LIFE 14ENV/IT/000414
Demonstrating Remote Sensing integration in sustainable forest management
FRESh Life

ACTION B3

Mapping SFM indicators

Deliverable

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

Viterbo, 30/03/2017

Summary

Goals

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

One of the taks of Action B3 is testing and evaluating methods coupling remote sensed information collected from RPAS with plot-level data to derive, maps of Forest Europe's Sustainable Forest Management (SFM) indicators: "Defoliation (# 2.3)", "Forest damage (# 2.4)", "Tree species composition (# 4.1)" and "Area covered by introduced tree species (# 4.4)"[1].

Product of this tasks are maps for the pilot study areas of Caprarola, Pennataro and Rincine of the SFM indicators (Defoliation, Forest damage, Number of tree species and Area covered by introduced tree species). Maps of SFM indicators are provided in vector and image format (Deliverable B3.3_Maps of SFM indicators.rar). All the maps were devised by visual image interpretation of the true color orthomosaics (ground resolution 10 cm/pixel) acquired by drone-remote sensing with the small fixed-wing unmanned aerial vehicle eBee (SenseFly).

This report provides technical explanations on approaches adopted for mapping each single SFM indicator.

Milestones and Deliverables

The B3's 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	7/2017

[1] Forest Europe, UNECE and FAO, 2011. State of Europe's Forests 2011. Status and Trends in Sustainable Forest Management in Europe. In: Ministerial Conference on the Protection of Forests in Europe, Forest Europe Liaison Unit Oslo.

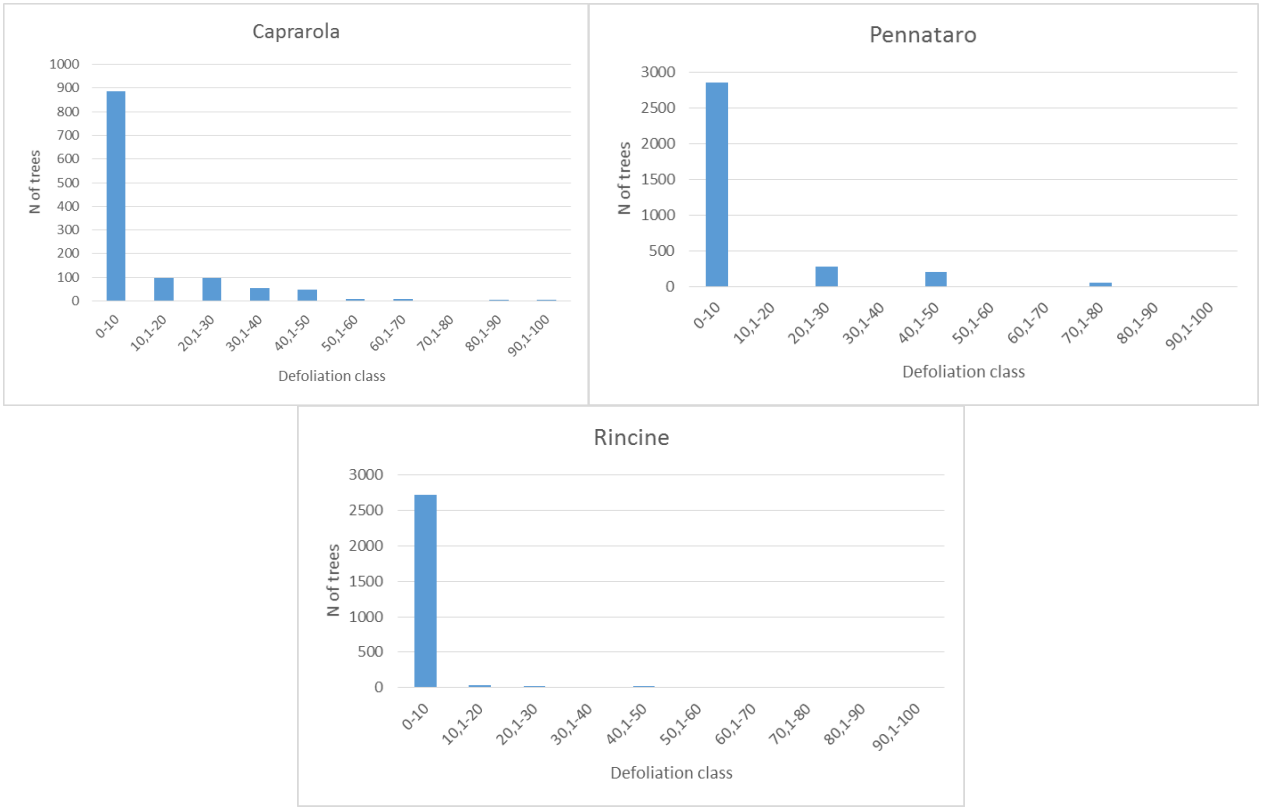
forest compartment level	

Methodology

Defoliation (# 2.3)

Forest Europe definition of SFM indicator 2.3 is «*Defoliation of one or more main tree species on forest and other wooded land in each of the defoliation classes "moderate", "severe" and "dead"* ». This indicator is a proxy of tree health status and vitality, and it is usually monitored on field plots by visual assessment from the ground of tree crown condition. In our project, tree crown defoliation was one of the parameters collected during field sampling activities in action B2. Defoliation was estimated from visual assessment as needle/leaf loss in the assessable crown as compared to a reference (healthy) tree. Defoliation was assessed in 5% steps. Defoliation of 100 percent indicates dead trees. A summary of the relative frequency of defoliation classes observed in the study areas is shown in Figure 1. Tree crown defoliation is lower than 10% on most of the surveyed trees.

