LIFE14 ENV/IT/000414
Demonstrating Remote Sensing integration in sustainable forest management
FRESh LIFE

ACTION B2
New data acquisition

Deliverable
Technical report

Florence, 30/09/2017

Summary

Aims
UNIMOL (University of Molise) is the beneficiary partner responsible for this action. The main aim of Action B2 is to acquire new remote sensing data and new forest inventory data in the demonstration sites. These new data will be 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 is to complete the repository data with the acquisition of those data not yet available in the study areas.
Action B2 has been implemented as follows:

- Assessment of data collected in Action B1;
- Acquisition of new geospatial data;
- Acquisition of new field data.

Milestones e deliverables
In the Action B2, the following milestones and deliverables are expected:

Name of the milestone	*Deadline*
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

Name of the deliverable	*Deadline*
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

Progress
Assessment of data collected in Action B1
The evaluation of the data acquired in Action B1 was carried out based on the requirements necessary to carry out the Action B3 (Mapping SFM indicators), in order to put the ones not available or not suitable in the list of the missing data.
For each demonstration site, the inventories data were evaluated according to the following criteria:
- type of survey;
- size of the sampling plots;
- sampling scheme;
- year of execution;
- precision of the geographical position of the center of the plots.

Regarding the type of survey, only plots with fixed radius were considered suitable for the purposes of the project for the following reasons:
- angle count sampling units (relascope sampling) have different and unknown size and are not suitable for integration with remote sensing data;
- surveys carried out on transect are intensive and are not usually conducted in the context of inventory campaigns.

Regarding the minimum size of the trees to be measured, in all the plots a diameter at breast height (dbh) > 2.5 cm was considered, which is suitable for the project purposes.

However, llots had different size in the demonstration sites, ranging between a minimum of 314 m^2 and a maximum of 1000 m^2. For the purpose of the project, the plots should have the same size and shape in order to be able to compare the results between the different demonstration sites.
In addition, the plots should be selected by a sampling scheme to apply statistical estimators of SFM indicators: this condition is not respected in the areas of Rincine and Caprarola.
Another important criteria for evaluation is the time lag between field data and remote sensing data, which should be not greater than 5 years: this condition is respected only in the area of Bosco Pennataro.
In addition, the precision of the geographical position of the center of the inventory plots is important when the estimation of SFM indicators is based on the integration of remote sensing and field data. For the study area of Rincine, the beneficiary partner UCVV has indicated that the GPS receiver used to collect the x,y coordinates of existing field plots had a low precision (error > 5 meters), which is not suitable for the project's needs. Taking into account such information, we conducted a preliminary test in the area of Rincine to assess the quality of the data already available. In particular, we combined some LiDAR derived metrics with data from the existing plots in order to assess the relationships between the growing stock measured in field and LIDAR-derived metrics. The relatively low coefficient of determination we obtained (R^2=0.42) confirmed that the quality of field data already available in the area of Rincine (Figure 01) is not suitable for the purposed of the project.

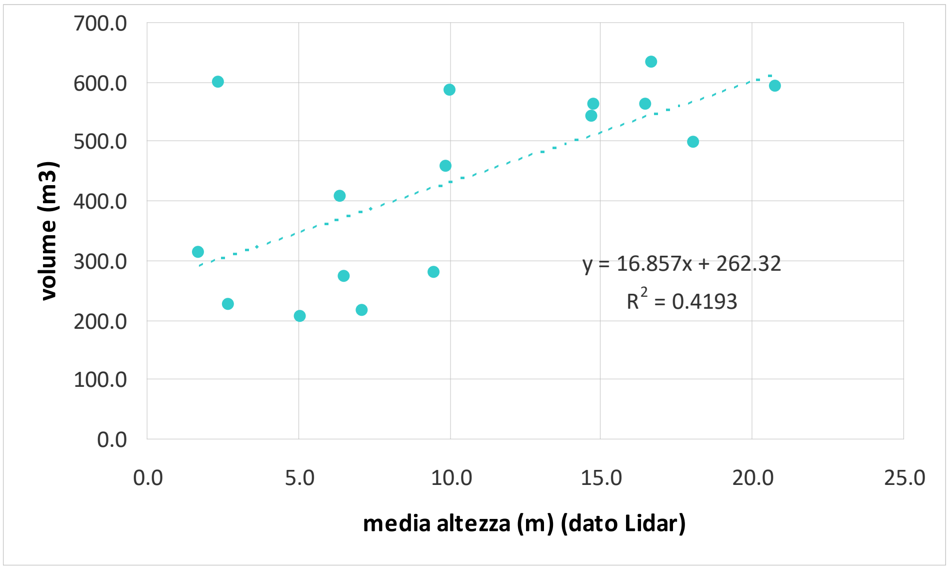


Figure 1 - Correlation between the mean of the heights extracted by the CHM (Canopy Height Model) and the volume measured in the plot inventories of the Rincine study area.

