LIFE 14ENV/IT/000414

Demonstrating Remote Sensing integration in sustainable forest management

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ACTION B3

Mapping SFM indicators

Deliverable "Maps of the European Forest Types for the pilot study areas"

DIBAF – University of Tuscia

Viterbo, 31/01/2017

Summary

General goals of B.3 Action

University of Tuscia is the Beneficiary responsible for implementation of Action B3 - Mapping SFM indicators.

The goals of the Action B3 are to test and evaluate methods coupling remote sensed infomation collected from RPAS with plot-level data to derive:

1. maps of European Forest Types (EFTs) for the project pilot study areas;
2. maps of selected Forest Europe SFM indicators (growing stock, number of tree species, area covered by introduced tree species, defoliation/forest damage).

This report summarize the data and methods applied in the production of the maps of the EFTs in the three pilot study areas of Caprarola, Bosco Pennataro and Rincine, as first project deliverable products of Action B.3. (see scheme below).

Milestones and Deliverables

The B.3 Project Milestone is

Milestone name	*Deadline*
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

The B3's Project Deliverable Products are

Deliverable name	*Deadline*
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 forest compartment level	7/2017

Methodology

Maps of European Forest Types for the pilot study areas were obtained by image interpretation of very high resolution 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 (Figure 1). Field survey data collected over fifty sampling units in each pilot study area were also processed to derive reference data for map accuracy assessment.

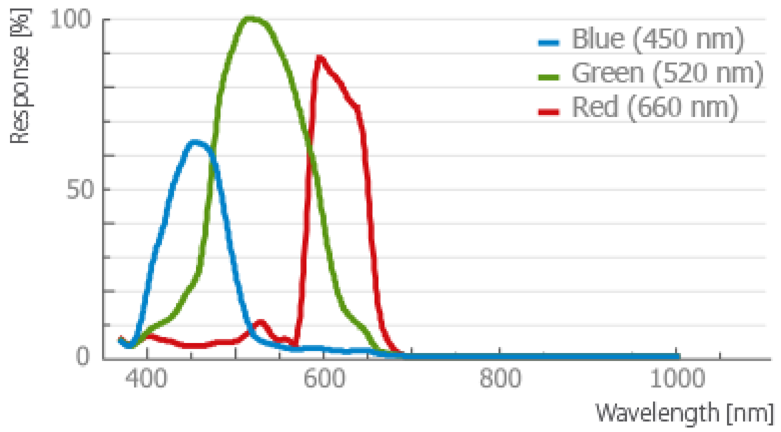

Figure 1. – Band responses of the RGB camera equipped on eBee UAV (source: https://www.sensefly.com/drones/accessories.html).

Visual Image Interpretation

The EFTs correspond to groups of ecologically distinct forest communities, dominated by specific assemblages of dominant trees (EEA, 2006[1]; Barbati et al., 2014[2]). The EFTs maps for the pilot study areas were derived by visual image interpretation, a qualitative image classification technique widely applied by forest practioners for forest cover typing. Differences in tone in the green band was the fundamental criterion for distinguishing tree dominant species. The high spatial resolution of RGB orthomosaic is fine enough that by a combination of tone, size, shape and texture criteria individual trees can be identified to genus or species by their branching habit and spectral response.

A common methodological setting finalized to European Forest Type mapping was adopted for image interpretation:

- minimum mapping unit 0.5 ha, according to FAO-FRA forest definition (2005): forest is a land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent.

- visual interpretation scale of 1:1500

- target EFTs classes to be mapped (based on prior knowledge of the EFTs classes occurring in the pilot test areas):

- 7.3 Apennine-Corsican mountainous beech forest
- 8.1 Downy oak forest
- 8.2 Turkey oak, Hungarian oak and Sessile oak forest
- 8.7 Chestnut forest
- 8.8 Other thermophilous deciduous forests
- 10.2 Mediterranean and Anatolian Black pine forest
- 13.2 Italian alder forest
- 14 Introduced tree species forest
- 99.2 Non forest

Based on these criteria three EFTs maps were produced for the pilot test area of Caprarola, Bosco Pennataro, and Rincine (Annex 1, Deliverable EFTs_Maps.zip).

