FRESh LIFE

Demonstrating Remote Sensing integration in sustainable forest management

LIFE Project Number
<LIFE14 ENV/IT/000414>

Short - Final Report
Covering the project activities from 07/09/2015 to 30/11/2019

Reporting Date
<29/02/2020>

LIFE PROJECT NAME or Acronym
<FRESh LIFE>

Data Project

Project location:	Italy
Project start date:	<07/09/2015>
Project end date:	<06/09/2019> **Extension date:** <30/11/2019>
Total budget:	€ 2,854,979
EU contribution:	€ 1,686,201
(%) of eligible costs:	60.39.00

Data Beneficiary

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2. List of abbreviations

- AISF: Accademia Italiana Scienze Forestali (Italian Academy of Forest Sciences)
- AIT: Associazione Italiana di Telerilevamento (Italian Society of Remote Sensing)
- BVLOS: Beyond Visual Line of Sight
- CAP: Common Agricultural Policy
- CHM: Canopy Height Model
- CREA: Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (Italian Council for Research in Agriculture and Economy)
- DSM: Digital Surface Model
- DTM: Digital Terrain Model
- EASA: European Aviation Safety Agency
- EEA: European Environmental Agency
- EFT: European Forest Types
- ENAC: Ente Nazionale per l'Aviazione Civile (Italian Civil Aviation Authority)
- ENG: English
- EVLOS: Extended VLOS
- FB: Facebook
- FLEGT: Forest Law Enforcement, Governance and Trade
- GCP: Ground Control Point
- ITA: Italian
- KIA: Kappa Index of Agreement
- KOM: Kick-Off-Meeting
- KPI: Key Performance Indicator
- LIDAR: Light Detection And Ranging
- NIR: Near Infra Red
- OA: Overall Accuracy
- OG: Operational Group
- PA: Producer's Accuracy
- RGB: Red, Green, Blue
- RPAS: Remotely Piloted Aircraft Systems
- SFM: Sustainable Forest Management
- SfM: Structure from Motion
- SISEF: Società Italiana di Selvicoltura ed Ecologia Forestale (Italian Society of Silviculture and Forest Ecology)
- UA: User's Accuracy
- UAV: Unmanned Aerial Vehicle
- UCVV: Unione di Comuni Valdarno e Valdisieve
- UNIFI: Università degli Studi di Firenze (University of Florence)
- UNIMOL: Università degli Studi del Molise (University of Molise)
- UNITUS: Università degli Studi della Tuscia (University of Tuscia)
- VLOS: Visual Line of Sigh

3. Executive Summary

3.1 General Progress

The FRESh LIFE project has started on September 7th, 2015, and ended on November 30th, 2019.
The project proceeded according to the expectations. All the project actions were in line with the project time table, without significant deviations from project budget. At the end, all the actions finished on November 2019 according to the project schedule.
Here follows a short description of the results achieved in each action, major details are given in chapter 5.1.
Action B1: the action started on September 2015 and finished in September 2016, as foreseen by the project time table. No unforeseen events have occurred. According to the project schedule, the deliverables and milestones were completed in time. Three demonstration sites were identified as indicated in the project proposal, we decided at the beginning of the project to add a fourth one. In January 2017 we reported that the proposed forth-area was difficult to flight over due to the limitations introduced by a change in the UAV regulation occurred in Italy. In a first phase we tried to evaluate the possibility to maintain such forth area but using satellite data instead of UAV. But after that the Benifiaciary Roma Natura (that proposed the inclusion of this area) withdrawn, we decided to stick to the original project proposal based on three areas. Existing data already available in the demonstration sites were collected and harmonized, and these data were used to implement a project information system with metadata in line with the INSPIRE Directive.
Action B2: this action has started on January 2016 and finished in September 2017. Few problems have occurred due to issues with the national regulation for drone flights that could not be taken into account at submission of the project proposal and before definition in Action B1 of the final perimeter of demonstration sites. Data collected in action B1 were assessed to create a list of missing data to be acquired in the demonstration sites during the action B2. Missing data were listed taking into account the needs for action B3. Field samplings were completed in the demonstration sites and the data were organized in a database ready to be used in action B3 to estimate SFM indicators. The acquisition of new remote sensing data by eBee drone was completed as well and the same is for the LIDAR data acquisition.
Action B3: the action has started on January 2016, and finished in December 2017. All the maps of SFM indicators have been produced for the three demonstration sites: maps of "EFTs", "Defoliation", "Forest damage", "Tree species composition", "Area covered by introduced tree species", "Growing stock" and "Above ground biomass" are now available and ready for Action B4.
Action B4: this action has started on January 2018 and finished on November 2019. The Forest Information System (FIS) were implemented by the UNIFI staff and installed in the offices of the local partners in the three demonstration sites. Several training activities were realized to allow managers to discover the potentials of the system also collecting feedback useful to adapt the FIS to the local management needs. The results achieved are evident and deeply described in the technical part of this report.
Action B5: this action has started on June 2018 and finished at the end of the project on November 2019. With this action we analysed up-scaling activities at different scale, taking into account both the extension of the proposed methodologies all around the demonstration sites, then the impacts on the policy tools at regional, national and European scale.
Action C1: this action has started on October 2015 and finished with the end of the project. The action aimed at the acquisition of information for quantitatively estimating the impact of the project in terms of the incremented sustainability of forest management in the project study areas. Following the indicators of progress, a complete analysis of the results achieved was performed as reported in the deliverables. During the entire project period, the coordinating beneficiary (AISF - Accademia Italiana di Scienze Forestali) has monitoring the project activities in the demonstration sites in order to keep them on track with deadlines and deliverables.
Action C2: this action has started on October 2015 and was active until the end of the project. The aim of the action was to evaluate how the activities carried out in the pilot areas will impact on the regional and national policy level. Key Performance Indicators (KPI) were defined by the analysis of the ante-project situation and then monitored until the end of the activities to evaluate the impacts and give important information for the developing of Action B5.
Action C3: this action has started in October 2015 and continued up to the end of the project. The first part of the action had the aim of collecting data for the analysis of the ante-project assessment. A questionnaire was implemented and data collected were used to understand how to maximize the impacts of the actions during the project's phases. At the end of the project when the impacts have become clear the post-project assessment was performed in detail for each demonstration sites. Information collected in other project actions, for instance from the up-scaling questionnaire, together with the feedbacks given by the local partners are the basis of this analysis.
Action D1: this action has started in September 2015 with the project website design, planning and publication, and continued until the end of the project. According to the schedule, the Website was online before January 2016 and the final version of the Communication Plan, including a summary in English, was provided with the second progress report. The project website (https://freshlifeproject.net/) was updated weekly with new information on project activities and results and will remain active after the end as explained in the after-LIFE plan.
Action D2: this action has started in July 2018 and finished in September 2019 with the Layman's Report publication. As foreseen in the proposal this publication was available in English/Italian language. To ensure that the contents reflect what was expected a specialized consultant was involved in the Layman's Report design and printing. The product is annex to this report both in PDF (ANNEX 01 – Layman's Report) than in printed version.

Action D3: this action is divided into two steps. The first step started in October 2015 and finished in March 2016, with the placement of the Introductory Information Boards inside the beneficiaries' premises and in the demonstration sites. The second part started in December 2018 and ended at the end of the project. Seven Final Results Information boards were produced and, after the presentation at the final event, positioned in the beneficiaries' premises.
Action D4: this action has started on July 2017 and continued up to the end of the project. The technical report was produced step by step when the results from the different actions arrived. A final version of the report was ready on December 2018 in schedule with the project proposal. Training sessions were performed with different stakeholders by each local partner together with the staff of the associated universities.
Action D5: this action has started on January 2018 and finished in December 2018 with the publication of the Report for Policy Makers. The core part of the report was produced by analyse the feedbacks from the Action B4 about the use of the FIS. Several meetings have been carried out with the local managers of the demonstration sites in order to ensure that the language used in the report was the most appropriate and understandable. The final version of the product is annex to this Final Report (ANNEX 02 – Report for Policy Makers) both in English and Italian as well as sent in printed version.
Action D6: the action has started in September 2015 with the kick-off meeting (KOM), and concluded on November 2019 with the organization of the final events. During the whole project period the participation to several national and international conferences has continued in order to disseminate the project aims and results. Different kind of workshop, seminars and meetings were organized involving students and different stakeholders. Scientific papers related to the project activities was published and videos were produced and uploaded on the project YouTube channel.
Action D7: this action has started in October 2015 and was active up to the end of the project. The permanent collaboration with the Italian Society of Remote Sensing (AIT) and the Italian Society of Silviculture and Forest Ecology (SISEF) was carried out by participating to their events and calls also taking part to the organization with special session dedicated to the project. Regarding the networking with other LIFE projects, the number of related projects with we have a successful collaboration increased year by year together with the possibilities to share results achieved. The started collaborations will continue after the end of the project as indicated in the After-LIFE Plan.
Action E1: this action has started in September 2015 and remained active up to the end of the project. Since the KOM in September 2015, the beneficiary partner "DEMETRA" has coordinating this action ensuring that all the partners (including stakeholders involved in project assessment) provided timely and reliable information. All the Project Monitoring Reports were provided in schedule and the last one is annex to Second Progress Report.
Action E2: this action has started in March 2019 but mainly carried out at the end of the project when a complete overview of project results and impacts was available. The After-LIFE Plan was developed following the instruction given by the commission and it goes through the analysis of key points of the project results' maintenance and dissemination. A complete three year After-Life period timetable was provided together with a plan for the updating of the FISs.
Action E3: this action has started in September 2015 and was active up to the end of the project. The study and evaluation of the project indicators were carried out continuously, whereas the impact of the actions became more and more visible. The deliverable "List of indicators with analysis of remote sensing contribution" was ready on December 2018 as schedule. The update of the online version of the project indicators was performed and approved by the project monitor.

3.2 Assessment as to whether the project objectives and work plan are still viable

The main objective of the project remained viable until the end and its relevance was demonstrated by the increasing interest in precision forestry applications and the contribution that the integration of remote sensing data collected by RPAS with the ones from field work gave to forest managers involved in the project. Changing in the context in which the project was moving were continuously monitored in order to analyse risks and develop emergency plans but the monitoring carried out in the demonstration sites indicated that the objective and activity planned in the project remained valid so apart from small corrections we went through the Actions until the project end.

3.3 Problems encountered

All the problems encountered were discussed with the project monitor and full description of the reasons was provided step by step in the previous reports together with the actions taken into account to avoid negative impacts on the project results. These major problems concerned the LiDAR data acquisition due to the modification in the national flying regulation with drones and the withdrawal of the beneficiary RomaNatura. The problems with the LIDAR data acquisition in some of the demonstration sites have been solved and the area covered with flights by our partner OBEN. Since new problems did not emerged since the last Progress Report all the details are provided in the Technical Part of each action.

4. Introduction

4.1 Description of background, problems and objectives

Sustainable forest management (SFM) is globally accepted as the main goal for forest policy and practice. In order to monitor, evaluate and report progress towards SFM in European regions, six rigorous, scientifically and policy robust headline criteria were endorsed, measured by a set of quantitative (35) and qualitative (17) Pan-European Indicators for

SFM. The system is meant to facilitate the evaluation of the achievements towards each criterion's goals and the subsequent progress in SFM advancement at regional, national or supra-national level. The formulation of seven quantitative SFM indicators under criteria 1, 2 and 4 (1.1 forest area, 1.2 growing stock, 1.3 age structure and/or diameter distribution, 2.4 forest damage, 4.1 tree species composition, 4.3 naturalness, 4.5 deadwood) requires data to be specified by forest types. In the last round of Forest Europe assessment, reporting by 14 categories of European Forest Types (EFTs) has been experimentally tested for a selection of forest type-based indicators. Stratification by EFTs substantially improves the quality of reported information, by providing an ecologically sound context to frame SFM indicators and interpret their temporal trends.
Because of the spatial variability of SFM indicators, even within the same forest type (e.g. growing stock, biomass, tree species composition), mapping their values and changes over time has the potential to aggregate complex information particularly in the case of forest management units (forest compartments) of medium- to large size (i.e. few hectares to dozen hectares). Indeed, there is a growing recognition that mapping is crucial not only for monitoring SFM indicators, but also to enable environmental institutions and decision-makers a better understanding of the flows of related ecosystem services.
In this perspective, the main technical challenges for mapping SFM indicators at the scale of forest management units are:

1. To define data sources, techniques and methods for mapping SFM indicators, at a spatial level appropriate for SFM decision-making (from the forest compartment to larger scales);
2. To ensure repeatability and reproducibility of mapping procedures, to make it possible to analyse changes in indicators values within the time horizon of forest and environmental planning. This point is critical for monitoring the effect of forest management activities on SFM indicators and evaluating its effectiveness by trend analysis against baselines;
3. To enable the aggregation of multiple indicator values, through multicriteria approaches, in order to allow end-users, forest managers and forest planners in primis, to evaluate and demonstrate success towards SFM, taking into account the increasing cross-sectoral complexity of the challenges launched by the new EU Forest Strategy (COM (2013) 659) and EU Biodiversity Strategy (COM (2011) 244):
    a. to meet the ambitious 20/20/20 targets for renewable energy, without undermining sustainability as regards wood supply and all other functions;
    b. to halt biodiversity loss in the EU by 2020;
    c. to make a major contribution to climate change mitigation and adaptation, without neglecting the other dimensions of SFM.
    d. to support the development of green economy.

Last not least, the mapping approach, in order to be widely applied, should demonstrate to be more attractive for forest data end-users, than current data collection systems based, to a large extent, on the forest inventory approach. In this regard, the proposed methods should demonstrate not only technical viability (potential to ease the monitoring of SFM indicators) but also economic viability, i.e. high-cost effectiveness for operational use in forest management planning.

4.2 Expected results

The general aim of the project is to implement new remote sensing technologies in forest management practices demonstrating that the spatial data created with this approach is able to increment the sustainability of forest management. Because spatial data will be used for mapping SFM indicators, expected results can be easily monitored in the demonstration sites. Expected results also include implementing, installing and using innovative Forest Information Systems at the forest management offices of the demonstration sites.
From this general expected result several more specific aims follow:

- we intend to demonstrate that the use of remote sensing to produce advanced spatial forest information is not a research activity anymore, but has the potential to ease, in a cost effective way, the monitoring of SFM indicators within current data collection systems based, to a large extent, on forest inventory;
- we expect to demonstrate that the information created with these new techniques is also extremely useful to improve decision-making in forest management, so as to evaluate progress towards SFM targets;
- we expect to improve the capability in implementing Forest Europe Criteria & Indicators (related to e.g.: carbon sequestration and biodiversity) or forest certification set of indicators.

4.3 Climate change and biodiversity related benefits

Climate change is an unprecedented issue in modern times, with significant implications for Europe's forested ecosystems, the economic benefits they provide, and the livelihoods of those who depend on them. Climate change is also a dynamic and complex issue that increases uncertainty about what future forests will look like. Despite this uncertainty, a forward-looking approach is needed in forest management decisions made today. SFM is based on the principle of maintaining and enhancing the long-term health of forest ecosystems while providing environmental, economic, social, and cultural opportunities for current and future generations.
In the face of an uncertain future climate, scenarios analysis and the availability of advanced spatial information (carbon

pool and carbon sequestration maps, forest types maps, Net Primary Productivity analysis, etc.) constitute important tools that decision makers and forest managers can use to explore potential changes in future climate and their anticipated impacts on forests and forestry. Such scenarios allow managers and other stakeholders to evaluate the potential consequences of a changing climate that could have significant effects on SFM and hence on the social and economic benefits that forests provide.
Reducing the risks caused by climate change is an immense challenge. Scientists, policy makers, developers, engineers, and many others can use the power of the combined benefits of geographic information system (GIS) and remote sensing technology to better understand a complex situation and offer some tangible solutions. Technology offers a means to assess, plan, and implement sustainable programs that can affect us 10, 20, and 100 years into the future.
Regarding the biodiversity related benefits, we must keep in mind that European forests offer a diverse set of habitats for plants, animals and micro-organisms. Consequently, forests hold the majority of the world's terrestrial species. However, these biologically rich systems are increasingly threatened, mainly as a result of human activities. Biological diversity is the basis for a wide array of goods and services provided by forests. The variety of forest trees and shrubs play a vital role in the daily life of rural communities in many areas, as sources of wood and non-wood products, as contributors to soil and water conservation, and as repositories of aesthetic, ethical, cultural and religious values. Forest animals are a vital source of nutrition and income to many people, and have a vital roles in forest ecology, such as pollination, seed predation, dispersal and germination, and predation on potential pest species.
Forest management planning should aim to maintain, conserve and enhance biodiversity on ecosystem, species and genetic level and, where appropriate, diversity at landscape level. For these reasons forest management planning and terrestrial inventory and mapping of forest resources should include ecologically important forest biotopes, taking into account protected, rare, sensitive or representative forest ecosystems such as riparian areas and wetland biotopes, areas containing endemic species and habitats of threatened species, as defined in recognised reference lists, as well as endangered or protected genetic in situ resources.
The combined use of GIS and remote sensing technologies with traditional forest inventory data can provide spatial information of the most commonly agreed biodiversity indicators which can be used by forest managers to support the implementation of SFM practices (e.g.: choosing the most correct silvicultural systems, rotation periods, and thinning regimes) and thus reducing the footprint on forest biodiversity.

4.4 Expected longer term results

The results of the project will yield the following EU-added value:

- Support in implementing the SFM criteria in Italian forest areas based on the most recently defined technological methods.
- Collection and organization of available data from representative Italian forest types, which will be an important starting point for future assessment in those and adjacent areas.
- Practical application of recently optimized methods of integration between remotely sensed and inventory data.
- Assessment and mapping of SFM criteria in pilot study areas.

The project, based on a set of SFM indicators mentioned in several official EU documents, builds on activities like assessment of stand structure, ground vegetation, deadwood, and forest types that have already been conducted on different levels at European scale (EU Level II and Level I plots, UN-ECE ICPs Forests, National Forest Inventories and remote sensing data).
These activities need an overall coordination, method harmonization and scale integration, to be a solid basis for the establishment of an integrated system to detect and evaluate changes in SFM in European forests. Otherwise, the high value of the huge amount of data and information already available and related network facilities cannot be combined and used at EU level.
The project gave also a contribution to the objectives of EU policy for adaptation to climate changes (EC Green Paper, 2007), providing information on status of forest ecosystems and their relative resilience and adaptation capability.
The project contributed to the reporting obligations of the Member States, as concerns the conservation status of forest habitats listed in the Habitat Directive and included in the Natura2000 network.
The project will complete the set of observation carried out under the LIFE+ project FutMon (Further Development and Implementation of an EU-level Forest Monitoring System), in 2009 and 2010.
The obtained harmonized methods for assessing key indicators of SFM at regional scale will be replicable in all EU

5. Administrative Part

The Grant Agreement was formally signed on the 22nd of July 2015, while the Life FRESh Project start date was defined on the 7th of September 2015.

Between September and November 2015, the Partnership Agreements within AISF and other beneficiaries were drafted and signed.
Currently all Partnership Agreements has been formally signed.
On the 7th September 2015, that was the Project start date, AISF and all partners organised the first internal Fresh Project's kick-off meeting in Florence at the Accademia Italiana di Scienze Forestali headquarters, Coordinating Beneficiary.
As agreed during the kick-off meeting, the Financial Manager (DEMETRA team) took up:
a) The support of the Project Manager in administrative management
b) The drafting of the Operative Manual that has to be approved by the partnership
c) The organisation of an internal formative activity through specific 'formative meetings'
d) The organisation of the document workflow between partners and Project management team
e) The drafting of the periodical reports foreseen under E1-Action
The writing of the Manual, headed by Associated Beneficiary Demetra, began before the training activity of December and finished with the document emission (after two revisions).
On the 22nd of December 2015, as foreseen in the FRESh LIFE project timetable, the Operative Manual was formally sent to all the Beneficiaries to allow the formal adoption by 31/12/2015 (Annex already sent - See the annex attached in the 2nd Progress Report).
In line with expectations, the Manual has been approved by all the beneficiaries and therefore is adopted and in force.
According to the previsions of E1 Action, an in-depth training activity has been organised towards all the project partners with particular regard to persons who have limited experience in EU projects management.
In July 2017, Revision 3 of the Operational Manual / Quality Plan was issued to review and improve the internal monitoring procedures.

Project Consortium and management structure

The Project Management (PM) was carried out by AISF whit the Project Manager, Prof. Gherardo CHIRICI, who was be responsible for the day-to-day management of the project and its operational execution.
The Project Manager coordinated all project activities and implemented the agreed strategies, the choice of techniques, and supervised the monitoring of the results. Moreover, he has undertaken all contacts and exchanges with the European Commission and acted as the consortium's designated representative in this respect. The Project Manager worked closely with the project's partners and oversaw that the project objectives are achieved.
Moreover AISF provided a nearly full time 'assistant' to Project Coordinator to ensure day-to-day management and sound control of the project.
Each partner has designated an Activity Leader, who has been responsible for organizing the work on the specific tasks.

The Steering Committee (SC) was composed by a representative Team Leader for each partner and was involved with recommendations regarding the adherence to the plan and the partners' responsibility as to the proper execution of the assigned activity. The Steering Committee, appointed at the beginning of the project, met on a regular basis (also by web meeting).

The Financial Management (FM) was carried out by Dr Simone Carrara (with over 5 years previous LIFE experience and specific financial management skills in EU programs), provided by DEMETRA partner.
The Financial Manager has been supported by AISF and DEMETRA administrative staff.

The Financial Manager the manager took care of the financial administration of the project, including ensuring proper completion and consolidation of the Financial Statements and their timely submission to the Commission.

The project management structure (PM, FM, SC) provided management tools to ensure a correct activity management complying with Life and Grant Agreement provisions, including:
- "Activity Reports" (distributed to project staff, design in order to record, on a daily basis, the time which each employee spends working on the project, the activities carried out, critical issues emerged, the deliverables concerned, the expenditures linked with each activities and any other relevant information relating to the project implementation);
- "Financial Reports" (distributed among partners, in order to guarantee a common way of cost registering);
- "Project Quality Plan – Operative Manual"

Project development has been monitored at two level: progress against work plan on day-to-day basis and technical monitoring project review meetings to verify general progress against overall plan and financial considerations.
The monitoring has been conducted by the Project Manager and other technical resources who collaborate in the activity.

A careful planning of the organization of monitoring activities (including areas of responsibility and authority) was ensured that everyone works together for a smoothly run project.
Progress of the project work has been monitored against the milestones and the objectives defined in the Monitoring Plan.
Quality Control was managed first at a activity level by Activity Leaders reporting to the Project Manager, the Financial

Manager and the Steering Committee.

In **Annex04** (FRESh Life Organization and Management Chart) can be found the updated Fresh Life Project overall Organization and management chart, with the names and levels of responsibility of the entire project.
In **Annex05** (FRESh Life Individual Management Chart) can be found also the specific management chart for each individual beneficiary.

5.1 Internal monitoring activities

In the period between March and May 2018, the Financial Management Team set up a specific internal monitoring activity.
For logistical reasons, four meeting days was planned in three regional areas where the partners are located; below is the schedule of the meetings:
- 12-14 of March 2018 Campobasso at the Molise Region headquarters: UNIMOL and REGMOL attended this meeting.
- April 27th 2018 VITERBO at the Università della Tuscia: UNITUS, CAPRAROLA, and OBEN attended this meeting.
- On the March 28th and May 10th 2018 FIRENZE at UNIFI and AISF headquarters: AISF, UNIFI and UCVV attended this meeting.

As provided in the Operative Manual and agreed with project partners, document workflow has been regulated and a cloud file on OwnCloud has been activated. (**150.217.83.201/owncloud)**
All the partners have free access to this file. The file has an expansive capacity and is structured in order to provide a correct storage of a large part of FRESh LIFE project documentation.
The Steering Committee, composed by a 'team leader' for each partners, reunited on the partners' meeting days. The Committee reunited several times (also via skype calls) for the project technical and administrative management.
The FRESh Life Project administrative coordination was carried out on time and in line with the Project previsions and aims.
The Project Manager and the Financial Manager were operating everyday - with AISF team support - to provide support to all the project Beneficiaries and allow the deadline's good management, especially in the final reporting period.

5.2 Changes in the project's management structure; partner withdrawn, replaced, etc.

Regarding the Project's Management Structure **one relevant change** emerged: Coordinating Beneficiary requested an Amendment of FRESh LIFE due to the withdraw of the associated beneficiary Roma Natura communicated the past 28/11/2017.
Due to this project amendment AISF also requested the extension of the project duration for two months to the end of November 2019.
The work load of Roma Natura was covered by the Coordinating Beneficiary Accademia Italiana di Scienze Forestali (AISF) and by the Associated Benificiaries Università degli Studi di Firenze (UNIFI) and DEMETRA.
The technical activities foreseen for RomaNatura in the action C1 and C3 were carried out by UNIFI that ensured their correct execution through his team. To guarantee the monitoring of the impact of the project envisaged by these actions an additional staff member was hired as a junior scientist.
This new member, together with the skills already in force within the UNIFI staff, allowed to cover all the technical activities foreseen for the outgoing beneficiary.
Regarding the other activities of RomaNatura, related to dissemination (Actions D6/D7) and project management (Action E1), the coordinator partner AISF and the beneficiary DEMETRA, ensured the correct execution by their team. Amendment Request was sent on July 30, 2018.
The Amendment number 3, was formally signed on 11/04/2019 (Ref. Ares (2019) 2554940 - 11/04/2019).
Finally, on 26/09/2019 we requested a last amendment (No. 4) related to AISF bank account modification: the Amendment was accepted on 06/12/2019 (document Ares (2019) 7567071).