All the activities described above were reached in time according to the scheduled deadline (16 February 2016).
On the basis of the assessment of the data from action B1, a list of missing data was created (i.e., data to be acquired in action B2):
- new LIDAR data from RPAS;
- new multispectral images from RPAS;
- new forest inventory data.

The assessment of existing data and the creation of a list of missing data to be acquired in action B2 were completed in time with the Milestone "List of missing data to be acquired in Action B2" (deadline 16/02/2016).

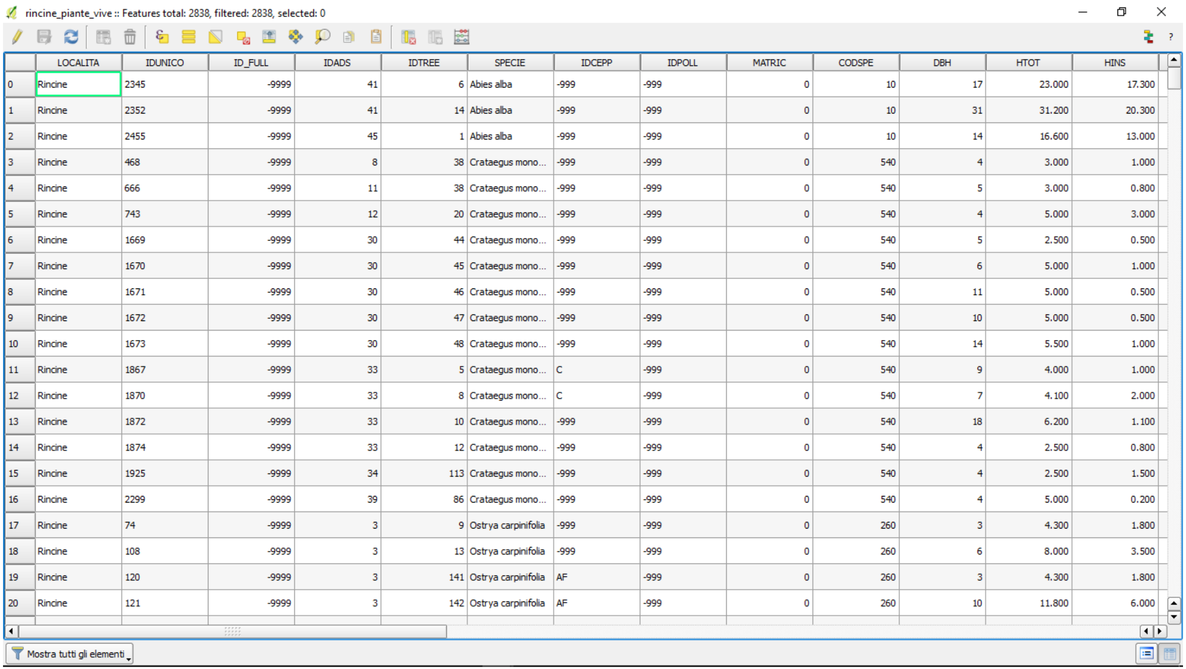
Acquisition of new field data

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 m^2) 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 details all the field measurements in terms of methods and variables to be collected. A copy of the sampling protocol is annexed to this deliverable. 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 (Figures 2 and 3).


