed for the vegetation characterization. All expected results were achieved and plots

Action	Results foreseen	Results achieved	Evaluation
	health status with information at tree, plot and stand level.	age, mean tree density, basal area, mean height.	were identified
A.2. Pedological survey	For each of the areas: - Geological classification - Soil type classification For each plot - Soil physical characterization. - Soil chemical characterization - Pools of organic C - N forms.	Geological and pedological classification; Soil and humus profiles description; Soil physico-chemical characterization and analyses of soil organic C and N pools at 0-10 and 10-30 cm depth	In line 3 more months than expected were needed for soil profiles and lab analyses. All expected results were achieved and plots were identified.
C.1. Realization of thinning intervention in Italy	Thinning implementation in Monte Morello forest and increase of stand characteristics.	traditional thinning 5.35 ha selective thinning 4.73 ha Trees number; Basal area; Basal area increment; Unstable trees; Mean stability; Structural heterogeneity	In line The Action was anticipated to perform administrative procedures. All expected results were achieved
C.2. Realization of thinning intervention in Greece	Thinning implementation in Xanthi forest and increase of stand characteristics.	traditional thinning 3.3 ha selective thinning 3.3 ha Trees number; Basal area; Biomass; Basal area increment; Unstable trees	In line All expected results were achieved
D.1. Monitoring and quantification of C pools in vegetation and soil	- C stock for above- and below-ground biomass. - Amount of litter and forest floor - Carbon stock in deadwood; - Soil organic C content - Harvested biomass.	- Reduction of C stock in biomass, stronger with selective thinning - litter input and forest floor increased - soil organic carbon increased - deadwood decreased. - harvested biomass chipped and transformed in energy	More than expected. The Action was anticipated to September 2015. All expected results were achieved. In addition to what foreseen: soil humus profiles; microbiological and enzyme analyses of litter and deadwood.

Action	Results foreseen	Results achieved	Evaluation
D.2. Monitoring and quantification of GHG emissions and Global Warming Potential	-Daily, seasonal and annual rates of CO_2, N_2O and CH_4 fluxes - Global warming potential - Detailed processes of degraded-forest GHGs emissions/uptakes	-short term increase of CO_2 emissions with selective thinning followed by a decrease -CH_4 uptake increased by selective thinning -N_2O fluxes close to zero -decrease of global warming potential two years after thinning.	More than expected. All expected results were achieved. In addition to what foreseen: litter and deadwood contribution to soil respiration,
D.3. Governance of the project results in the carbon voluntary market	- Processes of awareness or training of the stakeholders; - Awareness among the local population; - Quantification of the carbon credit number; - Governance of the carbon credits among different stakeholders .	Stakeholders identification and involvement. C credits generation and the years estimated to achieve a C gain calculated C sequestration potential considering vegetation, soil and gas exchanges Investigation of local visitors' demands and perceptions on peri-urban forests to include into management plans Calculation of CO_2 emissions compensation.	More than expected except for carbon credits brokerage, which was not implemented because C credits are still negative in the short term and with small areas and will be visible after an estimated period of 5 years. The Action has been anticipated. In addition: ecosystem services trade off analyses and economic value; forest wood-chain analysis.
D.4. Monitoring of technical-socio-economic assessment of the LIFE FoResMit project	- Proof of technical-social and economic viability. - Elaboration and analysis of data in terms of socio-economic impact on the local economy and population	Technical, social and economic viability and impact of FoResMit approach were evaluated.	More than expected. Multi-Criteria Decision Analysis and Circular economy approach adopted.
E.1. Project website	Project web site and Facebook page	Project web site (803,820 visits) and Facebook page (303 friends) continuously updating	In line
E.2. LIFE+ information boards	18 FoResMit notice boards	8 notice boards displayed in beneficiary public places and 4 in demonstration sites	In line
E.3. Layman's report	FoResMit Layman's report	600 Layman’s report in English, Italian and Greek produced, uploaded and distributed	In line
E.4 Diffusion	24 Posters	14,400 brochures in	More than expected