Fig. 1. Frequency distribution of tree defoliation classes in the study areas.



Considering the limited impact of defoliation in the study areas, we selected plots where trees with crown defoliation percentage is higher than 50% of the total tree crown have been detected, in order to verify whether such defoliation intensity is recognizable from the true color eBee orthomosaic. Crown defoliation was clearly detectable only on trees with severe damages, correspondent to trees with large parts of dead crown (70% to 99%), or on standing dead trees in the upper layer.

Based on this preliminary sensitivity check, the visual image interpretation of the RGB orthomosaic was targeted to mapping severely damaged and dead trees. We digitized all polygons of totally (defoliation class label=2) or partially (more than 70% defoliation class 1) defoliated crowns. The minimum mapping unit for delineating defoliation classes on individual trees was set ≥ 3 m^2. This threshold was selected according to the minimum surface of totally defoliated crown, distinguishable on the orthomosaic (Fig. 2).

Accordingly, maps of the density of severely damaged and dead trees at the forest compartment level were produced for the pilot study areas (Annex 1, figures 3-5). The highest class of defoliation density mapped at the forest compartment level is below 1 tree ha^{-1} in Caprarola and Pennataro and can reach nearly 7 trees ha^{-1} in Rincine.

Fig. 2. An example of partially and totally defoliated crowns identified by visual interpretation of the RGB orthomosaic of the study area of Caprarola.

Forest damage (# 2.4)

Forest Europe definition of SFM indicator 2.4 is «*Forest and other wooded land with damage, classified by primary damaging agent (abiotic, biotic and human induced)*». Indicator 2.4 refers to the forest area damaged by abiotic (wildfires, storms, avalanches, etc) or biotic disturbances (e.g. insects and diseases). In the project pilot study areas forest damage occurred recently in Rincine case study only, due to a windstorm occurred in march 2015. The map of forest damage indicator for Rincine was derived by visual interpretation

of true color orthomosaics (ground resolution 10 cm/pixel), with a minimum mapping unit 0,25 ha. Forest area affected by wind damage appear as clear felled areas in the orthomosaic (Annex 1, Figure 6), due to the salvage logging operations carried out after the storm event. The total forest area affected by wind damage in Rincine is however negligible, amounting to just above 3 ha (Annex 1, Figure 7).

Tree species composition (# 4.1)

Forest Europe definition of SFM indicator 4.1 is «*Area of forest and other wooded land classified by number of tree species occurring*». The indicator is intended to monitor the area of forest that consists of one tree species alone or several tree species. The number of tree species indicator is generally quantified from field plot dbh measurements, by calculating the number of tree species exceeding the 5% of total plot basal area.
There are of course some technical limitations to map the actual number of tree species in a given forest area from a classification of the eBee orthomosaic, due to the following reasons:
- some tree species are found only in the understory and do not reach the upper canopy layer;
- previous findings from the European Forest Types mapping activity (cf. *Deliverable B3 Maps of European Forest Types*) proved that the spectral and spatial resolution of the eBee orthomosaic allows to feasibly distinguish by visual interpretation only the dominant tree species covering a given tract of forest land. In this regard, the visual classification proved to be more accurate than semi-automatic classification for forest cover typing (cf. *Report on the technical and economic viability of using high resolution optical data to stratify by European Forest Types (EFTs) medium-to large size forest management units).*
Considering these limitations, mapping the number of tree species occurring within a given forest compartment can be feasibly performed using the number of EFTs as a proxy (conservative estimate) of the number of tree species. Accordingly, the range of variability in the number of tree species occurring at the forest compartment level varies between 1 and 3 in Caprarola and Pennataro (Annex 1, Figures 8 and 9), and can reach 5 tree species in Rincine (Annex 1, Figure 10).

Area covered by introduced tree species (# 4.4)

Forest Europe definition of SFM indicator 4.4 is «*Area of forest and other wooded land dominated by introduced tree species*». Introduced tree species are tree species occurring outside their natural vegetation zone, area or regions (also known as exotic or alien species). These areas are mapped under the class *14 Introduced tree species forest* of the EFTs. In our case studies, forest areas covered by introduced tree species are found only in Rincine. The spatial distribution of areas covered by introduced tree species in Rincine is shown in Annex 1, Figures 11-12. These areas cover about the 25% of the pilot study area (70 ha ca) and are represented by reforestations with Douglas fir (*Pseudotsuga menziesii*) or other introduced conifers (e.g. *Chamaecyparis lawsoniana*). The minimum mapping unit for this indicator is the same as for EFTs maps (0,5 ha).

Annex 1

Figure 3. Maps of density of defoliated trees within each forest management unit in the study area of Caprarola. Threshold values were determined according to quantiles.