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[1] EEA, 2006. European Environment Agency (2006). European forest types. Categories and types for sustainable forest management and reporting. EEA, Report No. 9/2006

[2]. Barbati A, Marchetti M., Chirici G., Corona P. (2014). European Forest Types and Forest Europe SFM indicators: Tools for monitoring progress on forest biodiversity conservation. FOREST ECOLOGY AND MANAGEMENT, vol. 321, p. 145-157, ISSN: 0378-1127, doi: 10.1016/j.foreco.2013.07.004

Ground plot EFTs classification

In order to quantify how well the visual image interpretation worked in the different pilot test areas, ground truth data collected in fifty sampling units for each pilot study area, during Action B2, were processed to assign each plot with a EFT class. Sampling units size is 23 m^2, corresponding to a square region of 230x230 10 cm^2 pixels in the orthomosaic.

Dominant tree species at plot level was identified using relative basal area proportion. Two alternative approaches were tested to identify the forest species with the highest relative value of basal area in each plot:

A. Relative basal area proportion out of total plot basal area
B. Relative basal area proportion out of the basal area of the 5 trees with the largest diameter in the plot (dominant trees)

The rationale of using two different approaches for sampling units classification into EFTs is to evaluate whether differences in classification of reference data might appear when using dendrometric based (A) vs more forest cover based (B) criteria for the identification of the dominant tree species at plot level.

Accuracy assessment of EFTs maps

The accuracy of EFTs classification was assessed by four indices:

Overall accuracy (OA); OA quantifies the percentage of plots classified correctly according to ground plot based EFTs classification;

Kappa index of agreement (KIA); KIA reflects the difference between actual agreement and the agreement expected by chance; KIA = (OA-c)/(1-c) where c is the overall probability of random agreement. The use of KIA is especially relevant when some classes are more likely to be encountered during field sampling than others. Thus, some of the apparent classification accuracy given by OA measures could be due to chance, rather than to the ability of the photo-interpreter.

Producer's accuracy (PA); PA quantifies how accurate is the map from the perspective of the producer; i.e. for a given mapped EFTs PA quantifies the percentage of plots that are labelled correctly on the map.

User's accuracy (UA); UA classifies how accurate is the map from the perspective the user; i.e. number of plots correctly identified in a given map EFTs class out of the number of ground plots assigned to that map class;

Validation of EFTs of the pilot test areas

Caprarola

In this pilot study area mapped EFTs classes (3) are more than those observed in sampling units (2). Accordingly, map accuracy assessment is reported only for two EFTs classes and is missing for class 8.8 Chestnut forest.

Table 1 reports OA and KIA indices calculated according the two approaches (A, B) for the classification of the fifty plots into EFTs. Table 2 reports PA and UA values for each EFTs class. The validation accuracy is the same for A and B approach, because the fifty sampling units in Caprarola pilot test area were classified into the same EFTs class using the two approaches.

The overall accuracy is very high, exceeding 90%. The high KIA value (0.82) attests to the good performance of the visual classification. PA and UA are the same for the two mapped EFTs, “7.3 Apennine Corsican mountainous beech forest” and “8.2 Turkey oak, Hungarian oak and Sessile oak forest”, and are higher than 85%.

Table 1. OA and KIA measures for the EFTs of Caprarola.

Field data classification	Classification	
	Visual Image Interpretation	
	OA	KIA
A) Total basal area	0,92	0,82
B) Basal area of dominant trees	0,92	0,82

Table 2. PA and UA of the EFTs map of Caprarola.

A) *Validation based on total basal area*		
EFTs	*PA*	*UA*
7.3 Apennine Corsican mountainous beech forest;	0,94	0,94
8.2 Turkey oak, Hungarian oak and Sessile oak forest;	0,88	0,88
B) *Validation based on basal area of dominant trees*		
EFTs	*PA*	*UA*
7.3 Apennine Corsican mountainous beech forest;	0,94	0,94
8.2 Turkey oak, Hungarian oak and Sessile oak forest;	0,88	0,88

Bosco Pennataro

Accuracy results for the study area of Bosco Pennataro are reported in Table 3 and Table 4. Even in this case study, the two approaches (A, B) applied to assign EFTs to field plots produced similar outcomes.