Action	Results foreseen	Results achieved	Evaluation
material preparation	12,000 leaflets/brochures/factsheets etc ready for use in dissemination events 2,400 various branded items 6 roll-up panels Electronic materials for conferences and events.	English and Italian 61 posters (42 posters put in Florence area municipalities) 5 rolls-up 150 children books 650 usb flashes, 200 keyrings, 200 block-notes, 350 small notebooks, 500 small information packages, 250 folders, 900 pens, 800 pencils, 100 magnets, 100 brooches, 50 bags, 20 t-shirts, 20 k-ways and 20 huts for a total of 4,320 FoResMit gadgets.	
E.5. Press and media releases	30 publications on different media: 25 General articles and 5 technical articles.	26 general articles on national and International media 11 technical and scientific publications on peer reviewed national and international journals 8 University theses	More than expected
E.6. Networking	- Identification of other projects - sharing of data, information and technical experience - Sharing of diffusion networks - Clusters with 7 projects	Clusters with 9 LIFE projects Participation at 7 common events Organization of 3 joint events Participation at 2 COST actions	More than expected
E.7. LIFE FoResMit manual	FoResMit manual in Italian, Greek and English	600 FoResMit manual in English, Italian and Greek uploaded and distributed	In line
E.8. Demonstration workshops, seminars, conferences and other events	2 meetings 4 workshops 2 demo tracks for each area	2 international meetings 3 technical workshops 6 seminars 2 public events 2 demo tracks for each area	More than expected
E.9. Dissemination to Institutions and	Successful communications to EU and national Institutions	4 workshops dedicated to	In line

Action	Results foreseen	Results achieved	Evaluation
policy makers	and policy makes	policy makers Involvement of Regional and local authorities, Ministries of Environment of Italy and Greece, Rete Rurale Nazionale	
E.10. International fairs and other events	participation at minimum 6 events between international conferences and fairs. Maximum dissemination in the involved countries and beyond	Participation at 8 fairs and 27 events	More than expected
E.11. Digital supports for international diffusion	1 Project video and distribution	Production of preliminary video. Production of 2 final videos in Italian, English and Greek.	In line
E.12. After-LIFE Communication Plan	FoResMit After-LIFE Communication Plan	Completed	In line
F.1. Project management	Management of project activities	Continuous contact between all project partners and project meetings	Great beneficiaries' collaboration
F.2 Project monitoring	Monitoring of project activities	monthly indication of operative activities and monthly summary of the project activities	Great help from monitoring team
F.3 Audit	Audit Report	Not needed	Amendment N° 3 to grant agreement LIFE14 CCM/IT/000905

6.4 Analysis of benefits

1. *Environmental benefits*

Direct / quantitative environmental benefits:

C stock and sequestration

Both thinning leads to a loss of C-stock in the short-term period, due to biomass harvesting, which is recovered because of increased primary productivity and consequent C sequestration. The better performance is shown from the traditional thinning scenario in absolute terms. Nonetheless, in relative terms (C-sequestration/Biomass released after the thinning) the two scenarios have the same performances (about 12%). To confirm this trade-off between the C sequestration and the thinning system, the measurements on biomass and soil C-sequestration capacity should be repeated after 5 years from the thinning actions (2 years is a very short period considering the forest temporal dynamics). Summing the C-sequestration capacity of above- below-ground biomass and soil, and subtracting the C lost due to the soil emissions, the recovering time of the C-stock lost as result of silvicultural treatments is 3 years in the thinning from below scenario and 5 years in the selective thinning scenario.

	Baseline	Traditional thinning	Selective thinning
Changes in C-stock ($tCO_2\ ha^{-1}$)	0.0	-144.9	-219.6
of which ($tCO_2\ ha^{-1}\ yr^{-1}$):			
Above-ground/Below-ground biomass	0.0	-139.2	-208.8
Deadwood	0.0	-5.7	-10.8
Annual volume increment ($m^3\ ha^{-1}\ yr^{-1}$)	12.2	26.0	17.3
C-sequestration in above/below ground biomass ($tCO_2\ ha^{-1}\ yr^{-1}$)	17.7	37.8	25.2
C-sequestration in soil ($tCO_2\ ha^{-1}\ yr^{-1}$):	-19.6	11.6	17.7
of which ($tCO_2\ ha^{-1}\ yr^{-1}$):			
Sequestration	1.3	33.3	36.9
Emissions (taken with negative sign)	-20.9	-21.7	-19.2
C-sequestration: soil + biomass ($tCO_2\ ha^{-1}\ yr^{-1}$)	-1.89	49.4	42.9
Changes in C-sequestration ($tCO_2\ ha^{-1}\ yr^{-1}$) compared to the baseline scenario (Δ)	-	51.3	44.8

GHGs emissions

The project measured the exchange between soil and atmosphere of the three GHGs: CO_2, CH_4 and N_2O, providing data set covering a gap of information from Mediterranean forest ecosystem.

The effect of selective thinning showed a short-term increase during thinning operations followed by a decrease 2 years after thinning. Being CO_2 emissions the most important contributor to GWP (around 98 %) and being strongly dependent on temperature, data from the same period should be compared among treatments, to avoid biases due to climate variability.

