DEMONSTRATING REMOTE SENSING INTEGRATION IN SUSTAINABLE FOREST MANAGEMENT

FRESh LIFE

REPORT FOR POLICY MAKERS

LIFE 14 ENV/IT/000414

FRESh LIFE

“Demonstrating Remote Sensing integration in sustainable forest management”

LIFE Project Number
LIFE14 ENV/IT/000414

PARTNER

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Contents

FRESh Life project steps

DATA ACQUISITION

- Inventory data (position, plants list and aggregated data from the existing plots);
- Remote sensing data (orthophotos, multispectral and LiDAR data);
- Management plans with their maps;
- Auxiliary data (topographic maps, land use maps, etc.).

FOREST INVENTORY DATA COLLECTION

50 squared plots of 23mx23m (plot size = 529 m²) have been sampled where all plants (trees and shrubs) with a dbh > 2.5 cm were inventoried. The spatial position of the inventory plots (x, y coordinates of the centre of the plot) were acquired with GNSS receivers with a sub-meter accuracy. The following information were measured in each plot:

- Position, species, diameter, height, crown area, health status, and microhabitat of living trees;
- Position, diameter, height, and decay class of standing dead trees, stumps and down deadwood.

REMOTE SENSING DATA ACQUISITION

From the images acquired with eBee the following products have been elaborated:

- 2 point clouds (RGB and NIR) with an average of 20-40 points/ m²;
- 2 Digital Surface Models (DSM) with spatial resolution of 50 cm;
- 2 orthophotos (RGB and NIR) with spatial resolution of 10 cm.

From the LiDAR data we obtained the following products:

- Dense points cloud with an average of 70-120 points/ m²;
- Digital Terrain Model (DTM) with spatial resolution of 50 cm;
- Digital Surface Model (DSM) with spatial resolution of 25-50 cm;
- Canopy Height Model (CHM) with spatial resolution of 50 cm.

SUSTAINABLE FOREST MANAGEMENT INDICATORS MAPPING

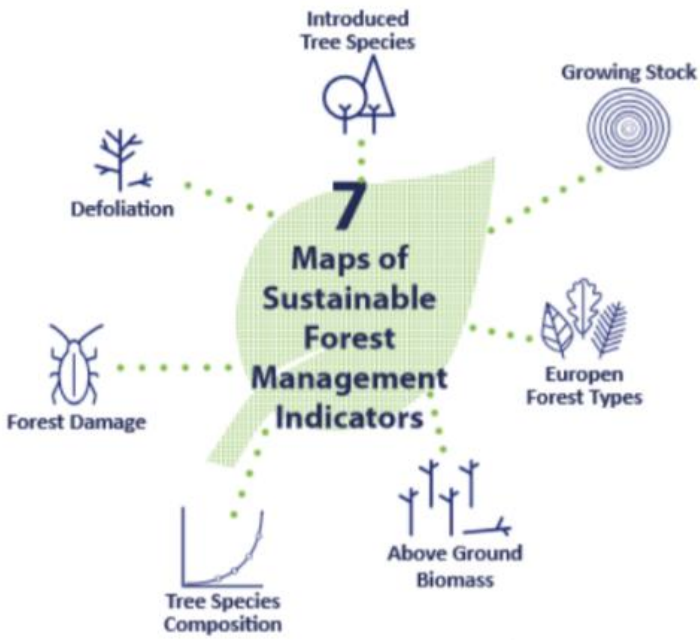
Indicators derived from ***multispectral data***

- Map of the European Foret Types (EFTs);
- Defoliation;
- Forest Damage;
- Tree Species Composition;
- Introduced Tree species. Indicators derived from LiDAR data
- Growing Stock;
- Above Ground Biomass.

FOREST INFORMATION SYSTEM (FIS)

To provide managers of the study sites with a useful forest management support tool, all data acquired and processed within the FRESh LIFE project were organized in a GIS-based FIS. A georeferenced data package was prepared in order to use GIS software used by managers and local foresters who were trained fore it’s use.
All data collected during the project were stored in the FIS provided at the scale of the forest management units.

Challenges to map Sustainable forest management Indicators



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 sustainable forest management in Europe region six rigorous, scientifically and policy robust headline criteria were endorsed, measured by a set of quantitative and qualitative 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. 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 of medium- to large size (i.e. hundreds to several thousand 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.

FRESh LIFE innovative methods

Climate change is an unprecedented challenge and significantly impacts the functioning of forest ecosystems and the services they provide. The complex nature of climate change increases the uncertainty associated with predicting future forest ecosystem dynamics and requires an adaptive management approach. Forest managers therefore need monitoring and analysis tools to assess the current conditions of forest resources and their capacity to supply ecosystem services. Geographic information systems (GIS) and remote sensing are useful tools to quantify sustainable forest management (SFM) indicators to support local decisions.

SFM is widely recognized as a key objective of forestry policy and practices. To monitor, evaluate, and track progress toward SFM in Europe at the regional, national and international levels six key criteria were adopted and measured through a suite of quantitative and qualitative Pan-European indicators of forest management.

The FRESh LIFE – Demonstrating Remote Sensing Integration in Sustainable Forest Management (LIFE14/IT000414) project aims to develop innovative methods to integrate forest inventory data collected in the field with remote sensing information to estimate selected SFM indicators across space at the local scale. Within the project, high-resolution data were collected at three sites in central Italy using drones equipped with light detection and ranging (LiDAR) and optical sensors. Automated and semi-automated mapping methods were then used to spatially characterize the variables used to assess forest physiognomy and conditions at the scale of the forest management unit.

Benefit of FRESh Life in Demonstration Sites

RINCINE

The potential of the Forest Information System (FIS) provided by the project has led the managers to consider the possibility of extending the surveys from the demonstration site to the entire forest to have the data necessary as a basis for the new management plan based on the methodologies developed in FRESh LIFE. The growing stock data, provided by the FIS at the scale of the single forest unit, are extremely useful, for example, in preparing timber auctions.