6. Technical Part

FRESh LIFE contributes in ensuring repeatability and reproducibility of forest mapping procedures at EU level, so that methodologies and products are consistent with the activities of the European Forest Data Centre (EFDAC) and with the Forest Information System for Europe (FISE) of the European Commission.
Demonstration activities were developed in the project study areas, which are located in Tuscany, Lazio and Molise Regions of Italy, and that can be easily replicated in different biological, environmental, social and economic contexts.
The goals of demonstration activities were:
1. to test and to evaluate the technical and economic feasibility of integrating Earth Observation data collected by satellite, manned aerial platforms and Remotely Piloted Aircraft Systems (RPAS) with plot-level data from forest

inventories, to map Forest Europe SFM indicators.
2. to develop Forest Information Systems, aggregating multiple indicator maps, to support forest managers in evaluating success towards SFM at the scale of the forest management unit.

6.1 Progress per action

6.1.1 Action B1: Existing Data Acquisition and Harmonization

Foreseen start date: 01 October 2015	Actual start date: 08 September 2015
Foreseen end date: 30 September 2018	Actual (or anticipated) end date: 30 September 2016

The aims of Action B1 were: to select the demonstration sites; to acquire existing (available) data in the selected sites; to harmonize data acquired in the demonstration site; and to implement a project information system that will be used by project partners to perform project actions.
All the data from Action B1 were prepared in the form of shapefile or raster and they have been included in the Forest Information System developed in Action B4.
This action concluded in September 2016. Three demonstration sites (Bosco Pennataro, Caprarola, Rincine) were identified as indicated in the project proposal. A fourth site (Decima Malafede) has been added at first to replicate the project methodologies in other forest ecosystems but then removed due to the withdrawal of the partner RomaNatura (see the approved Amendment Nr.3 to the Grand Agreement dated April 2019); existing data were collected and harmonized for implement the project information system with metadata in line with the INSPIRE Directive. All the deliverables and milestone were respected in time.

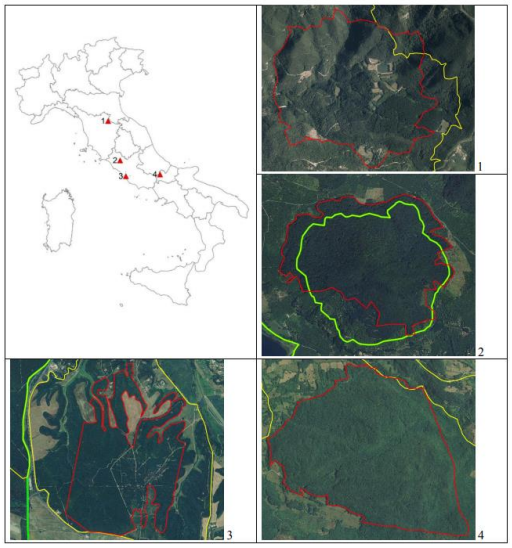

Figure 1. Distribution of demonstration sites (1. Rincine, 2. Caprarola, 3. Decima Malafede, 4. Bosco Pennataro)

Concerning the indicators of progress of the action:

- number of field plots acquired;
- percent of study areas covered by remotely sensed data;
- percent of study areas covered by forest management plans;
- percent of harmonized information layers on the total number of information layers;

Acquisition of existing (available) data
For each demonstration site UNIFI, in collaboration with UNIMOL and UNITUS, under the coordination of AISF, has collected a series of data already available from the beneficiaries UCVV, Municipality of Caprarola and Molise Region. In particular, the following data have been acquired: inventory data (geographical location of the sample plot, raw data from the fieldwork and data aggregated at the plots level); remote sensing data (orthophotos, multispectral data and LiDAR data); forest management plans and their cartographic attachments (forest compartment maps and forest types maps); auxiliary data (eg., topographic maps, land use maps, etc.).

Dati		*Rincine*	*Caprarola*	*Decima Malafede*	*Bosco Pennataro*
Dati inventariali	Ploto a raggio fisso	16 plot (anno 2004)	65 plot (anno 2006)	Nd	77 plot (anno 2013-2014)
	Aree relascopiche	Nd	144 aree	Nd	59 aree (anno 2005)
	Transect	Nd	68 transect	Nd	3 transect (anno 2005)
Dati Telerilevati	Ortofoto	Periodo 1954-2015	Periodo 1989-2008	Periodo 1989-2008	Periodo 2005-2012
	Dati multispettrali	Nd	Spot (anno 2006), RE (anno 2011), IRS (anno 2012)	Spot (anno 2006), RE (anno 2011), IRS (anno 2012)	Spot (anno 2006), IRS (anno 2012)
	Dati LiDAR	Anno 2015 (formato .las)	Nd	Nd	Nd
Piani di gestione	Piano	Periodo di validità 2005-2019	Anno 1989, anno 2007	Nd	Periodo di validità 2008-2017
	Particellare	Si (formato .shp)	Si (formato .shp)	Nd	Si (formato .shp)
	Tipi forestali	Si (formato .shp)	Si (formato .shp)	Nd	Si (formato .shp)
Dati ausiliari	Carta topografica	CTR10k	CTR5k-10k, IGM25k	Nd	CTR10k, IGM25k
	Carta dei suoli	Si (formato .shp)	Carta geologica	Carta geologica	Carta geologica
	Carta uso suolo	Si (formato .shp)	Si (formato .shp)	Si (formato .shp)	Si (formato .shp)
	Carta viabilità	Si (formato .shp)	Si (formato .shp)	Nd	Si (formato .shp)

Table 1. Table of existing data available

Data harmonization

The data acquired in digital format (geographical location of the inventories data, remote sensing data, maps annexed to forest management plans and auxiliary maps) were harmonized by projecting all these data in a common geographical reference system: UTM Zone 32 North, Datum WGS84.

The maps of forest types were then reclassified by adopting the European Forest Type classification system developed by the European Environmental Agency (EEA, 2006).

As regards the inventories data, it was observed that:

- the position of the plots in the areas of Rincine and Caprarola was chosen with a subjective criterion;
- inventory plots had different size in the demonstration sites, ranging between a minimum of 314 m^2 and a maximum of 1000 m^2;
- in the demonstration sites, the estimation of the growing stock in the inventory plots was carried out using different volume tables.

In order to harmonize the estimation of the growing stock in the plots, the single tree volumes were recomputed in each study area using a common volume table as suggested by the COST Action E43 "Harmonization of National Forest Inventories in Europe: Technique for Common Reporting". To this end we used the volume tables developed by the Italian National Forest Inventory.

ID Area	*ID Plot*	*Specie*	*Diametro*	*Altezza*	*Numero piante*	*Area basimetrica*	*Volume*	*Biomassa1 (kg)*	*Biomassa2 (kg)*	*Biomassa3 (kg)*	*Biomassa4 (kg)*
(n)	*(n)*	*(nome)*	*(cm)*	*(m)*	*(n)*	*(m2)*	*(m3)*	*(kg)*	*(kg)*	*(kg)*	*(kg)*
2	1	Faggio	5	13.6	1	0.002	0.01	7.6	4.3	0.2	12.1
2	1	Faggio	30	24.0	1	0.071	0.84	535.3	113.1	16.8	665.2
2	1	Cerro	10	17.6	2	0.016	0.13	43.7	9.8	1.3	54.7
2	1	Cerro	30	24.0	1	0.071	0.82	549.2	99.8	14.6	663.6
2	1	Cerro	35	24.8	3	0.279	3.36	775.7	140.1	20.6	936.4
2	1	Cerro	40	25.6	5	0.616	7.65	1045.0	188.1	27.7	1260.7
2	1	Cerro	45	26.3	4	0.620	7.91	1358.0	243.8	35.9	1637.7
2	1	Cerro	50	26.9	3	0.569	7.43	1715.6	307.4	45.3	2068.4
2	1	Cerro	55	27.4	4	0.927	12.33	2118.5	379.2	55.9	2553.6
2	1	Cerro	60	27.9	3	0.820	11.11	2567.5	459.1	67.7	3094.4
2	1	Acero opalo	5	13.6	3	0.006	0.04	7.8	7.2	0.4	15.5
2	1	Acero opalo	10	17.6	10	0.077	0.66	36.9	15.1	0.9	53.0
2	1	Acero opalo	15	20.0	6	0.104	0.99	92.6	30.3	2.0	124.9
2	1	Acero opalo	20	21.6	2	0.063	0.64	177.5	53.4	3.6	234.5
2	1	Carpino nero	20	21.6	1	0.031	0.33	206.1	52.4	5.6	264.2
2	1	Carpino nero	25	22.9	1	0.049	0.55	341.9	84.2	9.1	435.2
2	2	Faggio	50	26.9	2	0.393	5.24	1671.2	347.4	52.5	2071.1
2	2	Faggio	55	27.4	3	0.689	9.38	2063.6	428.3	64.9	2556.7
2	2	Faggio	60	27.9	1	0.283	3.92	2500.8	518.5	78.6	3097.9
2	2	Faggio	65	28.4	3	0.962	13.56	2983.5	618.0	93.8	3695.4
2	2	Cerro	60	27.9	1	0.283	3.83	2567.5	459.1	67.7	3094.4
2	3	Faggio	5	13.6	8	0.016	0.11	7.6	4.3	0.2	12.1
2	3	Faggio	10	17.6	2	0.016	0.14	43.0	11.5	1.4	55.9

Table 2. Example of armonized dataset of single trees following the guide line proposed by COST Action E43.

Implementation of the project information system

The data acquired and harmonized by UNIFI were used to create a project information system that was updated with new data from actions B2 and B3.

at the conclusion of the actions all these indicators of progress have reached the 100%.

Milestones

M1 Completion of data acquisition data 15/01/2016

M2 - Project information system with metadata in line with the INSPIRE Directive data 15/05/2016

Deliverables

D1 - Database with harmonized data according to Cost Action E43 15/03/2016

D2 - Technical report 15/07/2016

6.1.2 Action B2: New Data Acquisition

Foreseen start date: 15 January 2016 Actual start date: 15 January 2016
Foreseen end date: 30 September 2017 Actual (or anticipated) end date: 30 September 2017

The main aim of this action was to acquire new remote sensing data and new forest inventory data in the demonstration sites. These new data were used with existing data collected in Action B1 to create the dataset needed for the implementation of Action B3 (Mapping SFM indicators). The final scope of Action B2 was to complete the repository data with the acquisition of those data not yet available in the study areas.
This action was divided into three main parts: assessment of collected data in Action B1, acquisition of new geospatial data, and acquisition of new field data.
As reported in the Progress Report in June 2016, the first part of this action was concluded on schedule with the assessment of data collected in Action B1 and the production of a list of missing data. This information was used to plan the new data acquisition, that were new remotely sensed data and new field data. Both the data acquisitions are now concluded as reported in the MidTerm Report of April 2017. The few problems encountered for the LIDAR data acquisition in the demonstration site of Caprarola are been solved and the area covered with a flight by our partner OBEN. This action concluded at the end of September 2017 and all the deliverables and milestone were respected in time.
Concerning the indicators of progress of the action:

- number of geo spatial data acquired per study area;
- number of new geo spatial data in line with INSPIRE directive metadata on the total number of new geo spatial data acquired;
- number of new field plot acquired per study area;
- number of new field plot harmonized following reference definitions from COST E43 on the total number of new field plots;

at the conclusion of the actions all these indicators of progress have reached the 100%.

Acquisition of new field data
Based on the assessment of data collected in Action B1 with the creation of a list of missing data, we decided to carried out a new campaign of field surveys in all the project's demonstration sites, as already foreseen in the approved proposal in order to reduce the time gap between the field data and the new geospatial data. In each site, 50 squared plots with sides of 23 meters (plot size = 529 m2) have been selected by UNIMOL in collaboration with UNITUS, two subcontractors (CREA and UNISI) and UNIFI using the one-per-stratum stratified sampling scheme (Brus et al., 1999; Barabesi et al., 2012). More details about the sampling scheme are described in the deliverable "Assessment of data collected from Action B1 and list of missing data" presented as an annex of the progress report. In each plot, all plants (trees and shrubs) with a dbh > 2.5 cm are inventoried. The spatial position of the inventory plot (x, y coordinates of the center of the plot) are acquired with GNSS receivers with a sub-meter accuracy. In order to standardize the collection of data in the plots, UNIMOL in collaboration with UNIFI and UNITUS prepared a common sampling protocol, which report in detail all the field measurements in terms of methods and variables to be collected.. Fieldworks were concluded in the sites of Rincine, Caprarola and Bosco Pennataro in November 2016. All the field measurements were carried out without any relevant problems. Between November 2016 and January 2017, the quality of the data was evaluated, then all the field data were used to create a harmonized database. For each demonstration site four spatial databases were created (living trees, stumps, standing deadwood, lying deadwood); for each surveyed element (trees, stumps, standing dead trees and lying deadwood) the spatial position within the plot was computed and implemented in a Geographical Information System.

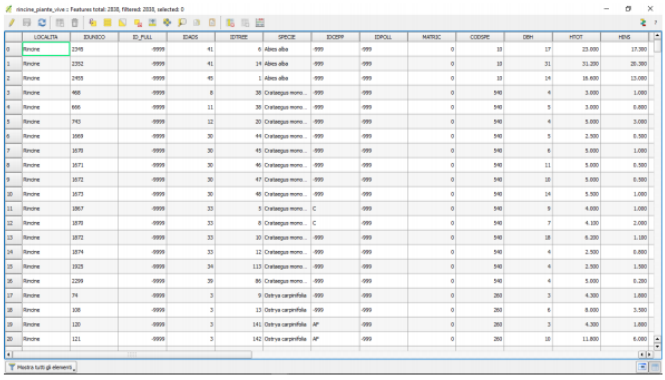

Table 3. Example of database for living trees visualized in the Geographic Information System

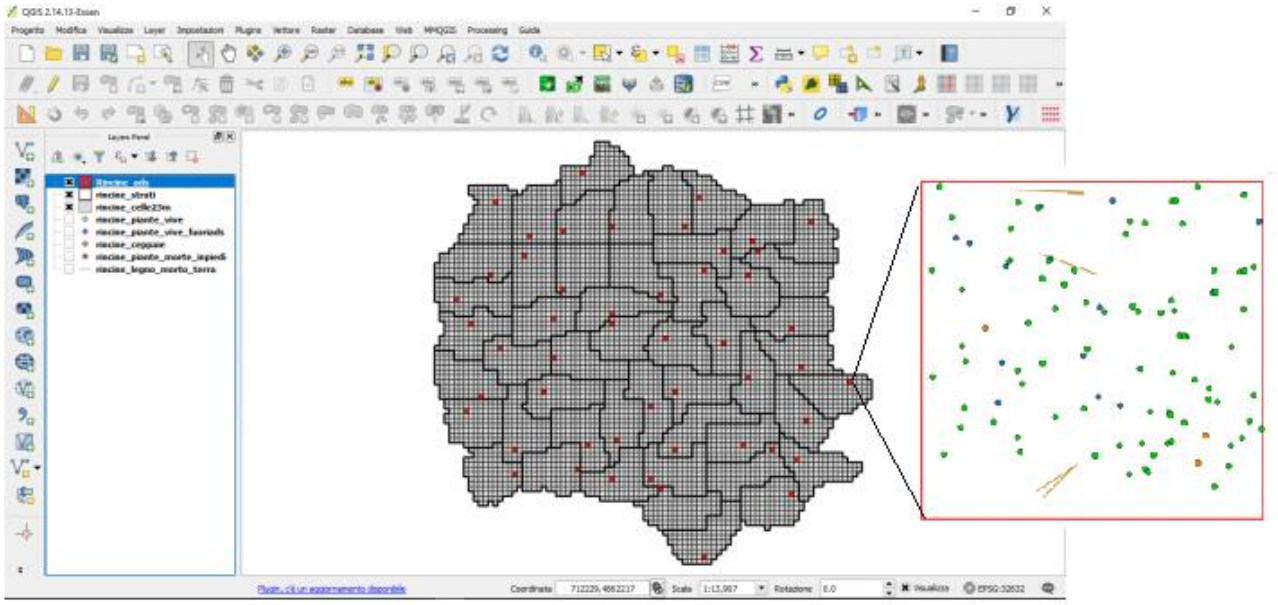

Figure 2. Distribution of the 50 field plots in the site of Rincine (above) and example of the spatial database with the position of the surveyed elements within the plot, visualized in the Geographical Information System (below) (in order: living trees (green dots), stumps (orange dots), standing dead trees (blue dots) lying deadwood (brown lines))

Acquisition of new remote sensing data

We acquired both multispectral and laser scanning data for the study areas of Rincine, Caprarola and Bosco Pennataro. For multispectral data we used two sensors (RGB and NIR cameras) carried by the fixed wing RPAS "eBee", which has been purchased by UNIFI specifically for the purposes of the project. For laser scanning data we used a Lidar sensor carried by helicopter (Octocopter) RPAS developed by the beneficiary partner Oben. Regarding the multispectral data, 12 ground control points (GCP) were placed in each area before RPAS acquisition using 50x50 cm targets; the x,y coordinates of each GCP were registered by a global navigation satellite systems (GNSS) using a Trimble Juno 3B Handheld receiver observing the pseudorange of both GPS and GLONASS. Data collection lasted for approximately 10 minutes for each GCP with a 1-sec logging rate. SenseFly eBee fixed-wing RPAS was used for multispectral data acquisition. The RPAS weighs approximately 537 g without payload and has a maximum flight time of 45 minutes under optimal weather conditions. The eBee is equipped with an onboard GNSS to provide rough positioning. In this project, the eBee was equipped with two cameras: a Canon S110 near infra-red (NIR) camera and a SONY WX RGB camera as the payload. The sensor produces two types of images: Canon S110 NIR takes pictures of 12.1-megapixel in the green (550 nm), red (625 nm), and NIR (850 nm) wavelengths, while the SONY WX takes pictures of 18.2 MP in the red (660 nm) green (520 nm) and blue (450 nm) wavelengths. Software eMotion 2 version 2.4.2 was used to simulate, to plan and to monitor the flight. The total acquisition area was 1298 ha with a total of 23h40'of flights. In the site of Caprarola, the eBee acquisition was done between May 23th and May 27th, 2016. Two days were needed to measure GCP, while two days were needed to acquire the multispectral data. To cover the entire area, 5 RGB flights (483 images) and 5 NIR flights (564 images) were done, respectively. In the site of Bosco Pennataro, the eBee acquisition was carried out between June 26th and June 30th, 2016. Also in this area two days were necessary to measure GCP and 2 days were needed to acquire the multispectral data. To cover the entire area, 6 RGB flights (608 images) and 7 NIR flights (689 images) were necessary, respectively. In the site of Rincine, eBee acquisition was done between July 26th and July 29th, 2016. Two days were used to measure GCP, and two days were needed to acquire the multispectral data. To cover all the study area, 4 RGB (506 images) and 5 NIR (682) flights were needed, respectively. The block of images was processed for each area and each sensor. The RPAS images were processed using the Agisoft PhotoScan (Agisoft LLC, 2017) to create a 3D point cloud. Agisoft Photoscan combines SfM (Structure from Motion) and photogrammetric algorithms for 3D reconstruction from unorder but overlapping imagery. This software was chosen as previously found to be suitable for forest applications. Photoscan offers a user-friendly processing pipeline that combines proprietary algorithms from computer vision SfM and stereo-matching algorithms to accomplish the tasks of image alignment and multiview stereo-reconstruction. Image alignment consisted of the sparse reconstruction of 3D geometry by detecting and matching image feature points in overlapping images using SfM techniques. The estimation and optimization of the camera orientation and internal parameters are the main outputs of thisstage. Consequently, GCPs were used to improve the estimates of camera position and orientation, allowing for more accurate model reconstruction. Their coordinates were imported and placed using a guided approach. After the optimization of camera position a dense point cloud and a Digital Surface Model (DSM) were computed by Agisoft Photoscan. The DSM were than used to Ortorectify the RPAS images. The results of the images processing produced the following remote sensing products for each area: two dense point clouds (NIR and RGB) (ranging between 20-40 point m^2), two DSMs (50 cm resolution) and two ortophotos (RGB and NIR 10 cm resolution) (Figure 3). All the remote sensing products elaborated from the new multispectral data acquired by eBee were projected into the

coordinate system used by our project: UTM 32N WGS84. For each of these products a metadata INSPIRE was created..

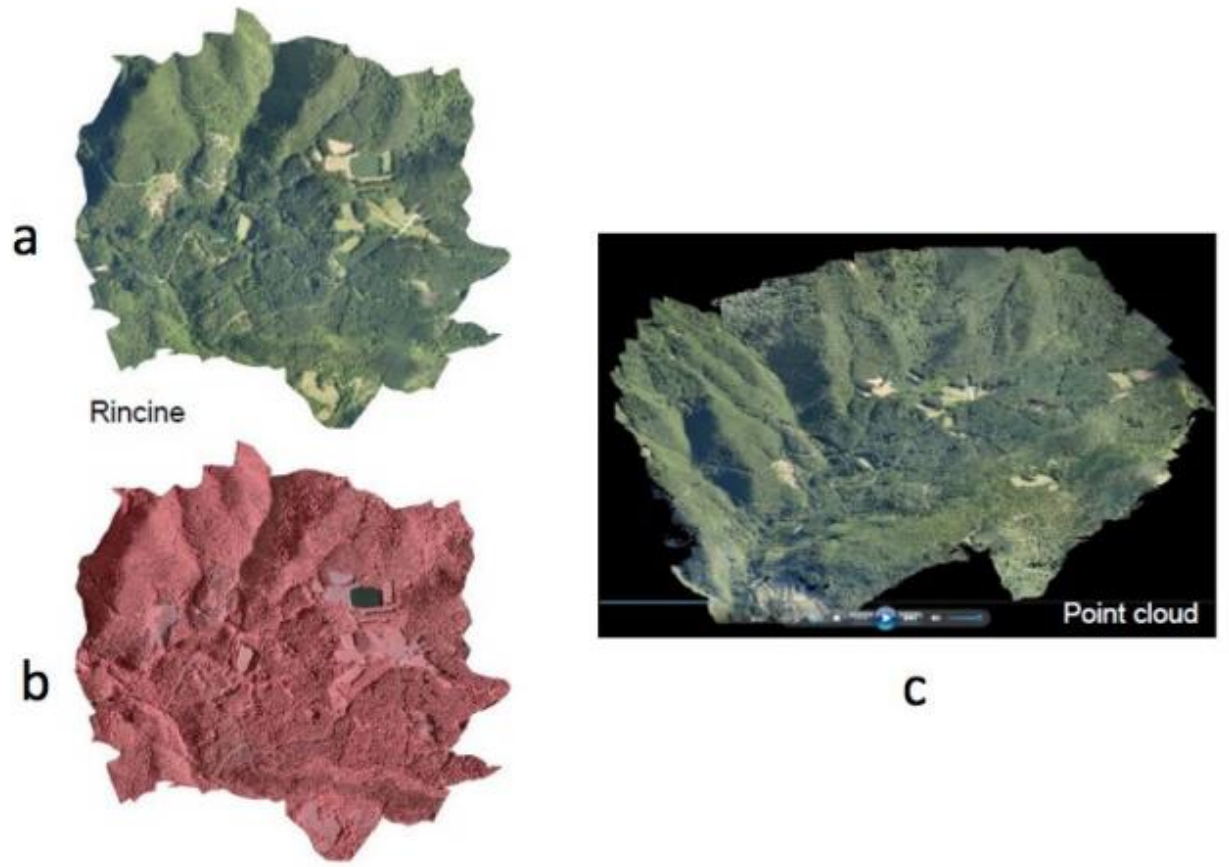

Figure 3. Some examples of the remote sensing products elaborated from the new multispectral data acquired by eBee: a – RGB ortophoto with 10 cm resolution; b – NIR ortophoto with 10 cm resolution; c – 3D model from the dense point clouds

Regarding the new LIDAR data, the acquisition was completed in all the demonstration sites. The LIDAR sensor was carried by the octocopter, the drone developed by the beneficiary partner OBEN. However, because of the changes introduced by ENAC in the national drone flight regulation, which has limited the use of this platforms, in particular by forbidding any operation beyond what can be done in constant visual contact of the pilot with the drone, and in any case within a short distance (500 m) from the pilot position, we were able to fly with octocopter over 75% of the total area of the demonstration sites; in the remaining 25% of the area it was not possible to fly with drone since some areas are mostly unavailable in the central part or in relatively deep valleys far from the clearings suitable for piloting. For this reason and in order to get the LIDAR data for the entire demonstration sites, we used a light helicopter instead of the octocopter as platform to fly with LIDAR sensor over inaccessible areas. It is worth of noting that the light helicopter has technical characteristics (e.g., flight profile, flight altitude above canopy top, flight speed) which allow to emulate very well the flight of a drone as already experienced by OBEN in various situations where the light helicopter was used to overcome regulatory limitations. This solution has been found suitable to solve the problem without any need for amendments in project budget and permits full demonstration of the capabilities of the LIDAR sensor carried by the drone, in view of the new regulations that will soon permit drone flights also beyond visual line of sight. Indeed, with a higher productivity per hour, the impact of the rental of the light helicopter is entirely sustainable within the budget already envisaged. The pre-processing of the LIDAR data was performed by OBEN using Cloud compare and Terrascan softwares. The results of the LIDAR processing provided the following remote sensing products for each area: a dense point cloud (ranging between 70-120 point/m2) (Figure 4), a Digital Terrain Model (DTM) with a spatial resolution of 50 cm, a DSM with a spatial resolution of 25-50 cm, and a Canopy Height Model (CHM) with a spatial resolution of 50 cm. All the remote sensing products elaborated from the new LIDAR data acquired by OBEN were projected into the coordinate system used by our project: UTM 32N WGS84. For each of these products a metadata INSPIRE was created..

