# Post-fire regeneration dynamics in mountain forests of the Alps: from seedling to landscape


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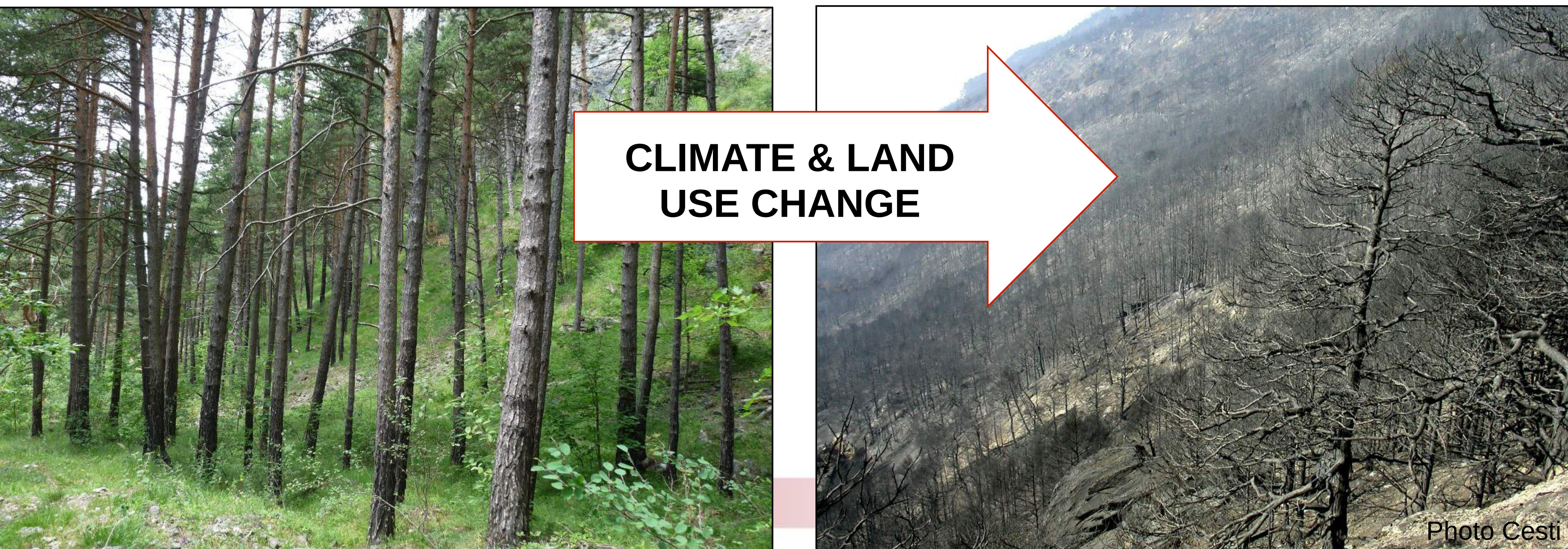
TESAF Dipartimento Territorio e Sistemi Agro-Forestali

# Fire regime in the Alps

- Winter-early spring fire season (peak: February-March)
- Low/medium intensity surface fires
- Average size < 10 ha

- Longer fire season (increase in summer lightning fires)
- More stand replacing crown fires (mostly in coniferous forests)
- Increase in size and severity



# POST-FIRE MANAGEMENT?

active

passive


# Long term research on wildfire effects and post-fire management in the Italian Alps

# Main objectives

To assess the impact of different post-fire management activities on the restoration of coniferous forests after stand replacing wildfires