OA index is around 75%, but KIA values, ranging between 0.35 and 0.37, highlight more difficulties in recognizing EFTs forest types in this area by visual interpretation. PA denotes over-mapping of class “7.3 Apennine Corsican mountainous beech forest” (0.57 (B)<PA<0.71(A)) compared to class “8.2 Turkey oak, Hungarian oak and Sessile oak forest” (0.74 (A)<PA<0.79(B)). Class “8.8 Other termophilous deciduous forests” was not recognized and mapped by visual interpretation, resulting in null values of UA and PA. Accordingly, while all the plots belonging to the “Turkey oak, Hungarian oak and Sessile oak forest” class are correctly detected (UA around 1%), beech plots (7.3) are correctly identified in the map just over in one third of the cases (UA=36%).

Table 2. OA and KIA measures for the EFTs map of the pilot study area of Bosco Pennataro.

Field data classification	Classification	
	Visual Image Interpretation	
	OA	KIA
A) Total basal area	0,74	0,37
B) Basal area of dominant trees	0,76	0,35

Table 4. PA and UA of the EFTs map of Bosco Pennataro.

A) Validation based on total basal area		
EFTs class	*PA*	*UA*
7.3 Apennine Corsican mountainous beech forest	0,71	0,36
8.2 Turkey oak, Hungarian oak and Sessile oak forest	0,74	1,00
8.8 Other thermophilous deciduous forest	-	0,00
B) Validation based on basal area of dominant trees		
EFTs class	*PA*	*UA*
7.3 Apennine Corsican mountainous beech forest	0,57	0,36
8.2 Turkey oak, Hungarian oak and Sessile oak forest	0,79	0,97
8.8 Other thermophilous deciduous forest	-	0,00

Rincine

In this pilot study area mapped EFTs classes (8) are more than those observed in sampling units (6). Accordingly, map accuracy assessment is reported only for six EFTs classes and is missing for two classes (8.1 Downy oak forest, 13.2 Italian alder forest).

Visual interpretation shows a very high accuracy equal to or greater than 90% (Table 5). The high KIA value (0.86-0.92) highlights as well a very good performance of the visual classification.

PA and UA values quantified based on the validation approach (A) are very high (≥85%) for all mapped EFTs, except for the class "8.8. Other thermophilous deciduous forest" (UA=1, but PA= 0.6).

Following the validation approach (B), while UA values of the classes "7.3 Apennine Corsican mountainous beech forest" and "8.2 Turkey oak, Hungarian oak and Sessile oak forest", are perfect (1), their corresponding PA value decrease to 0,50 and to 0,83, respectively. Class "8.8. Other thermophilous deciduous forest" is perfectly mapped in terms of PA (1), but has a very low UA value (0,20).

Accuracy of EFTs dominated by coniferous species (10.2 and 14) is very high: UA and PA are greater than 0,85 in both cases.

Table 5. OA and KIA measures for the EFTs map of the pilot study area of Rincine.

Field data classification	Classification	
	Visual Image Interpretation	
	OA	KIA
A) Total basal area	0,94	0,92
B) Basal area of dominant trees	0,90	0,86

Table 6 PA and UA of the EFTs map of Rincine.

A) Validation based on total basal area		
EFTs class	*PA*	*UA*
7.3 Apennine Corsican mountainous beech forest	1,00	1,00
8.2 Turkey oak, Hungarian oak and Sessile oak forest	1,00	1,00
8.7 Chestnut forest	1,00	1,00
8.8 Other thermophilous deciduous forest	0,60	1,00
10.2 Mediterranean and Anatolian Black pine forest	1,00	0,85
14 Introduced tree species forest	0,95	0,95
B) Validation based on basal area of dominant trees		

EFTs	*PA*	*UA*
7.3 Apennine Corsican mountainous beech forest	0,50	1,00
8.2 Turkey oak, Hungarian oak and Sessile oak forest	0,83	1,00
8.7 Chestnut forest	1,00	0,67
8.8 Other thermophilous deciduous forest	1,00	0,20
10.2 Mediterranean and Anatolian Black pine forest	0,92	1,00
14 Introduced tree species forest	0,95	1,00