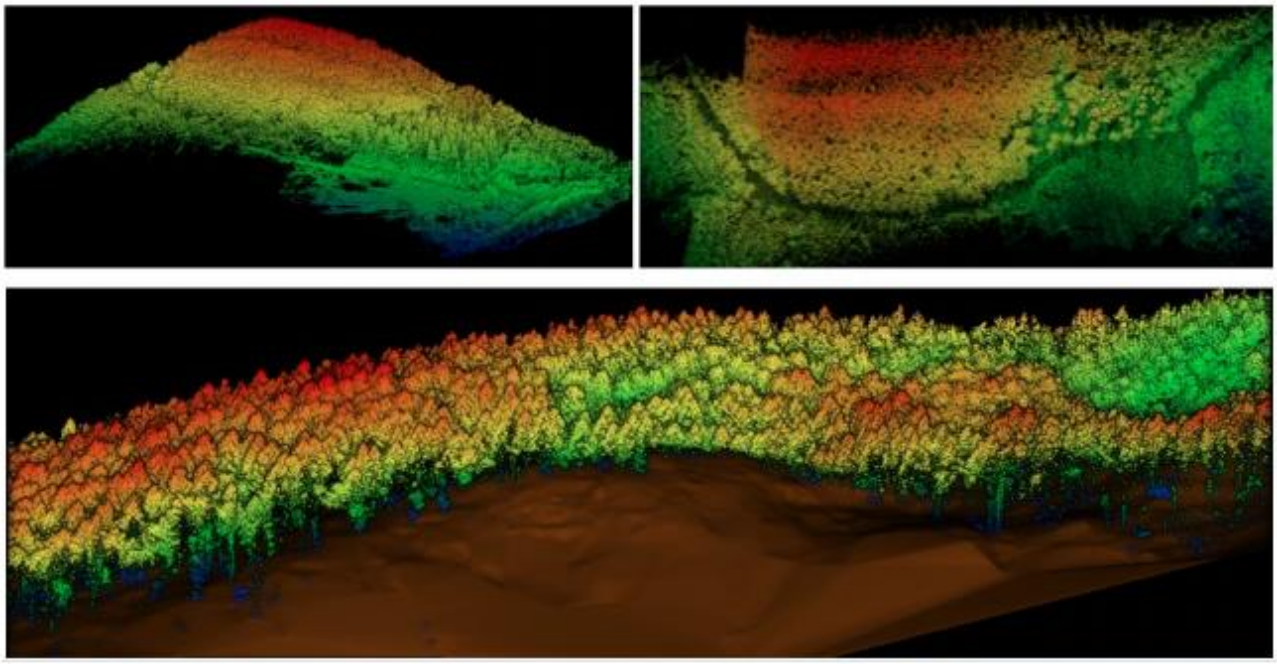

Figure 4. Some examples from the dense point cloud obtained in the demonstration site of Rincine

In addition, a data quality check of the LIDAR products was performed by OBEN in the site of Rincine; this check was possible thanks to the availability of a LIDAR data taken in 2015 over the area of Rincine, which was acquired as existing data in Action B1. It is worth of noting that the unpredictable changes in the national rules for flight with drone caused a very hard work for OBEN team to guarantee the products set out in the design phase of the project. Especially in the site of Caprarola, which is a Site of Community Importance of the Natura 2000 network and a Regional Nature Reserve, the acquisition of the LIDAR data has been postponed because of a delay in the release of the authorizations by the competent authorities. In particular, the regional authority (Lazio Region) has released its authorization, which foresee that the flights can be done in Summer 2017 over the site of Caprarola, as in this period the flight does not disturb the species of birds living in the area; however, in spite of many requests and reminder we waited until the end of August for the authorization that must be released by the local authority (the Regional Nature Reserve). Once we received all the the authorizations, the flight was performed in two sessions during September 2017 (6 th and 22 th).

Milestones
M1 - List of missing data to be acquired in Action B2 16/02/2016
M2 - Acquisition of new remotely sensed data and new inventory data 16/03/2017
M3 - Completion of the Project information system with metadata in line with the INSPIRE Directive 16/07/2017
Deliverables
D1 - Assessment of data collected from Action B1 and list of missing data 16/02/2016
D2 - Database of harmonized new acquired data 16/05/2017 D3 - Technical report 16/09/2017

6.1.3 Action B3: Mapping SFM indicators

Foreseen start date: 15 January 2016 Actual start date: 15 April 2016
Foreseen end date: 15 December 2017 Actual (or anticipated) end date: 15 December 2017

The Action is aimed at demonstrating the feasibility of integration of data collected in Actions B1 and B2 for mapping SFM indicators, at the spatial scales appropriate for the SFM decision-making, in the pilot areas. The focus of the activity is to test and evaluate methods coupling remote sensed information (LiDAR and multispectral data) collected from RPAS, with plot-level data, to derive: i) maps of selected Forest Europe SFM indicators; ii) a stratification of medium to large scale forest units by EFTs, so as to optimize the spatial estimation of SFM indicators.
UNITUS is the beneficiary responsible for implementation of Action B3; UNITUS has produced in time all the deliverables of the action that describe the results of elaborations on data collected in the previous actions.
The goals of the Action B3 was to test and evaluate methods coupling remote sensed infomation collected from RPAS with plot-level data to derive: maps of European Forest Types for the pilot study areas; maps of selected Forest Europe SFM indicators. This section summarizes the technical results achieved in the production of forest types maps in the pilot study areas of Caprarola, Bosco Pennataro and Rincine by segmentation and semi-automatic classification of true color orthomosaics (ground resolution 10 cm/pixel), processed from image data collected in the visible spectrum by a camera

equipped on eBee (SenseFly) small fixed-wing unmanned aerial vehicle. The map accuracy levels of products derived from segmentation and semi-automatic classification approaches (hereafter referred to as 'semi-automatic classification') are compared with those of maps derived by visual interpretation. Technical details on the visual interpretation mapping methodology were provided in the Report of the Deliverable "Maps of the European Forest Types for the pilot study areas".

The map of growing stock were realized following processing the huge amount of information from LIDAR point cloud data, in order to derive a number of LIDAR variables (called metrics) that can be tested for correlation with the variables of interest, i.e. growing stock and aboveground biomass. To this end, the sampling surface of the 23x23 m 4 sampling units (529 m2) covering the full spatial extent of each test site was used as reference grid to process LIDAR metrics. Reference values of the variables of interest were devised by processing sample data collected in 50 sample units of the sampling surface during Action B2. The design-based Tessellation Stratified Sampling (TSS) combined with One-Per-Stratum Stratified sampling (OPSS) approach, allowed to the achieve the so-called spatially balanced sample that is, a sample in which units are well spread throughout the test sites, being uniformly placed (i.e., selected with uniform probability density) in (50) equal size strata of the study areas. This task of Action B3, by combining field and LIDAR data acquired in Action B2, attempted to spatially estimate the variables of interest by linear regression (albeit with imperfect accuracy) over the sampling surface covered by LIDAR data acquisition in the three sites. The overall data processing workflow leading to the production of maps is displayed in the figure below. In the subsequent sections, technical details on each data processing step are given.

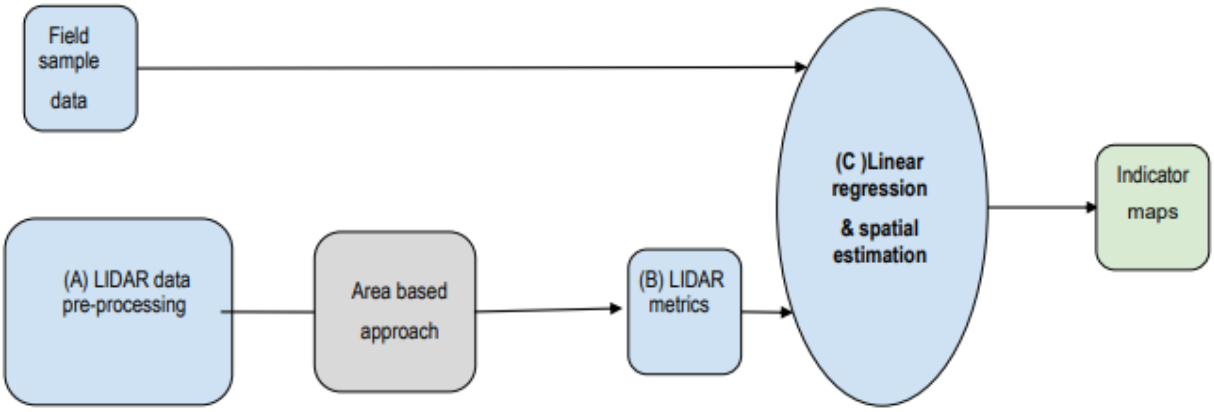

Figure 5. Methodological workflow for the spatial estimation of the SFM indicators of interest

Summarizing results achieved in the three test areas we can draw the general conclusion that the spatial estimation of the growing stock and aboveground biomass indicators using LIDAR height-based metrics as predictors led to disparate results in the three test sites. Moderate to strong linear relationships were found in Bosco Pennataro and Rincine, with R^2 from linear regression ranging from 0.44 to 0.80 for the growing stock and from 0.42 to 0.68 for aboveground biomass respectively. The independent variable x is in both cases related to mean of heights of all first returns. In Caprarola test site the goodness of fit of the prediction models is much lower, though the R^2 indicate that one quarter of the variation of growing stock or aboveground biomass is explained by the LIDAR height-based metric, specifically the mean heights of returns between 1/3 and 2/3 of the maximum height of all first returns. A possible explanation of the different performances of the predictive models in the three test sites can be the different canopy penetration of the LIDAR, which affected the amount of ground returns and, accordingly, the quality of the derived raster DTM used for the normalization of the LIDAR point cloud. Despite the density of the LIDAR point cloud in Caprarola and Bosco Pennataro was much higher than in Rincine, only a very small percentage of returns were classified as ground (on average 2-3%). In Rincine the average proportion of ground returns was more consistent (16%), leading to a more accurate DTM, a more accurate estimation of the canopy height, variable to which both growing stock and aboveground biomass are correlated, and therefore a better overall fit of the regression model to the data. It can be concluded from this test that the quality of maps of growing stock and aboveground biomass SFM indicators in the three test areas seems to be heavily influenced by the density of ground returns. Scanning during the leaf-on season, combined with dense forest stands like those covering the test areas, caused ground surfaces hidden below crown foliage to be difficult to acquire, since the light hitting the leaves rarely reached the ground in the first place. But even so, the test demonstrates that is technically feasible to derive reliable spatial estimates of growing stock and above ground biomass by LIDAR-assisted inference, considering that optimal results were achieved in the most difficult conditions of Rincine test site, which has the highest heterogeneity in terms of forest types and spatial variability of the variables of interest. The limitations arising from a single flight in leaf-on conditions suggest that a LIDAR acquisition also during leaf-off season, by providing a better identification of the ground surface, would ultimately result in better LIDAR-assisted predictive models. When spatial estimates of the variables of interest are derived with a good model fitting, important benefits arise from an operational point of view:

- The final user may be able to process estimates of means, variability or total value of the indicators for areas of interest, e.g. forest compartments at a much higher accuracy or lower costs than using field survey only
- The final user may be able to map the variables of interest, with the limits of a predictive model, but at a much higher spatial resolution than would be possible by field survey.

At the end of the Action all the expected indicators were mapped for the three demonstration area except for the ones that had no relevance due to the particular features of the forest ecosystems. Here below a table that summarize the maps of the indicators produced for each demonstration site.

Demonstration site	growing stock (# 1.3)	ground biomass (# 1.4)	number of tree species (# 4.1)	area covered by introduced tree species (# 4.4)	defoliation (# 2.3)	forest damage (# 2.4)	EFTs classification
Rincine	X	X	X	X	X	X	X
Caprarola	X	X	X	no relevance	X	no relevance	X
Bosco Pennataro	X	X	X	no relevance	X	no relevance	X

Table 4. Progress in mapping of SFM indicators for each study area (X = done)

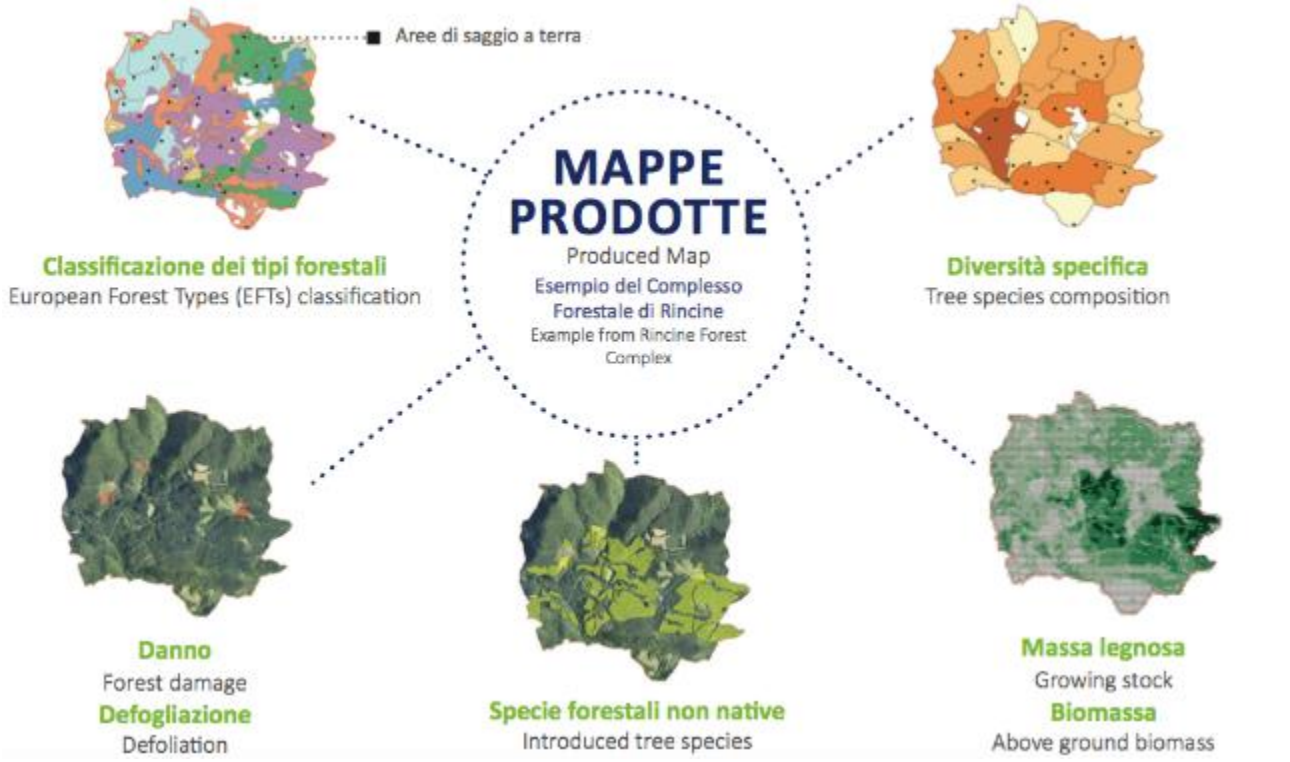

Figure 6. Example of the SFM indicators maps created for the demonstration site of Rincine.

The maps of the indicators are available in the deliverables together with GIS files and explanation of estimation methodologies. As requested after the MidTerm Report, an update of the deliverable "Report on the technical and economic viability of using high spatial resolution data to stratify by European Forest Types (EFTs) medium to large size forest management unit" with the economic viability evaluated and based in real figures was produced and submitted with the Progress Report on October 2018. In the same Progress Report also further details on near infrared acquisition campaign were provided, please refer to it for more details.

We concluded the action in December 2017 as indicated in the project proposal with all the deliverable and milestone reached on schedule. Regarding the indicators of progress:

- area covered by growing stock map in selected study areas;
- area covered by above ground biomass map in selected study areas;
- area covered by EFTs maps in selected study areas;
- number of SFM indicators maps for the selected study areas;

at the conclusion of the actions all these indicators of progress have reached the 100%. We refer to the deliverables for

more details on the activities carried out and the results achieved.

Economic viability considerations. Time and costs to process indicators maps

A quantification of the time required to produce the maps of the growing stock and above ground biomass indicator is reported in the table below. This time is compared with the time required for field data collection in the sample plots for the same indicators, as recorded in the specific data collection sheet.

Test site	*Time required to process indicators maps (hours)*				*Time spent for field survey(hours) 50 plots*
	LIDAR Pre-processing	*Modelling*	*Spatial prediction*	*TOTAL*	
Rincine	3	1	~6	10	135
Caprarola	3	1	~5	9	140
Bosco Pennataro	3	1	~4	8	289

Table 5. Quantification of time required to process indicators maps in the three test sites

An evaluation of costs of mapping growing stock and above ground biomass indicators is reported in Tables 6-9. The hourly rate of a Technician for LIDAR data processing is based on market prices (60 €/hour). The hourly rate of a Junior technician for field sample data collection is calculated based on the additional staff contract costs (15 €/hour). The costs of each step of the process (Field sample data collection, Lidar acquisition, LiDAR Processing and map production) are detailed in Tables 6- 7. The total cost of producing maps of the growing stock and above ground biomass indicators is the sum of the costs of these three stages of the mapping process. The total cost is estimated for each test site and it is reported in Table 8. The total cost is significantly affected by the cost of LiDAR data acquisition and, to a lesser extent, by the cost of field survey. Applying the same sampling intensity used in the project (1 plot of 529 m2 every 5 ha), the cost of field survey on 50 plots, calculated on the basis of the hourly rate of an experienced professional as result of market prices (40 €/hour), would amount to 18,000 € (Table 9). Based on this assessment, one can argue that the cost of business as usual scenarios, i.e. traditional forest inventory, reaches the (average) cost of LiDAR derived indicators maps when the number of sampling plots equals to 70 units ca (point B, Figure 7). At this sampling intensity, the total area covered by sample plots is 3.7 ha, i.e. the 1.4% of the test area. At the same cost, the LiDAR based approach provides maps of the indicators and related benefits for the users.

Test site	*Time*	*Staff*	*Total time*	*Unit cost*	*Total cost*
	Hours per person	Number	Hours	€/hour	€
Rincine	135	3	405	15	6075
Caprarola	140	3	420	15	6300
Bosco Pennataro	289	3	867	15	13005

Table 6. Costs of field sample data collection in 50 plots, in the three test sites.

Test site	*Lidar acquisition*			*LIDAR Processing and map production*		
	Area	*Unit cost*	*Total cost*	*Time*	*Unit cost*	*Total cost*
	ha	€/ha	€	hour	€/hour	€
Rincine	250	70	17500	10	60	600
Caprarola	250	70	17500	9	60	540
Bosco Pennataro	200	70	14000	8	60	480

Table 7. Costs assessed for Lidar acquisition, LIDAR Processing and map production in the three test sites

Test site	*Field sample data collection*	*Lidar acquisition*	*LIDAR Processing and map production*	***TOTAL COST***	
	€	€	€	€	€/ha
Rincine	6075	17500	600	24175	97
Caprarola	6300	17500	540	24340	97
Bosco Pennataro	13005	14000	480	27485	110

Table 8. Total costs of the maps of the growing stock and above ground biomass indicators in the three test sites

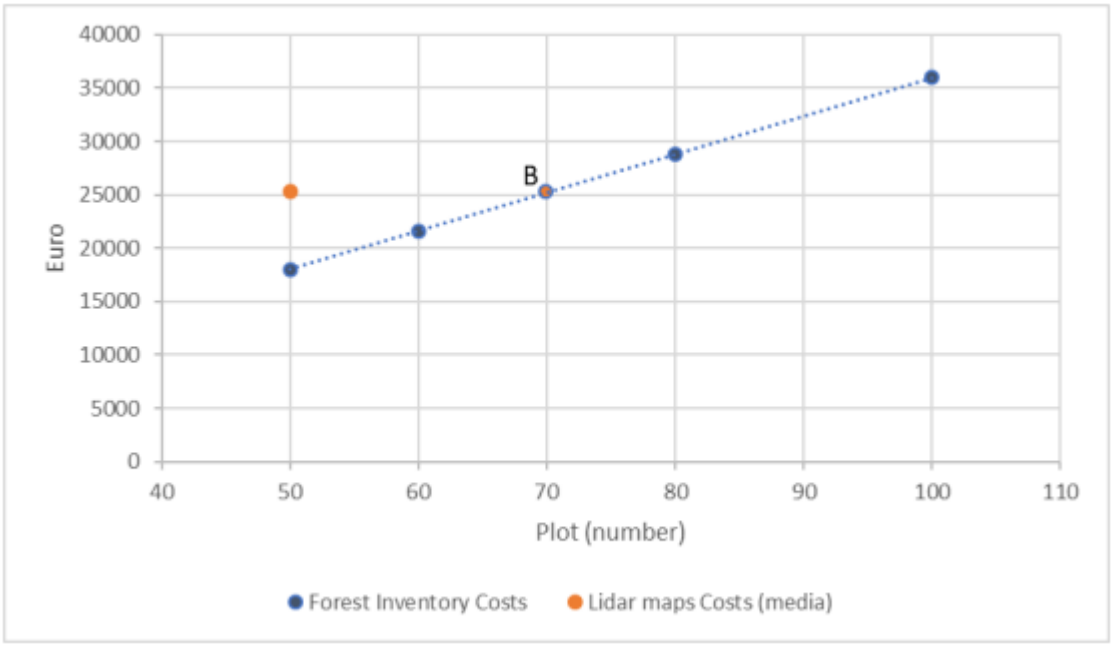

Figure 7. Comparison of forest inventory costs by increasing the number of sampling units, with the average cost of Lidar derived Maps growing stock and above ground biomass indicator (based on 50 plots)

In conclusion, despite the cost of business as usual, i.e. traditional forest inventory in sample plots, is lower than the cost of LIDAR derived maps of growing stock and aboveground biomass indicators for sample sizes < 70 units, it must be emphasized that the final benefits of the two approaches cannot be compared. In fact, in ordinary field-work the value of the indicators is known only for a relatively small fraction of the sampling surface, while (good) regression models derived from LIDAR data allow the spatial estimation of these variables over all the sampling units of this surface.

Milestone:

- Report on the technical and economic viability of coupling remote sensed information, collected from RPAS, with plot-level data to map selected Forest Europe SFM indicators at operational scale 09/2017

Deliverable

- Maps of European Forest Types for the pilot study areas 12/2016
- Report on the technical and economic viability of using high spatial resolution optical data to stratify by European Forest Types (EFTs) medium- to large size forest management units 2/2017
- Maps of SFM indicators “Defoliation (# 2.3)”, “Forest damage (# 2.4)”, “Number of tree species (# 4.1)” and “Area covered by introduced tree species (# 4.4)” for the pilot study areas 3/2017 Report on the technical and economic viability of using very high spatial resolution optical data for mapping forest health and tree species related SFM indicators at the forest compartment level 4/2017
- Maps of SFM indicators: “Growing stock (# 1.3)” and “Above ground biomass (# 1.4)” for the pilot study areas 6/2017 Report on the technical and economic viability of using geostatistical methods and techniques for the spatial estimation of growing stock and above ground biomass, at the 7/2017

6.1.4 Action B4: Forest Information System Implementation

Foreseen start date: January 2018	Actual start date: January 2018
Foreseen end date: November 2019	Actual (or anticipated) end date: November 2019

The aim of this action was to use the information collected in action B1, the ones acquired in action B2 and the results of the elaborations of action B.3 into a Forest Information System (FIS) to support their implementation in real local forest management activities. A FIS is generally considered as a working tool. It is designed to help forest manager to perform certain recurrent tasks. The use of decision support systems has grown substantially in recent years as a result of the increased availability of field and remote sensing data at multiple scales. To provide managers of the demonstration sites with a useful forest management support tool, all data acquired and processed within the FRESh LIFE project were

organized in a GIS-based Forest FIS. A georeferenced data package was prepared for each demonstration site by ensuring that spatial layers could be visualized on any GIS software available to managers. In cases where managers did not already have a GIS platform, the QGIS open-source software was used and training sessions were organized to familiarize managers with the software. All data collected during the project were stored in the FIS, including preexisting data (e.g., road and traffic information, management plans, and regional topographic and hydrographic maps), newly acquired data (orthophotos, DTM, DSM, and inventory data) and processed data (EFT classification and SFM indicator maps). Wherever possible, data were organized and provided at the scale of the individual forest units. Managers were encouraged to test the tool and provide feedback on how to tailor the FIS to the specific management needs of the individual demonstration areas.

Rincine

In Rincine the FIS has been made available for the guards and office employees that use it during their daily work of forest management. More in details the office located in Rufina, not far from the demonstration site, has the responsibility regarding the issue of cutting authorizations in relation to the management of the hydrogeological protective restrictions.

During this kind of activities, the FIS can help in different ways:

- evaluation of the residual coverage after the various types of forest chop;
- accurate measurement of the cutting surfaces that determine total uncovering for best environment control;
- more correct evaluation of the maximum annual surface area allowed for cutting;
- accurate description of the forest structure for thinning purposes;
- technical support in the creation of new tracks and forestry roads;

Regarding more conservative and monitoring activities, following the aims of the Sustainable Forest Management, the classification in European Forest Types, available at the scale of the single forest unit, is a useful tool for the decision maker during the activities planning in the forest. Another example is the analysis of the “Defoliation” indicator map that allow to monitoring pests and results of the fighting activities (Thaumetopoea pityocampa, Thaumetopoea processionea Dryocosmus kuriphilus).