rincine_piante_vive :: Features total: 2838, filtered: 2838, selected: 0

	LOCALITA	IDUNICO	ID_FULL	IDADS	IDTREE	SPECIE	IDCEPP	IDPOLL	MATRIC	CODSPE	DBH	HTOT	HINS
0	Rincine	2345	-9999	41	6	Abies alba	-999	-999	0	10	17	23.000	17.300
1	Rincine	2352	-9999	41	14	Abies alba	-999	-999	0	10	31	31.200	20.300
2	Rincine	2455	-9999	45	1	Abies alba	-999	-999	0	10	14	16.600	13.000
3	Rincine	468	-9999	8	38	Crataegus mono...	-999	-999	0	540	4	3.000	1.000
4	Rincine	666	-9999	11	38	Crataegus mono...	-999	-999	0	540	5	3.000	0.800
5	Rincine	743	-9999	12	20	Crataegus mono...	-999	-999	0	540	4	5.000	3.000
6	Rincine	1669	-9999	30	44	Crataegus mono...	-999	-999	0	540	5	2.500	0.500
7	Rincine	1670	-9999	30	45	Crataegus mono...	-999	-999	0	540	6	5.000	1.000
8	Rincine	1671	-9999	30	46	Crataegus mono...	-999	-999	0	540	11	5.000	0.500
9	Rincine	1672	-9999	30	47	Crataegus mono...	-999	-999	0	540	10	5.000	0.500
10	Rincine	1673	-9999	30	48	Crataegus mono...	-999	-999	0	540	14	5.500	1.000
11	Rincine	1867	-9999	33	5	Crataegus mono...	C	-999	0	540	9	4.000	1.000
12	Rincine	1870	-9999	33	8	Crataegus mono...	C	-999	0	540	7	4.100	2.000
13	Rincine	1872	-9999	33	10	Crataegus mono...	-999	-999	0	540	18	6.200	1.100
14	Rincine	1874	-9999	33	12	Crataegus mono...	-999	-999	0	540	4	2.500	0.800
15	Rincine	1925	-9999	34	113	Crataegus mono...	-999	-999	0	540	4	2.500	1.500
16	Rincine	2299	-9999	39	86	Crataegus mono...	-999	-999	0	540	4	5.000	0.200
17	Rincine	74	-9999	3	9	Ostrya carpinifolia	-999	-999	0	260	3	4.300	1.800
18	Rincine	108	-9999	3	13	Ostrya carpinifolia	-999	-999	0	260	6	8.000	3.500
19	Rincine	120	-9999	3	141	Ostrya carpinifolia	AF	-999	0	260	3	4.300	1.800
20	Rincine	121	-9999	3	142	Ostrya carpinifolia	AF	-999	0	260	10	11.800	6.000

Mostra tutti gli elementi

Figure 2 - Example of the database for living trees visualized in the Geographical Information System.