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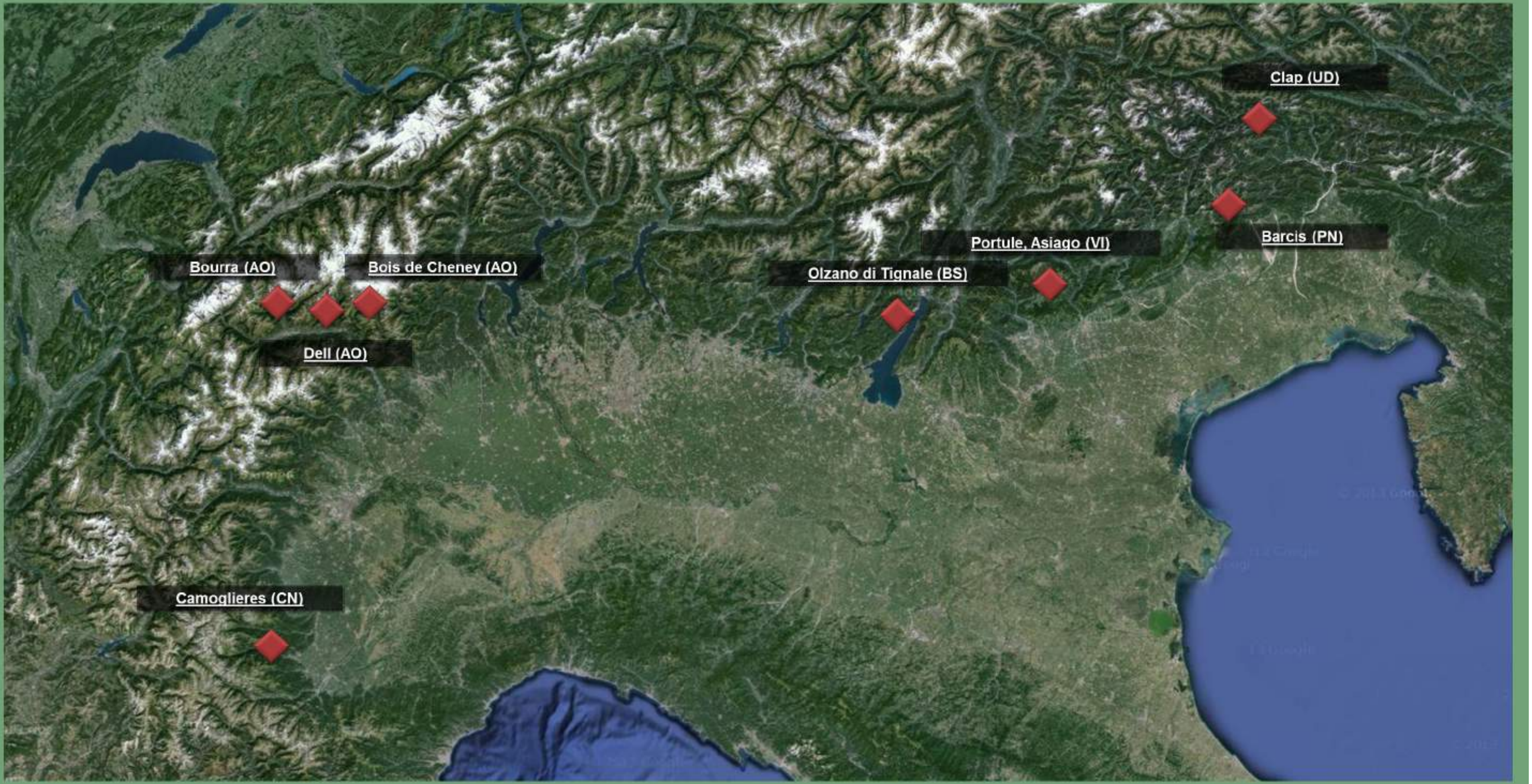
To assess the impact of different post-fire management activities on the restoration of coniferous forests after stand replacing wildfires

- *Natural regeneration dynamics?*

- *Combined effect of natural disturbance and human intervention?*

- *Effectiveness and ecological consequences of current restoration practices?*

# Study sites in the Italian Alps



# Study sites in the Italian Alps

Coniferous forests

High severity stand-replacing crown fires

Recent (less than 30 years)