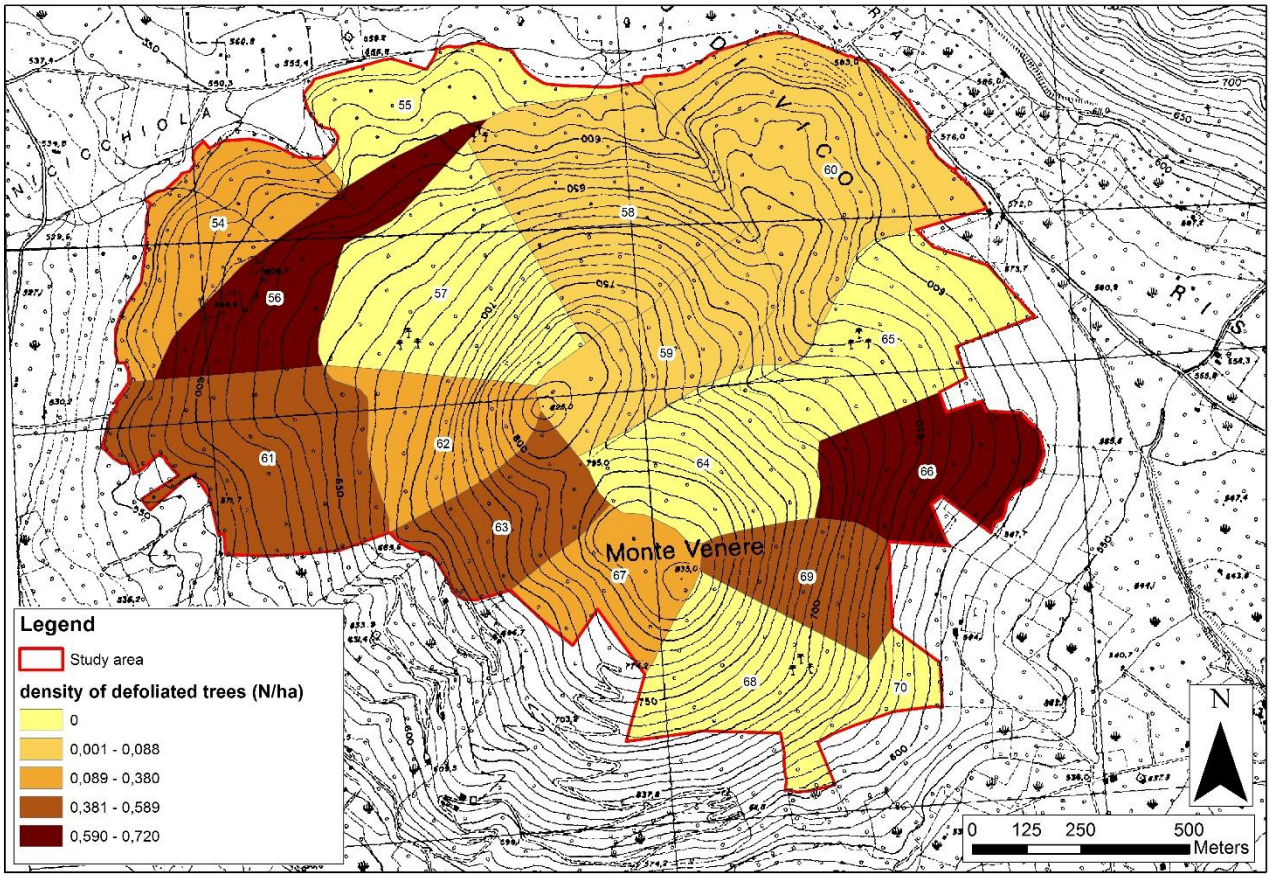


Figure 4. Maps of density of defoliated trees within each forest management unit in the study area of Pennataro. Threshold values were determined according to quantiles.