Concluding remarks

Summarizing and comparing results from the three pilot areas we can draw the following conclusions:

from the map producer's point of view

- EFTs "7.3 Apennine Corsican mountainous beech forest" and "8.2 Turkey oak, Hungarian oak and Sessile oak forest" are reliably mapped based on approach A validation (0.88<PA<1 for Caprarola and Rincine, 0.71<PA<0.74 for Bosco Pennataro). Validation based on the approach B results in a lower PA for Rincine and Bosco Pennataro for the class "7.3 Apennine Corsican mountainous beech forest" (0.50 and 0.57 respectively) and gives similar results to approach A for the class "8.2 Turkey oak, Hungarian oak and Sessile oak forest" (0.83 Rincine, 0.79 Bosco Pennataro)
- EFTs "8.7 Chestnut forest" is perfectly mapped according to both approaches in Rincine (PA=1)
- EFTs "8.8 Other thermophilous deciduous forest" is not recognized in Bosco Pennataro; an explanation can be the low image quality of the orthomosaic, due to high cloud cover at the time of the flight. The same forest type is perfectly recognized in Rincine, according to approach B (PA=1), and mapped with lower reliability according to approach A (PA=0.60).
- EFTs dominated by coniferous species (10.2 and 14), observed in Rincine only, are reliably mapped based both validation approaches (0.92<PA<1).

from the map user's point of view,

- EFTs “7.3 Apennine Corsican mountainous beech forest” and “8.2 Turkey oak, Hungarian oak and Sessile oak forest” are reliably mapped based on approach A and B in Caprarola and Rincine (0.88<UA<1). In Bosco Pennataro while the class 8.2 is well recognized (0.97<UA<1), class 7.3 is over-mapped, resulting in low UA (0.36);
- EFTs “8.7 Chestnut forest” and EFTs “8.8 Other thermophilous deciduous forest” are perfectly mapped according to approach A in Rincine (OA=1), while approach B provides lower accuracy (OA=0.67 and =0.20 respectively).
- EFTs dominated by coniferous species (10.2 and 14), are reliably mapped based on both validation approaches (0.85<PA<1).

In conclusion, findings from the visual interpretation of the RGB orthomosaic in the three study areas highlight that a high per-class thematic accuracy for forest type mapping (PA and OA>85%) can be achieved on a very fine spatial scale (minimum mapping unit=0.5 ha), even within forest areas with heterogeneous fine-scaled spatial pattern of tree dominant species (e.g. the test area of Rincine).

Annex 1

Figure 1. EFTs mapped by visual interpretation in the study area of Caprarola.