CAPRAROLA

The demonstration area is subjected to ancient public land use requirements, such the right for local community's members to collect fallen wood for firewood. In addition, as Caprarola test site is included in a Regional Natural Reserve, the public accessibility and use of the area for leisure activities is a high priority, although forest ageing may cause tree/branch collapse incidents, posing danger to visitors. In this perspective, the Forest Information System provided by the project can offer a concrete opportunity to support local forest management decision-making in regulating and improving the public use of the forest.

BOSCO PENNATORO

The cartographic approach of FIS is very useful to support local forest decision making. It allows to collect and store data to produce several thematic maps that are highly useful to display the state of forest and to support discussion among forest decision makers involved in the management. The thematic maps offer the opportunity to have common documents to discuss and take decision about forest harvesting and other forest-related activities

Standardization in field data acquisitions

The first action of the project B.1 had the aims to acquire existing field data for the demonstration site. The first step was to acquire the data of the forest management plans.

At the end of the data collection we found that there were a lot of differences among data available for the three demonstration sites. Firstly, forest inventory plots where not standardized in sample scheme, size, and in field protocol measurements, while the standardization in field acquisition is necessary when SFM indicators need to be compared each other's. Secondary, in the demonstration sites, the estimation of the growing stock in the inventory plots was carried out using different volume tables.

The not standardization of data was due to differences in forest regulations among different Italian regions and European countries. Moreover, the different Italian forest regulations do not report a standard scheme to follow to acquire field forest inventory plots for forest management plans because they follow the traditional way to acquire field data and leave to each forest technician freedom in choosing the protocol. So, forest technicians traditionally locate the plots with subjective criterion and without following a rigorous sample schema. In the action B.2 of the project we demonstrated that the use of standard field sampling, following a rigorous field data acquisition protocols, that mimic the one of Italian National Forest Inventory, is useful to acquire standardized data to quantify SFM indicators among different demonstration sites placed in three different regions.

For our experience in FRESh LIFE, the policy makers need to consider the possibilities to add in the forest regulation an article that identifies a standardized methodology (i.e. sampling scheme, data acquisition protocol, and volume estimation) to acquire data of forest inventory plots for forest management plans, because, this is important for two reasons:

- **to compare data among different forests and among different forest types;**
- **to use data from different plans to estimate regional SFM indicators.**

We think that the implementation of the new article in the forest regulation is easy because it is possible to add a protocol that mimic the one of Italian National Forest Inventory, for which it is important to remember that:

- **geographic coordinates are acquired with low-cost GNSS;**
- **the area of each field plot is only 530 m^2;**
- **the field data acquisition protocol already exists;**
- **the equation to estimate biomass and growing stock are standardized for the wall Italy and implemented in open-access software (e.g. Package R-CRAN ForIT: Functions from the 2nd Italian Forest Inventory (INFC) - https://rdrr.io/cran/ForIT);**
- **the field sampling scheme is easy to be implemented using a sample GIS Tool.**

We know that a standardization at Eu level could be useful too, but it will be difficult, because National Forest Inventory are different among different EU countries and a European Forest Inventory do not exist now. So, firstly we would like to suggest to EU Commission the implementation of a standardized EU Forest Inventory, that will be useful to quantify SMF Indicator at Eu level, before thinking to standardize the acquisition of forest inventory plots for forest management activities.

Use of Unmanned Aerial Vehicle

The use of Unmanned Aerial Vehicle (UAV) in forest management is particularly advantageous for the following reasons:

- The spatial resolution of drone imagery, in the order of few centimeters, due to the low flying altitude of small drones; this feature augment the capability of visual interpretation of the imagery;
- High temporal resolution: the comparatively lower cost of operation and maintenance of small drones allow users to acquire imagery more frequently than with conventional remote sensing technologies such as commercial satellite and piloted aircraft imagery; possibility of making acquisitions in near real times in the case of specific events;

Possibility to carry out multi-sensor acquisitions due to the availability of UAV equipped with multispectral or LiDAR optical instruments.

In the FRESh LIFE project two UAV were used: an octocopter and a fixed wing.