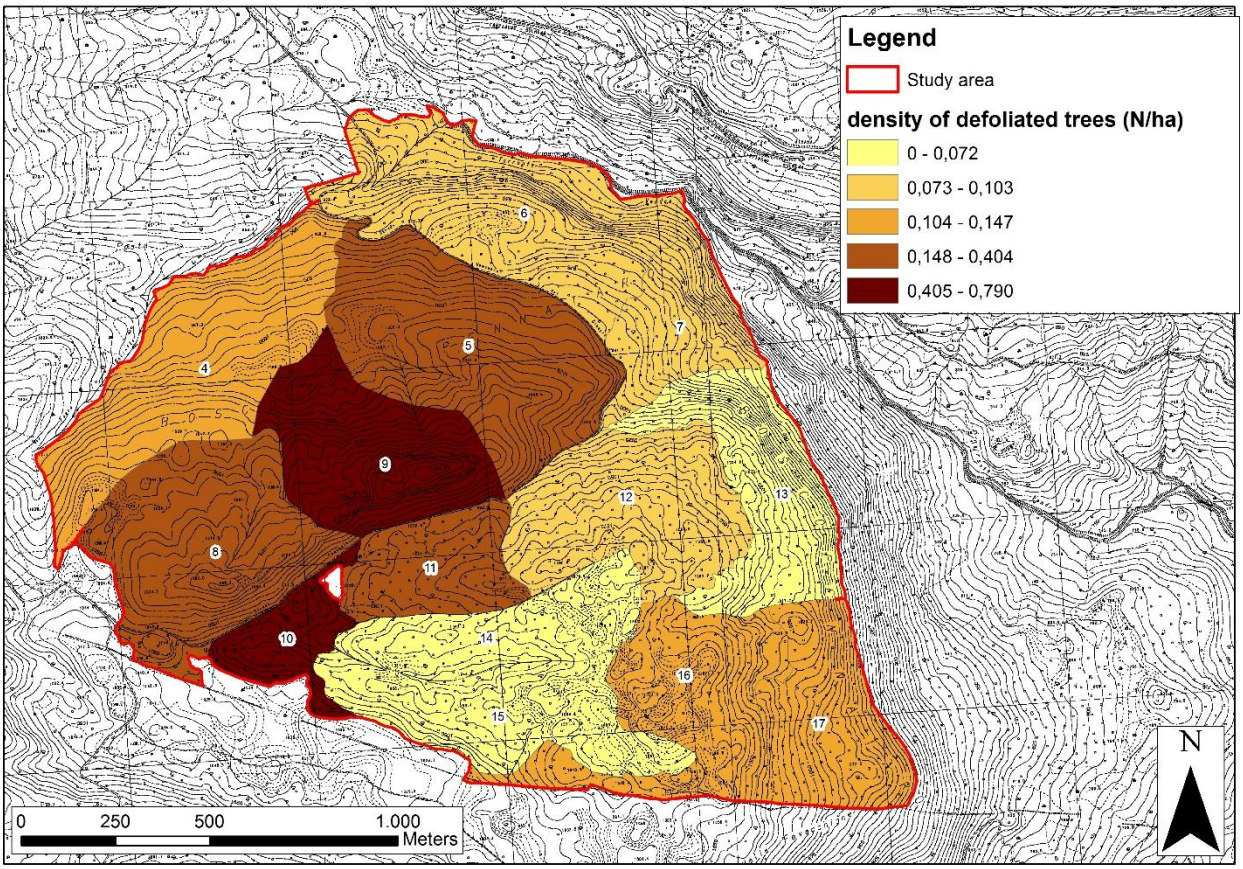


Figure 5. Maps of density of defoliated trees within each forest management unit in the study area of Rincine. Threshold values were determined according to quantiles.

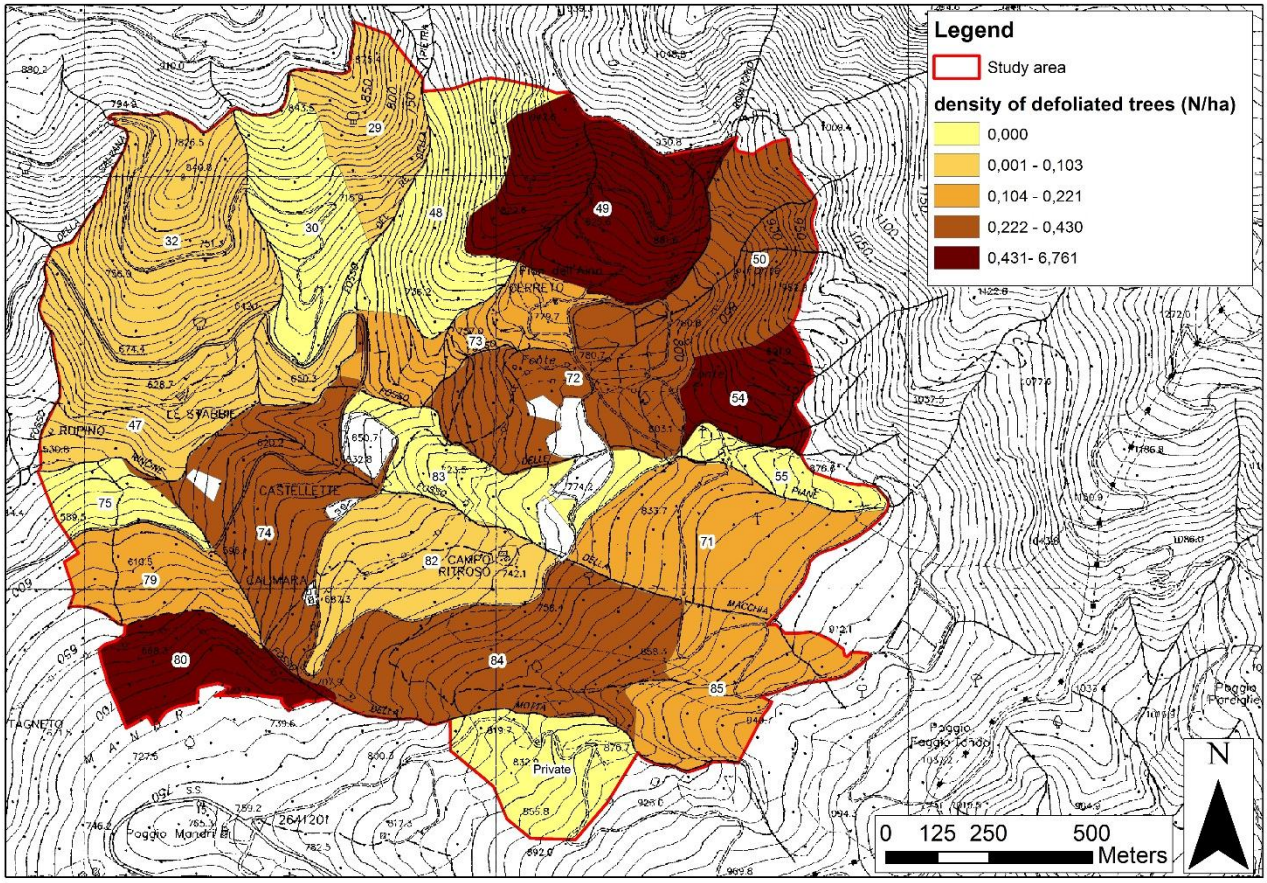


Figure 6. Map of forest damage in the study area of Rincine displayed on high-resolution image acquired by eBEE.