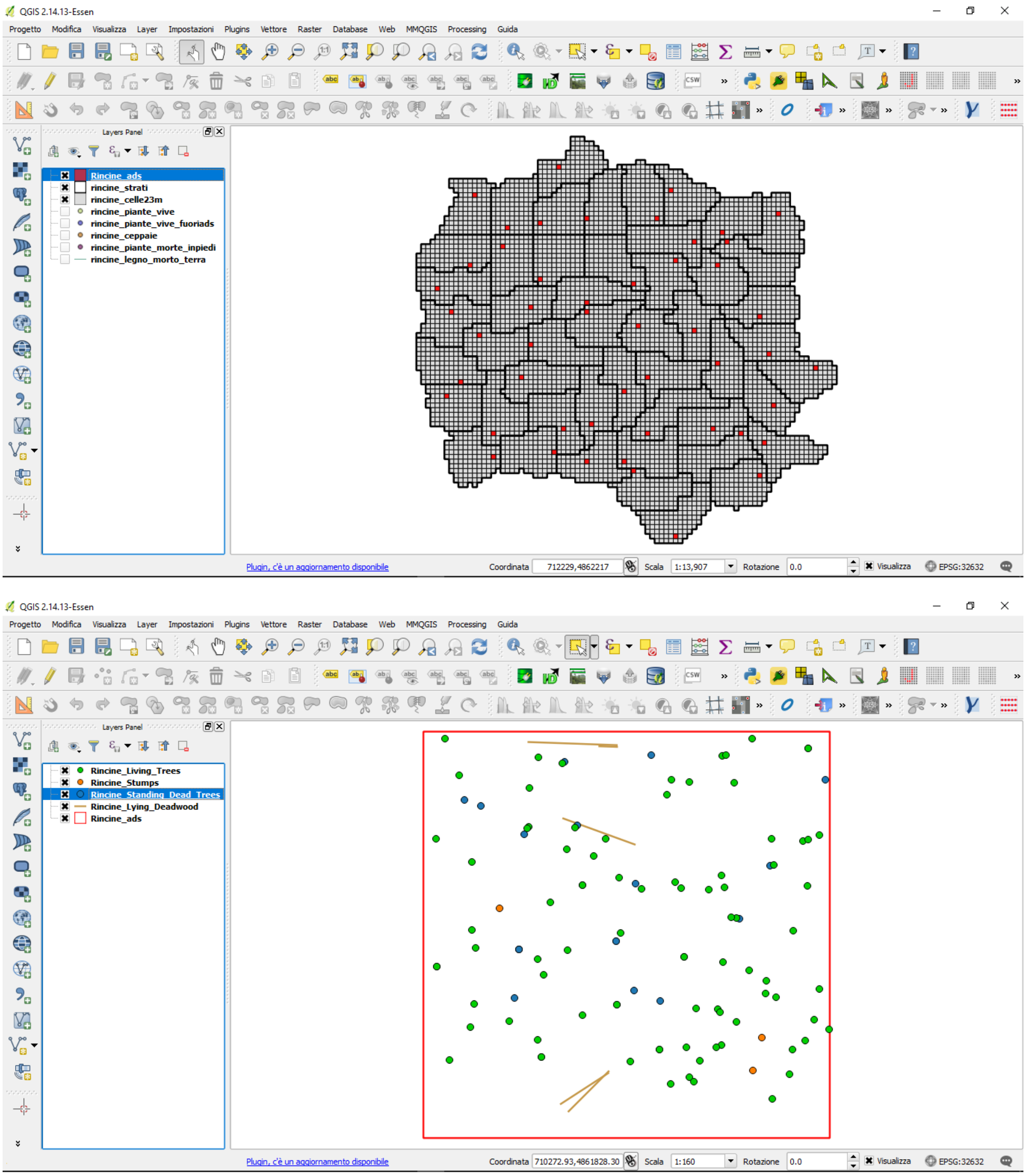


Figure 3 – Distribution of the 50 field plots in the site of Rincine (above) and example of the spatial database with the position of the surveyed elements within the plot, visualized in the Geographical Information System (below) (in order: living trees (green dots), stumps (orange dots), standing dead trees (blue dots) lying deadwood (brown lines))

Because the new field data were collected using a common sampling protocol, with common methods and definitions, the data harmonization was carried out as follows: creation of the unique database and projection of the spatial data into the coordinate system used by our project (UTM 32N WGS84). A metadata INSPIRE was created for each data included in the database, here below an example.

Title	FRESh LIFE - LIFE14_ENV/IT/000414 - rincine_ads_celle	
Abstract	Database of the plots in the demonstration sites of Rincine	
Common constraints	It includes the Database of the plots of the demonstration sites in polygon format. The characteristics for each plot are indicated in the database.	
Date	creation	2016-12-31
Keywords for the theme (max. 4)	Rincine FRESh LIFE Sustainable Forest Management Demonstration Site	
Topic category	environment	
	Italy	
	North [deg]:	43,88
	East [deg]:	11,64
	South [deg]:	43,87
	West [deg]:	11,61
Language	English	
Charset	utf8	
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Figure 4 – Example of a first page of the metadata INSPIRE created for the shape file (polygons) of the field plots in the site of Rincine.

The complete harmonized database of new filed data is annexed to this deliverable.

<u>Acquisition of new remote sensing data</u>

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.

The flight parameters used in the three demonstration areas were the same and are summarized in Table 1.

	SONY WX	Canon S110 NIR
Flight altitude above ground level	145 m	145 m

Camera	Canon S110 RGB	Canon S110 NIR
R	660 nm	625 nm
G	520 nm	550 nm
B	450 nm	-
NIR	-	850 nm
Overlap	80%	90%
Sidelap	75%	85%
Focal length	4 mm	5 mm
ISO Sensibility	ISO-100	ISO-1600
Shutter speed	1/2000 sec	1/2000 sec
Image dimension	4608 x 3456	4000 x 3000
Field of view	200 x 150 m	168 × 126 m
Estimated ground sampling distance	0.050 m	0.042 m

Table 1 - Parameters used during the RPAS image acquisitions with two different cameras: RGB and NIR.

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. A summary of the flights carried out by eBee drone is reported in Table 2.