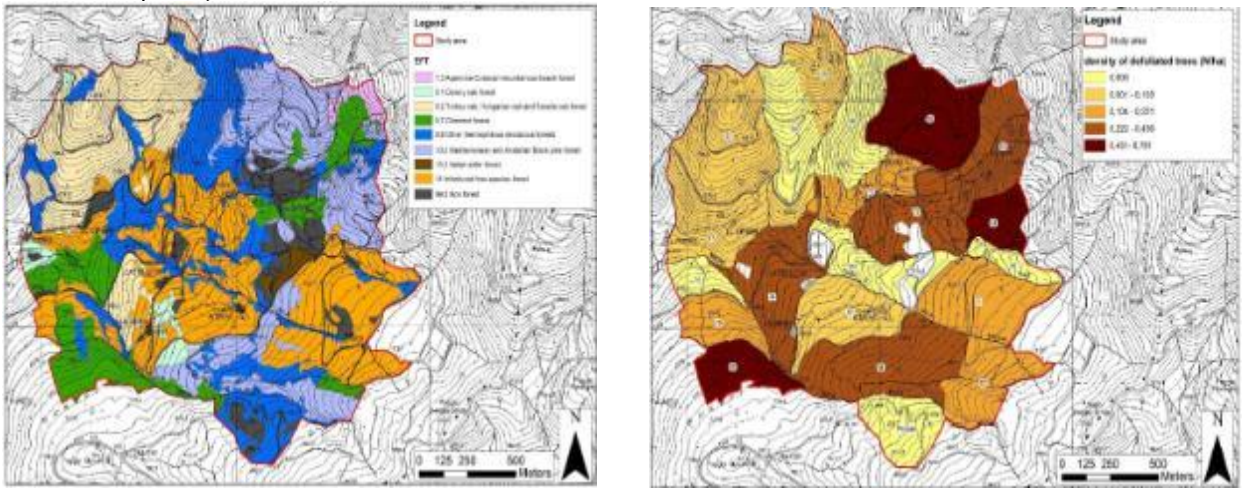

Figure 8. Map of the European Forest Types (left) and Defoliation (right) for the demonstration site of Rincine. Both the maps are available on the Forest Information System

Switching to the quantitative data available in the database, the analysis of the maps allows an easy evaluation of growing stock for auction, sales and planning. Due to the high resolution of the data acquired by the drones the data about the growing stock are estimated not only at the scale of the single forest unit but available pixel by pixel.

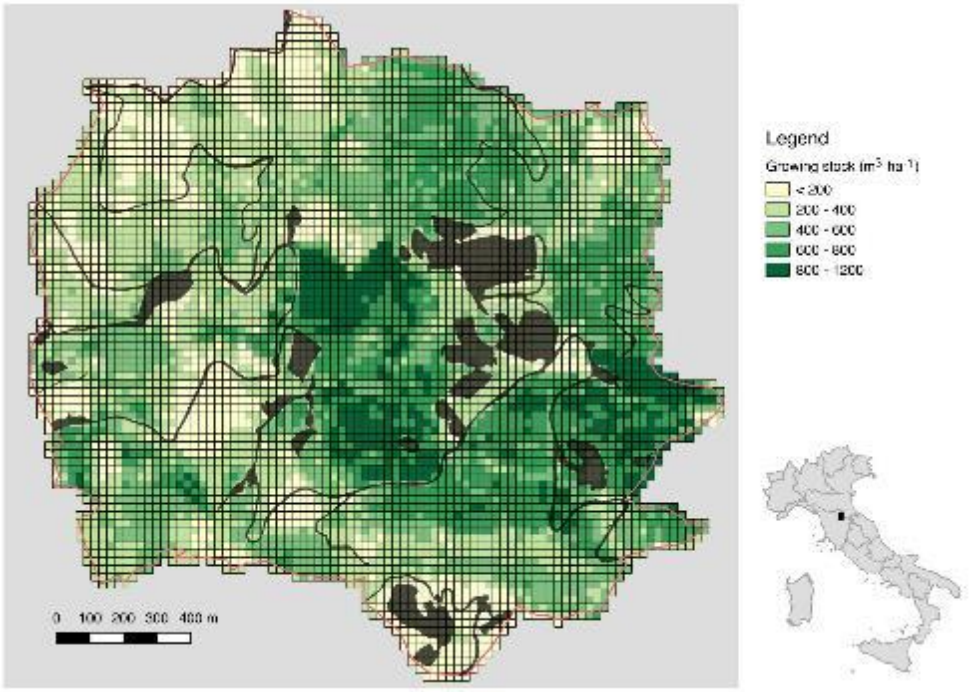

Figure 9. Map of the Growing Stock for the demonstration site of Rincine. This map is available in the FIS and allow a large amount of elaborations related to the Sustainable Forest Management

Other activities of the forest manager in which the FIS can help include:

- analysis of the forest structure for «one tree silviculture»;
- technical support for tracks and forestry roads planning and realization (due to the high resolution of the Digital Terrain Model produced from the LiDAR data);
- easy control of the Introduced Tree Species evolution with the possibility of acquired data frequently and during the different phenological phases;
- evaluation of the evolution of artificial and natural forest gaps;
- evaluation of damage due to wild animals grazing.

The potential of the Forest Information System provided by the project has led the Forest Manager of Rincine to consider the possibility of extending the surveys from the demonstration site to the entire forest in order to have the data necessary to base the new management plan on the methodologies developed by FRESh LIFE project. In Italy the management plan is required for all the properties that exceed 100 ha, so the relationship between the Sustainable Forest Indicators provided by the FIS and the management plans is extremely important. Not only for the state forest like Rincine but for all the forest owners of the territories around. The management plan is one of the most important tool in the forest sector because it gives the direction of the management both regarding how much and where to cut than for the monitoring and conservation of all the other ecosystem services provided by the forests.

<u>Bosco Pennataro</u>

The FIS developed within the FRESh LIFE project, represents an innovative tool for the Molise Region. Till now the forest office of Molise Region used the “ProgettoBosco” as decision support system, within which it is possible to collect information as text, excel and access formats. The cartographic approach of FIS makes it very attractive and useful for forest decision making. FIS is a GIS package of layers, directly developed within the project; the user can also add layers already available from other sources or developed and imported from other projects. This characteristic makes the use of FIS very flexible and adaptable thus allowing to extend its use to several other forests different from the study site of the FRESh LIFE project. The staff of regional office for forest issues of Molise Region is using FIS to assess: forest cover, tree species abundance, forest health and damage and forest productivity. All this information can be displayed within a layout as thematic maps, highly useful to support discussion among forest decision makers. Currently, the FIS has been installed on a workstation in the regional office (Figure 10) and on some portable devices as smartphone and tablet (Figure 11).

Figure 10. FIS were installed on the workstation of management and planning office of Molise Region.

The portability of FIS represents an interesting, innovative and useful mode to use FIS directly in the field. The positioning capability of mobile devices allows to navigate in the forest, throughout forest management units, directly with FIS, observing the correspondence between assessed forest indicators and the real conditions of the forest.

Figure 11. Practical demonstration of FIS use in the field (Bosco Pennataro).

The use of FIS facilitates the share of information, as for example with Carabinieri Forestali, which are in charge for surveillance activities. In this case, the use of FIS, especially the portable version, is strongly helpful. This is a crucial aspect for facilitating the communication among decision makers of forest-related issues. In addition, the portable FIS allows to add new georeferenced information (text and photos) directly in the field, and thus to get a real time update of the FIS based on real data. The possibility to enrich the FIS with other data and cartographic layers, collected also in different time scales, represents a further advantage for regional employees as they can assess the trend of forest management and address it accordingly.

The good results obtained with FIS represent a prominent expectation to enlarge and improve the use of FIS for other forests, starting with regional forests and in the future also for other public forests and maybe private ones. First, it is significant to underline that the information already collected and developed by FRESh LIFE project strongly support the development of a new Forest management plan for Bosco Pennataro. For this purpose, the FIS plays an important role due to the necessity of verifying the boundaries of forest and of forest management units. The information already stored in the FIS allow to assess and produce new layers useful to describe the forest management units, as for example average, min and max elevation, timber volume, basal area, tree height, tree diameter and other important characteristics necessary to describe the forest management units. These informations, if necessary, can also be transferred in the "ProgettoBosco" in order to have a structure of management plan similar to the ones of other forests. Further perspectives about the use of FIS regard the assessment of forest biodiversity, especially regarding the habitat trees abundance and distribution. The availability of information about the number and the habitat value of trees represent a further step for allowing the habitat identification directly in forest. It also helps in the assessment of the appropriate number of habitat trees to be released in the forest, balancing timber production and biodiversity conservation. In addition, the FIS represents a useful tool for dissemination and training activities for different purposes as for example forest inventory, cartography, geomatics, orienteering in the forest. Finally, the FIS structure can be straightforwardly repeated for the management of sites of the Natura2000 network, fostering the identification of potential threats and the definition of priority functions of lands, promoting the conservation of biodiversity.

Caprarola

Since its implementation in the GIS software in headquarter of the Municipality of Caprarola or in authorized laptop (all layers of the QGIS FIS project have been packaged into a USB pendrive to move the project to other computers), the FIS has offered a concrete opportunity to support local forest management decision-making in regulating and improving the public use of the forest. Based on the old management plans, the forest compartment of Monte Venere is subdivided in 17 forest management units, identified by numbers. Dendrometric variables and forest attributes summed up the main features of each unit. Recently, datasets of all forest management plans are been included in the FIS. The parameters implemented in the FIS are listed in Table 2.

Forest Management Plan	Parameters reported for each forest management unit	Name of the layer
1960 - 1971	Number and description of forest management units, Forest Species, Unit Area(ha), Age, Basal area (m^2ha^{-1}), Mean diameter (cm), Biomass of beech, oaks and other forest species (m^3)	Boschi.shp*
1973 – 1987	Number and description of forest management units, Forest Species, Unit Area(ha), Age, Basal area (m^2ha^{-1}), Mean diameter (cm), Biomass of beech, oaks and other forest species (m^3)	Boschi.shp*
1989 – 2000	Number and description of forest management units, Forest Species, Unit Area(ha), Age, Basal area (m^2ha^{-1}), Mean diameter (cm), Biomass of beech, oaks and other forest species (m^3)	Boschi.shp*
2007 – 2022	Number and description of forest management units, Forest Species, Unit Area(ha), Age, Basal area (m^2ha^{-1}), Mean diameter (cm), Biomass of beech, oaks and other forest species (m^3)	Boschi.shp*

Table 9. Datasets implemented in the Forest Information System.

Given that the borders of forest management units have not changed over time, it is possible comparing dendrometric parameters for each unit during the last fifty years. Including datasets in the FIS provides to do it automatically and more easily. In addition, datasets collected in the Freshlife project can be compared to historical ones. Especially, the Map of the indicator "Tree species composition" (# 4.1) was compared to the historical map of forest management units. The differences between the two maps result from different survey techniques, but also point out the natural evolution of the forest stands in terms of specific composition. It means that updating the boundaries of the forest units is necessary to take in account the existing tree species composition. A more detailed map in terms of specific composition could help local forest managers to detect areas for harvesting purposes (i.e. oak forest types), according to the law. The proposal new map provides useful information to support local forest management decision-making also in regulating and improving the public use of the forest. In the test area, silvicultural activities are ruled by a Regional law (art. 34 bis L.R. 39/2002): forest harvesting for wood production purposes are forbidden in the beech forest types growing at low elevations. These forest habitats are considered essential for Regional nature conservation purposes. Only forest harvesting activities aimed at the conservation of beech forest stands or for reasons of public safety are permitted. In addition, Caprarola test site is included in a Regional Natural Reserve so that the public accessibility and use of the area for leisure activities are relevant. In this perspective, monumental or remarkable trees differ from others of their species owing to their unusual size, their age, or their unusual shape, which means that they are of special natural, historical, cultural, or landscape interest. Characteristics such as their height, trunk diameter or crown shape make these trees of public interest and therefore protected by law. According to the Law 10/2013 (art. 7), the Municipality has to realize and update an inventory of very large trees within municipal boundaries.

Based on FIS datasets (e.g. indicator # 1.3 Growing stock, # 1.4 Above ground biomass), forests tracts with very large trees are been identified. At the same time, trails connecting very large trees are pointed out in the footpath map of Monte Venere in order to notify them to the general public and create an educational and natural itinerary. Trail map of the test area is implemented in the FIS database.

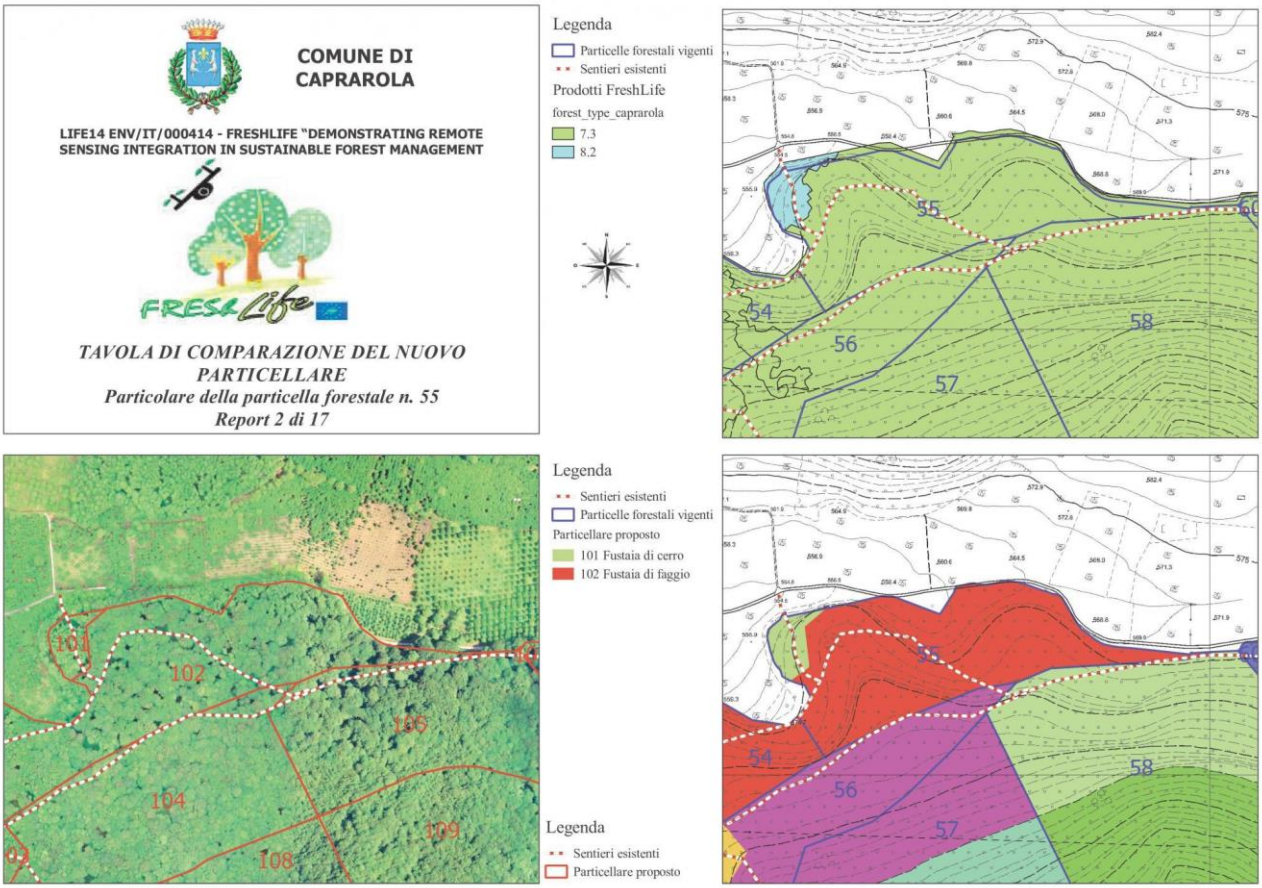

Figure 12. FIS of Caprarola with trails path

We concluded the action in November 2019 as indicated in the project proposal with all the deliverable and milestone reached on schedule. Regarding the indicators of progress:

- percent of completion of the Forest Information Systems created by AISF;
- completion of the installation of the FIS in the three forest management offices of the demonstration sites;

at the conclusion of the actions all these indicators of progress have reached the 100%. We refer to the deliverables for more details on the activities carried out and the results achieved.

6.1.5 Action B5: Upscaling project results

Foreseen start date: June 2018	Actual start date: June 2018
Foreseen end date: September 2019	Actual (or anticipated) end date: November 2019

The aim of this action was to analyse the results obtained at local level in the demonstration sites investigating the possible impacts on the Italian Forest Plan and the replicability at European level, to provide suggestions and new guidelines for improving the future updates of the forest plans through the adoption of new remotely sensed imagery. The analysis of the upscaling possibilities follows different levels starting from the European to the local scale.

EU Forest Strategy

The EU Forest Strategy is the framework to coordinate and ensure coherence in forest-related policies, and to ensure the contribution of EU forests and the forest-based sector to the EU's objectives and targets.

The *'Our Forests, Our Future*' conference, organized by the EU Commission, took place in Brussels on 25-26 April 2019 to analyze and discuss opportunities and challenges for enhancing the contribution of the forest sector to the main EU priorities. During the conference was clearly confirmed that the Strategy's objectives are: ensuring that all forests in the

EU are managed according to sustainability criteria; and strengthening our contribution towards sustainably managing forests and reducing deforestation at global level. A recent review of the strategy found out significant progress implementing the planned action towards achieving these objectives. The Strategy and its priorities are fit for addressing the role of forests and related EU policies for the implementation of the 2030 Agenda in the EU and globally.

Pursue aims such as "*coordinate and ensure coherence in forest-related policies*" and "*ensuring that all forests in the EU are managed according to sustainability criteria*", results in the needs of tools and methodologies that allow to collect, share and elaborate, harmonized data from all over Europe. To ensure a Pan-European point of view, harmonized and quite simple methodologies are essential in order to allow all country to "do their part" in collecting these data. Indicators, and in particular the idea to map it, are extremely useful to monitoring the diffusion end the impacts of Sustainable Forest Management (SFM) criteria.

During the FRESh LIFE project, we make strong efforts to ensure that the methodologies used were replicable at different scale and adaptable to different forest ecosystems. European Forest Types Classification was used and database were created by following the guidelines from the COST Action E43 and the INSPIRE Directive for the harmonization of metadata. We developed a strong and efficient workflow that could give an important contribute in a bottom-up approach to the EU Forest Strategy.

Going through one of the document presented by the Directorate General for Agriculture and Rural Development during the *'Our Forests, Our Future*' conference (https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/events/documents/forestry-conference-2019-brochure_en.pdf) we tried to outline how some of the results achieved by the project could be integrated in the EU Strategy to help achieve its goals.

EU Forests contributing to innovation, growth, jobs, and the circular bioeconomy

"*Wood and other forest products make an essential contribution to economic growth and to raising living standards. In the EU, they are still a significant source of welfare in some countries and regions."*

In this section we can read, for example, that "*60 % of the EU forests are privately owned, with approximately 16 million forest owners*". Tools like the Forest Information System (FIS) developed within our project are extremely useful to allow private owners to have access to high precision data and indicators that are essential on the way of a harmonized SFM approach. In situation like Italy, where the single private forest unit have typically also a small extension (in ha), decision support systems such as the FIS are the only way private owners can access to these kind of data. The poor economy of the small forest private owners wouldn't allow them to reach the standards of the public forest management creating problems in ask them to follow the SFM criteria. The FIS approach, if developed at a regional, national and even European scale, could allow all actors of the forestry sector to access harmonized and wall-to-wall data and indicators to following the SFM aims. Give a Pan-European point of view, starting from the single private owners, could results in a better understanding of the EU Forest Strategy allowing everybody to accept national and international dispositions in forest management that sometime may seems incomprehensible at local level.

In the same section were underlined how in the last years both the Common Agriculture Policy than the EU-funded research have tried to "*connected to innovation and deployment, also by the revised Bioeconomy Strategy that will further scale-up the role of forest-based biomass to replace non-renewable materials and products, whilst protecting the environment and ensuring circularity*". Despite this, while "*forest stocks in EU forests are steadily increasing, the EU harvests less than 70% of its annual wood growth*". The availability of Pan-European data and indicators on the SFM could be useful also in this case to improve people knowledge about the complexity of forest sector. In period like this one, with a renovate attention to climate change topics, give free access to good and complete information about the Europe forest assessment allow people to better understand the meaning of the EU Forest Strategy and reduces the likelihood of protests triggered by a lack of knowledge. Meanwhile, the availability of harmonized and high precision data could improve the precision of the growing stock estimation and consequently the efficiency of a European forest management planning that take into consideration the different aspects of SFM.

EU Forests fighting climate change

"*Sustainable forest management is necessary to fight climate change. Forests and forestry are key contributors to EU's ambitious energy and climate policy and the targets defined for 2030*"

In this section that talking about the key role of forests and wood in carbon storage and sequestration become clear how much Sustainable Forest Management is important to maintain and improve these ecosystem services provided by our forests. The commission underline also the importance of SFM in "*address forest fires, pests and other disasters, promoting prevention, supporting coordinated and quick response mechanisms, and assisting restoration of damaged*

areas".

The use of UAV's due to low cost of flight campaigns and the quite short time needed to organize it, have a key role in this emergency situation. The methodologies tested in our project allow to create decision support system that can be up-dated easily by acquiring new remote sensing images by drones. During the emergencies, such as forest fires or wind storms, this could be fundamental to monitoring the forest damaging and quickly elaborate information useful to the managers during and after the disasters. The advent of new satellites services that gives daily images of the entire globe is also useful in these emergency situation and these products can be used combined to the images taken by drones to "feed" the decision support systems.

Although sometimes the "forest management" is seen as one of the factors that affect negatively the biodiversity and ecosystem services providing, SFM goes completely in other direction by has a central role in conserve and restore also these ecological aspects of the ecosystems. The EUs biodiversity and rural development policies promote the integration of biodiversity and sustainable forest management and projects like FRESh LIFE giving tools to better understand and disseminate these topics. The mapping of the SFM indicators taken into account by our project is an example of how different forest variables, called "indicators" in this case, can be estimated for big areas in order to create maps useful both for monitoring than dissemination activities. Focusing in our project to the forest health and wood production, the same methodologies could be applied to study more biodiversity related aspects in order to obtain information useful, for example, in Natura 2000 areas management. The quantitative approach developed within these methodologies has also strong potentials in estimate and "quantify" the ecosystem services provided by the European forests, helping the EU in addresses how ecosystem services can be better enhanced through policy design and implementation.

EU addressing international forest challenges

"*The EU and the Member States actively promote Sustainable Forest Management in pan-European (FOREST EUROPE) and international forest-related fora and processes (e.g. UNFF, FAO, ITTO, the UN Convention on Biological Diversity), including the 2030 Agenda and its Sustainable Development Goals (SDGs).*"

Looking to a Pan-European or international point of view projects such as FRESh LIFE are fundamental due to their harmonized approach. All the methodologies developed in our project are replicable and extensible both in different than in larger area. The project workflow to obtain the SFM indicators maps were simply codify and could be applied to any kind of ecosystems and scales with small adjustments related to the remote sensing data acquisition. The decision to adopt international standard such as the guidelines from the COST Action E43 and the INSPIRE Directive for the harmonization of metadata, allow us to share data and elaboration with collaborators from all over Europe. Tools like the FIS that we have created for the demonstration sites, could be extremely useful in a Pan-European forests management planning to quantify all the indicators needed in the ratification and respect of international agreements and agenda.

This is true even more at global scale where the EU is involved in development cooperation to support improved governance and promote forest conservation through FLEGT and REDD+ (Reduced Emissions from Deforestation and Forest Deg- radation) activities. Especially in developing countries where the lack of data is the norm, methodologies like the ones developed in our project could help, for example, in REDD+ strategy developing and promoting. The forest inventory is often missing in these countries but is the base for all the following activities such as FLEGT and REDD+. The estimation of variabilities like the Growing Stock or the Above Ground Biomass in countries where is not so easy to access both to existing data than to the territory at all could take advantage of the results achieved from our project. The integration of different vectors in data acquisition (UAVs, satellites, etc.) to create a workflow that allow the up scaling of the project results at a scale useful in these contexts take the name of hierarchical sampling

Report on the state of forests and forest sector in Italy (RAF Italia)

Last year the Forest Office of the Ministry of Agricultural, Food and Forestry Policies (Mipaaf) published the first "Report on the state of forests and forest sector in Italy". The report makes a review on the *state of art* of different aspects that involved forests, from the policies to the economic and ecological situation, describing also best practices developed in these years all around Italy. The report, in Italian, is available at this link: https://www.reterurale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/8%252F4%252F1%252FD.f8bffe877b6ff2584b21/P/BLOB%3AID=19231/E/pdf

Our coordinator, Professor Gherardo Chirici, contributed to the report with a chapter on the Precision Forestry in Italy where he included some of the results achieved by the project. Lessons learned during project activities are used to present the new trends in forestry, to remark the potential of remote sensing data and the importance of Spatial Decision Support Systems (like our Forest Information System) as a tools to meet the goals of Sustainable Forest Management. Furthermore, data harmonization and free access have been indicated as one of challenges for future development of the sector following

what has been made clear by FRESh LIFE.