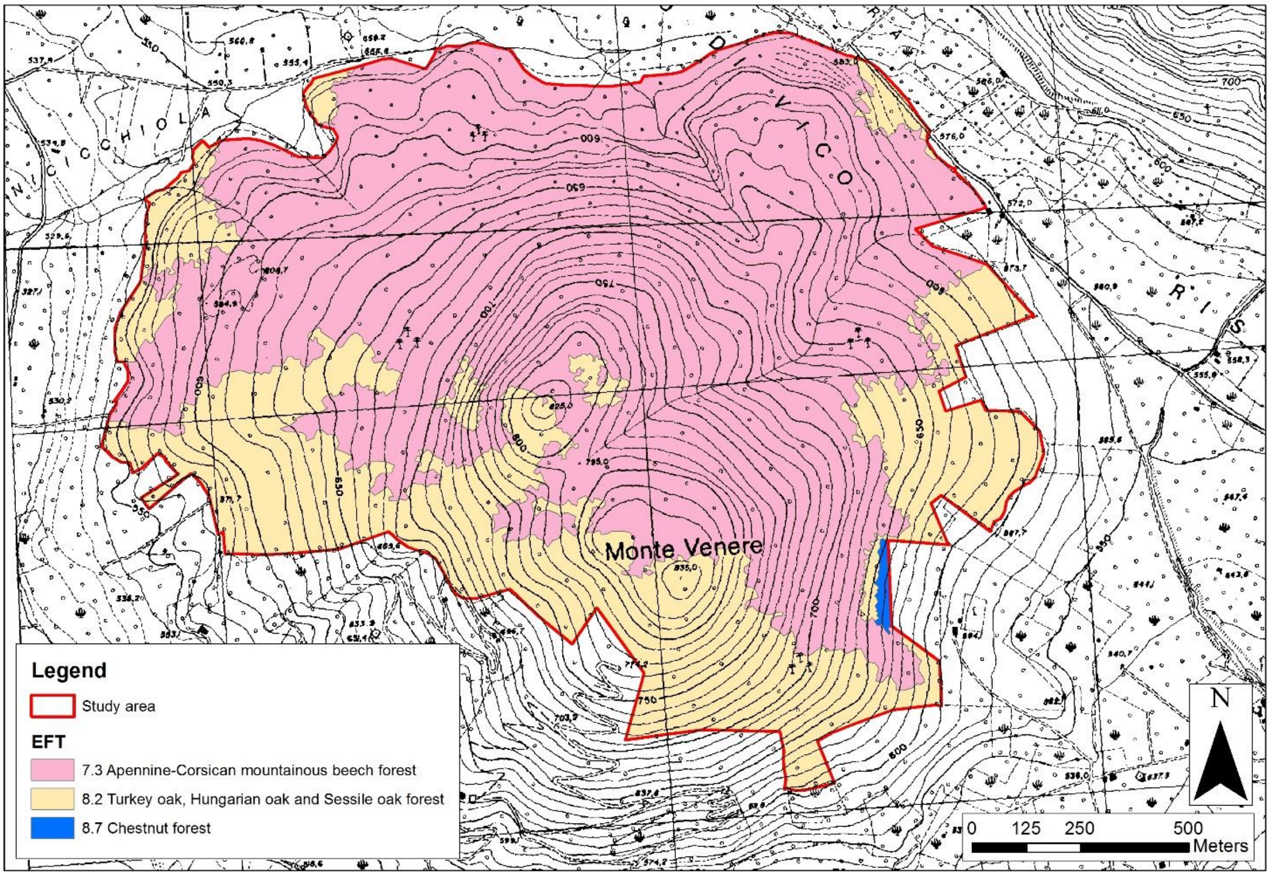

Figure 2. EFTs mapped by visual interpretation in the study area of Caprarola displayed on high-resolution orthomosaic acquired by eBEE.