	Control	Traditional	Selective	Saving
CO_2 ($Mg\ ha^{-1}\ y^{-1}$)	39.8	40.0	37.5	2.38
CH_4 uptake ($kg\ ha^{-1}\ y^{-1}$)	-2.40	-2.21	-2.90	0.49
N_2O ($kg\ ha^{-1}\ y^{-1}$)	0.675	0.876	0.772	-0.10
GWP ($Mg\ ha^{-1}\ y^{-1}$)	39.82	40.1	37.4	2.40

Bioenergy production

In order to assess the efficiency of bioenergy production, CO_2 emissions were quantified during all forest-wood chain phases net of avoided CO_2 emissions deriving from the energy conversion of the woodchips and the consequent non-use of fossil fuels. This aspect is related to the "carbon neutrality" concept of bioenergy system in the carbon cycle.

	Woodchips	Methane	Gasoline
Lower Calorific Power (ICP)	3,4 MWh t^{-1}	10 kWh m^3	11,6 MWh t^{-1}
Plant efficiency	0,85	0,90	0,85
Useful thermal energy	3468 MWh	3468 MWh	3468 MWh
Quantity	1200 t	409929 m^3	351 t
CO_2 emissions	0	800 t CO_2	1136 t CO_2

Climate resilience

Through dendrochronological analysis we evaluated the site-specific effects of thinning on forest resilience. *Quercus cerris* trees were less affected by drought events and revealed a greater growth recovery capacity both in the short and long-term after drought. Selective thinning, favouring the

more drought resistant and resilient species (*Quercus cerris*), appeared more appropriate for increasing and/or improving the resilience at the stand level under future drought intensification.
Moreover, selective thinning showed a reduction of the instable trees number of 33% and increased the mean single tree stability of 4% after two years from treatment, thus improving stability of the forest stands. Considering the structure heterogeneity, results demonstrated that in terms of both diameter and height the selective thinning increased these variables variability significantly (about 10%).

Qualitative environmental benefits

Qualitative benefits of selective thinning include i) the improvement of aesthetic attractiveness and recreational value because of the better accessibility and landscape; ii) the decrease of fire risk because of the decrease of dead trees and the inflammable material in the forest; iii) the maximization of synergies among ecosystem services; iv) the maintenance of hydrological protection and soil structure.
Sustainability of the silvicultural treatment will be even more evident in the long-term, allowing forest regeneration and vegetation succession towards a more natural ecosystems dominated by broadleaves. Facilitating the introduction of late successional native broadleaves species means to help restoring natural functioning processes (e.g. natural regeneration, or more generally, self-organization), increasing their stability, resilience and self-perpetuating capacity.

2. *Economic benefits*

The average annual income for the forest owner was estimated in 337.8 € yr^{-1} ha^{-1} for the traditional thinning scenario, and 515.8 € yr^{-1} ha^{-1} for the selective scenario. These values were estimated hypothesizing that the price of local woodchips does not vary substantially over the next 15 years.
Overall, the results of MCDA analysis underline that in a degraded forest the improvement of ES supply could be reached by means of silvicultural actions. The “Baseline scenario” is the worst solution. On the contrary, the selective thinning seems to be the most rational and sustainable forest management option, because with comparable cost for the forest activity, it assesses better earnings from wood valorisation, improvement in recreational attractiveness and comparable C-sequestration capacity.
The estimated Consumer Surplus (CS) is 10.04 € per visit. Consequently, the current economic importance of recreational benefits in Monte Morello forest is 179.2 € ha^{-1} yr^{-1} (baseline scenario), while - in accordance with the visitors’ preferences - in future years the potential economic benefits related to the recreational opportunities could increase to 193.2 € ha^{-1} yr^{-1} in the thinning from below scenario and to 231.9 € ha^{-1} yr^{-1} in the selective thinning scenario.

3. Social benefits (e.g. positive effects on employment, health, ethnic integration, equality and other socio-economic impact etc.).

Concerning the importance of ES provided by Monte Morello forest, results show that the recreational opportunities provided by forest to the local community were considered the most important ecosystem service, followed by the climate change mitigation. Conversely, the wood products production was considered a marginal ecosystem service by respondents.
The priority score of each image representative of different forest restoration scenarios was used as an indirect measure of visitor attendance to estimate the change in the number of visitors after the thinning from below and selective thinning. The hypothesis is that the attendance of a site is directly related to the preferences assigned for that site. Currently, the annual number visitors of Monte Morello forest (baseline scenario) is equal to 18,475 visitors yr^{-1}. Therefore, in the thinning from below scenario is assumed an increase of visitors by 7.8% (19,916 visitors), while in the selective thinning is assumed an increase of visitors by 29.4% (23,908 visitors).