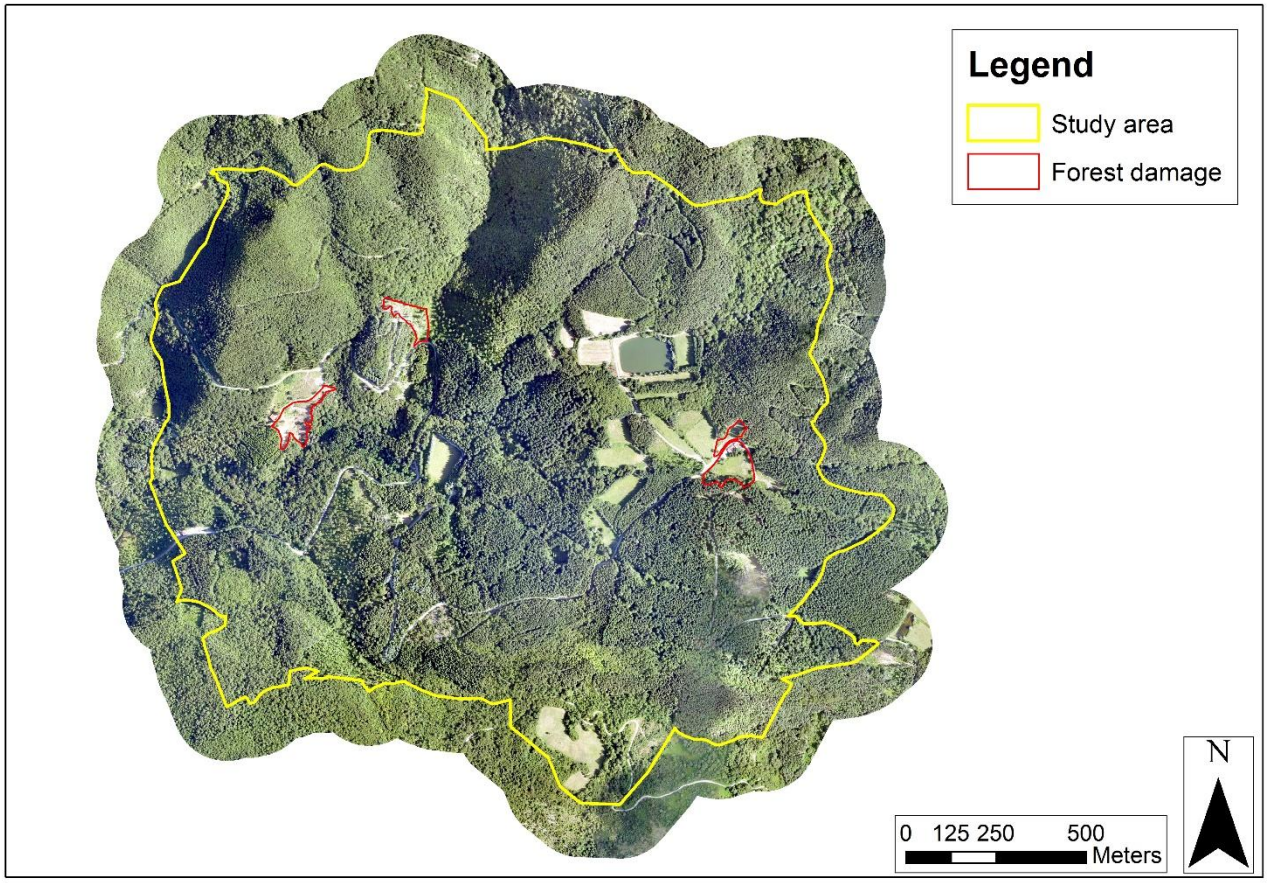


Figure 7. Map of forest damage in the study area of Rincine.