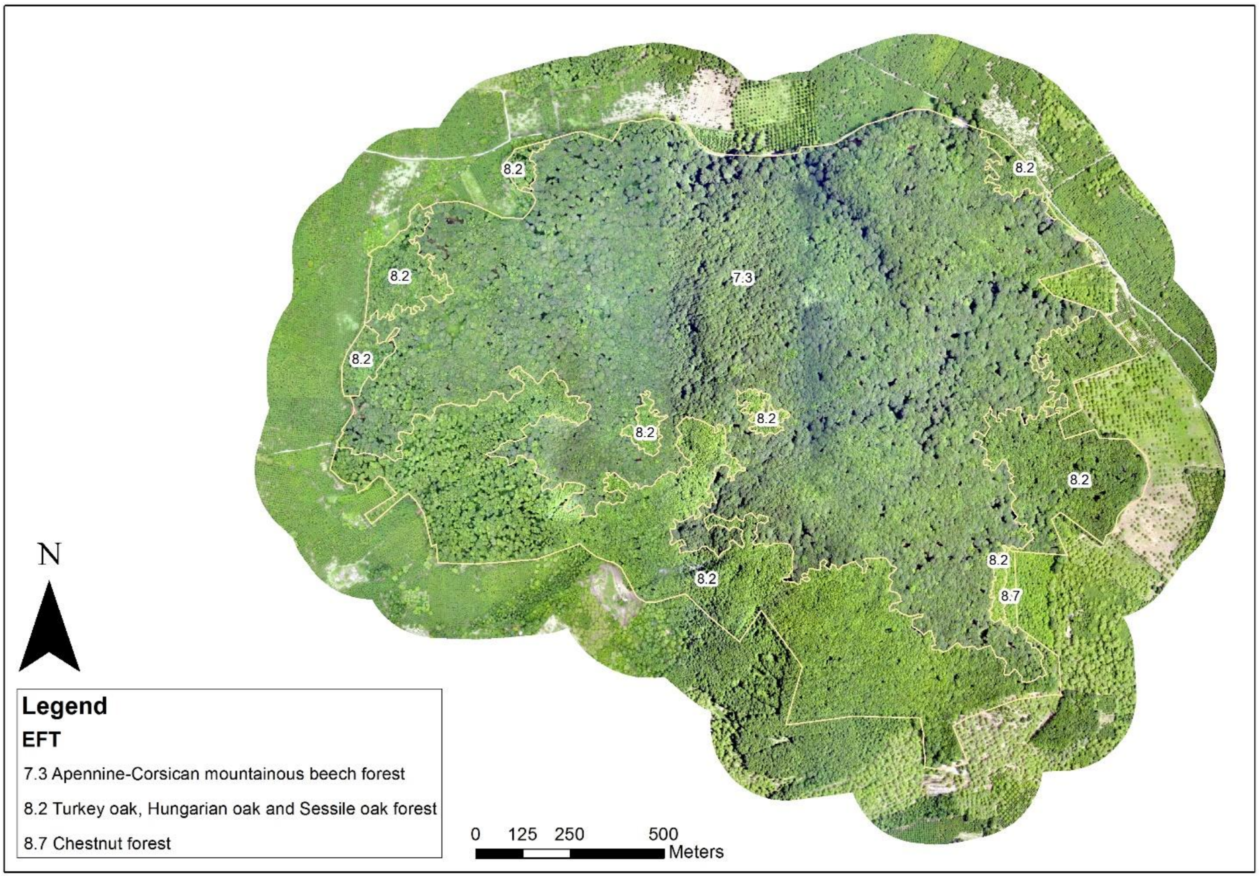

Figure 3. EFTs mapped by visual interpretation in the study area of Pennataro.