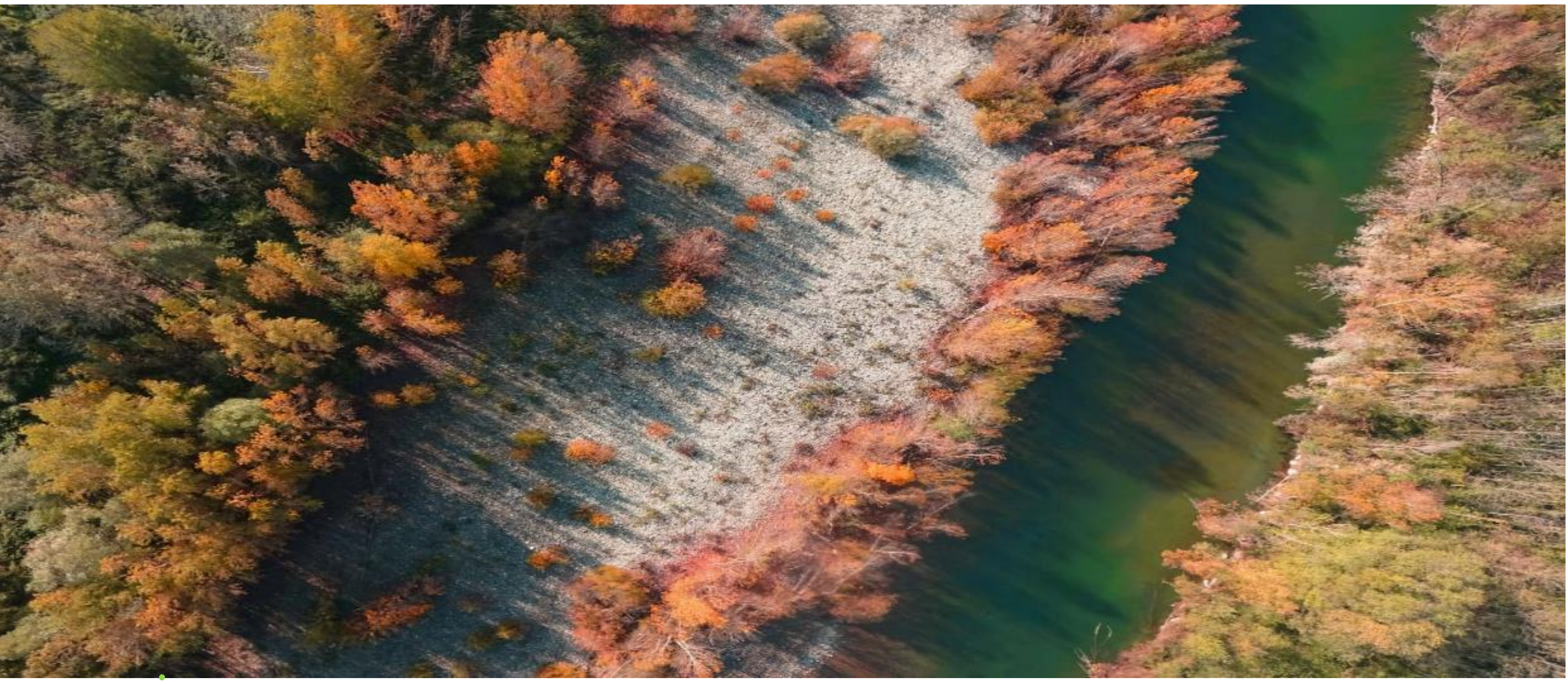
OCTOCOPTER

- Diameter of 1,8 m
- Total weight 15 kg
- Flight range 20 minutes
- Operating height 20 m above the canopy
- Possibility to cover from 20 to 50 ha in a day
- Equipped with ultralight Yellowscan LiDAR that allows to obtain point-clouds with a density of 50 points/m²

FIXED WING

- eBee model from SenseFly
- Camera with RGB and NIR (near infrared) sensors capable of Acquiring high definition multispectral images
- Wingspan 98 cm
- Weighs 700 g
- Maximum flight time of 45 minutes
- Possibility to cover over 60 ha with a single flight
- Created for photogrammetric applications able to create 3D digital models and high resolution orthophotos

Limitations on the use of UAV in forest mapping



The regulation on UAV flight changed three times during FRESh LIFE project and the pilots of our UAV had to update their license of UAV pilots two times. Moreover, the regulation was different among European countries. Fortunately, the new regulation of European Commission on drone rules, that will come into force as of 1st July 2020, have already take in consideration a correction. However, we think that is important to report to policy makers the difficulties that we had using UAV to map forest during FRESh LIFE.

VLOS (Visual Line of Sight) modality of UAV flights was the only one permitted by regulation during the FRESh LIFE. VLOS means that an aircraft without a pilot on board is flown in such a way that the aircraft can always be observed without aids like binoculars, camera or other aids, other than ordinary eyeglasses. Respect this modality of flight was too difficult during the project because acquiring Forest data with the UAV always in visual line of sight with the pilot is complicated. In fact, usually the open area where it is possible to takeoff were in forest open spaces where there were high trees on the border. Usually, immediately after the takeoff the pilot located in the take-off site lost the visual of the UAV. In our case, we mitigated the inconvenient with two pilots placed in two different areas of the forest (one at takeoff place without payload, and one on the top of the mountain equipped with the payload that was in visual line of sight with the UAV) that were in contact each other with VHF receivers.

Another limitation funded on the use of UAV to map forests was related to the permitted distance between pilots and UAV that the regulation identifies in 500 m. The permitted distance was too low, and many takeoffs were needed to respect the rule. The UAV we tested in the project can flight over 20 minutes with a distance from the pilot of 3 km, however, to respect the regulation it was not possible to exploiting their full potentiality. Moreover, it was difficult to find open-spaces useful for take-off to respect the rules "distances between UAV and pilot" because they were limited in our demonstration sites.

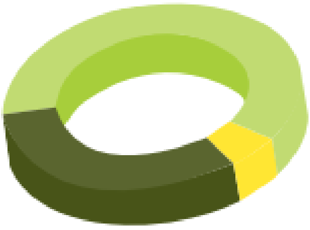
We know, that the new European drone rules have already take in consideration a correction of these limitations opening the possibility to fly in BLOS mode (the ability to operate an unmanned aircraft beyond the pilot's line of sight) and enlarge the distance between pilots and UAV requiring a special permit from the National Civil Aviation Authority (NCAA).

However, the policy makers need to consider the possibilities to classify all the forests, in rural area, as "*low-risk*" in order to open the possibility to flight there using BLOS modality and enlarging distances, without requiring a special permit.

This is important, especially, when UAV are used to map forest disturbances, after extreme events as for example fire and windthrow, because damage need to be map quickly. So, in that condition it is not possible to wait for the times of the authorization from the NCAA and could be important to have the possibility to flight on that area immediately without requiring a permission in order to quantify the damages.