4. *Replicability, transferability, cooperation*

The FoResMit project activated a series of actions aiming at maximizing the replicability of the silvicultural treatments and transferability of results:

- Networking with other LIFE projects with the aim to i) transfer the silvicultural approach, ii) exchange observations in different ecosystems, iii) plan for future cooperation.
- Demonstration workshops and technical meetings dedicated to experts, forest managers and policy makers
- Commitment of local and regional authorities (Comunità Montane, Città Metropolitana, Regions, Ministries) in Italy and Greece for selective thinning implementation
- No needs of ad hoc legislation in Italy and Greece, because the treatment can be applied with the existing forest law and will be included in management plans of local entities in Italy and Greece. Selective thinning has already inserted in the new plan of «XANTHI- GERAKA-KIMMERION» public forest cluster and will be applied in 3 clusters in the next 3 years.
- Several contacts with Forestry Cooperative Organizations in Greece were established and contracted to perform cutting activities in the future.

5. *Best Practice lessons:*

Magnitude and directions of the impact of thinning depend on site-specific pedological, climatic and vegetational factors, degradation level and development stage of the forest stand.

- Pine plasticity allow positive response even in later stage when soil fertility sustain pine growth, with an even faster recovery in case of harsh degradation.
- The initial stand structure determines which species favor with selective thinning: in case of natural vegetation, such as *Quercus Cerris*, its presence should be favored in order to increase forest resilience.
- Thinning implementation method may affect C cycling: heavy machinery and prolonged operations influence CO_2 emissions, with an increase proportional to intensity.
- The current forest management strategy did not optimize the productive function because the wood harvested is wholly allocated for bioenergy production. The economic value and the lifespan of wood products can be increased by means of the wood harvested valorization.
- The valorisation of wood biomass as renewable energy source – both for wood products (i.e. bio-textiles, bioplastics) and energy purpose – has still a wide range of potential improvement strategies.

6. Innovation and demonstration value

<u>Multidisciplinary approach</u>

The project proposed an integrated view of ecosystem services offered by the forest and of thinning impact evaluation. Partnership included experts on vegetation, soil, GHGs exchanges, carbon credits, involvement of local communities and visitors' perception. The analysis of the five pools and the three GHGs identified by IPCC and EU regulations covered gaps in the knowledge and allowed to adopt an integrated view of processes and impacts.

<u>New methodological approaches and demonstration</u>

Selective thinning is an advancement of the commonly used traditional thinning, based on a new perspective of the forest and its services. To monitor and evaluate the impact of thinning up to date and innovative methodologies were used, also comparing their best performance (e.g. methods for deadwood determination, upscaling of GHGs with GIS analysis, use of terrestrial laser scanner). Using Multiple-Criteria Decision Analysis (MCDA) allowed the objective comparison of different forest management alternatives in order to be able to choose the alternative that allows greater enhancement of ES.

<u>Trade off and synergies among ecosystem services</u>

The project pointed out that a rational and efficient forest management practice is a "win-to-win" approach for the sustainable management of degraded forests. The selective thinning can enhance wood biomass from forests simultaneously producing positive impacts on other ecosystem services

(recreational activities and climate change mitigation). The wood products valorisation has been marginally considered in the present case study due to the low quality of raw materials obtainable from a degraded black pine forest. However, higher ES values are expected if a part of the wood volume harvested is delivered for wood packaging or poles both in terms of carbon stocked and of income from timber sales.
It was demonstrated by MCDA analysis and AHP approach that selective thinning with valorisation of the wood assortment at the selling point - is considered the best solution according to the circular bioeconomy principles, since it allows to reach higher prescribed cut (52% respect to the traditional system).

7. Policy implications

During the project was assessed together with Tuscany Region authorities that the implementation of selective thinning doesn't need a specific Regional legislation, but it can be already applied. This was an important achievement since changing legislation is a long process. Thus, selective thinning can be applied as a good practice by private and public managers. However, in Italy laws are at regional level and can differ among regions, which is a potential barrier. For this reason, a work with "Rete Rurale Nazionale" was initiated, and the FoResMit approach has been included in the National and Regional forest reports (RAF Italia and RAF Toscana).
Deadwood management is another important aspect that merit in future attention because its double role as C stock and CO_2 source and it is object of a new proposal linked to FoResMit project.
MCDA must be considered a tool of support in decision making processes but not a decision-maker itself; consequently, outputs and results must be deeply analysed and discussed before taking them for granted.