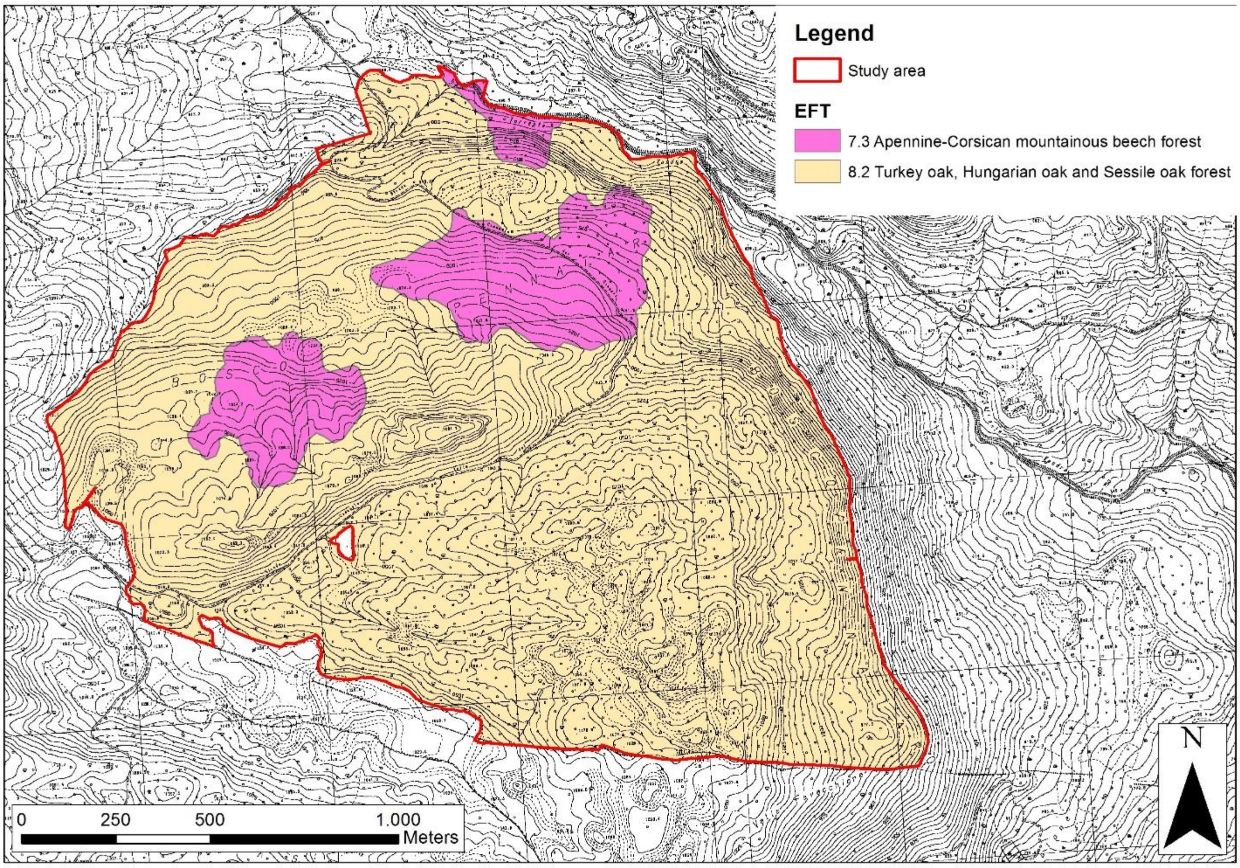

Figure 4. EFTs mapped by visual interpretation in the study area of Pennataro displayed on high-resolution orthomosaic acquired by eBEE.

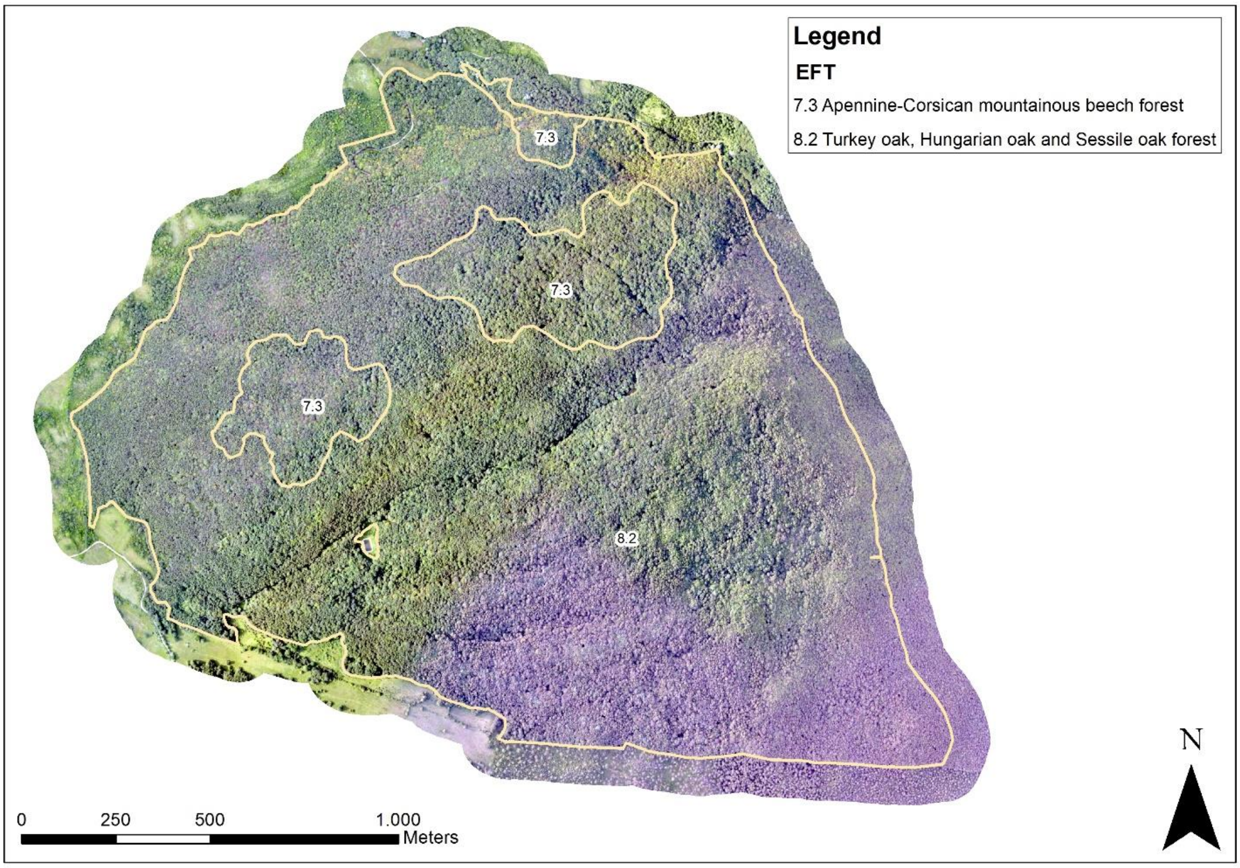

Figure 5. EFTs mapped by visual interpretation in the study area of Rincine.