The average cost of SFM Indicators mapping process

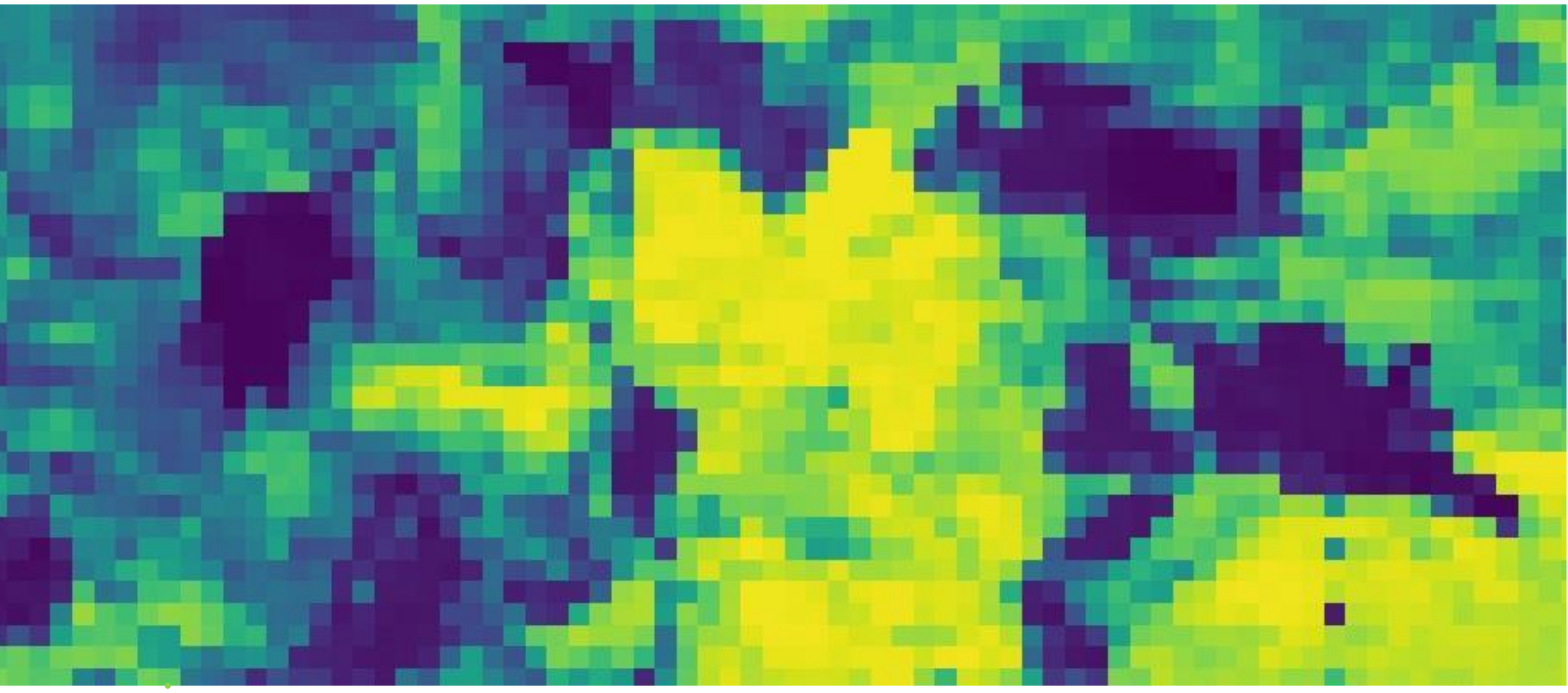
The average cost of SFM indicators mapping process referred to 5 ha and refers to the average cost of the three data collection and processing techniques applied in FRESh Life to map SFM indicators. The cost of traditional field survey, regarded as "business as usual", amounts to more than one third of the total cost.



If we quantify the time required to produce the maps of Forest Europe SFM indicators:

- Defoliation
- Forest damage
- Number of tree species
- Area covered by introduced tree species

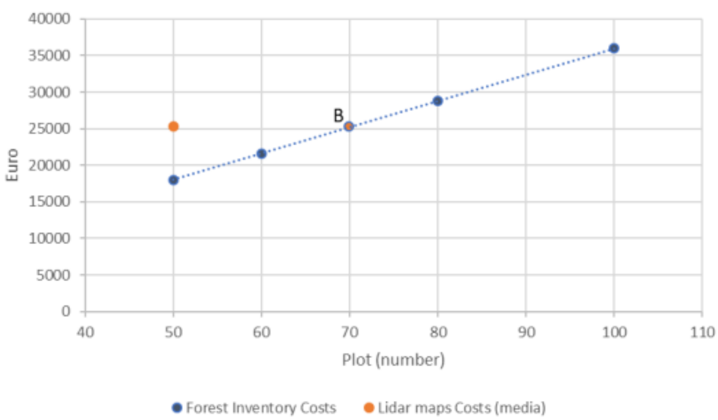
We can report that the time is compared to the time spent for field data collection in the 50 sample plots for the same indicators, as recorded in the specific data collection sheet. Based on cost analysis in the three test sites, the total cost of SFM indicators maps at the forest compartment level by remote sensing is largely influenced by the cost of photogrammetric UAV data acquisition rather than the labor cost of visual interpretation of UAV images. Overall, the economic feasibility of using fix wing photogrammetric UAV images to map SFM indicators is demonstrated by a total cost for mapping these SFM indicators much lower (4770-5250 €) than costs for field surveys (18000 €). These costs are calculated using the same sampling intensity used in the project (1 plot of 529 m^2 - every 5 ha) and the hourly rate of an experienced professional as result of market prices (40 €/hour).
More importantly, it must be noticed that these two approaches cannot be compared as plot-level information on these SFM indicators is provided only for a very small fraction of the test areas (about 1% of 250 ha)



If we quantify the time required to produce the maps of Forest Europe SFM indicators:

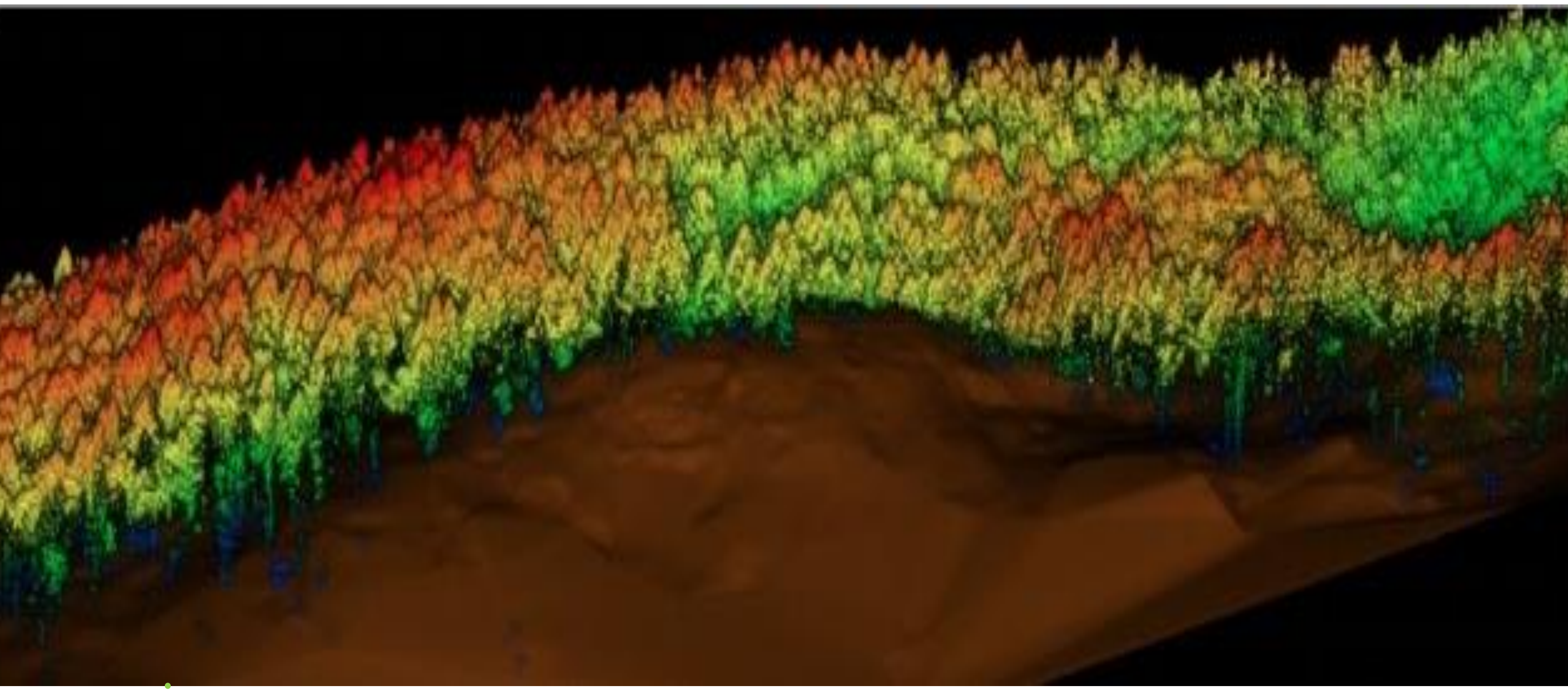
- Growing stock volume
- Biomass

We found that 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 m^2 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 €. 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. At this sampling intensity, the total area covered by sample plots is 3.7 ha, i.e. the 1.4% of the test area.



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.**

Importance of 3D RS data to map SFM



From the start of the project the use of remote sensed (RS) data in forestry has increasing in all EU also thanks to UAVs. FRESh LIFE demonstrated that the use of high-resolution RS data improved the estimation of SFM and give the ability to obtain map that can be used in Forest Information Systems (FIS). On the variety of data that we tested to map SFM, the three-dimensional data, which can describe tree or canopy high, have been demonstrated by FRESh Life to be essential to quantify with high accuracy SFM, especially growing stock volume and biomass.

The three data that we used were obtained by two different UAVs and two different types of RS data:

- LiDAR data from optocopter UAV
- Photogrammetric data from fix-wing UAV.

We demonstrated that LiDAR data acquired by UAV are good data on which it is possible to obtain Canopy Height Model (CHM) because can detect terrain and top canopy structures. However, as mentioned by other authors in literature, in the last years, from 3D photogrammetric data, that can describe the top of forest canopy, it is also possible to derive CHM if the data are used in conjunction with high resolution Digital Terrain Model (DTM).

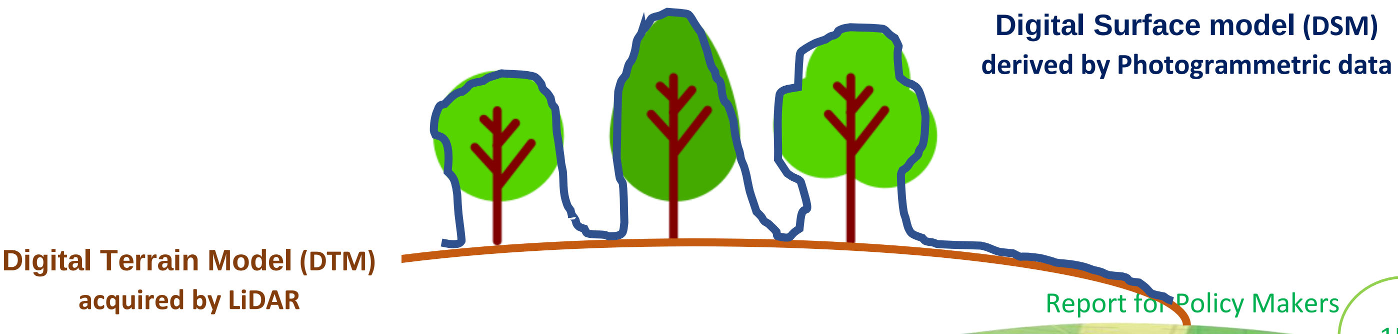
The policy makers need to take into consideration that photogrammetric UAV are less expensive comparing to the one equipped with LiDAR. In fact, in the last two years a lot of photogrammetric UAV, that can flight automatically, are present in the market with a cost of around 1000€. So, if they decided to invest some many in the equipment for their organization may be the use of photogrammetric UAV that can obtain 3D data and optical data could be preferable, comparing to the use of LiDAR UAV.

Moreover, it is important to remark that in some EU countries, as for example the Nordic countries such as Norway, Sweden, Finland, in the past 20 years, the use of airborne laser scanning (ALS) has been widely used for forest inventory purposes and has become the standard data source for operational forest inventories. So, forest managers do not need to acquire these types of data using UAV, reducing a lot of the cost of deriving SFM maps because they can use free available data acquired by the governments. However, in some countries, such Italy, the use of UAV equipment with LiDAR is mandatory because there is not a full cover of ALS data. In fact, in the figure, it is possible to see the available ALS data in Italy that are not present wall-to-wall.