| | |
|---|---|
| Size range | 25 - 3185 ha |
| Time span | 1990 - 2016 |

# Post-fire restoration strategy and management

human impact

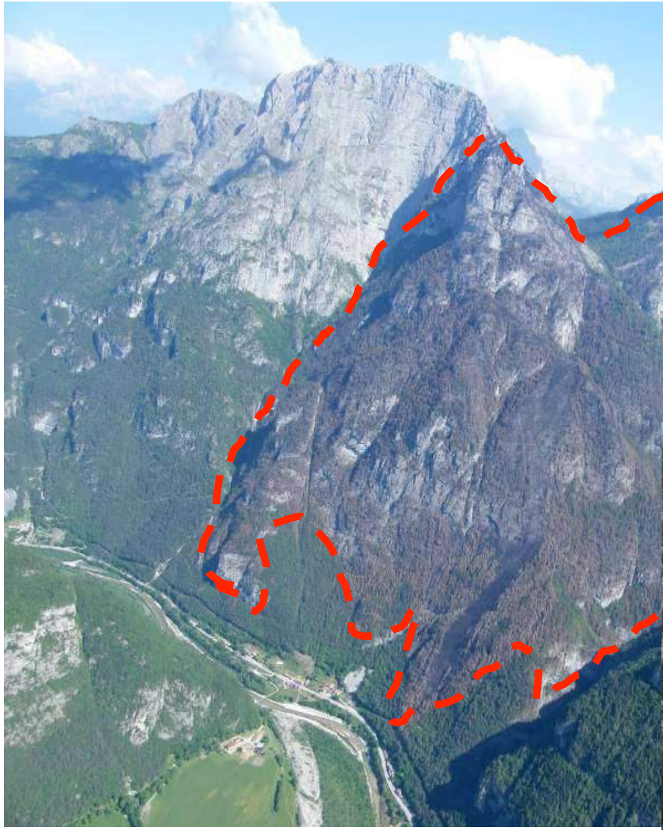
\- → +

**No intervention**

**Cut and release**

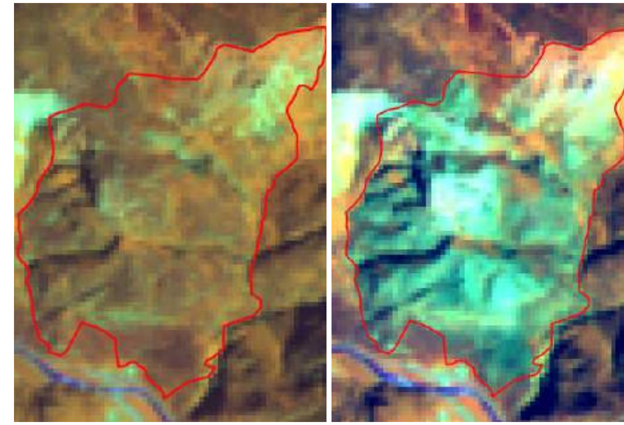
**Salvage logging**

**Salvage logging + plantation**

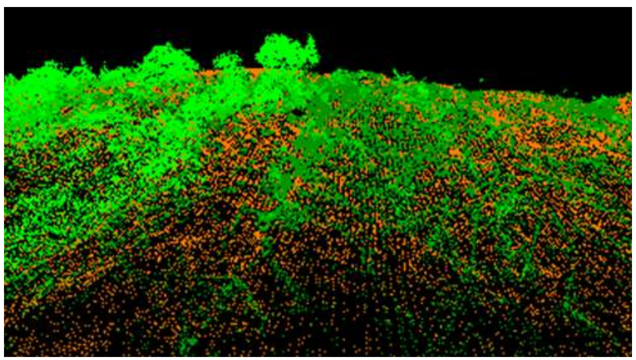


- Landscape
- Stand
- Seedling

# Dataset implementation



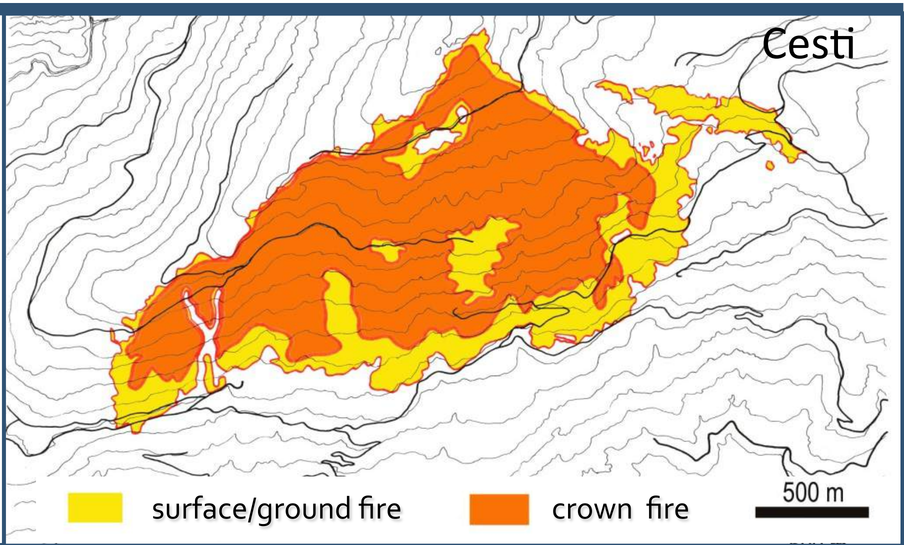
- Field data
- GPS location
- Temperature and soil moisture
- Hemisph. photos
- Aerial photos
- Landsat images
- LiDAR data




# Nus/Verrayes wildfire (AO)

## 12/03/2005

- burned area: 257 ha (160 ha pure *P. sylvestris* forest)
- stand replacing fire
- high severity