Going through the report there are others topics on which our up scaling activities will concentrate in the future. The third Italian Forest Inventory was almost ready and recently changing in the data access policy are allowed researchers of our team to test some of the methodologies developed at larger scale by using data from the field plots of the inventory sampling. This kind of studies, together with the will expressed by the ministry in the report to improve the spatial and informatics capacities of the forest inventory given us the possibility to raise project impacts on forest policy at national scale. First results are already available with the publication of the paper "*Wall-to-wall spatial prediction of growing stock volume based on Italian National Forest Inventory plots and remotely sensed data.* Chirici et al. 2019" available for download at this link: https://www.sciencedirect.com/science/article/pii/S0303243419305306

In the chapter focused on the forest policy the authors of the RAF Italia 2019 emphasize how the lack of harmonization of laws and prescriptions between different regions doesn't help to having a clear understanding of the Italian situation in the field of forest management. The competence for these issues is left to the regions but a coordination effort would be necessary at least to obtain a unique statistic system which allows photographing and monitor the state of the forests regarding, for example, forest harvesting. The Forest Information Systems developed for the three demonstration sites of FRESh LIFE project are a good starting point to think over the possibility to harmonized data and methodologies even from different regions and forests ecosystems. Using the lessons learned during our project, different regions could start this harmonization effort for example by: giving free online access to the data for the private owners, adopt the European Forest Types classification, according on a unique coordinate reference system, standardize the metadata following guidelines from the COST Action E43 and the INSPIRE Directive. This approach would be necessary in order to more easily connect the forest planning at different scale and increase the capability to pursue the aims of Sustainable Forest Management.

On 2018 a new national law was approved in Italy trying to give the direction for a national forests strategy. Despite the competences for forests management remains to the regions, this law introduces important news for the forests sector, regarding for example the new technologies. Our coordinator and other people from the team actively participated in the discussion that led to the approval of the new law. The collaboration is continuing during the writing of the implementation decrees by sharing knowledges achieved by FRESH LIFE and assure that lesson learned are taken into account to move the national forest strategy towards Sustainable Forest Management.

Impacts at regional level

At regional level the up-scaling activities contributed in setting up new programs for helping and boosting the forestry sector from an economic and technological point of view.

Starting from the forest complex of Rincine, where the potential of the Forest Information System provided by the project has led the forest manager to consider the possibility of extending the surveys from the demonstration site to the entire forest in order to have the data necessary to base the new management plan on the methodologies developed by FRESh LIFE project.

The same occurs for an additional forest area in Tuscany: "Riserva Naturale Statale Biogenetica di Vallombrosa" where we developed a Forest Information System (FIS) to support the revision of Forest Management Plan and to give to the students of forestry courses of University of Florence the opportunity to use FIS during their field courses. The area covered this FIS is around 1000 ha and the spatial data related to Forest Indicators were generated using UAV photogrammetric data acquired by eBEE and the LiDAR data acquired by aircraft in 2015 by Tuscany Region.

In Italy the management plan is required for all the properties that exceed 100 ha, so the relationship between the Sustainable Forest Indicators provided by the FIS and the management plans is extremely important. Not only for the state forests like Rincine and Vallombrosa but for all the forest owners of the territories around. The management plan is one of the most important tool in the forest sector because it gives the direction of the management both regarding how much and where to cut than for the monitoring and conservation of all the other ecosystem services provided by the forests.

These experiences are important to push the regional administrations to include the new methodologies and technologies, proposed by project like our, in the implementation of Common Agricultural Policy (CAP). The CAP is the greater way for financing and supporting agriculture and forestry at regional level. Our local partners, together with the universities associated, are in continuous dialogue with regional representatives to give them the information needed to move the regional forest policy towards Sustainable Forest Management through Precision Forestry methodologies. In this way, strong network was already established with Tuscany and Molise Regions also to lay the groundwork for harmonization efforts at national level as explained in the previous paragraphs. Through the UNIFI we collaborate with other projects like GOSURF (https://go-surf.it/) that aim to create an Operational Groups (OG) inside the European Innovation

Partnership (EIP-AGRI). The aims of this project are in line with the ones of the FRESh LIFE and they take inspiration from the results of our project to create a Forest Information System that integrate the local ones (like the ones created in our demonstration sites) inside a bigger one operative at regional scale. A decision support system (DSS) that allow to increase the areas managed following the Sustainable Forest Management. Last year also University of Udine contacted our coordinator to discuss about the possibilities to collaborate for create a new Operational Groups on the same topics but for the Friuli Venezia-Giulia Region. The project has just been approved.

On a smaller scale "Blue Biloba" the spin-off born by the FRESh LIFE experience, is working with private forest owners selling services of remote sensing acquisition, indicators estimation and creation of small decision support systems for forest plans and others activities. Disseminate these new approaches to forest management among different stakeholders has a key role in increasing their awareness and allow them to access the new funding lines proposed by the CAP.

Technical challenges for the project results up scaling

Results achieved by FRESh LIFE project demonstrate the potential on the integration of high resolution remote sensing data in Sustainable Forest Management. The scale on which the projects was focused was related tothe single forest unit in order to give local forest managers tools specific designed for their territories.Remote Sensing(RS)data acquired by UAVs (Unmanned Aerial Vehicle)proved their effectivenessby improving the precision of indicators estimation compared to other kind of RS data. Starting from 2014 when the project was approved, the use of UAVs data for forest application increase year by year together with the availability of new models and sensors. Studies, carried out in different types of forest ecosystems, have shown that the use of UAVs data offers new opportunities for monitoring forest resources at high spatial and temporal resolution. Nevertheless, their use for forest inventory is hindered by the high costs of acquiring UAV data with full coverage (wall-to-wall) of areas larger than, say, 10 km^2 (Dandois and Ellis, 2013; Whitehead et al., 2014).Besides the costs, another serious limitation to the practical use of UAVs in forestry is national aviation regulations. Regardless of the large differences among national legislations, current aviation regulations in general play a main role in defining the area-range for which UAVs can be operated and the size of the aircrafts used. The requirement of conducing UAV operations within a visual line of sight (VLOS) often limits the area that can be covered by each flight as the UAV must be visible at all times with the naked eye.
Limitations of the allowable weights of UAVs also indirectly affect the range of operation of these systems by hindering the use of large, heavy, and long-lasting batteries.It is therefore clear that the methodologies proposed by FRESh LIFE project needs some kind of adaptation to applied it to a larger scale. Thinking to an up scaling of the project results to regional or national scale immediately confronts us with the problem of the impossibility of acquiringwall-to-wall UAVs data of the entire study area. In the demonstration sites where the area was around 200-300 ha, this is not a problem; even in the small up scaling activities related to the forest management plan of Vallombrosa and Rincine where the area, around 1000 ha, allowed a full coverage by UAVs with a still low cost. The technical challenge to explore the potential of UAVs data in forest inventories hasbeen taken up by many authors in the past years. Where a full coverage acquisition isn't possible, even in the presence of a large field survey database, another wall-to-wall data is required to link together the different layers and improve the accuracy of the estimation models. The proposed way isto combine multiple RS data using, in our case, UAVs samples and a wall-to-wall satellite coverage as suggested by Puliti et al. (2018). According to his method, the combination of UAV data with satellite imagery might lead to an increase of the precision of estimators of key forest properties and also enable the production of maps. This approach may therefore benefit from the high resolution UAV data and from the large coverage of satellite imageries and, potentially, offer a cost-effective alternative to existing methods for large-area forest surveys. The satellite data used in this study are those of Sentinel-2multispectral mission that also lend well with our cases for their high spectral, spatial, and temporal resolution (Drusch et al., 2012).Taking into account the results achieve by these studies and the ones of FRESh LIFE project an up scaling activities could concern the improvement of the estimates of the Italian National Forest Inventory with a hierarchical model-based inference framework(Saarela et al., 2016). With the same method proposed by Puliti et al. (2018) we can try to combine inventory data from the Italian National Forest Inventory(INFC)plots with RS data from Sentinel-2and UAVs. Adding a sample of RS data acquired by UAVs flying on the inventory plots it is possible to increase the accuracy of the variables estimation both compared to the Model-based inference procedure (inventory data simple spatialization) and the Model-based inference method with wall-to-wall Sentinel-2 data. As indicated in the project proposal the use of UAVs data in this workflow result in the possibility to update the INFC values by entering new UAVs RS data that are easier and faster to acquire than RS data from other vectors. As already indicated in the previous paragraphs within the collaboration with some Regions and with the Forest Office of the Ministry of Agricultural, Food and Forestry Policies(Mipaaf),our coordinator and the rest of team are promoting these new methodologies trying to get them included in the new national forest strategies.

6.1.6 Action C1: Local monitoring

Foreseen start date: October 2015	Actual start date: October 2015
Foreseen end date: September 2019	Actual (or anticipated) end date: November 2019

The aim of the action was to acquire information for quantitatively estimating the incrementation of the area managed with Sustainable Forest Management (SFM) in the study areas and, at the same time, to maintain the project activities in the different local sites on track respecting deadlines and deliverables.
The action was under responsibility of the coordinating beneficiary that acquired information from the responsible beneficiaries in the three demonstration sites also trough the compilation of questionnaires, meetings and field visits.

According with the project proposal, the indicators of progress for this action are:

- frequency of meetings and field visits with local stakeholders;
- % of scheduled deliverables and milestones;
- % incremented area with Sustainable Forest Management (SFM) in each study area;
- number of SFM indicators calculated in each study area.

Frequency of meetings and field visits with local stakeholders
Each university team, in coordination with AISF, was responsible for the supervision in the local sites of its competence. By frequently meetings and field visits with the local stakeholders, they maintained the project activities on track respecting deadlines and deliverables. The organization of meetings and field visits characterized all the project phases and activities starting from the existing data acquisition (Action B.1) to the Action B.5 regarding the up-scaling of the project results. With the new data acquisition completed (Action B.2), and the elaboration of the data (Action B.3), we had a new intense period of close collaboration with local stakeholders during the Action B.4 for everything related to the installation and testing of the Forest Information System (FIS).

Figure 13. Technical meeting with local stakeholders, coordinated by UNITUS on the 14th June 2018

After making the FIS operational, the meetings continued to assist in its daily use in the offices of the local managers. Local partner and related universities collaborated in this direction also to lay the groundwork needed to define the project results up-scaling strategy. In addition to the interaction between the partners, local managers organized also meeting with stakeholder external from the project to share results achieved and try to extend the knowledge around the possibilities offered by Sustainable Forest Management integration in their daily work, more details about this topic are available in the section 6.1.7.

% of scheduled deliverables and milestones

AISF is monitoring all the activities of the beneficiaries making sure that the responsible for the implementation of the actions are doing their work on schedule with the project's indication. Until now all the deliverables and milestones were reached in time with what is indicated in the project proposal.

% incremented area with Sustainable Forest Management (SFM) in each study area

With the conclusion of the Action B.4 and B.5 we started to evaluate the impacts of the project activities on the area managed with SFM. The monitoring of this indicator of progress will continue in the after LIFE period when the local managers will become more and more familiar with the FIS and can take advantage of its potential. Until now we can record an increase of SFM applications with the entire area of the demonstration sites covered by this kind of management and the possibility, see for example what happened in Rincine, to extend the application to other territories around the sites. Both Rincine than Bosco Pennataro will create the new forest management plan taking into account the results achieved by our project thus extending the area with SFM.

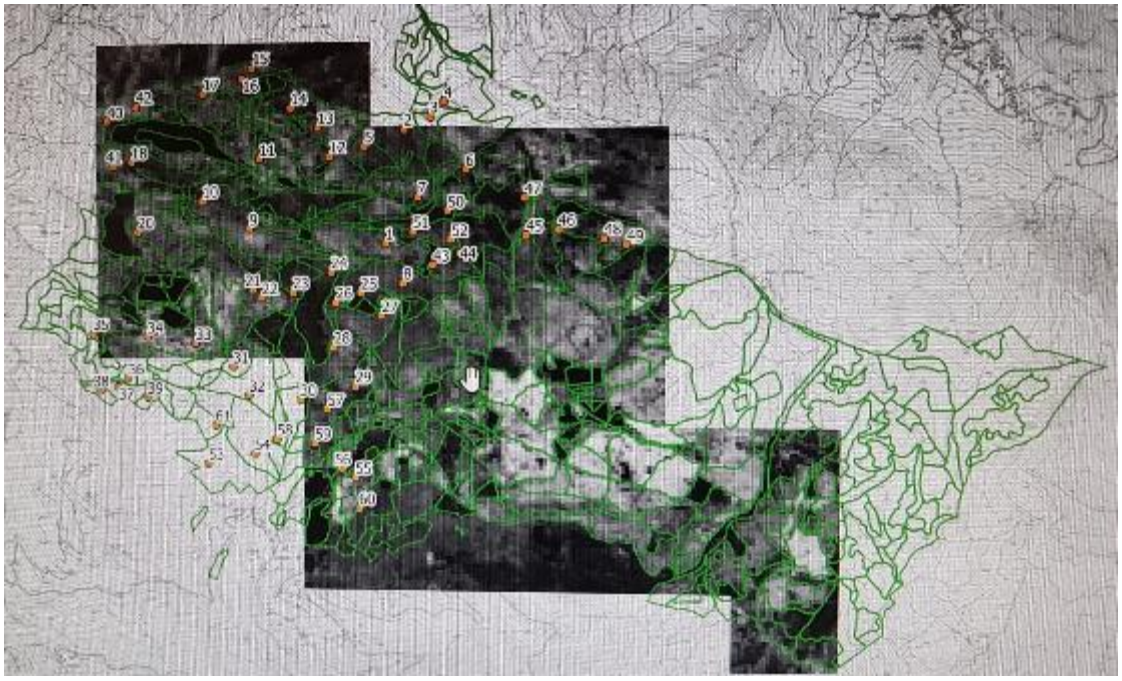

Figure 14. Example of field surveys extension out from the demonstration site in Rincine to cover the area of the new forest management plan

Number of SFM indicators calculated in each study area

With the conclusion of Action B.3 and B.4 all the SFM indicators proposed were estimated and uploaded in the FIS of each demonstration site. Please note that the different between Table 3 and Table 10 are related only at the kind of indicator of progress the table referred to. All the seven SFM indicators were calculated for each demonstration site but not all had enough relevance to be convert into a map. The table below focus on the fact that the process needed to obtain the estimation was done for each indicator even if, at the end, there was no way to produce the map.

Demonstration site	growing stock (# 1.3)	ground biomass (# 1.4)	number of tree species (# 4.1)	area covered by introduced tree species (# 4.4)	defoliation (# 2.3)	forest damage (# 2.4)	EFTs classification
Rincine	X	X	X	X	X	X	X
Caprarola	X	X	X	X	X	X	X
Bosco Pennataro	X	X	X	X	X	X	X

Table 10. Progress in mapping of SFM indicators for each study area (X = done)

Milestones

M1 –Final local monitoring status evaluation 31/10/2019

Deliverables

D1 –Mid-term local monitoring report 31/07/2017D2

D2 - Final local monitoring report30/11/2019

6.1.7 Action C2: Large scale monitoring

Foreseen start date: October 2015	Actual start date: October 2015
Foreseen end date: September 2019	Actual (or anticipated) end date: November 2019

With this action, the coordinating beneficiary AISF evaluates how the activities carried out in the three pilot areas will impact on the regional and national policy level. This was carried out mainly by direct interaction with partners and stakeholders. The replicability of the activities at national and European level is discussed deeply in the section 6.1.5 of this report. Large scale monitoring was planned at the beginning of the project and carried out at the end of the project when the results from the pilot study areas were clear. In order to evaluate how the activities carried out in the three pilot areas have impacting on the regional and national policy level, the definition of a set of KPIs (Key Performance Indicators) was completed by consultation of partners and stakeholders that helped the coordination team to ensure that KPIs capture critical success factors perceived by partners and stakeholders as those results of project actions that determine satisfaction of their requirements/objectives.

The following KPIs were taken into account:

- knowledge and use of RPAS and data derived;
- cost of management;
- transparency in management of public forests;
- knowledge of their property by the private owners;
- percentage of forests managed with SFM;
- knowledge and use of SFM indicators.

For each of these indicators some related questions were included in the questionnaire sent in the first phases for an ante-project assessment. Moving in an unknown space created by the introduction of such innovative technologies this first assessment was essential to understand the starting point of the project and consequently adjust the activities of the last years in order to maximize the impacts. After the conclusion of the actions of group B these impacts are evident and together with a maturated knowledge on the social and economic assessment of the demonstration areas, it allows us an analysis of the post-project assessment without the need to re-submit the same questionnaire. The close collaboration between local partner and the related universities ensure a complete monitoring of the KPIs and their variation in the project period. Despite this, a new questionnaire was developed to explore up-scaling potentials and needs of the project. The main targets of this questionnaire are European stakeholder interested in up-scaling collaborations and suggestions related to results achieved by our project but, by spreading it to the list of contacts collected during the demonstration events, we collected also information good to integrate the large-scale monitoring of the KPIs.

Knowledge and use of RPAS and data derived

Since the project proposal was prepared and approved the use of RPAS in the forest sector has become more frequent year by year, so with it also the knowledge of the stakeholders about the use of RPAS and data derived. Both in the research world than in the projects approved by the EU commission these topics have become central exploring different possibilities in use RPAS data derived for forest management and monitoring. The demonstration events that we organized during the first project year were one of the first occasions in which peoples take contact with RPAS. This was reflected in the great participation in those events that today is more difficult to obtain due to the increasing knowledge of people about RPAS and all the related topics.

Despite the knowledge about RPAS is increased, the user of these systems and data derived are still few and frequently related to demonstration or research purposes. The reasons for the low uptake of this topics are better explained in the technical report of action B4 and B5 where we explored the limits of RPAS applications in forest sector and the new technologies developed in these years to reach similar results.

Focusing on our project activities the impacts on the demonstration site stakeholders was very high. Less specialized managers, such are employers from municipalities or regions offices, that were completely out from these topics when the project started, are now aware of the potentials of new technologies and methodologies for forest management and monitoring. The availability of tools like the Forest Information System that we realized provide them with a huge amount of high resolution data that they can use to improve their management practices. Consequently, stakeholders from the forest sector working around the demonstration sites are forced to get in contact with this new Sustainable Forest Management knowledge. Freelance professional worker and private companies were involved in demonstration events

and the changes in the way public bodies manage forest directly impact on their daily work.

Cost of management

As we highlight in the technical reports it is difficult to analyse the impacts of project activities on the cost of management variation. Products made available from FRESh LIFE project are hardly comparable with the "business as usual" situation with the consequent impossibility of a simple costs comparing. Data acquisition and elaboration with the methodologies proposed by our project leads to high resolution results that naturally needs higher costs but at the same time they have potentials that are not comparable with normal inventory data.

In a "business as usual" scenario tools like the Forest Information System are useless but the knowledge acquired by forest managers involved in our project change the way they manage their forest and with it their needs of data precision and availability for the Sustainable Forest Management.

One of the After-Life activities will be the monitoring of how freelance professional worker and private companies will take into account these variations in forest management policies and only later we can talk about cost analysis including not only the economic costs assessment but also considering the positive impacts on the entire forest sector of the areas.

Transparency in management of public forests and Knowledge of their property by the private owners

The demonstration approach of the LIFE project allowed us to organize a lot of events in the last years. Frequently these events were organized in the demonstration sites or in the local manager's premises giving the citizens of the area the possibilities to participate to the technologies and methodologies transfer. Despite the Forest Information Systems are not yet public the results achieved by the project were explained in Notice Boards installed both outside, in the demonstration sites, then inside the local manager's offices where people can read it to better understand the choices regarding the management of forest resources in the area where they live.

Percentage of forests managed with SFM

All the area of the selected demonstration sites is now managed following the indication of Sustainable Forest Management but the potentials showed by the Forest Information Systems created by the project allow us to go further. For more details about the increase in the area managed by Sustainable Forest Management please refer to the section 6.1.5 where within the upscaling discussion a complete analysis of this indicator was deeply presented. Same results are presented also in the deliverable of Action C2: "Report of the large-scale monitoring" attached to this Final Report.

Knowledge and use of SFM indicators

During the action B4, when the Forest Information System was activated in the local manager's offices, they started to explore the potentials of the SFM indicators. Sure the local stakeholder initially thought that these indicators are only another quantitative variables useless for their daily work but soon they have discovered the potentials of the high resolution data present in the FISs. The uses of the FISs and the SFM indicators contained in it are described more in details in the Technical Report of Action B4. Despite other indicators the important features recognized by the stakeholder in the SFM indicators are the harmonization at the European level and the strictly connection between quantitative and spatial values. This allow forest managers to use the indicators both for the daily work of local planning then in the participation to national or international calls and proposals about forest management and monitoring.

During the last year of project activity particular attention was paid to disseminate this knowledge outside from the partner offices to the freelance professional worker and private companies active around the demonstration sites. The great participation of the local communities in the final events organized in Palermo and Caprarola during November 2019 prove the increasing interest in the practical application of the new technologies for the forest sector. Furthermore, SFM indicators have proved to be easy to understand and apply that is a key feature for their usability at a local management scale, outside the research world.

6.1.8 Action C3: Socio Economic Impact of the project actions on the local economy and population

Foreseen start date: October 2015	Actual start date: October 2015
Foreseen end date: September 2019	Actual (or anticipated) end date: November 2019

The Italian Academy of Forest Science is the coordinator beneficiary of the FRESh LIFE project, directly responsible for Action C3 - Socio Economic Impact of the project actions on the local economy and population. In this action, a socio-economic impact assessment was used to examine how the proposed use of advanced remotely sensed data will affect

current and future activities of the involved stakeholders. To this end the following indicators were considered:

- Changes in the way the forest managers are able to set up their routine work;
- More sustainable use of forest resources according to the set of indicators defined by Forest Europe, the former Ministerial Conference on the Protection of Forests in Europe;
- Changes in employment and income levels from the forest sector;
- Changes in the aesthetic quality of the forest landscape

Analysis of such factors is an important component of the socioeconomic impact assessment. Another important step in conducting a socioeconomic impact assessment, is gain an understanding of community values and concerns about forest resources and management.

Analysis of ante-project assessment

This analysis was carried out by the coordinator in the first stages of the project, thanks to the support of the local Universities and within the framework of the local forest authorities involved in the project, in order to produce questionnaires that were distributed at the different stakeholders: forest managers, private companies, and citizens, to analyze both the ante-project situation.
The questionnaire was implemented on the google platform "modules" in order to easily disseminate it between the project's stakeholders. This platform allows to easily analyze the questionnaire's answers by viewing them as graphs, step by step, meanwhile that the peoples answered the questions. Overall, we received 139 answers, which is a sufficient number to analyze the ante-project assessment of the demonstration areas. From the analysis of these answer a strategy was elaborated in order to maximize the impacts of the actions during the project's phases.

It was clear that there was a lack of knowledge about the RPAS systems and their application, all around the different actors of the forest sector. In addition, it was evident the need of information accessible for all stakeholders to give them the opportunity to better understand the potentiality of the forest ecosystems and the necessity of their management. All the respondents confirmed that the project's activities meet some needs really present in the territories examined. More details about the structure of this first questionnaire and the analysis of the collected answers is available in the deliverable of this action named “Analysis of ante-project assessment”.

Analysis of the post-project assessment

Working for four years strictly in contact with the local realities of the demonstration sites allowed to better understand the situation highlighted by the ante-project assessment. The local dynamics that lead to this situation became clearer by discussing with local managers and stakeholders during the project activities that were continuously updated in order to maximize the impacts. Feedbacks from local partners, especially in the last year of project activities, were all collected and became the base for the post-project assessment. Having a good understanding of the situation, also given by discuss with the audience of the events that we organized, gave us the possibility to go through the post-project assessment without the need to resubmit the same questionnaires of the beginning.
Important information for this action are also derived by the analysis of the KPIs performed in the Action C2. More details about the changing in the way the stakeholders perceive and use RPAS technologies and data derived are available in the deliverable “Report of the large-scale monitoring”, together with a discussion about how local people interact with the forest ecosystem of their territory.
To complete the understanding of the dynamics triggered by the project activities a new questionnaire was also prepared. The questions are more related to the up-scaling activities so details are explained in the Action B5 but the analysis of the answers gave us information also useful to the post-project assessment indicators analysis.
The most significant impacts on the indicators come from the introduction of the Forest Information System in the demonstration sites. Despite the system was similar for each site, the peculiarities of the three situations resulted in different uses of the FIS so the analysis on the changes in the way the forest managers are able to set up their routine work need to be performed separately. More details about this analysis are presented in the deliverable “Analysis of post-project assessment” that is attached to this Final Report.

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Rincine –Tuscany
In the demonstration site of Rincine the FIS has been made available for the guards and office employees that use it during their daily work of forest management. The office located in Rufina, not far from the demonstration site, has

the responsibility regarding cutting authorizations in relation to the management of the hydrogeological protective restrictions. During this kind of activities, the FIS can help in different ways:

- evaluation of the residual coverage after the various types of forest chop;
- accurate measurement of the cutting surfaces that determine total uncovering for best environment control;
- more correct evaluation of the maximum annual surface area allowed for cutting;
- accurate description of the forest structure for thinning purposes;
- technical support in the creation of new tracks and forestry roads.

The analysis allowed by the FIS, results in an easily set up of the manager's daily work due to the very high resolution data which also reduce the risk of incurring penalties in the event of an offense.Further the introduction of the SFM indicators also results in a more sustainable use of forest resources, the availability of these data at the scale of the single forest unit is extremely useful regarding more conservative and monitoring activities. The classification in European Forest Types change the way how the decision maker planningthe activities in the forest like with the "Defoliation" indicator map that easily allow to monitoring pests and results of the fighting activities.Other activities of the forest manager in which the FIS can help are:

- analysis of the forest structure for «one tree silviculture»;
- technical support for tracks and forestry roads planning and realization (due to the high resolution of the Digital Terrain Model produced from the LiDAR data);
- easy control of the Introduced Tree Species evolution with the possibility of acquired data frequently and during the different phenological phases;
- evaluation of the evolution of artificial and natural forest gaps; •evaluation of damage due to wild animals grazing

These new tools change the way how local authorities manage the forests and influence directly the employment and income levels from the forest sector. Better managed territories need more people to work on it and increase the value of forest resources, automatically results in more opportunities and good income levels for the person involved. For instance, the decision taken by the Forest Manager of Rincine to extend the surveys from the demonstration site to the entire forest, in order to have the necessary data to base the new management plan on the methodologies developed by FRESh LIFE project, create new job opportunities. The spin-off of the University of Florence "BlueBiloba", in charge for these acquisitions, hireda group of young researchers for the field survey and involved further freelance professional workers in technical evaluations.