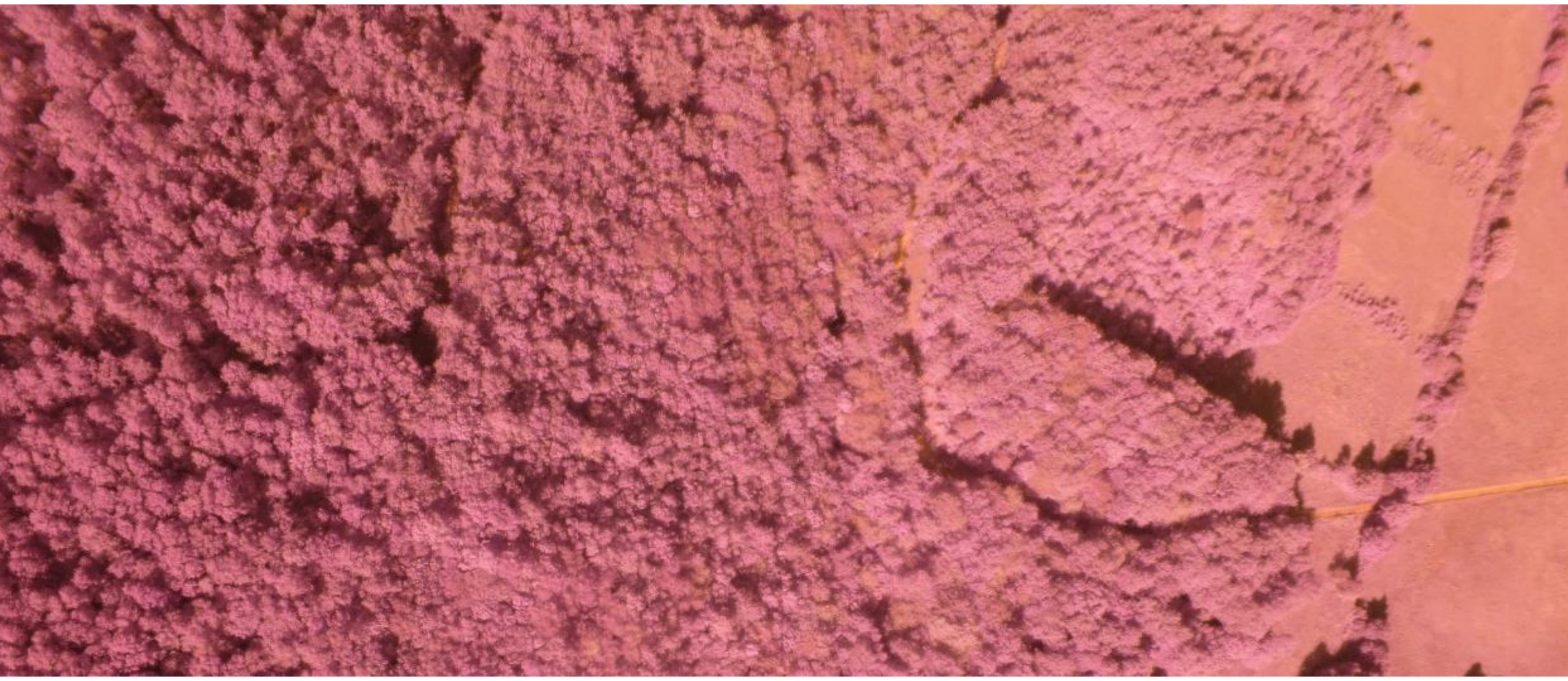
From the experience of FRESh LIFE, we can suggest to the policy makers of countries that do not have a wall-to-wall ALS coverage to try to find financial equipment to conclude the acquisition for the wall-county, because forest owners could be helped to reduce the cost of deriving map of SFMs. In fact, if ALS data will be available wall-to-wall the use of UAVs could be reduced just to update the national data where there are some changes as for example clear-cuts.
Moreover, if a high-resolution Digital Terrain Model from LiDAR is available it is possible to update CHM using low-cost photogrammetric UAV.

Moreover, we would like to report to policy maker that that in the last two years the photogrammetric data acquired by airplane have been demonstrated to be suitable for mapping SFMs for large area. In fact, due to the high costs of repeated acquisitions of LIDAR datasets over large areas, it was demonstrated that combining LIDAR and stereo-photogrammetry is suitable to create CHMs over large areas. This approach would consist of using stereo pairs of aerial photographs for mapping canopy surfaces and using LIDAR for mapping ground topography. Hybrid 'photo-lidar' CHMs would be obtained by computing the difference between these two layers. As ground elevations in most areas remain unchanged over at least a few decades, CHMs could be produced with each new aerial photo survey once a lidar digital terrain model (DTM) had been acquired. Moreover, aerial photos taken at different moments in the past could be used also to map former forest heights, with the possibility of creating long-term retrospective time series of CHMs from historical photographs.

So, we suggest to policy maker to ask to provider that usually already acquire ortomosaic for them over Europe to ask as product of the survey not only ortomosaic, as they already done, but also the 3D data obtained by the stereo-photogrammetry acquisition with airplane because these type of data can help forest managers to map SFMs.



