What UAV remote sensing can tell us about sustainability of forest management at operational level: lessons learned from the FRESHLIFE project

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Outline

1) Sustainable forest management (SFM) and information needs

2) What makes UAV remote sensing special for SFM?

3) UAV remote sensing in the FRESHLIFE project & lessons learned
1) Sustainable forest management (SFM) and information needs

The evaluation of SFM at operational scale, requires SFM indicators to be monitored at the spatial scale where forest takes place = forest compartments (scale: tens of hectares)

SUSTAINABLE FOREST MANAGEMENT: QUESTIONS

- WHAT IS THE AREA OF FOREST?
- WHAT ARE THE STOCKS AND GROWTH RATES OF THE FORESTS?
- WHAT IS THE ABOVEGROUNDBIOMASS of FOREST?
- WHAT IS THE HEALTH STATUS of the FOREST?
- HOW MUCH FOREST AREA IS DAMAGED BY ABIOTIC OR BIOTIC DISTURBANCES EACH YEAR?
- HOW MANY TREE SPECIES ARE FOUND in the FOREST?

SFM indicators
- Growing stock
- Biomass
- Vitality
- Number of tree species
1) Sustainable forest management (SFM) and information needs

INFORMATION NEEDS = for each compartment, measures of SFM indicators
1) Sustainable forest management (SFM) and information needs

INFORMATION NEEDS = for each compartment, measures of SFM indicators = trend over time (monitoring)
2) What makes UAV remote sensing special for monitoring SFM?

**Fixed wing UAV+RGB camera**
(CANON S110, 18.1 Megapixels)

Pixel size~10-20 cm!

**SFM indicators**
- N. of Tree species
- Crown defoliation
- Area affected by damage
2) What makes UAV remote sensing special for monitoring SFM?

**DIRECTLY**

- Stand height

**Estimated SFM indicators**

- Volume
- AG Biomass

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Measuring with LiDAR

- Flight direction
- Canopy Height Model (CHM)
- Digital Surface Model (DSM)

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See C4i- Liu et al.
Comparative analysis of canopy heights estimated using UAV LIDAR & photogrammetry
3) UAV remote sensing in the FRESHlIFE project

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

Coordinator Prof. CHIRICI, University of Florence | Italian Academy of Forest Sciences, IT
Project duration: 2015-2019

https://freshlifeproject.net/

- Crown defoliation
- Damages
- AG Biomass
- N. of tree species
- Growing stock

7 gruppi di indicatori pan-europei di Gestione Forestale Sostenibile monitorati e mappati

test the feasibility to map selected SFM indicators, at the forest compartment scale, by integration of forest inventory & UAV RS
3 Demonstration Sites ~ 250 ha each

1 Rincine
Municipality of Londa (Florence, Tuscany)
Regional estate forest
Managed by Unione di Comuni Valdarno e Valdisieve

2 Caprarola
Municipality of Caprarola (Viterbo, Lazio)
Regional Nature Reserve of Lago di Vico
Site of the Natura2000 network
Managed by Municipality of Caprarola

3 Bosco Pennataro
Municipality of Vastogirardi (Isernia, Molise)
Site of the Natura2000 network
Managed by National Forest Service, Office for Biodiversity Isernia

3) UAV remote sensing in the FRESShLIFE project
3) UAV remote sensing in the FRESHLIFE project

Approach: integration of UAV and field plots data collection

18 MP RGB camera  
Yellscan

50 pairs of digital & field plots size 530 m²
### 3) UAV remote sensing in the FRESHLIFE project

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<th>UAV data</th>
<th>Methodological approach</th>
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3) UAV remote sensing in the FRESHLIFE project

- Differences in tone in the green band → distinguishing tree dominant species

- Combination of tone, size, shape and texture identification to genus or species

- Quality of the orthomosaic, can be worst in some areas (e.g. relief shadows, cloud cover)

See C4i- Wallace et al. Innovative data capture and algorithms for improving outcomes from UAV image-based point clouds of forests
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.
3) UAV remote sensing in the FREShLIFE project

Map of European Forest Types

Legend

- 7.3 Apennine-Corsican mountainous beech forest
- 8.1 Downy oak forest
- 8.2 Turkey oak forest
- 8.7 Chestnut forest
- 8.8 Other thermophilous deciduous forests
- 10.2 Mediterranean Black pine forest
- 13.2 Italian alder forest
- 14 Introduced tree species forest
Mapping the number of tree species occurring within a given forest compartment performed using the number of EFTs as a proxy of the number of tree species (conservative estimate)
• The visual classification of true color orthomosaics appears a feasible for mapping widespread European Forest Type classes, provided that images are acquired by the drone under optimal conditions
  • different phenological status of the species, resulting in a diverse spectral response;
  • absence of clouds;
  • homogeneous light and atmospheric conditions between flights