Bosco Pennatato -Molise

In the demonstration site of Bosco Pennataro managed by Molise Region,the FIS replaced the old Decision Support System (DSS) already in use in the offices. This one allowed to collect information as text, excell and access formats only. On the other side,the cartographic approach of the FIS has changed completely the way in which the employees are able to set up their daily workand lead to a higher quality of the results that they can achieve. The staff of regional officeutilizes FIS to assess: forest cover, tree species abundance, forest health and damage and forest productivity. All this information can be displayed within a layout as thematic maps, highly useful to support discussion among forest decision makers. Such tool reduces the possible delays due to misunderstanding in the collaboration with other managers of the territory like the Carabinieri Forestali, which are in charge for surveillance activities. Further important application fielded by Molise Region with the support of the University of Molise, regards the possibility to install the FIS on portable device such as smartphone or tablet. This function is on test by the staff of the regional office and allows to add new georeferenced information (text and photos) directly in the field, and thus to get a real time update of the FIS based on real data. Based on the results achieved by this testing phase, the local manager will consider the possibility to make the FIS, or part of it, open access to all users. Provide who work in the forest sector with such an innovative tool will have key consequence on their employment and income levels. Regarding the analysis of the changes in the aesthetic quality of the forest landscape the FIS could be use in the assessment of forest biodiversity, especially regarding the habitat trees abundance and distribution. The availability of information about the number and the habitat value of trees represent a further step for allowing the habitat identification directly in forest. It also helps in the assessment of the appropriate number of habitat trees to be released in the forest, balancing timber production and biodiversity conservation. The same could be in the management of sites of the Natura2000 network, fostering the identification of potential threats and the definition of priority functions of lands, promoting dissemination activities useful to involve local people.

Caprarola –Lazio

Since its implementation in the GIS software in headquarter of the Municipality of Caprarola, the FIS has offered a concrete opportunity to support local forest management decision-making in regulating and improving the public use of the forest. First of all, like in the other demonstration sites, the update data stored in the FIS leaded to an analysis of the changes occurred in the managed forest. The SFM indicator "Tree Species Composition" (#4.1) was used to highlight the evolution of the forest ecosystem and update the boundaries of the forest units' map that is the base of each forest planning activities. Access to high resolution data help local managers to better understand the forest and consequently the way to set up their daily work. Caprarola test site is included in a Regional Natural Reserve so that the public accessibility and use of the area for leisure activities are relevant. Using data from the SFM indicators "Growing

Stock"(#1.3)and "Above Ground Biomass"(#1.4)the staff of the Municipality of Caprarola identified the position of the monumental beech and Turkey oak. Monumental trees differ from others of their species owing to their unusual size, their age, or their unusual shape, which means that they are of special natural, historical, cultural, or landscape interest. Based on the FIS dataset trails connecting very large trees arebeen identified and pointed out in the footpath map of the demonstration site in order to notify them to the general public and create an educational and natural itinerary.

6.1.9 Action D1: Project Website

Foreseen start date: September 2015	Actual start date: September 2015
Foreseen end date: September 2019	Actual (or anticipated) end date: November 2019

As indicated in the project proposal, the Website https:// www.freshlifeproject.net/was updated at least three times per month with information about the project activities, results and events. During the whole project period, we published more than 100 posts that reached 28000 views and 6000 visitors, with peaks related both to the publication of posts and to the project's events (Figure 15).

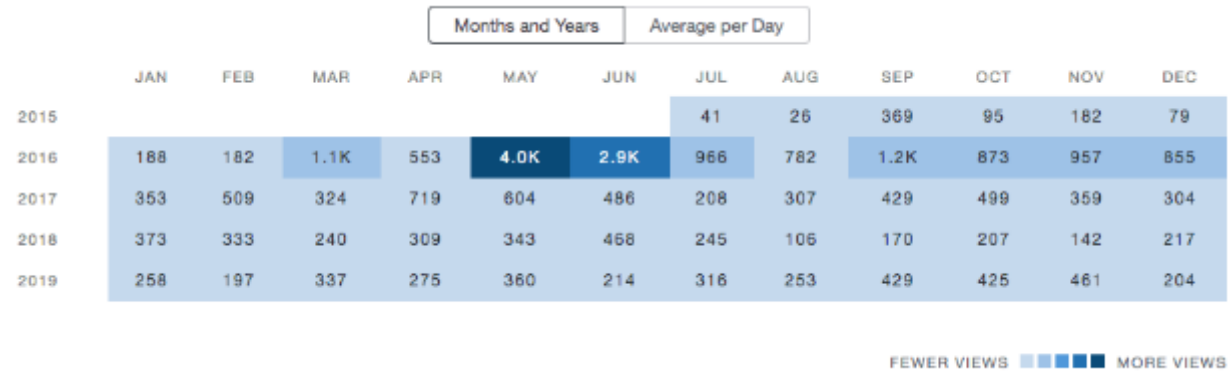

Figure 15. Summary of the website views during the whole project period

On the website are also available for the download all the project's products: deliverables, reports, papers, presentations posters. The Facebook page of the project still works as a forum for discussions around the project actions and results and now we have more than 300 "likes". During the most important events that we organized a live streaming was performed on our FB page reaching sometimes more than 500 views in few days. All the video recorded during the events are now available on the page or on the YouTube channel of the project (https://www.youtube.com/channel/UCy5FWqBnQBfpz91p4frGoEQ). The channel was quite active during the project period reaching more than 400 visualizations with the 8 video present on it. As explained in the AfterLIFE Plan al the social pages (website, FB page, YouTube Channel) will remain active after the end of the project sharing AfterLIFE activities, news from our network of projects and on the SFM topics. The Communication Plan expected within this action was sent with the Progress Report on October 2018 in a final version with a summary of the main elements in English.

6.1.10 Action D2: Layman's Report

Foreseen start date: December 2018	Actual start date: July 2018
Foreseen end date: July 2019	Actual (or anticipated) end date: September 2019

The Layman's Report is targeted at a non-specialist audience. It summarizes project activities and results providing a detailed overview of the project work and while not excluding technical language, it was broadly comprehensible to an interested general and non-specialist reader. To follow the indications of the project proposal and provide a product in line with what suggested by the Commission in the LIFE guidelines, an external subject with long experience about LIFE project reporting was involved. Compagnia delle Foreste took care of the graphic aspects of the Layman's Report ensuring that the contents were suitable for the public to whom the product is addressed. Before this, we had a long period of discussion with the local partners, to find the better way to communicate the results achieved by the project and select the topics to been included in the report. The strong connection between local forest managers and people they live around the demonstration sites was essential for this phase. Selected the right contents, we start working with Compagnia delle Foreste for the graphic project and the translation. The final product is a 16 pages Layman Report with text in double language (ita/eng) printed in 2500 copies. To ensure the dissemination of the report ,1500 copies were sent directly to the subscribers of the magazine "Sherwood" directed by Compagnia delle Foreste together with the number of winter 2019/2020. The remaining copies were distributed during the final events organized in Palermo and Caprarola and it will be available after the project's end in the partners's premises. A copy of the Layman's Report was sent to the commission

with this Final Report and also an PDF version was attached (ANNEX 01 – Layman's Report)

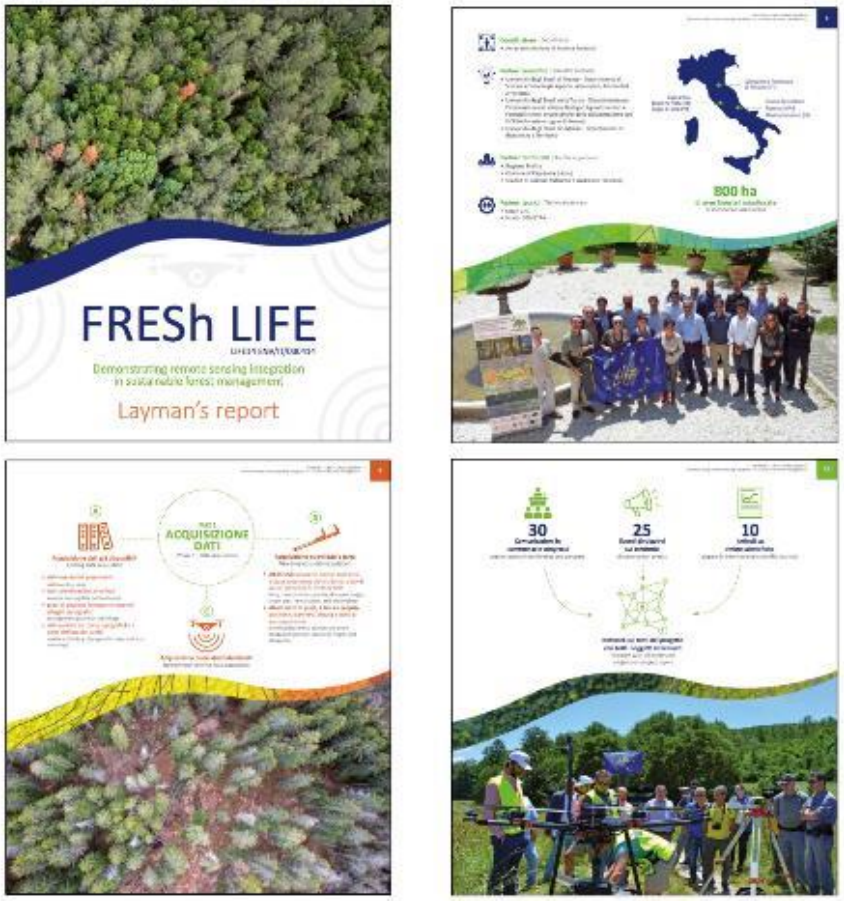

Figure 16. Pages from Layman's Report

6.1.11 Action D3: Life Notice Boards

Foreseen start date: November 2015	Actual start date: November 2015
Foreseen end date: July 2019	Actual (or anticipated) end date: September 2019

The first part of the action was completed in time according to the deliverable "Introductory Information Boards" (deadline 31/03/2016) and all the introductory and external Notice Boards were positioned. Here below some photos of the External Notice Board with a short description of the position in the demonstration sites.

Figure 17. External Information boards in the demonstration site of Bosco Pennataro; on the left the one positioned at the entrance of the visitor center of the Montedimezzo Forest Reserve; on the right the other one on the main access to the forest.

Figure 18. External Information boards in the demonstration site of Rincine; on the left the one positioned near the RPAS flying field in the demonstration area; on the right the other one on the main access to the forest.

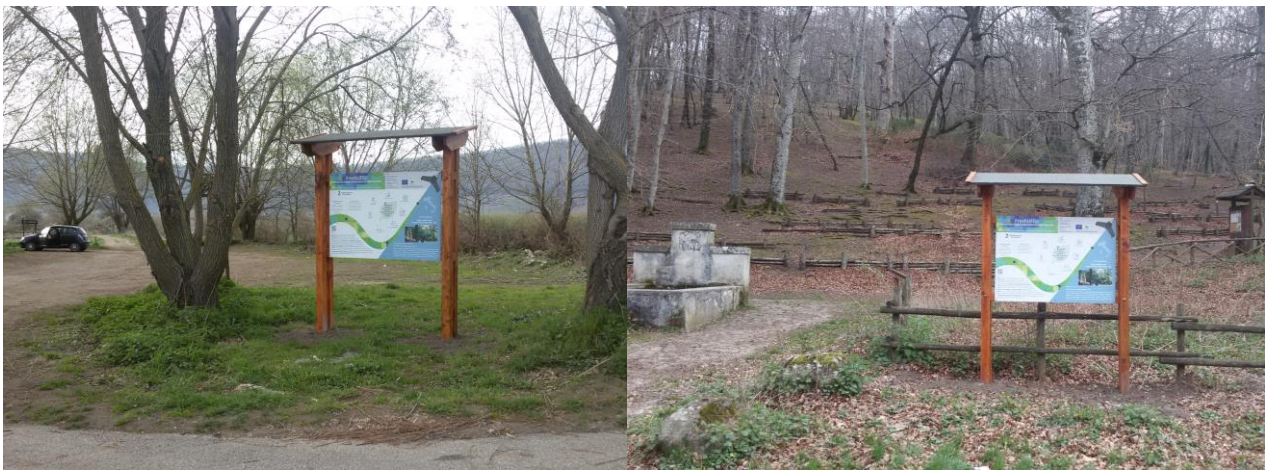

Figure 19. External Information boards in the demonstration site of Caprarola; on the left the one positioned out of the demonstration area near one of the main parking for visitors and turists; on the right the one on the main access to the forest.

We prepared also two roll-ups out of three expected in this action and the action stayed in standby until the end of project waiting for the results.

The second part started in December 2018, seven Final Results Information boards were produced and, after the presentation at the final event, positioned in the beneficiaries' premises, in the deliverable of the action D3 “Photos of final information boards placed at beneficiaries' premises” you will find more details about the positioning of the boards.

Figure 20. Final Results Information boards

As expected also one last roll-up was produced, we decided to use the same layout and contents of the Information Boards to have a product to show the results of the project during workshops, seminars and meetings.

Figure 21. The new roll-up during the Final Event in Palermo

6.1.12 Action D4: Technical Report and Training

Foreseen start date: July 2017	Actual start date: July 2017
Foreseen end date: July 2019	Actual (or anticipated) end date: November 2019

This action intends to transfer the results obtained from the project to experts with different skills by means of a Technical Report finalized to inform and train different figures: local authorities, technicians of environmental and forestall agencies, public bodies of forest areas, also at European level. This action also foreseen the realization of training sessions aimed primarily at technicians. The Technical Report is aimed to transfer to the technicians an adequate knowledge about the technology and use of the methodology we propose integrating remotely sensed technology to provide information

support to sustainable forest management. The drafting of the report was carried out by AISF with the help of UNIFI, UNITUS, UNIMOL for the scientific and technical support to reporting activities. The technical report was updated step by step when the results from the different actions arrived and it is based on what is written in the deliverables readjusted so as to return a complete summary of the project phases and results. With the conclusion of key action B4 about the FIS installation and feedbacks, the technical report was finalized on schedule with the deliverable "Technical Report" and is attached to this Final Report. In order to disseminate the results achieved by the project, an Italian version of the Technical Report was published on the Italian Journal of Forest and Mountain Environments published by the Italian Academy of Forest Sciences. On online version is available following this link: http://ojs.aisf.it/index.php/ifm/issue/view/148

Figure 22. First page of the Italian Journal of Forest and Mountain Environments that contain our Technical Report

Regarding the trainings, we organized some lessons with the student of the University of Florence in order to show how elaborate the data acquired in the project. And in April 2018, in collaboration with the Erasmus+ project GEONATURA, we had a training session in Glasgow where the participants guided by our staff, elaborate the data of FRESh LIFE in order to estimate indicators such as "Growing Stock" and "Above Ground Biomass". In addition to this, that what has already been indicated in the last Progress Report of October 2018, the training activities were continued. Here below an updated list with all the events organized by our project's team:

- On April 2019 in collaboration with the Erasmus+ project GEONATURA, we had a training session in Florence where the participants guided by our staff, elaborate the data of FRESh LIFE in order to estimate indicators such as "Growing Stock" and "Above Ground Biomass";

Figure 23. Participants to the training in Florence

- On June 2019 the Molise Region our local partner together with the University of Molise organized a three days training session that involved technicians and different stakeholders included the order of agronomists and forestry doctors. The classes explored all the FRESh LIFE workflow starting from inventory and UAV data collection to the elaboration and mapping of the SFM indicators. More details are available on our website: https://freshlifeproject.net/2019/06/27/training-session-in-molise/

Figure 24. Participants to the training organized from Molise Region during the demonstration flight

- Again in collaboration with the Erasmus+ project GEONATURA, other two training session were organized in Netherland and in Lisbon (September 2019) during the last year of project giving us the possibility to disseminate project's results to European audiences.

6.1.13 Action D5: Report for policy makers

Foreseen start date: January 2018	Actual start date: January 2018
Foreseen end date: November 2018	Actual (or anticipated) end date: November 2018

This report was needed to explain all the project results in terms of policy decision instruments. It is focused on the needs of decision-makers and on efficient communication of information in order to give a clear idea of the main results and conclusions achieved by the project. The contents to be inserted inside the report were prepared and with the help of our partner DEMETRA, that have a long experience in reporting the results of LIFE projects, the best way to present it from

a graphic and layup point of view was discussed. During the preparation of the report the collaboration with our local partner UCVV was essential: as a local forest manager the director of UCVV know the best way to communicate to policy makers from the point of view of the language to be used and the most captivating topics. All this work was necessary to create a report that is relevant, direct, clear, and coherent. According with project schedule the report for policy makers was ready for the end of 2018 in two different version ITA/ENG. (Deliverable "Report for Policy Makers" 31/12/2018). To maximize the impact of the report we decided to publish it as a long brochure with an explanation of main project phases but focusing on the leverage effects on the demonstration sites. Also some information about the cost efficiency were included and presented in a user friendly way to allow managers to appreciate it. We made a brochure for for Policy Makers was sent with this Final Report and an PDF version was attached (ANNEX 03 – Brochure Report for Policy Maker) and the Report for Policy Makers (ANNEX 02- Report for Policy Maker)

Figure 25a. Brochure of the Report for Policy Makers

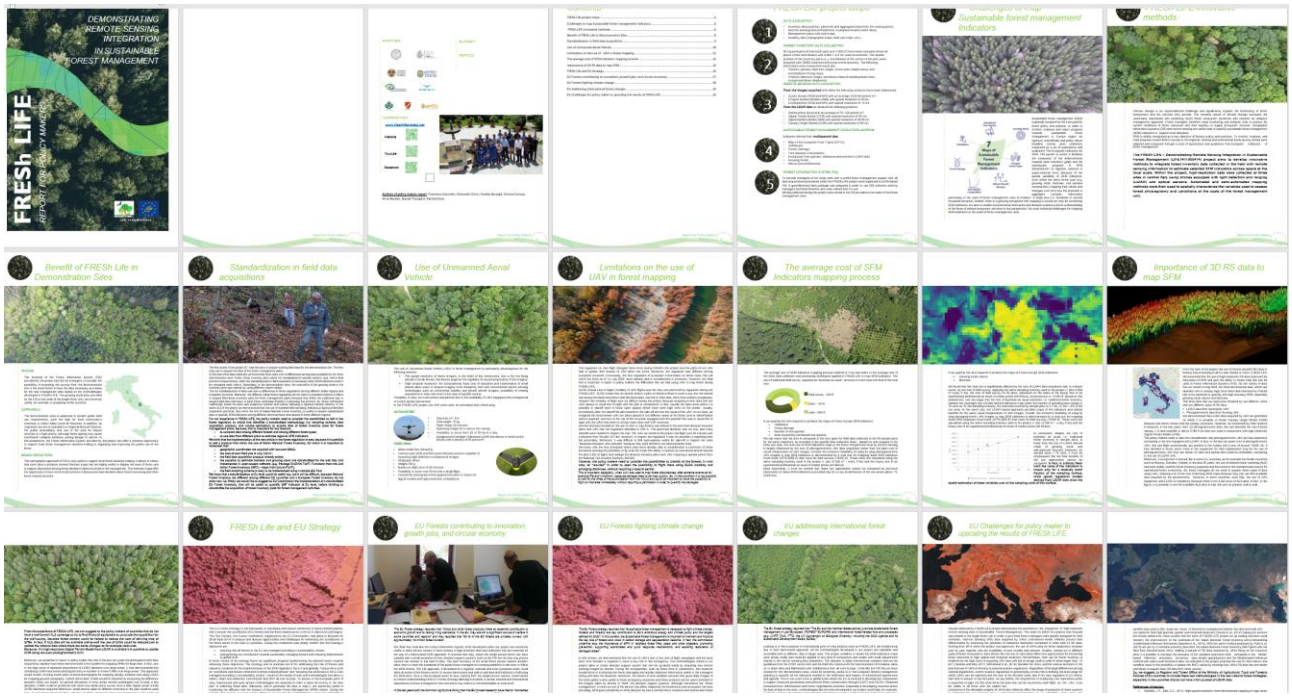

Figure 25b. Brochure of the Report for Policy Makers

6.1.14 Action D6: Workshops, seminars and meetings

Foreseen start date: September 2015	Actual start date: September 2015
Foreseen end date: July 2019	Actual (or anticipated) end date: November 2019

As indicated in the project proposal, several dissemination activities were promoted, addressing different targets, in order to ensure the best dissemination of the project results: national and regional agencies, local authorities, research institutions, environmental organizations, private companies, schools and any individual that may be interested in relevant issues.
Here below a list of the events we organize or participate within the Action D6 from the last reporting date (31/10/2018). All the details are presents on our website and on the FB page that contain a complete report of these events including photos and videos.

- 5 – 10 November 2018, participation at the IV National Congress of Silviculture in Turin with a session called "Forest monitoring and planning" complete dedicated to the FRESh LIFE project activities and results. A complete video of the session is available on our FB page;
- 29 January 2019, seminar “Geoinformatics in monitoring forest disasters” organized in Florence in collaboration with the Laboratory of Geomatics of the Faculty of Forestry, University of Agriculture in Krakow, Poland. A video of the event is available on our FB page;
- 23 March 2019, organization of the event “Learn to Love Forests” held in Florence on the occasion of the International Day of Forests. A video recorded during the live streaming of the event is available on our FB page;
- 1-5 April 2019, participation at the VI Mediterranean Forest Week in Lebanon to present the results of our project. We had a poster and a presentation at the Mediterranean Forest Model Network in a special session dedicated to the best practices for the sustainable forest management. PDF version of the poster and presentation are available on our website together with photos from the event;
- 10 April 2019, sponsorship and participation at the Workshop “Geomatics for environmental management” held in the Lecture hall of the School of Agriculture in Florence in collaboration with the Erasmus+ project GEONATURA. A video recorded during the live streaming of the event is available on our FB page;
- 7-8 May 2019, two days of monitoring visit in Molise with the participation of all partners. During the second day a field visit to the demonstration site was also organized to present the potentials of the FIS;
- 5 June 2019, demonstration flights with the students of the University of Florence during some upscaling activities of our project in Vallombrosa (FI);
- 22 June 2019, participation at the Southern Hub Workshop of Rosewood H2020 Project where we presented

how maps obtained by the integration of field data and UAV data can be useful for sustainable wood mobilisation;

- 21-25 June 2019, the Molise Region our local partner together with the University of Molise organized a three days training session that involved technicians and different stakeholders included the order of agronomists and forestry doctors. The classes explored all the FRESh LIFE workflow starting from inventory and UAV data collection to the elaboration and mapping of the SFM indicators. More details are available on our website: https://freshlifeproject.net/2019/06/27/training-session-in-molise/;
- 1-5 October 2019, participation at the XXV IUFRO World Congress in Curitiba (Brazil) where Anna Barbati (University of Tuscia) presented the results of our project in a session named "Innovative application of Unmanned Aerial Vehicles (UAVs) in Forest Science and Management" during which she talked about "What UAV remote sensing can tell us about sustainability of forest management at operational level: lessons learned from the EU funded FREShLIFE project". The presentation is available for download on our web site;
- 13 November 2019, Final Event of FRESh LIFE project organized in Palermo in collaboration with the XII SISEF National Congress. All partners attended the event, sharing results and suggestions. During the session we focused on the potential of the Forest Information System in helping the management of the demonstration sites: Toni Ventre explained the situation in Rincine while managers from Caprarola and Bosco Pennataro presented some posters with results achieved in these two areas. The presentation and posters are available for download from our site and you can find a complete video of the session on our FB page.
- 29 November 2019, second Final Event organized by the Municipality of Caprarola, local partner together with the University of Tuscia. During the day the results achieved from the project and the proposed methodologies will be presented to local stakeholders focusing on the potentials offer by the Forest Information System and Sustainable Forest Management for the territory around the demonstration site. A complete report of the day is available on our web site following this link: https://freshlifeproject.net/2019/12/03/report-from-the-final-event-in-caprarola-vt/;

Within the Action D6 we had also the publishing of some scientific papers. You can find the list of the papers in the "Publication" section of our website with also the possibilities to download the full articles. In the last year we also create a YouTube channel (https://www.youtube.com/channel/UCy5FWqBnQBfpz91p4frGoEQ) dedicated to the project where all the video produced during the project period were stored.

6.1.15 Action D7: Networking

Foreseen start date: September 2015	Actual start date: September 2015
Foreseen end date: July 2019	Actual (or anticipated) end date: November 2019

As indicated in Action D6 the permanent collaborations with AIT and SISEF are continuing through the participation to their congress and conference. Also in 2019 we had an entire session dedicated to our project in the XII SISEF National Congress during which we organized the Final Event. FRESh LIFE was also one of the sponsor of the congress helping with organization and funding. Most of the network activities were already reported in the list of Action D6 (6.1.14) but here below someone that were missed due to their particular networking nature:

- 10-12 December 2018, collaboration with a network created to quickly answer on the emergency caused by the "VAIA" windstorm in northern Italy. Our team participated with the acquisition of high resolution remote sensing data by UAV. Data derived were used from national bodies to better understand causes and consequents of the event;
- 22 March 2019, presentation of the shared activities within the final event of the LIFE project FutureForCoppices with which we had a strong scientific collaboration especially in the UAV data acquisition and elaboration;

From the list of paragraph 6.1.14 we want also highlight the participation at the Mediterranean Forest Model Network annual meeting in Lebanon and to the XXV IUFRO World Congress in Curitiba (Brazil). Both these were great occasions to sharing results achieved with our project and improved our network in order to maintain activities also in the AfterLIFE period. A complete list of the network created during the project period is available on our website together with a description to the sharing activities with each project.
Another important part of the networking has regarded the acquisition of UAV remote sensing data with our eBee on the demonstration sites of other project LIFE and not. The knowledge acquired on the use of UAVs allowed us to start many networking activities due to the potentials of these tools. Here below a short list of the flights organized following the request of UAVs data to test it in other projects or situations.