	Area	Number of Flight	Total Acquisition Time	Images
GCP	Caprarola		10h	
RGB	Caprarola	5	3h20'	483
NIR	Caprarola	5	4h20'	564
GCP	Bosco Pennataro		11h	
RGB	Bosco Pennataro	6	3h50'	608
NIR	Bosco Pennataro	7	4h35'	689
GCP	Rincine		8h	
RGB	Rincine	4	3h25'	506
NIR	Rincine	5	4h10'	682

Total	27	52h40'	3532

Table 2 – Number of flights, time acquisition and number of images acquired in each area with eBee drone using two different multispectral cameras: RGB and NIR

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 this stage. 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. A summary of the parameters used in Agisoft Photoscan to process RPAS images is shown in Table 3.

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 5). 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 and annexed to this deliverable together with the all the new data.

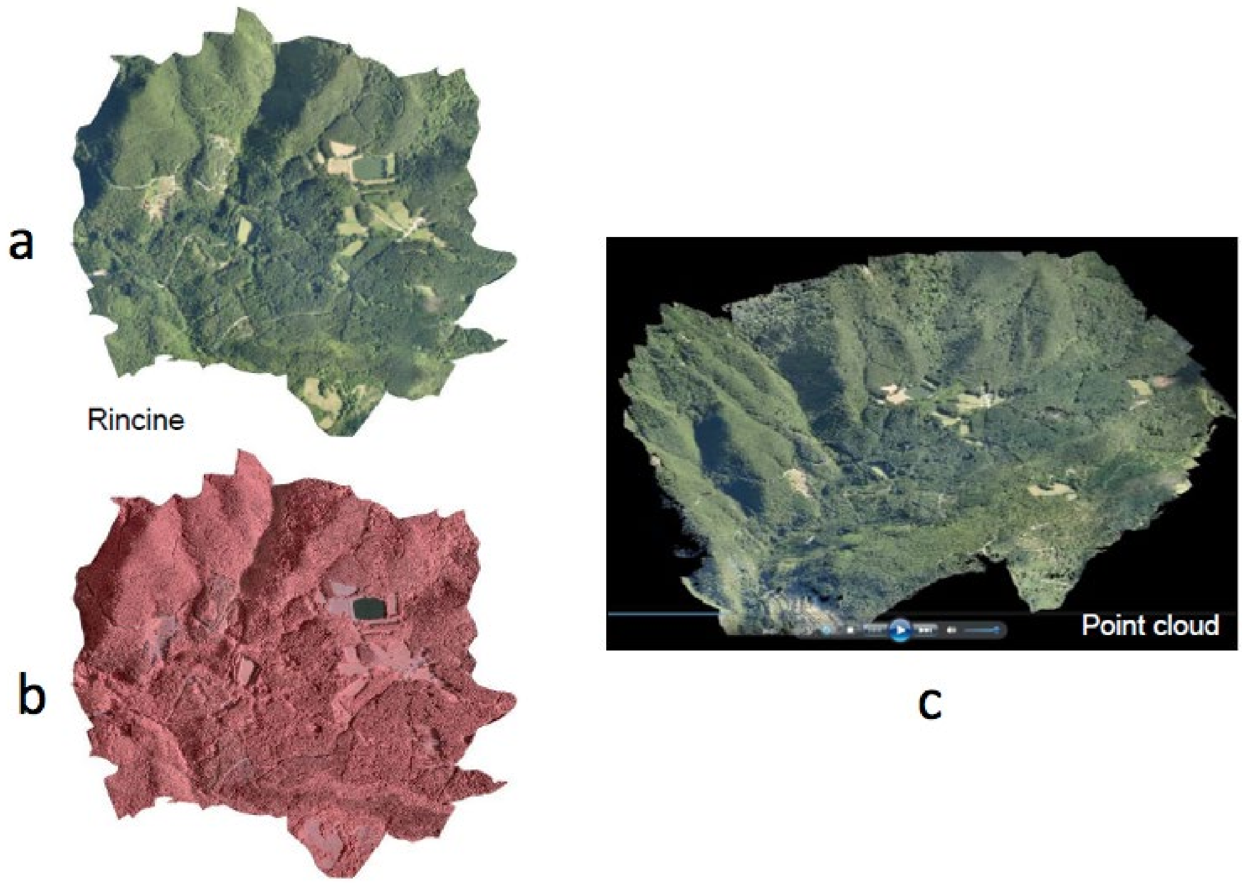

Figure 5 - Some examples of the remote sensing products elaborated from the new multispectral data acquired by eBee: a – RGB ortophoto with 10 cm resolution; b – NIR ortophoto with 10 cm resolution; c – 3D model from the dense point clouds