• high per-class thematic accuracy (PA and OA>70%), even within forest areas with heterogeneous fine-scaled spatial pattern of tree dominant species
Defoliation

"Defoliation of one or more main tree species on forest and other wooded land in each of the defoliation classes “moderate”, “severe” and “dead” »

3) UAV remote sensing in the FRESHLIFE project
3) UAV remote sensing in the FRESHLIFE project

Defoliation map, 2 classes

1 - Partially defoliated = more than 70% defoliation
2 - Totally defoliated (dead)

minimum mapping unit ≥ 3 m²
3) UAV remote sensing in the FRESHLIFE project
Forest damage

«Forest and other wooded land with damage, classified by primary damaging agent (abiotic, biotic and human induced)»

• Rincine case study only
• Windstorm occurred in March 2015
• Minimum mapping unit 0.25 ha, total area just above 3 ha
3) UAV remote sensing in the FRESHLIFE project

Forest damage map

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

Legend
- Study area
- Forest damage

Figure 7. Map of forest damage in the study area of Rincine.
• “Defoliation” is not a frequent phenomenon in the FRESHLIFE pilot study areas
• it is only detectable on standing dead trees or trees with severe crown defoliation (over 70% foliage loss) that are part of the dominant layer.
• The latter represents only a small part of the standing dead trees within our study areas, since most of them were found in the dominated layer
• Reliable maps of forest damage can be obtained by visual interpretation (much faster than mapping the indicators using field surveys)
3) UAV remote sensing in the FRESHLIFE project

Growing stock | AG Biomass

- High density of returns (50 points m$^{-2}$)
- but ground returns represent a minor share (3-12%)
### Indicator # 1.3 Growing stock

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<th>Study area</th>
<th>Selected metric</th>
<th>model equation</th>
<th>$R^2$</th>
<th>RMSE ($m^3$ ha$^{-1}$)</th>
</tr>
</thead>
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<tr>
<td>Rincine</td>
<td>$q_{mh}$</td>
<td>-52.559 + 36.647x</td>
<td>0.80</td>
<td>111</td>
</tr>
<tr>
<td>Caprarola</td>
<td>$h_{mean2}$</td>
<td>-155.069 + 33.093x</td>
<td>0.26</td>
<td>167</td>
</tr>
<tr>
<td>Bosco Pennataro</td>
<td>$h_{mean}$</td>
<td>-34.938 + 22.427x</td>
<td>0.44</td>
<td>84</td>
</tr>
</tbody>
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Predicted values (23*23 m sampling unit) at forest compartment scale (most relevant for operational purposes)

3) UAV remote sensing in the FRESHLIFE project
3) UAV remote sensing in the FREShLIFE project

Above Ground Biomass
• The quality of maps of growing stock and aboveground biomass SFM indicators seems to be heavily influenced by the density of ground returns

• **Scanning during the leaf-on season**, combined with dense forest stands like those covering the test areas, caused ground surfaces hidden below crown foliage to be difficult to acquire

• But even so, the test demonstrates that it is technically feasible to derive reliable spatial estimates of growing stock and above ground biomass by LIDAR-assisted inference, considering that optimal results were achieved in the most difficult conditions of Rincine test site

• **LIDAR acquisition also during leaf-off season**, by providing a better identification of the ground surface, would ultimately result in better LIDAR-assisted predictive models
Importance of an accurate planning of UAV Image and LIDAR data acquisition→ quality of classification for SFM indicator

Very good levels of accuracy reached under optimal data acquisition

UAV RS allows mapping & monitoring SFM indicators at the forest compartment scale, at a much higher spatial resolution than would be possible by field survey
Thank you!

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PAPERS

- Forest Inventory Attribute Prediction Using Lightweight Aerial Scanner Data in a Selected Type of Multilayered Deciduous Forest – Download
- A new approach with DTM-independent metrics for forest growing stock prediction using UAV photogrammetric data – Link

POSTERS

- Poster presented at XIV Conference AISSA – Download
- Poster presented at the PhDay 2017 – Comparison of Two Remote Sensing Techniques (Aerial and Terrestrial) With Traditional Field-Based Method for Forest Inventario – Download
- Poster presented at the VI Mediterranean Forest Week – Download

PRESENTATIONS

- Airborne LiDAR Scanning for Forest Biomass Estimation (OBEN) – Download
- Remote sensing from RPAS for forest resources monitoring – Download
- Workshop LIFE-IMAGE – Download
- RPAS “eBee” for environmental surveys – Download
- FRESH LIFE Demonstrating Remote Sensing Integration in Sustainable Forest Management – Download
- Presentations for the Mediterranean Model Forest Network “Best Practices” Session – Download
- Rilievi Lidar da APR per la stima di parametri di gestione forestale sostenibile – Download

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