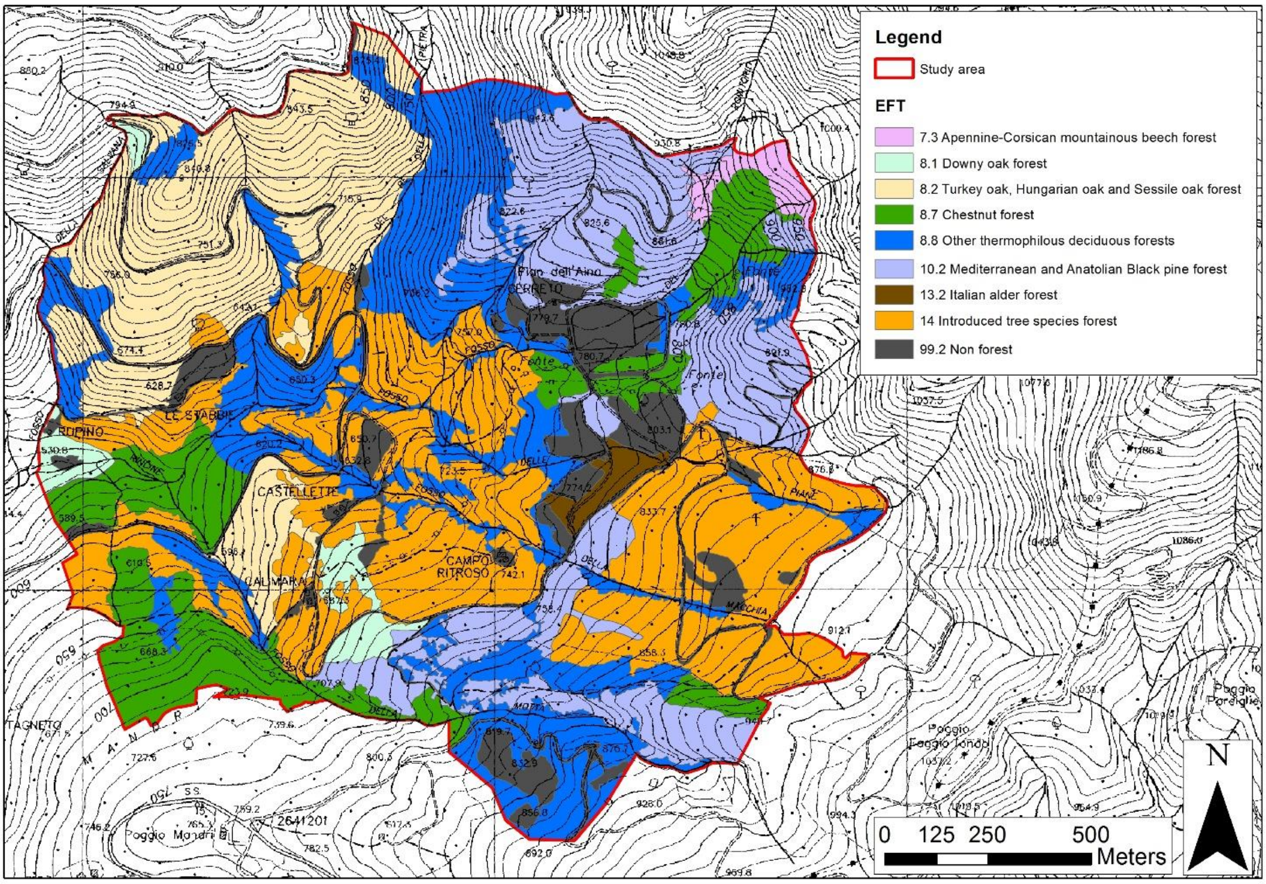

Figure 6. EFTs mapped by visual interpretation in the study area of Rincine displayed on high-resolution orthomosaic acquired by eBEE.