Align photos	Accuracy: high
	Pair selection: reference
	Key Point limit: 40000
	Tie point limit: 1000
Build mesh	Surface type: height field
	Source data: sparse point cloud
	Facecount: low (13544)
	Interpolation: enabled
Guided marker positioning	
Optimize camera alignment	Marker accuracy (m): 0.005
	Projection accuracy (pix): 0.1
	Tie point accuracy (pix): 4
	Fit all except for k4
	Number of GCPs: 12
Build dense cloud	Quality: Medium
	Depth filtering: mild
DSM generation	Source data: Dense point cloud
Ortophoto Mosaic	Source data: images and DSM

Table 3 - Parameters used in Agisoft Photoscan to process RPAS images acquired by eBee drone

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. A summary of the flights carried out by both octocopter drone and the light helicopter is provided in the Tables 4 and 5.

Site	Flight altitude (m)	Total Acquisition Time	Number of Flights	Number of Flight Strips	Hectares covered by octocopter	Hectares covered by octocopter + helicopter
Bosco Pennataro	70	4h40’	24	97	195	259
Rincine	70	4h00’	20	88	178	236
Caprarola	70	5h00’	30	60	140	241

Table 4 – Time, number of flights, number of flight strips and hectares covered by LIDAR data using the octocopter.

Site	Flight altitude (m)	Total Acquisition Time	Number of Flights	Number of Flight Strips	Hectares
Bosco Pennataro	70	6h00’	5	22	94
Rincine	70	5h00’	4	20	82
Caprarola	70	10h00’	7	41	120

Table 5 – Time, number of flights, number of flight strips and hectares covered by LIDAR data using the light helicopter. For technical reasons (approaching trajectories), part of the areas covered by helicopter duplicate those already taken by octocopter.

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/m^2) (Figure 6), 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 and annexed to this deliverable together with the all new data.

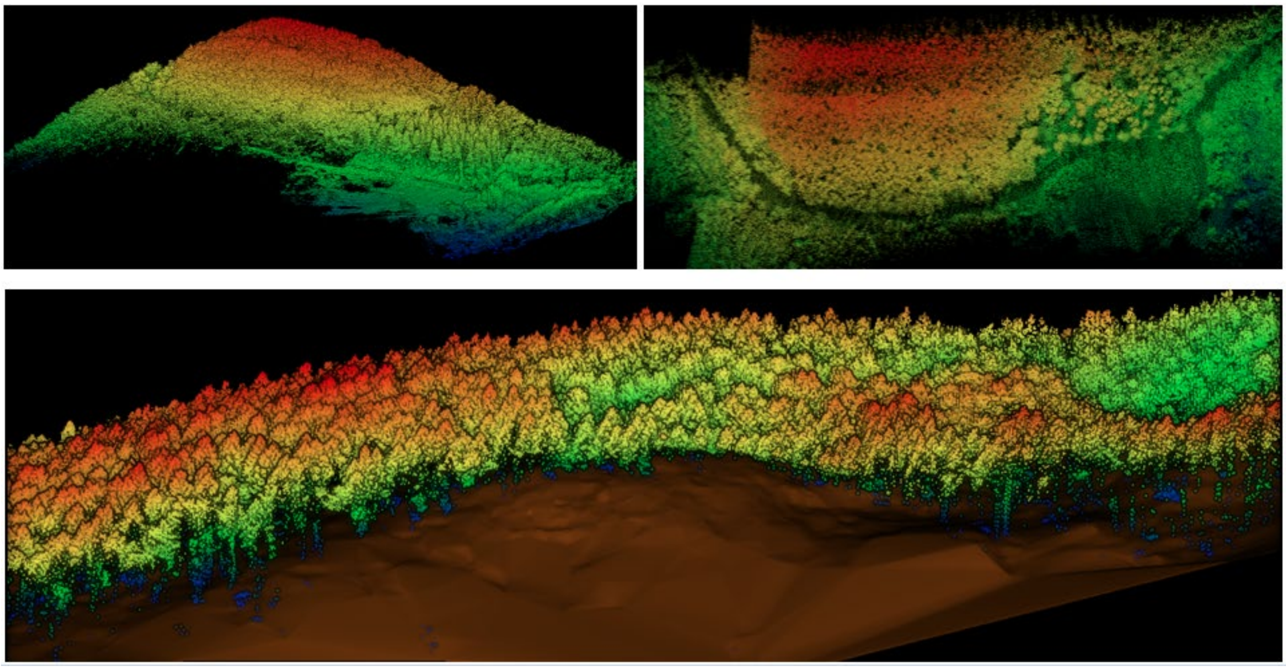

Figure 6 – Some examples from the dense point cloud obtained in the demonstration site of Rincine

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). The data collected were elaborate by OBEN as described above and are now available for the activities of Action B3 (Figures 7 and 8).