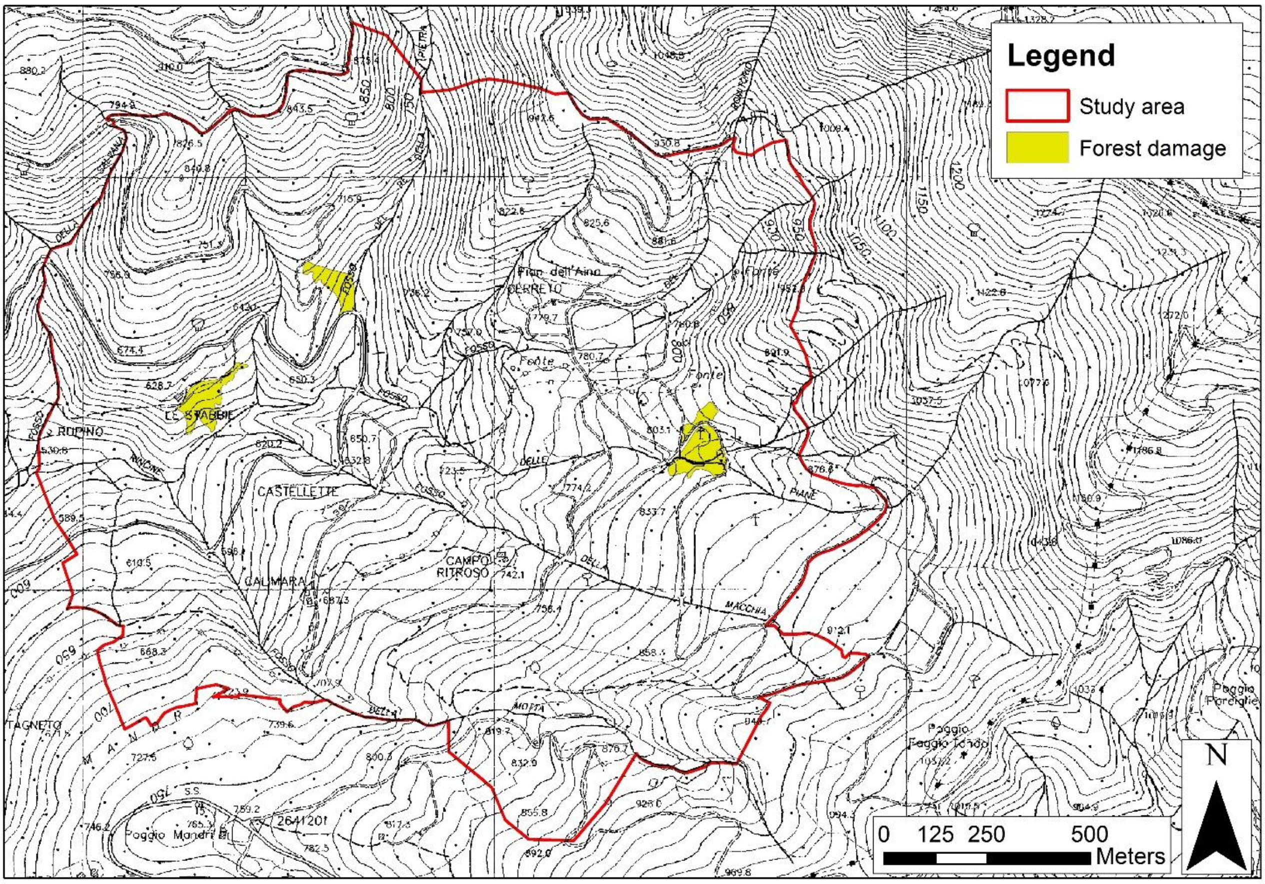


Figure 8. Maps of “number of tree species” expressed in term of number of EFTs within each forest management unit in the study area of Caprarola.

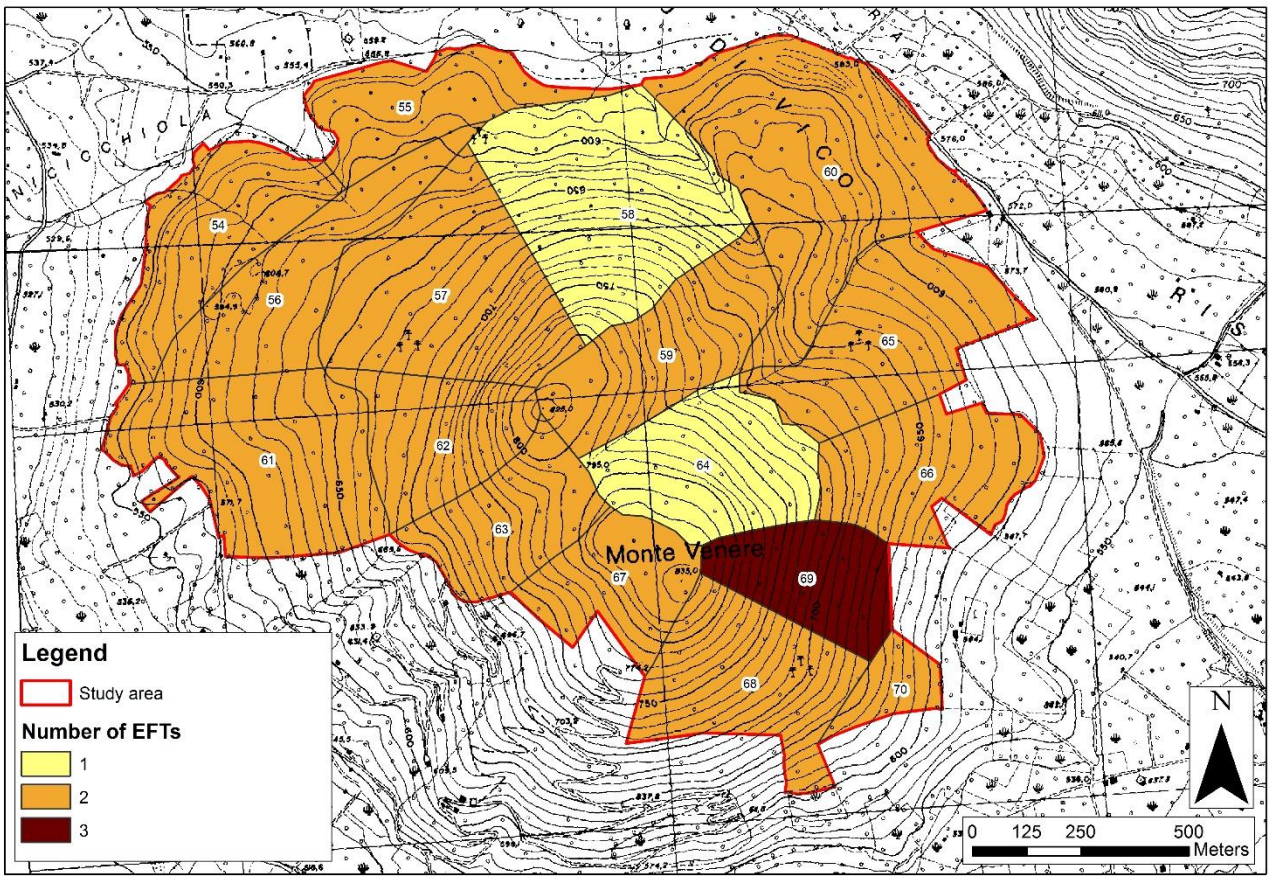


Figure 9. Maps of “number of tree species” expressed in term of number of EFTs within each forest management unit in the study area of Pennataro.