FRESh Life and EU Strategy

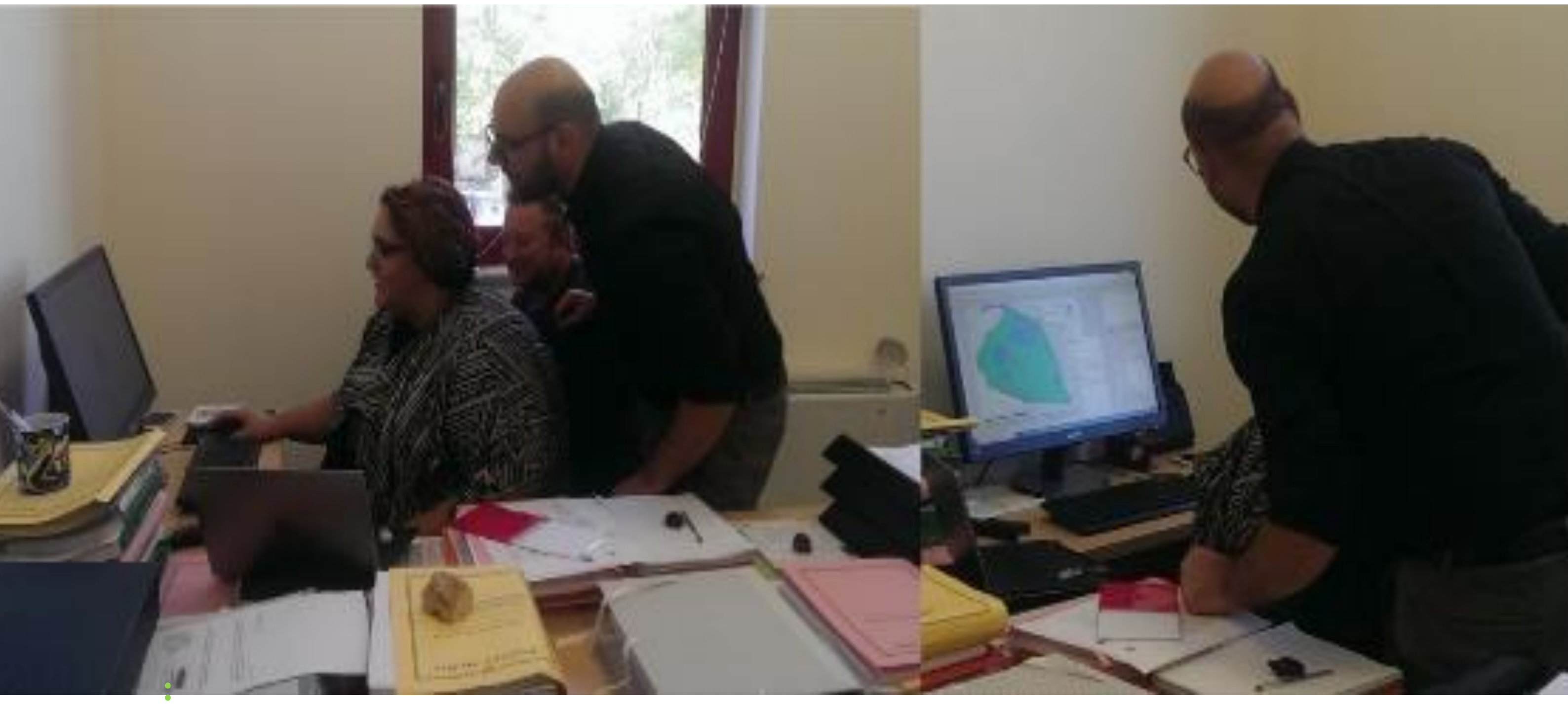


The EU Forest Strategy is the framework to coordinate and ensure coherence in forest-related policies, and to ensure the contribution of EU forests and the forest-based sector to the EU's objectives and targets. The 'Our Forests, Our Future' conference, organized by the EU Commission, took place in Brussels 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 confirm that the Strategy's objectives are:

- ensuring that all forests in the EU are managed according to sustainability criteria;
- 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 circular economy



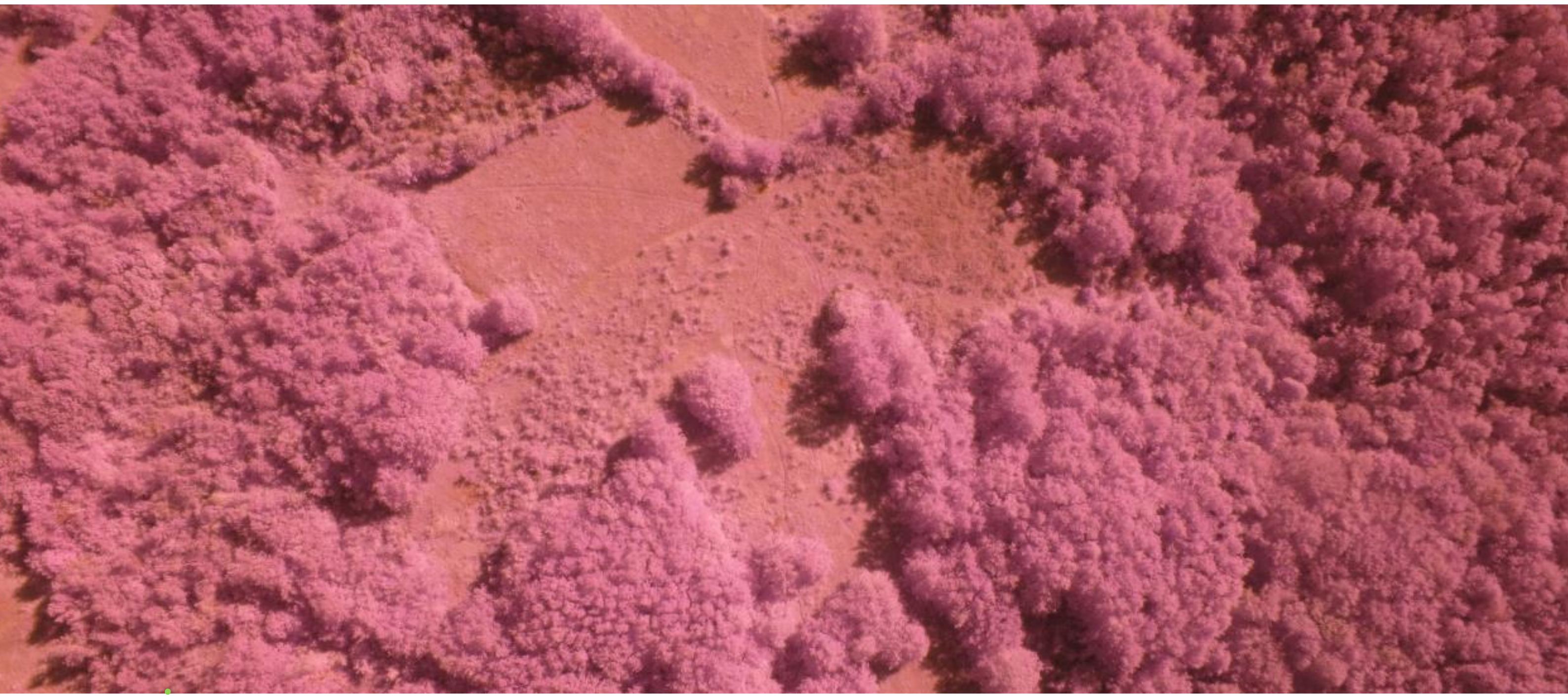
The Eu Forest strategy reported that "Wood and other forest products make an essential contribution to economic growth and to raising living standards. In the EU, they are still a significant source of welfare in some countries and regions" and they reported that "60 % of the EU forests are privately owned, with approximately 16 million forest owners".