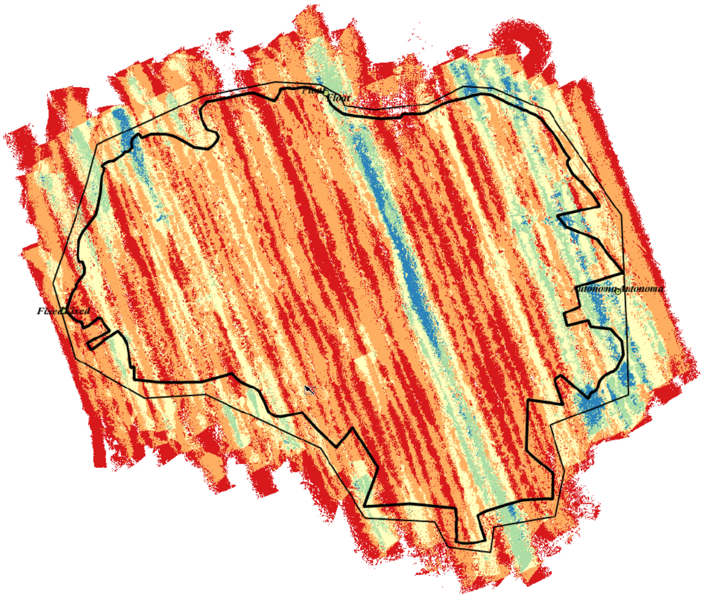

Figure 7 – Area covered by the flights in the demonstration site of Caprarola, different color indicate the number of flight strips on the same point

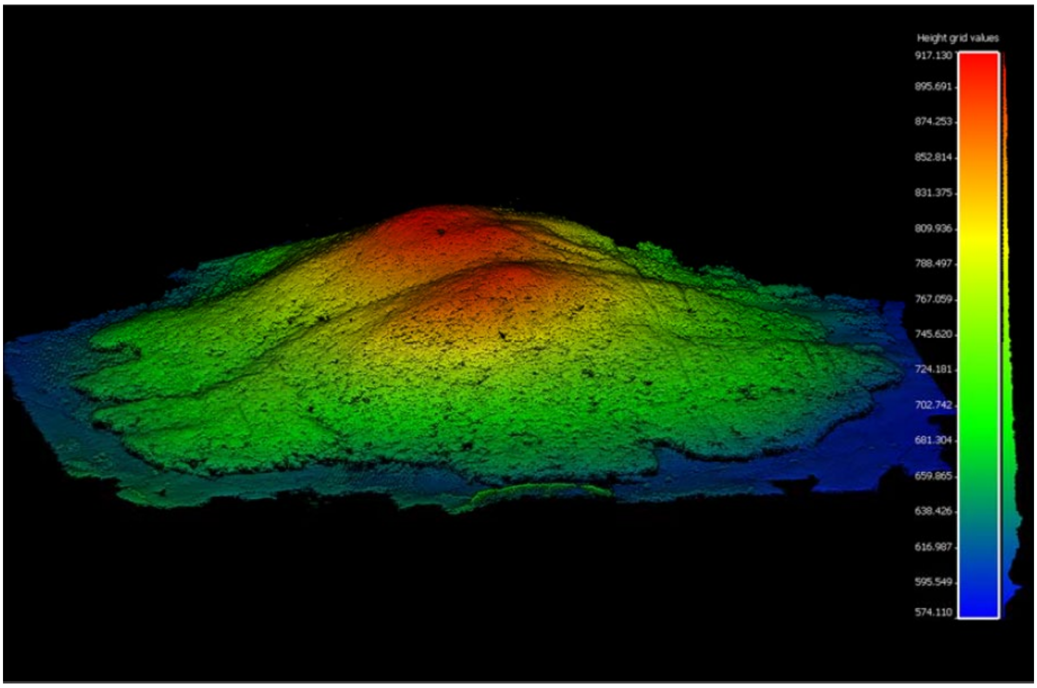

Figure 8 – Point cloud of Mount Venere inside the demonstration site of Caprarola