Date	N. of flight	Area covered (ha)	Description
01/07/19	4	190	Networking activities with LIFE Future for Coppices in south Tuscany
10/12/16	12	550	Acquisition on coastal forests in the Monteverdi Marittimo area to test cutting monitoring for forestry companies
11/12/16	5	450	Acquisition on coastal forests in the Monteverdi Marittimo area to test cutting monitoring for forestry companies
07/04/18	2	50	Riparian vegetation acquisition for river management in collaboration with UNIFI
15/12/18	2	90	Flights to test potentials in soil erosion monitoring after forest wildfires
07/06/19	5	190	Flights on the Natural Reserve of Vallombrosa to acquire data for the new forest plan
30/06/19	2	100	Acquisition of data to compare the results of two different management methods on beech forests of Tuscany Apennine
23/09/19	2	90	Acquisition for thinning planning due to the realization of new ski slopes
11/11/19	6	120	Riparian vegetation acquisition for river management in collaboration with UNIFI

Table 11. Networking flights with eBee

More details about the networking activities and achievements are reported in the deliverable “Networking Final Report” attached to this Final Report.

6.1.16 Action E1: Project Management and monitoring of the project progress

Foreseen start date: July 2015 Actual start date: July 2015
Foreseen end date: July 2019 Actual (or anticipated) end date: November 2019

The Financial Manager DEMETRA with the assistance of administrative staff of AISF monitored the projects activities day by day in order to guarantee that the rules governing the Project and the responsibilities of the Partners in implementing the work were respected. The contingency plan, prepared to devise remediation actions in case of unexpected situations or severe divergence from assumptions and planning, worked excellently, thanks to the strong network created with all the referents within the project beneficiaries. This allowed the project coordinator a fast problems solving in in responding to the problems that arose in the project period. The financial partner "DEMETRA" coordinated a part of this action by collecting and elaborating the Financial Report that was updated by each beneficiary every three months up to the moment of the last reporting available on the dedicated sections of this Final Report.

6.1.17 Action E2: After Life Plan

Foreseen start date: March 2019 Actual start date: March 2019
Foreseen end date: December 2019 Actual (or anticipated) end date: December 2019

This action was aimed to set out how the partnership will continue disseminating the results of the project over the coming years. In the last six months of project activities we discussed about this topic with each partner especially with the local ones that are related to the demonstration sites. All the feedback received were analysed and presented to the beneficiaries during the last project meeting in the occasion of the Final Event organized in Palermo on November 2019. After this last meeting we wrote an AfterLife Plan that take into account all the partners’

suggestions about how organize the activities in the three years after the project end. The AfterLIFE Plan is in Deliverable Action E2 - After LIFE Plan (Deliverable Action E2 - After LIFE Plan) to this Final Report and is organize in six section concerning:

- project Website;
- scientific research and publications;
- project products dissemination;
- forest Information Systems updating;
- project results up-scaling;
- maintenance of the Project Network.

Also a section focused on the After-Life use of EU funded equipment and consumable wad included, together witha timetable showing the project activities schedule.

6.1.18 Action E3: Indicators

Foreseen start date: September 2015	Actual start date: September 2015
Foreseen end date: July 2019	Actual (or anticipated) end date: November 2019

This action is aimed to compile the information needed to complete the indicator tables (quantitative and qualitative) that were submitted with the first Progress and Final Reports. For each selected indicator we evaluated how remote sensing technologies can contribute in supporting the sustainable forest management. Starting from what indicated in the project proposal we defined the indicators and submit it with the first progress report in line with the deliverable "Indicators submitted with First Progress Report". The project indicators were validated following the indications provided by the monitoring team NEEMO. The online form was compiled by indicating all the indicators considered relevant for the project activities. According to the project timetable the indicators will be compiled again at the end of the project when all the impacts will be more evident and quantifiable. Selected indicators are the follow:

- 1.5 Project area/length;
- 1.6 Humans (to be) influenced by the project;
- 4.2.1 Sustainable Forest Management;
- 4.2.2 Provision of forest datasets for the European Data Centre;
- 7.3 Natural and semi-natural habitats;
- 11.1 Website;
- 11.2 Other tools for reaching/raising awareness of the general public;
- 12.1 Networking;
- 12.2 Professional training or education;
- 13. Jobs;
- 14.1 Running cost/operating costs during the project and expected in case of continuation/replication/transfer after the project period;
- 14.2.1 Capital expenditure expected in case of continuation/replication/transfer after the project period;
- 14.3 Future funding;
- 14.4.3 Entry into new geographic areas;

A complete analysis of the remote sensing contribution to each of these indicators was performed and results collected in the deliverable “List of indicators with analysis of remote sensing contribution” that was ready in time with project schedule and attached to the Final Report (Deliverable Action E3 - List of indicators with analysis of remote sensing contribution).We refer to the deliverable for all the details about the action and we also send the excel file generated by the online submission of the indicators updated to the end of the project (Action E3 “Indicators submitted with Final Report).

6.2 Main deviations, problems and corrective actions implemented

The Life Fresh Project ended with a satisfactory outcome and according to the timing identified during the proposal phase. This result has been reached thanks to the correct management of the team involved in the project and thanks to the continuous collaboration with the Monitoring Team. Some small appropriate adjustments and modification were made throughout the life project to answer to some needed that were not predictable during the proposal phase. However, the adjustment and modifications were always agreed with the Monitoring team. Moreover, a continuous monitoring plan between the beneficiary and partner of the project and the collaboration with the Monitoring team were the basis to correct timely the problems that occurred during the project life. The collaboration allowed to correct immediately with corrective actions all the problems that have occurred. In fact, the problems gradually encountered were correctly reported and addressed, with specific and agreed corrective actions. The corrections and the reports of problems were widely discussed during the monitoring visits and in the Mid Term and Progress Reports.
In this last conclusive phase, there were no further deviations or problems, other than those already addressed and resolved previously in Mid Term and Progress Report.

For specific details on some problems raised during the Mid Term Report evaluation process, refer to the responses reported in the Support Document 01 – REPLIES TO MID TERM REPORT EVALUATION

6.3 Evaluation of Project Implementation

Action	Foreseen in the revised proposal	Achieved	Evaluation
B1 Existing data acquisition and harmonization	Objectives: acquisition over the selected study area of existing (available) data, data harmonization, and the implementation of a project information system that will be used by project partners to perform project actions. Expected results: - acquisition of available data in the selected study areas; - data harmonization; - implementation of a project information system; - one technical report;	All the available data were acquired, harmonized and used for the implementation of the project information system. A technical report was produced at the end of the action in September 2016.	Indicators of progress: - number of field plots acquired; - percent of study areas covered by remotely sensed data; - percent of study areas covered by forest management plans; - percent of harmonized information layers on the total number of information layers; All these indicators of progress have reached the 100%.
B2 New Data Acquisition	Objectives: assessment of collected data in Action B1, acquisition of new geo spatial data, acquisition of new field data, completion of the Project information system with metadata in line with the INSPIRE Directive. Expected results: - acquisition of new data in the selected study area; - completion of data harmonization; - one technical report;	An assessment of data acquired in Action B1 was made in order to create a list of missing data. Acquisition of new field data was completed in the demonstration sites of Bosco Pennataro, Caprarola and Rincine. New remote were the three demonstration sites. The complete database of new field data was harmonized and added to the project information system.	Indicators of progress: - number of geo spatial data (remote sensing data) acquired per study area: completed at 100% (3/3 multispectral data and 3/3 Lidar data); - number of new field plot acquired per study area: completed at 100% (50 plots for each study area); - number of new data harmonized: completed at 100%
B3 Mapping SFM indicators	Objectives: cutting-edge statistical methods for the spatial extrapolation of plot-level data on growing stock and above ground biomass, visual and semi-automatic classification of EFTs, visual and semi-automatic classification for deriving maps of selected SFM indicators at the forest compartment level. Expected results: report evaluating	Using data from Action B2 the following product were produced: - maps of EFTs for each demonstration site by both visual and semi-automatic classification; - maps of four SFM indicators (Defoliation, Forest damage, Tree species composition and Area	Indicators of progress: - area covered by growing stock map in selected study areas: completed at 100% (3/3 demonstration area); - area covered by above ground biomass map: completed at 100% (3/3 demonstration area); - area covered by EFTs maps in selected study areas:

	the technical and economic viability of the proposed integrated approach for mapping EFTs and selected SFM indicators on a technical scale	covered by introduced tree species); A report on the technical and economic viability of using high spatial resolution optical data was produced.	completed at 100% (3/3 demonstration area); - number of SFM indicators maps for the selected study areas: completed at 100;
B4 Forest Information System implementation	Objectives: use the information created in B3 into a Forest Information System (FIS) to support their implementation in real local forest management activities. Expected results: set up Forest Information Systems in the forest management offices of the three demonstration sites.	The Forest Information Systems (FIS) were implemented and installed in the offices of the local partners in the three demonstration sites. Several training activities were realized to allow managers to discover the potentials of the system also collecting feedback useful to adapt the FIS to the local management needs.	Indicators of progress: - Percent of completion of the Forest Information Systems created by AISF: completed at 100%; - Completion of the installation of the FIS in the three forest management offices of the demonstration sites: completed at 100% (FIS installed in 3/3 demonstration site);
B5 Upscaling project result	Objectives: analyse the results obtained at local level in the study areas investigating the possible impacts on the Italian Forest Plan and the replicability at European level. Expected results: guidelines both for national and regional authority levels reporting how the operative implementation of the advanced methods based on remote sensing may affect forest policy instruments.	An analysis of up-scaling activities at different scale, taking into account both the extension of the proposed methodologies all around the demonstration sites, then the impacts on the policy tools at regional, national and European scale was performed. Guidelines for improving regional and national forest policy tools were produced.	Indicators of progress: - Number of people and authorities contacted for implementing the upscaling project: 50+ people were involved in the preparation and finalization of the Upscaling project, specially during the part related to policy tools; - Number of Countries involved: 10; - Feedbacks received after the preparation of the upscaling project: enough feedbacks were received to allow the validation of the projects, we will look for more to come in the AfterLIFE period; - Number of Countries from whom the feedbacks are received: 10;
C1 Local monitoring	Objectives: acquire information for quantitatively estimating the impact of the project actions in terms of the incremented sustainability of forest management in study areas, monitoring of Sustainable Forest Management indicators, and if it has improved decision-making in forest management. Expected results: The local monitoring is expected to maintain the project activities in the different local sites on track respecting deadlines and deliverables.	All the indicators were estimated for each area. All the deliverables and milestones were reached in time with what is indicated in the project proposal and all the beneficiaries were involved in meetings and field visits with the coordination team and local stakeholders.	Indicators of progress: - % of scheduled deliverables and milestones: 100% of deliverables and milestone were reached on time; - % incremented area with sustainable forest management in each study area: all the area of the demonstration sites is now managed following SFM indications and some managers decided to extend the area covered by the FIS; - number of sustainable forest management indicators calculated in each study area: completed at 100% (6 of 6 SFM indicators for each study area);

C2 Large Scale Monitoring	Objectives: monitor if the project is correctly implemented at national level by evaluating how the activities carried out in the three pilot areas will impact on the regional and national policy level. Expected results: - acquire information on the relevance of the local results achieved in pilot areas to a wider scale level; - KPI formulation and evaluation	KPIs were defined and included in a questionnaire in order to collect the info needed for an ante/post monitoring of project impacts. First result from the questionnaires were analysed and evaluated. An analysis of the KPIs in the post project situation was performed and impacts analysed.	Indicators of progress: - number of national stakeholder participants to meetings and field visits: a total of 2000+ individuals were reached; - % of scheduled deliverables and milestones: 100% of deliverables and milestone were reached on time;
C3 Socio Economic Impact of the project actions on the local economy and population	Objectives: Through a socio-economic impact assessment we will examine how the proposed use of advanced remotely sensed data will affect current and future activities of the involved stakeholders. Expected results: compilation of a large number of questionnaires from the stakeholders involved in the three different test areas.	A questionnaire was developed and distributed in order to investigate the socio-economic characteristics of the demonstration areas. We received 139 answers, sufficient number to analyse the ante-project assessment of the demonstration areas. At the end of the project the post-project assessment was performed in detail for each demonstration sites.	Indicators of progress: preparation, compilation and analysis of questionnaires at the beginning and the end of the project in the three different study areas: completed at 100% (questionnaires submitted at the beginning of the project and analysis of the post project situation performed with information collected in other project actions, for instance from the up-scaling questionnaire, together with the feedbacks given by the local partners).
D1 Project Website	Objectives: in order to ensure a good visibility to the project activities and to improve the communication between beneficiaries, a project website will be developed. Expected results: - project website periodically updated. - Dissemination Plan	The project website was developed and published online on September 2015. The Website was updated at least three times per month with information about the project activities, results and events. We published more than 100 posts that reached 28000 views and 6000 visitors. Facebook page and YouTube channel were created and updated	Indicators of progress: - indicator on the state of readiness for creation of website: 100% (website publication); - indicator on the website update frequency: updated at least three times per month as foreseen; - indicator on the state of readiness: completed at 100% (Communication Plan produced)
D2 Layman's Report	Objectives: A Layman's Report will be produced at the end of the project. Expected results: - the Layman's Report will be delivered to the Commission at the end of the project. - N° 3000 of Layman's Report (10 pages) are expected to be printed. It will be produced in Italian and English language.	As foreseen in the proposal this publication was available in English/Italian language. To ensure that the contents reflect what was expected a specialized consultant was involved in the Layman's Report design and printing.	Indicators of progress: - Number of Report printed with respect to those foreseen: we can consider this indicator reached at 100 % because even if printed 2500 copies, instead of the 3000 foreseen, we sent more than half directly at home to 1500 subscribers; - Steps for implementation of Report: reached at 100%
D3 Life Notice Boards	Objectives: An important phase of the dissemination activities will foresee to divulgate-disseminate by information board the objectives of the project to local stakeholders, general public and decision makers. Expected results: - n. 6 Introductive Information	Introductive Notice Boards were produced and positioned in the premises of the beneficiaries. External NB were produced and positioned inside the demonstration areas. Finale Results NB were produced.	Indicators of progress: -percentage of notice boards realized upon the whole foreseen: 8 Introductive Information Boards against the 6 foreseen, 3 rolls-up realized against the 3 foreseen, 4 External NB produced against the 3 foreseen, 7 Final Results

	boards - n. 6 Final Results Information boards - n. 3 rolls-up - n. 3 External notice boards	Three different rolls-up were created in order to be used in the dissemination activities, the last one focused on the project results	Information Boards realized against the 6 foreseen.
D4 Technical Report and Training	Objectives: this action intend to transfer the results obtained from the project to experts with different skills. Expected results: - Technical Reports; - 3 Training Sessions (20 persons each);	The technical report was ready on December 2018 in schedule with the project proposal. Training sessions were performed with different stakeholders by each local partner together with the staff of the associated universities.	Indicators of progress: - Number of training sessions held with respect to those foreseen: 10+ instead of the 3 foreseen; - Number of trained persons with respect to those initially foreseen: 100+ instead of the 60 foreseen; - Steps for implementation of Report: 100% with production and distribution.
D5 Report for policy makers	Objectives: a report for policy makers will be prepared in order to explain all the project results in terms of policy decision instruments. Expected results: - publication of a Report to be distributed at the national level; - publication of the report on the website, in Italian and English;	The core part of the report was produced by analyse the feedbacks from the Action B4 about the use of the FIS. Several meetings have been carried out with the local managers of the demonstration sites in order to ensure that the language used in the report was the most appropriate and understandable.	Indicators of progress: - Steps for Implementation of Report: 100% with final production and distribution; - Number of printed copies of the report: 500 copies were printed; - Number of distributed copies of the printed report: 300 copies already distributed; - Number of downloaded electronic copies of the report: 100+
D6 Workshops, seminars and meetings	Objectives: In order to ensure the best dissemination of project results, several dissemination activities will be promoted, addressed to different targets, comprising: national and regional agencies, local authorities, research institutions, environmental organizations, private companies, schools and any individual that may be interested in relevant issues. Expected results: - 4 workshops - at least 4 seminars - at least 3 media and press meetings - 12 meetings/excursions for students - 1 technical scientific paper - 3 brochures (ENG/ITA) - 1 project video - Participation of Partners to at least 6 international/national conferences in order to disseminate project activities and results;	During the whole project period the participation to several national and international conferences has continued in order to disseminate the project aims and results. Different kind of workshop, seminars and meetings were organized involving students and different stakeholders. Scientific papers related to the project activities was published and videos were produced and uploaded on the project YouTube channel.	Indicators of progress: - number of dissemination events organized with respect to those foreseen: 4/4 workshops, 3/3 media meeting, 12/12 meeting/excursion for students. - number of participants/event: a total of 1500+ individuals were reached; - number of European bodies invited and their geographical distribution: we had contact with the Slovenian LIFE delegation, with the Iraqi Ministry of Environment and with the coordinator of a polish LIFE project and a lot of other contacts due to the participation at the Mediterranean Model Forest Network and Rosewood Project (H2020).

D7 Networking	Objectives: promote clustering activities with other EU networks, initiatives and projects (including other LIFE and LIFE+ Projects) connected to the project topics and sectors, e.g. organization of common events to share results and experiences and publication of news about the project on their newsletters; create synergies among stakeholders all over the EU to promote the adoption of forest/environmental technologies by local authorities and private sector. Expected results: - organization of 2 networking events; - 2 permanent collaborations with relevant networks will be established; - participation to at least 3 events of other networking projects;	The permanent collaboration with AIT and SISEF networks was going on by participating to their events and calls. Regarding the networking with other LIFE projects, we increased the number of related projects and we have a successful collaboration also with others project at regional and national scale. An European and extra-EU network was also established due to the participation at important international conferences and meetings.	Indicators of progress: The main indicator is the level of networking, based on the number of networking events organized: 2/2 networking event organized, 2/2 permanent collaborations with relevant networks established, 3/3 participation at events of other networking projects.
E1 Project Management and monitoring of the project progress	Objectives: have the full control of project activities, to intervene promptly in order to give the EC the certainty of a sound management of contractual issues and to give clear indications to project staff about management rules. Expected results: - 1 Partnership agreement signature - 1 Steering Committee appointment - 1 Quality Plan	The Financial Manager DEMETRA with the assistance of administrative staff of AISF monitored the projects activities day by day in order to guarantee that the rules governing the Project and the responsibilities of the Partners in implementing the work were respected.	Indicators of progress: All the three products foreseen in the expected results were produced and sign. The four foreseen report were produced and sent to the commission.
E2 After Life Plan	Objectives: this action includes the activities devoted to set out how the Partnership will continue disseminating the results of the project over the coming years. Expected results: - dissemination on project website (papers, brochures, news); - institutional Dissemination for stakeholders; - participation of Partners to international and national conferences in order to disseminate project activities and results - 1 After Life Communication Plan	The After-LIFE Plan was developed following the instruction given by the commission and it goes through the analysis of key points of the project results' maintenance and dissemination. A complete three year After-Life period timetable was provided together with a plan for the updating of the FISs.	Indicators of progress: - Indicator of readiness of After-LIFE Communication Plan: 100% --> "After-LIFE Communication Plan" complete; - Indicator of possible delays with respect to the project time schedule: no delays on project time schedule;
E3 Indicators	Objectives: this action is aimed to compile the information needed to complete the indicator tables (quantitative and qualitative) that will be submitted with the first Progress and Final Reports. Expected results: for each indicator the most promising remotely sensed source of information and elaboration technology will be	The project indicators were submitted in time following the indication provided by the monitoring team NEEMO. The online form was compiled by indicating all the indicators considered relevant for the project activities. According to the project timetable we updated	Indicators of progress: the first submission was completed in time with the action's deliverable and the indicators were submitted again with the Final Report.

	analysed.	the indicators at the end of the project taking into account the activities' impacts and results	

How project amendments, if presents, led to the results achieved and what would have been different if the amendment has not been agreed upon.

Among the amendments requested the most important in terms of technical consequences was the one related to the withdraw of the associated beneficiary Roma Natura. In a short period, they have changed twice their organization structure (including the Director). These changes are extraordinary and were not foreseeable during the preparation of the FRESh LIFE project proposal or at its beginning. On the other hand, these changes determined a redefinition of the priorities in the activities of Roma Natura. Resulting in the impossibility for their staff to carry out the actions envisaged by the FRESh LIFE project. We were forced to ask changes in responsibilities of some activities that were carried out by different beneficiaries in respect of what foreseen and an extension of the project duration for two additional months. This extension was necessary for allow the three partner, that carried out the activities due to RomaNatura withdraw, to reorganize the work in order to reach the aims and reporting back the expenses. The approbation of the Amendment was essentials and allowed us to carry out all project actions in accordance with the original timescale without any prejudice to the achievement of the objectives and the production of the expected results. In case this amendment hadn't been accepted the project would not be able to produced a part of the communication and dissemination results. Thus would have meant a decrement of the quality of project outputs and impacts.

Description of the results of the replication efforts

The results of the replication efforts were deeply described in the section 6.1.5 of this Report and in the deliverable "Guidelines for improving regional and national forest policy tools". Please refer to these products for more details about this topic.

Effectiveness of the dissemination activities and comment about any major drawbacks

NETWORK
During the project a network were created to involve subjects active on different scale all united by a new approach to Sustainable Forest Management. The use of drones and innovative methodologies, for example 3D modelling, allowed us to reach people outside from the forest sector and more interested for example in robotics and sensors. All local partners were involved in technical trainings on the use of Forest Information Systems and Decision Support Systems. At the final stage we achieved to create a strong network from local to international scale linking together who work in the forests with the policy makers that write laws and regulations for the forest sector.

DISSEMINATION
During the remote sensing data acquisition phase of the project, the organization of demonstration flights at each demonstration site was especially successful. Each event, organized in collaboration with local partners, included an introduction to the project topics and objectives, followed by drone flights, live data processing, and the generation of final data products. These events, advertised through the project website and social media, were attended by students, scientists, local managers, professionals, and institutions, that became part of a network of contacts that we after used to disseminate all project results. After these first events we continued to participate at workshops, seminars and meetings that leaded us to had more than 40 occasions of dissemination to different audiences and stakeholders.

INNOVATION DISSEMINATION THROUGH RESEARCH COMMUNITY
Parallel to these dissemination activities, has been continued the participation to congress and meeting, in addition seminars were organized at universities and research centers to focus on technical and scientific topics. FRESh LIFE project has also organized special sessions at SISEF, AIT and National Silvicolture Congress. To date, the project has led to the publication of 10 papers in international peer-reviewed journals and over 30 oral presentations and posters at conferences.

Policy impact

During the last year of project, we focused on the policy implications of our activities and results. The collaboration

with our local partners was essential: as local forest managers, some of the directors know the best way to communicate to policy makers from the point of view of the language to be used and the most captivating topics. From the knowledge achieved by these discussions we produced the Report for Policy Makers, a tool that was used in the events that each beneficiary organized to disseminate the project methodologies and innovations in terms of best practices of management. As we reported in the section 6.1.5 some of our suggestions have already been taken into consideration regional bodies and included in pilot projects. We look forward to analyse the policy impacts that they will produce. Both at national and international scale the strong network created during the four years of project leaded us to participate to important events were our Forest Information Systems were presented as best practices. This, together with the efforts made by our coordinating team in participating at national and international tables of discussion about the future of forest management, had strong impacts that we can appreciate in some of the last document produced both from EU and Italian national government. A deep analysis of these implications was performed in Action B5 and reported in the deliverable "Guidelines for improving regional and national forest policy tools".

6.4 Analysis of benefits

SFM indicators requires data to be specified by forest types. Indeed, stratification by EFTs provides ecologically sound context to frame SFM indicators and interpret their temporal trends. Because of the spatial variability of SFM indicators, mapping their values and changes over time has the potential to aggregate complex information, particularly in the case of forest management units (forest compartment) of medium- to large size (i.e. few hectares to dozen hectares). Mapping is crucial not only for monitoring SFM indicators, but also to enable environmental institutions and decision-makers a better understanding of the flows of related ecosystem services.
However, there are technical challenges for mapping SFM indicators at the scale of forest management units. Main technical challenges are:

1. to define data sources, techniques and methods for mapping SFM indicators;
2. to ensure repeatability and reproducibility of mapping procedures;
3. to enable the aggregation of multiple indicator values in order to allow end-users, forest managers and forest planners *in primis*, to evaluate and demonstrate success towards SFM.

Environmental benefits
The environmental problem targeted by FRESh LIFE deals with the technical challenges mentioned above, as the project aims is to demonstrate the feasibility of integration of data collected from forest inventories with remotely sensed information for the spatial estimation of selected Forest Europe quantitative indicators of SFM.
We selected a set of ten indicators to assess the long-term environmental benefits of project actions, in terms of both direct/quantitative and qualitative environmental benefits. However, it is worth of noting that monitoring the effect of project activities on indicators, and evaluating its effectiveness by trend analysis against baselines is critical because the time horizon of forest and environmental planning is longer than the project duration. For this reason the indicators have been selected to assess the effects of project actions on three main environmental themes targeted by the project: 1) sustainability of forest management, 2) public awareness, 3) reduction of emissions**.**
Sustainability of forest management and reduction of emissions are directly connected with environmental benefits, such as wood supply for renewable energy without undermining the sustainable use of forest resources, contributing to climate change mitigation and adaptation without neglecting the other dimensions of SFM, and reducing the emissions from fossil fuels.
Instead, public awareness is indirectly linked with environmental benefits provided by the project; indeed, it has been recognized that increasing the number of people that are informed on how important is the forest for human wellbeing, and how important is forest management and monitoring for a sustainable use of natural resources is a way to contribute both to the implementation of SFM criteria, to the development of a green economy and, more in general, to give high visibility to environmental problems and/or solutions connected to forest ecosystems management and biodiversity conservation.
The set of indicators was also selected taking into account the Project Specific Indicators table.