We think that 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 this 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 in comprehensible at local level.

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".

So, 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, as say in the previous section, 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



The Eu Forest strategy reported that "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 context, the Sustainable Forest Management is important to maintain and improve the key role of forests and wood in carbon storage and sequestration become. In fact, 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".

In this context, we demonstrated that 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. 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 windstorms, this could be fundamental to monitoring the forest damaging and quickly elaborate information useful to the managers during and after the disasters. Moreover, the advent of new satellites services that gives daily images of the entire globe is also useful in these emergency situations 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 considered 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 changes

The Eu Forest strategy reported that "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)."

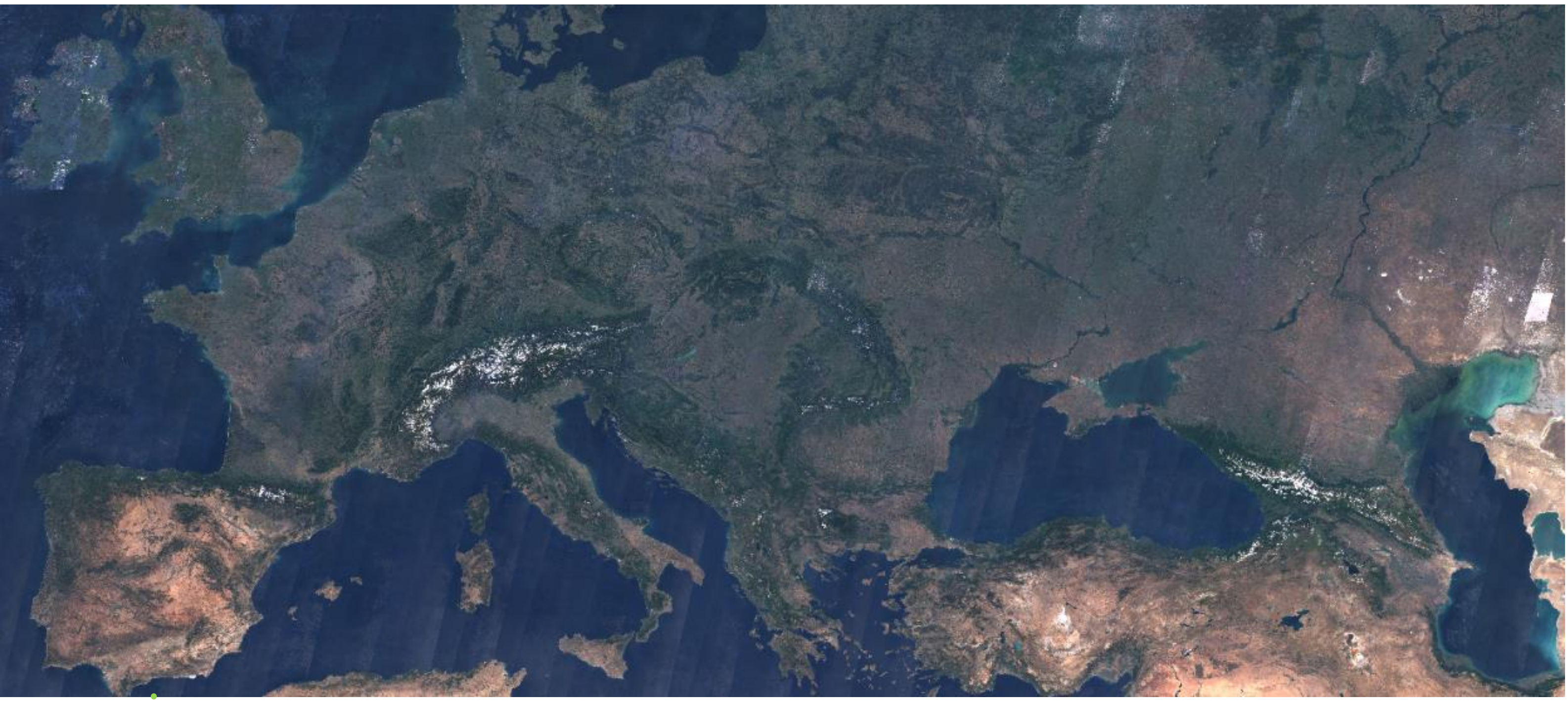
Looking to a Pan-European or international point of view projects such as FRESh LIFE are fundamental due to their harmonized approach. All the methodologies developed in our project are replicable and extensible both in different than in larger area. The project workflow to obtain the SFM indicators 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 Degradation) 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.

We suggest to policy maker to find some economic instrument that can help forest owners to use in their forest companies UAVs and FIS. Some of this economic instrument could be potentially add to the measures in the Rural Development Plans related to innovations.

EU Challenges for policy maker to upscaling the results of FRESh LIFE

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 to the 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 effectiveness by 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, 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, also if the new regulation of EU drone, had tried to answer to that limitation. As say before, 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 acquiring wall-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 has been 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 is to 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 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-2 multispectral 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.

So, we suggest, to Regions and Forest Office of the Ministry of Agricultural, Food and Forestry Policies of Eu countries to include these new methodologies in the new national forest strategies, especially in the countries that do not have a full covered of LIDAR data.

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FRESh LIFE

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