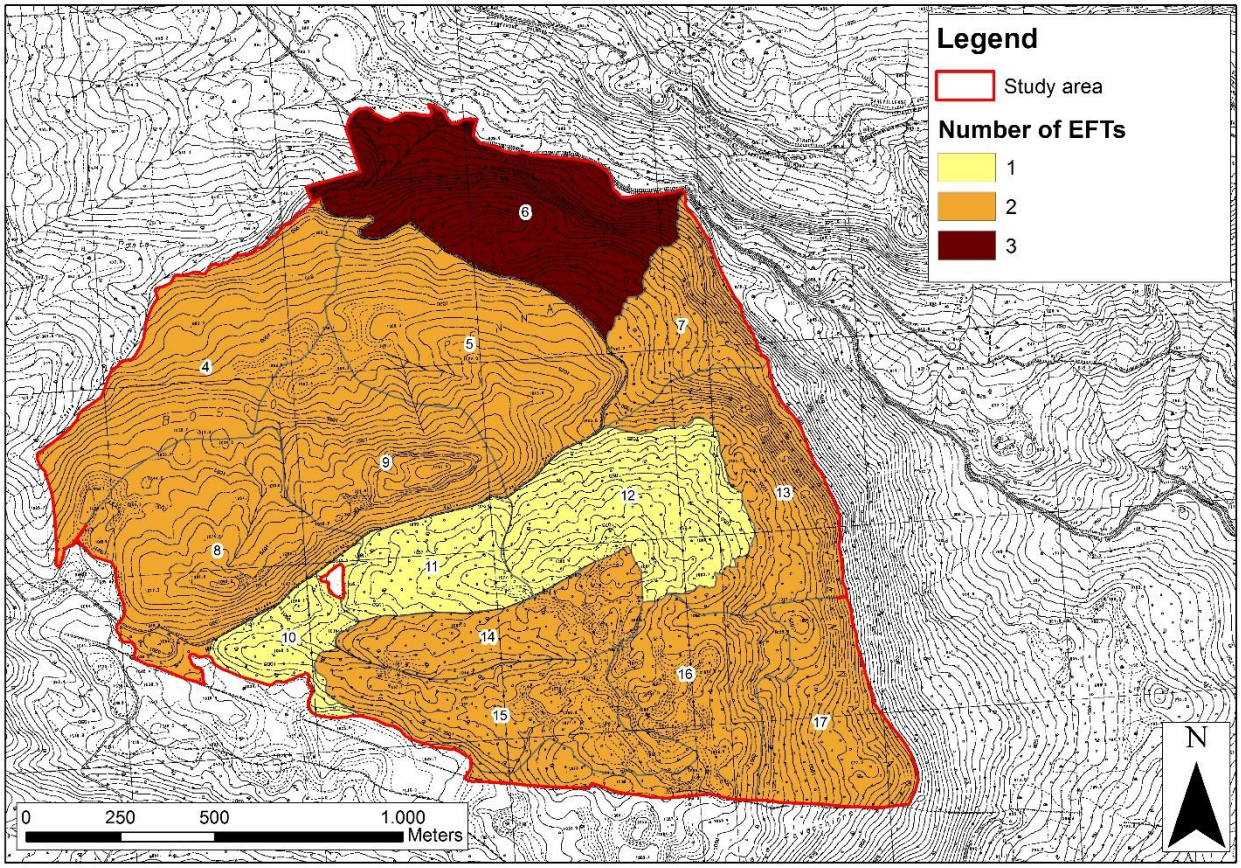


Figure 10. Maps of “number of tree species” expressed in term of number of EFTs within each forest management unit in the study area of Rincine.