The selected indicators are:

1) forest area in the demonstration sites managed with a forest management plan approved by the competent authority (unit: hectares);
2) number of SFM indicators taken into account for mapping purposes (unit: count);
3) forest area mapped per each SFM indicator (unit: hectares);
4) number of proposed methods suitable for operational use in forest management planning (high-cost effectiveness) (unit: count);
5) number of datasets provided for the European Data Centre (unit: count);
6) number of individuals reached by demonstration events (e.g., demonstration flights and seminars) and networking (unit: count);
7) number of visits of project website (unit: count);

8) number of visits of project videos (unit: count);
9) number of publications/report (unit: count);
10) use of drones as aerial survey platforms instead of manned aerial vehicles (airplanes or helicopters) in the demonstration sites (unit: hectares).

Indicators 1-5 refer to sustainability of forest management, indicators 6-9 refer to public awareness, and indicator 10 refers to reduction of emissions.
The selected indicators have been computed at the beginning of the project (year 2015), at the date of the Mid-Term Report (year 2017), and monitored on a per year basis for the project duration until the end (year 2019) (Tables 5-14).

Demonstration site	Total area	Forest area managed with a forest management plan			
		2015	2017	2018	2019
	ha	ha	ha	ha	ha
Bosco Pennataro	277	277	277	277	277
Caprarola	240	240	240	240	240
Rincine	276	276	276	276	726

Table 12. Forest area in the demonstration sites managed with a forest management plan approved by the competent authority (updated on December 2019).

SFM indicator	Map							
	2015		2017		2018		2019	
	Yes	No	Yes	No	Yes	No	Yes	No
European Forest Types	0	1	1	0	1	0	1	0
Growing stock	0	1	1	0	1	0	1	0
Age structure and/or diameter distribution	0	1	0	1	1	0	1	0
Forest damage	0	1	1	0	1	0	1	0
Tree species composition	0	1	1	0	1	0	1	0
Naturalness (Area covered by introduced tree species)	0	1	0	1	1	0	1	0
Deadwood (Aboveground Biomass)	0	1	0	1	1	0	1	0
Count	0	7	7	0	7	0	7	0

Table 13. Number of SFM indicators taken into account for mapping purposes (updated on December 2019).

SFM indicator	2015	2017	2018	2019
	ha	ha	ha	ha
European Forest Types	0	793	793	793
Growing stock	0	276	793	793
Age structure and/or diameter distribution	0	0	793	793
Forest damage	0	793	793	793
Tree species composition	0	793	793	793
Naturalness (Area covered by introduced tree species)	0	0	276	276
Deadwood (Aboveground Biomass)	0	0	793	793
Count	0	2379	5034	5034

Table 14. Forest area mapped per each SFM indicator (updated on December 2019).

Methods	Map							
	2015		2017		2018		2019	
	Yes	No	Yes	No	Yes	No	Yes	No
European Forest Types classification	0	1	1	0	1	0	1	0
Growing stock assessment	0	1	1	0	1	0	1	0
Age structure and/or diameter distribution assessment	0	1	0	1	1	0	1	0
Forest damage assessment	0	1	1	0	1	0	1	0
Tree species composition classification	0	1	1	0	1	0	1	0
Naturalness classification	0	1	0	1	1	0	1	0
Deadwood assessment	0	1	0	1	1	0	1	0
Count	0	7	4	3	7	0	7	0

Table 15. Number of proposed methods suitable for operational use in forest management planning (high-cost effectiveness) (updated on December 2019).

Data	Map							
	2015		2017		2018		2019	
	Yes	No	Yes	No	Yes	No	Yes	No
Inventory plots	0	1	3	0	3	0	3	0
Map of European Forest Types	0	1	3	0	3	0	3	0
Map of growing stock assessment	0	1	1	0	3	0	3	0
Age structure and/or diameter distribution database	0	1	0	1	3	0	3	0
Map of forest damage	0	1	3	0	3	0	3	0
Maps of tree species composition	0	1	3	0	3	0	3	0
Map of naturalness	0	1	0	1	1	0	1	0
Map deadwood	0	1	0	1	3	0	3	0
Count	0	8	13	3	22	0	22	0

Table 16. Number of datasets provided for the European Data Centre (updated on December 2019).

Type of event	2015	2017	2018	2019
	Num.	Num.	Num.	Num.
Demonstration flights	0	260	100	50
Seminars	0	100	300	400
Networking	0	150	200	250
Other demonstration events	0	200	200	300
Count	0	710	800	1000

Table 17. Number of individuals reached by demonstration events (demonstration flights and seminars) and networking (updated on December 2019).

2015	2017	2018	2019
Num.	Num.	Num.	Num.
812	16747	23000	28000

Table 18. Number of visits of project website (updated on December 2019).

2015	2017	2018	2019
Num.	Num.	Num.	Num.
0	181	1614	2500

Table 19. Number of visits of project videos (updated on December 2019).

2015	2017	2018	2019
Num.	Num.	Num.	Num.
0	5	7	10

Table 20. Number of publications (papers/abstracts) (updated on December 2019).

Demonstration site	2015		2017		2018		2019	
	Drone	Airplanes or helicopters	Drone	Airplanes or helicopters	Drone	Airplanes or helicopters	Drone	Airplanes or helicopters
	ha	ha	ha	ha	ha	ha	ha	ha
Bosco Pennataro	0	0	647	64**	-	-	-	-
Caprarola	0	0	393	0	-	-	-	-
Rincine	0	276*	630	58**	-	-	500	-
Total	0	276	1670	122	-	-	500	-

Table 21. Use of drones as aerial survey platforms instead of manned aerial vehicles (airplanes or helicopters) in the demonstration sites (updated on December 2019).

* Area covered in 2015 by a helicopter with a Lidar sensor before the project start date; this data has been acquired in Action B1 as existing data available for the site of Rincine.

** Net area added by helicopter (excluding duplicated areas).

Since the project start date, the following progress can be observed:

1) forest area in the demonstration sites managed with a forest management plan approved by the competent authority (unit: hectares): in forest complex of Rincine the potential of the Forest Information System provided by the project has led the forest manager to extend the surveys from the demonstration site to the entire forest in order to have the data necessary to base the new management plan on the methodologies developed by FRESh LIFE project, the same will happen soon in the Natural Reserves around the demonstration sites of Bosco Pennataro (Table 5);
2) number of SFM indicators taken into account for mapping purposes (unit: count): before the project start date, no maps of SFM indicators were available in the demonstration sites, as is customary to current forest management practices in Italy, both for private and public forest properties; at the end of the project period, thanks to the activities developed by FRESh project especially in Action B3, the number of SFM indicators taken into account for mapping purposes has significantly improved, at least in the demonstration sites (Table 6);
3) forest area mapped per each SFM indicator (unit: hectares): the mapped area has increased to cover all the demonstration sites exceptions for some specific indicators that due to their estimation methods resulted no-consistency for the demonstration sites (Table 7);
4) number of proposed methods suitable for operational use in forest management planning (high-cost effectiveness) (unit: count): the project is demonstrating that the proposed method for mapping SFM indicator using similar data to that acquired in Actions B1 and B2 and the methodological approaches adopted in Action B3 are suitable for operational use in forest management planning (Table 8);
5) number of datasets provided for the European Data Centre (unit: count): since the project start date, the number of datasets has significantly improved thanks both to the forest inventory data acquired in Actions B1 and B2, and to the maps generated in Action B3 (Table 9);
6) number of individuals reached by demonstration events (e.g., demonstration flights and seminars) and networking (unit: count): the analysis of this indicator give important information about the change in perception about the project topics. The demonstration flights with drones were more participated in the first years demonstrating that these new technologies for forestry applications were still unknown in the Italian context. With the increase of knowledge, in the following years, the attention has shifted on other types of events more related on the results presentation and potentiality discussions (Table 17).
7) number of visits of project website (unit: count): since the project start date the number of visit of project website has increased year by year (Table 18), demonstrating the effectiveness of communication strategy adopted by FRESh project, also to improve public awareness about environmental problems and SFM;
8) number of visits of project videos (unit: count): video is a very appealing communication tool, as demonstrated by the progress of this indicator (Table 19); at the end, two videos were realized and published on our YouTube Channel together with the ones filmed during the events. Starting from 2018 this indicator takes also into account the visualizations of videos posted on our Facebook Page for the online streaming.
9) number of publications/report (unit: count): at the end of the project 10 pubblication were preparated and published on national and international scientific journal (Table 20). The first were related more to the acquisition and elaboration methodologies while the last explore the potential of the management tools created by the project.
10) use of drones as aerial survey platforms instead of manned aerial vehicles (airplanes or helicopters) in the demonstration sites (unit: hectares): since the project start date, the area covered by flights carried out by helicopter in the demonstration sites has decreased by almost 56%, while the area covered by drone has significantly improved (Table 21), contributing positively to the reduction of emissions from fossil fuels, at least in the demonstration sites. The estimate of this indicator stopped at the end of 2017 when the acquisition was completed and all the area of the demonstration sites were covered. On 2019 we had a new acquisition campaign due to the upscaling of the project FIS in the area around the demonstration site of Rincine.

<u>Economic and social benefits</u>

Taking into account the interest generated by the project about the potential uses of new technologies in forest management, forest inventory and forest monitoring applications, our impression is that:

- cost saving opportunities are expected when mapping SFM indicators is a target for forest management. Here below (Figure 26) we report some information about the average cost of the three data collection and processing techniques applied in FRESh LIFE SFM indicators mapping process. The cost of traditional field survey, regarded as "business as usual", amounts to more than one third of the total cost. More details about the economic viability of the methodologies proposed by the project were discussed in the deliverables of Action B3 "*Report on the technical and economic viability of using high spatial resolution optical data to stratify by EFTs*" and "*Report on the technical and economic viability for estimation of growing stock and above ground biomass*".

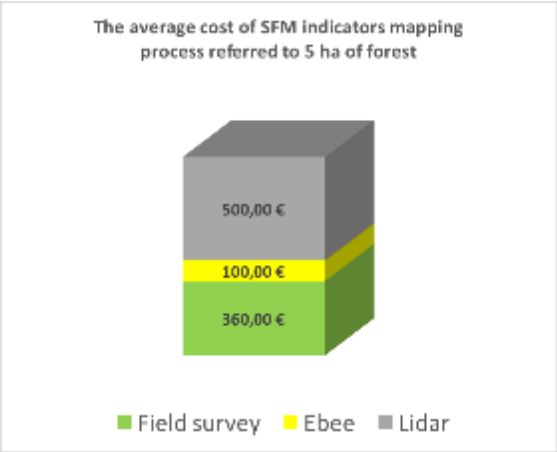

Figure 26. Cost Analysis

- new business opportunities are possible in the near future, for instance for private company or spin-off dealing with drone, remote sensing data analysis and Forest Information Systems development for forest inventory and forest monitoring. In fact, some Private and Public forest companies involved in Forest Management activities have request to Bluebiloba Spinoff of University of Florence that was born also thanks to FRESh LIFE, to implement in the next three years FIS in their forests. These requests were received by UNIFI, DEMETRA and BLUEBILOBA after dissemination activities because the companies were able to understand the economic benefits of FIS implementation and the use of data acquired in UAV to reduce the cost of forest management planning activities. These companies, in partnership with Bluebiloba, DEMETRA and UNIFI are applying to have some found from the measures or Rural Development Plans related to Innovation such as measure 16.2 and 16.1 in order to cover a part of the cost of customized Forest Information System and data acquisitions.
  So, the FreshLIFE was able to open new markets for private companies thanks to the possibilities to demonstrate concretely to Forest Companies that UAV data and FIS are able to improve the quality of daily forest companies work improving the quality of information reducing the costs.

- new job opportunities are expected in the near future, as the new technologies implemented in the project are becoming more and more a tool used in different disciplines; the interest on these new technologies was well demonstrated by the number of participants to the dissemination events and the number of visitors to our web-based communication tools. This part was discussed in details in the deliverable of Action C3 "*Analysis of post-project assessment*" that is attached to this Final Report. Performing the post-project situation analysis, we explored the changes in employment and income levels from the forest sector for each demonstration sites.

Replicability, transferability, cooperation

The project methodologies present innovative solutions for some key aspect of the Sustainable Forest Management such is, for instance, the management plan. We already presented the replication efforts started in the demonstration sites of Rincine and in the Natural Reserve of Vallombrosa (see section 6.1.5) and the transfer of skills actuated with the GOSURF project in Tuscany and with other public bodies in Friuli Venezia Giulia and Molise (Deliverable Action B5 "*Guidelines for improving regional and national forest policy tools*"). Again on the transferability of the project results, in a cooperative point of view, we highlighted all the networking activities in the deliverable of Action D7 "*Networking Final Report*" that is attached to this Final Report. During the four years of project we had a lot of occasion to share first the methodologies proposed, by testing it in other projects actions, and second the results achieved in the form of best practices lessons.

Best practice lessons

During the last year of project, we were selected by the LIFE project GOPROFOR as a Best Practices. The project aims to "distill" the GOOD PRACTICES.from LIFE projects of forestry interest realized throughout the European Union between 1992 and 2018. For good practice they mean an instrument for the application of nature conservation, in relation to forest themes in a broad sense. The good practice must be.validated, possibly through scientific evidence, in detail described and, therefore, perfectly replicable. After a validation procedure the Forest Information System that we produced for the demonstration sites was included in the best practices database (*https://www.lifegoprofor-gp.eu/best-practice/115/ita*).

Figure 27. LIFE project GOPROFOR – Best Practices

Innovation and demonstration value

The project has a high innovation and demonstration value, both at national and international level. We discussed this point deeply in the section 6.1.5 talking about the innovations that results achieved by our project could have in the policy tools at national level and in the European Forest Strategy. Lesson learned and products could be useful to implement forest law and planning activities on the way to Sustainable Forest Management. The technologies used, like RPAS and data derived, gave to our project an extremely innovative connotation if we think at ante-project situation of five years ago when these kind of systems were totally unknowing in the forest sector. This has given to our project a high demonstration value, especially in the first years when the demonstration flights that we organized were the first occasions to see this kind of technologies in action for many employees of the forest sector. More details about the demonstration value of the project are discussed in the section 6.1.14 and 6.1.15 as well as in the tables 11-13 of the previous sections were that value was reported in a quantitative way.

Policy implications

This topic was already discussed in several parts of the report so we refer to the section 6.1.5 regarding the Up-Scaling activities, to the section 6.1.13 about the Report for Policy Makers and to all the related products such as the "*Guidelines for improving regional and national forest policy tools*" and the "*Report for Policy Makers*" both annexes (DELIVERABLE 01 - Deliverable Action B5- Guidelines for improving regional and national forest policy tools; ANNEX 02 – Report for Policy Makers) to this Final Report. A summary of the policy implication was also included at the end of section 6.3.

7. Project Specific Indicators

The key project indicators (KPI) were updated on line and re-submitted at the end of the project following the indication provided by the monitoring team NEEMO. The online form was compiled by indicating all the indicators considered relevant for the project activities. The excel file of the submitted indicators is annexed to this report as Deliverable of Action E3 "Indicators submitted with Final Report" (DELIVERABLE 04 - Action E3 "Indicators submitted with Final Report).

The list of KPI is as follow:

- 1.5 Project area/length
- 1.6 Humans (to be) influenced by the project
- 4.2.1 Sustainable Forest Management
- 4.2.2 Provision of forest datasets for the European Data Centre
- 7.3 Natural and semi-natural habitats
- 11.1 Website
- 11.2 Other tools for reaching/raising awareness of the general public
- 12.1 Networking
- 12.2 Professional training or education
- 13. Jobs
- 14.1 Running cost/operating costs during the project and expected in case of continuation/replication/transfer after the project period
- 14.2.1 Capital expenditure expected in case of continuation/replication/transfer after the project period
- 14.3 Future funding

- 14.4.3 Entry into new geographic areas

1.5 Project area/length
At the end of the project the conservation or improvement of the status of the project area in the specific contexts has been reached. In the demonstration site of Rincine (Specific context: Continental Firenze), the methods used by FRESh LIFE project to map SFM indicators with remote sensing technologies will be extended from the area of the demonstration site to a larger area in order to update the new forest management plan for all the forest managed by UCVV. Thus, 5 years beyond we can expect that in Rincine the conservation or improvement of the status of the project area will cover about 800 ha. In addition, the approach developed by FRESh LIFE project to map the growing stock volume has been replicated in the Nature Reserve of Vallombrosa over an area of about 1200 ha to update the forest management plan of the Reserve and to create a Forest Information System.

1.6 Humans (to be) influenced by the project
The use of new remote sensing technologies proposed by our project for forestry applications, specially the use of UAV, have a great appealing for forest operators but also for students and the citizens of the demonstration sites. For this reason, the number of humans influenced by the project was high. This indicator has been quantified taking into account the total number of participants to demonstration flights at the end of the project (Tab. 10, section 6.4).

4.2.1 Sustainable Forest Management
The objective of adapting forest management to sustainability criteria has been reached in each specific context. At the end of the project, the area of all demonstration sites is managed based on the SFM approach. In the site of Rincine (Specific context: Continental Firenze) the area under SFM has been extended from the area of the demonstration site to a larger area of about 730 ha (Tab. 5, section 6.4) using the methods implemented by FRESh LIFE project to map SFM indicators for the entire forest managed by UCVV. For this reason, 5 years beyond we can expect that in Rincine the area under SFM will cover about 800 ha.

4.2.2 Provision of forest datasets for the European Data Centre
The target of providing forest datasets for the European Data Centre has been reached in each demonstration site. As reported in Tabs. 6 and 7 (section 6.4) a total of 6 SFM indicators has been taken into account for mapping purposes in each specific context, and a map for each SFM indicator has been provided in each demonstration site. In the site of Rincine (Specific context: Continental Firenze) 7 SFM indicators have been mapped, including the indicator Naturalness, which was not considered in remaining sites because no introduced tree species were present. The number of forest datasets provided for the European Data Centre ranges between 7 in the sites of Bosco Pennataro and Caprarola and 8 in the site of Rincine (Tab. 9, section 6.4). All the data set produced by our project are correlated with metadata following the INSPIRE instructions that facilitate their use in the European context.

7.3 Natural and semi-natural habitats
The area of existing natural and semi-natural habitats and their status in the demonstration sites has been stable during the project duration, as foreseen at the beginning of the project. The spatial datasets produced by our project in each demonstration site with remote sensing technologies provide additional information to forest manager to monitor the impact of climate changes on forest resources.

11.1 Website
The project website was an important tool to reach the general public. At the end of the project the total number of visits of the website was equal to 28000 (Tab. 11, section 6.4). We estimated that the num. of unique visits was done by about 5000 individuals, with an average visit duration of about 5 minutes. We estimated that the awareness raising of the general public through the project website was about 2000 individuals.

11.2 Other tools for reaching/raising awareness of the general public
This indicator has been quantified taking into account the following data: number of participants to other demonstration events, number of publications, and number of visits of project video (Tabs. 10, 12, 13, section 6.4). At the end of the project, about 700 individuals participated to other demonstration events, 10 publications were published on national and international scientific journal, and about 2500 visits of project video were registered. We estimated that 600 individuals were reached by publications in each specific context, and 300 individuals were awareness raising in each context. The project video were and will be very useful to reach and raising awareness of the general public. The demonstration events were important to explain to the general public the use of remote sensing technologies for forestry applications and raising the awareness of individuals.

12.1 Networking
The number of individuals reached at the end of the project by networking, seminars, demonstration flights and other demonstration events amounted to about 2500 individuals (Tab. 10, section 6.4). Most of them were not expert on remote sensing technologies. The participation of professionals and students in higher education to these events was great

occasion to improve their awareness on the use of new remote sensing technologies for forestry applications.

12.2 Professional training or education
This indicator has been quantified taking into account the number of participants to seminars at the end of the project, which was about 800 participants (Tab. 10, section 6.4). The seminars were very useful to train students in higher education, professionals, members of interest groups, and laymen,

13. Jobs
For Job, the num. of expected FTE is confirmed at the end of the project.

14.1 Running cost/operating costs during the project and expected in case of continuation/replication/transfer after the project period
The economic viability considerations carried out in our project to process indicators maps show that, despite the cost of business as usual, i.e. traditional forest inventory in sample plots is lower than the cost of remote sensing derived maps, the final benefits of the two approaches cannot be compared. In fact, in ordinary field work the value of the indicators is known only for a relatively small fraction of the sampling surface, while spatial model derived from remote sensing data allow the spatial estimation of SFM indicators over all the forest surface. In addition, once the remote sensing data have been collected the cost expected in case of continuation after the project period is lower.

14.2.1 Capital expenditure expected in case of continuation/replication/transfer after the project period
To assess this indicator we did an overall estimation of the capital expenditure needed to acquire equipments/tools to be used for setting up the method to be replicated/transferred in the Mediterranean and Continental regions.

14.3 Future funding
To assess this indicator we did an overall estimation of the beneficiaries'own contribution (e.g. University) for setting up the method to be replicated/transferred in the Mediterranea and Continental region.

14.4.3 Entry into new geographic areas
The territories where we expect to replicate/transfer our project are located in Central Italy. In particular, the method used in our project to map the growing stock volume has been already replicated in the Tuscany Region in following territories: a) in the Nature Reserve of Vallombrosa over an area of about 1200 ha; b) along the Tuscan coast to assess the volume in stone pine forests over an area of about 10660 ha.

8. Comments on the financial report

8.1 Summary of Costs Incurred

Complete the following table to show the project costs incurred compared to the approved budget and comment on each of the cost categories focussing particularly on discrepancies compared to the allowed flexibility of the 20% limit (cf. Article II.22 of the General Conditions).

PROJECT COSTS INCURRED				
	Cost category	Budget according to the grant agreement in €*	Costs incurred within the reporting period in €	%**
1.	Personnel	2.016.418	1.956.220	97,0%
2.	Travel and subsistence	181.800	90.883	50,0%
3.	External assistance	242.160	385.778	159,3%
4.	Durables goods: total non-depreciated cost	88.350	52.396	59,3%
	- *Infrastructure sub-tot.*			
	- *Equipment sub-tot.*	*88.350*	*52.396*	*59,3%*
	- *Prototype sub-tot.*			
5.	Consumables	38.400	27.497	71,6%

6.	Other costs	113.866	131.103	115,1%
7.	Overheads	173.985	182.420	104,8%
	TOTAL	2.854.979	2.826.297	99,0%

*) If the EASME has officially approved a budget modification through an amendment, indicate the breakdown of the revised budget. Otherwise this should be the budget in the original grant agreement.
**) Calculate the percentages by budget lines: e.g. the % of the budgeted personnel costs that were actually incurred

8.3 Partnership arrangements

Partnership financial arrangements are described in detail in the Operative Manual (E1 action project deliverable, annex attached in the previous Progress Report) that were distributed and deeply explained to all administrative representatives.

Each beneficiary is expected to enter information in its own financial tables and to submit (using a specific cloud folder, initially on Dropbox platform, from 2018 on Owncloud platform) the updated tables to the CB every three months, together with the electronic copies of the timesheets and the copies of receipts and invoices, with a clear reference to the project.
Furthermore each beneficiary annually submit to the CB, via cloud platform, the copies of this documents, bearing the project stamp and signature for a certified copy. The expenditure should be divided by category of expenditure and in ascending chronological order.
All other financial documents (pay slips, bank transfers, purchasing orders and much more) should not be submitted to the CB but should be readily available in paper and electronic format from each beneficiary for 5 years following the conclusion of the project.
The CB is responsible for the global financial reporting implementation, on the basis on each beneficiary's financial table.

8.4 Certificate on the financial statement

In Accordance with Art. II.24.2, the official registration number, organisation, full name and address of the approved auditor or competent and independent public officer who are to establish the certificate for the payment of the balance, shall be included in the signed payment request. The auditor's report (to be included with the final financial report) must follow the format of the standard audit report form available on the LIFE website.

As described in letter amendment n°1 to Grant Agreement LIFE FRESh received from EASME in 2016 December (EASME.B.3/AS ARES(2016) 7353988 – the article II.23.2 of General Conditions provides the certificate on financial statements only for the beneficiaries for which the total contribution in reimbursement form is at least 325.000 €.

None of the FRESh LIFE project beneficiaries reaches this amount and therefore we do not expect to appoint an external independent auditor.

8.5 Summary of costs per action

Action type	Budgeted person-days	Estimated % of person-days spent
All projects when applicable Action A: Preparatory actions		
NAT and CLIMA projects Action B: Purchase/lease of land and/or compensation payment for payment rights		
ENV projects Action B: Implementation actions	7.787	103%
GIE projects Action B: Core actions		
NAT projects Action C – Concrete conservation actions		

CLIMA projects Action C: Implementation actions		
ENV and GIE projects Action C: Monitoring of the impact of the project action	1.171	101%
NAT and CLIMA projects Action D: Monitoring and impact assessment		
ENV and GIE projects Action D: Public awareness/61ommunication and dissemination of results	1.907	79%
NAT and CLIMA projects Action E: Communication and Dissemination of results		
ENV and GIE projects Action E: Project management	2.171	112%
NAT and CLIMA projects Action F: Project management (and progress)		
TOTAL	**13.036**	**101%**