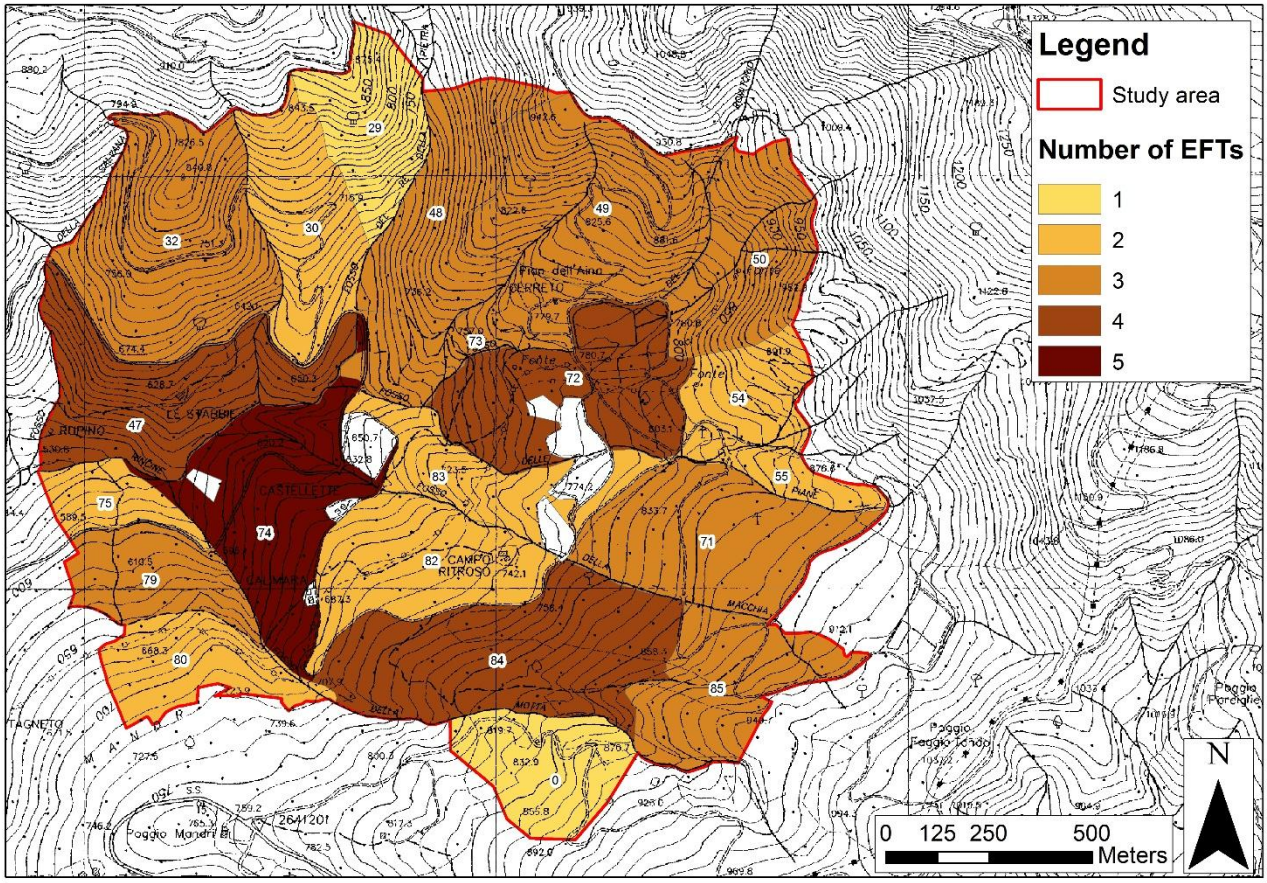


Figure 11. Map of “introduced tree species” in the study area of Rincine displayed on high-resolution image acquired by eBEE.

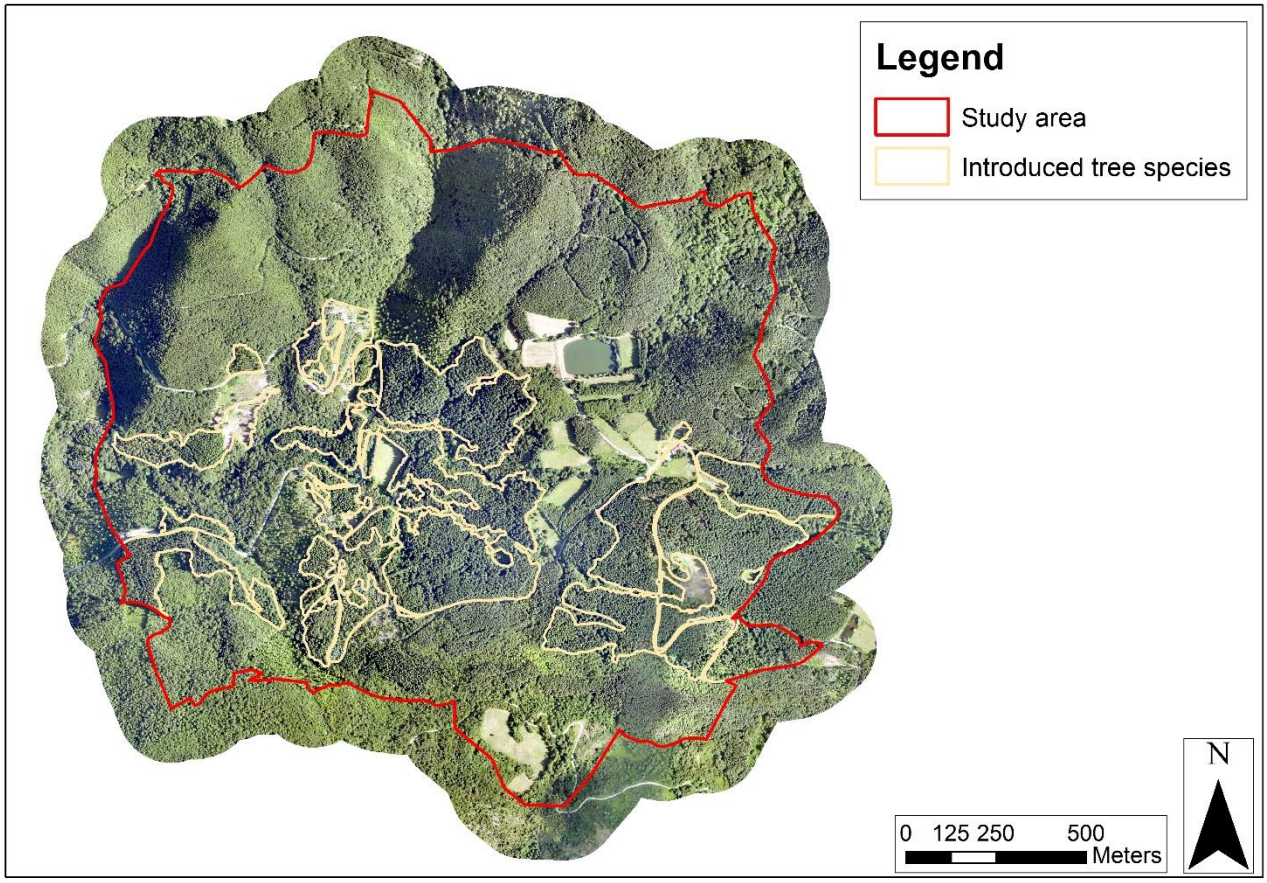


Figure 12. Map of “introduced tree species” in the study area of Rincine.