# Post-fire restoration strategy and management

human impact

\- +

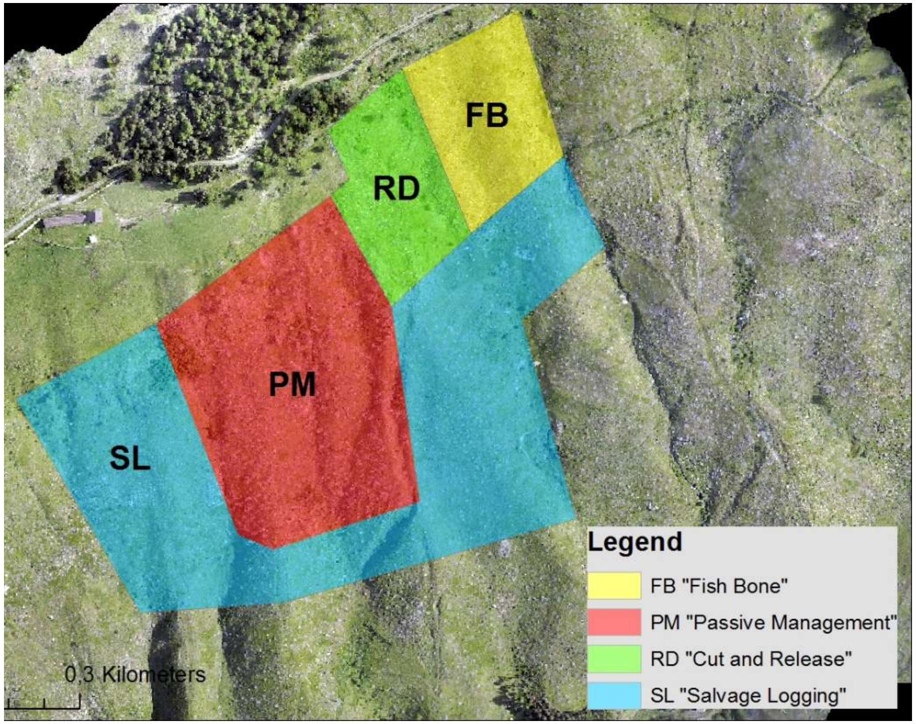
**No intervention**

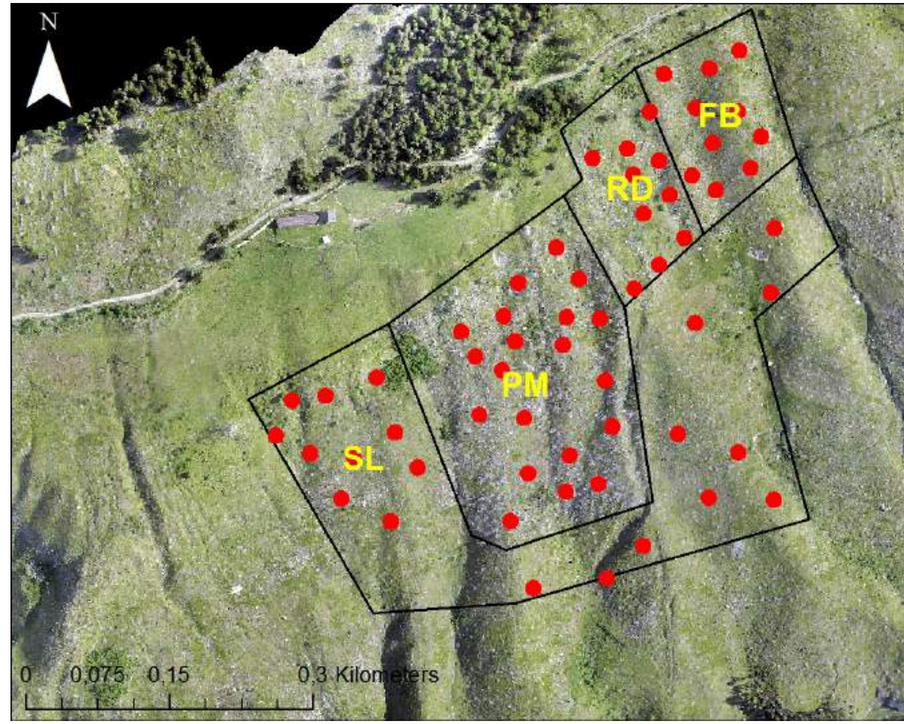
**Felling + no removal (random direction)**

**Felling/branches removal (fishbone)**

**Salvage logging**

# Macrosite field survey




**Post-fire treatments areas:**

- FB “Fish Bone” > 1 ha
- RD “Cut and Release” > 1 ha
- PM “Passive management” > 3 ha
- SL “Salvage Logging” > 5 ha

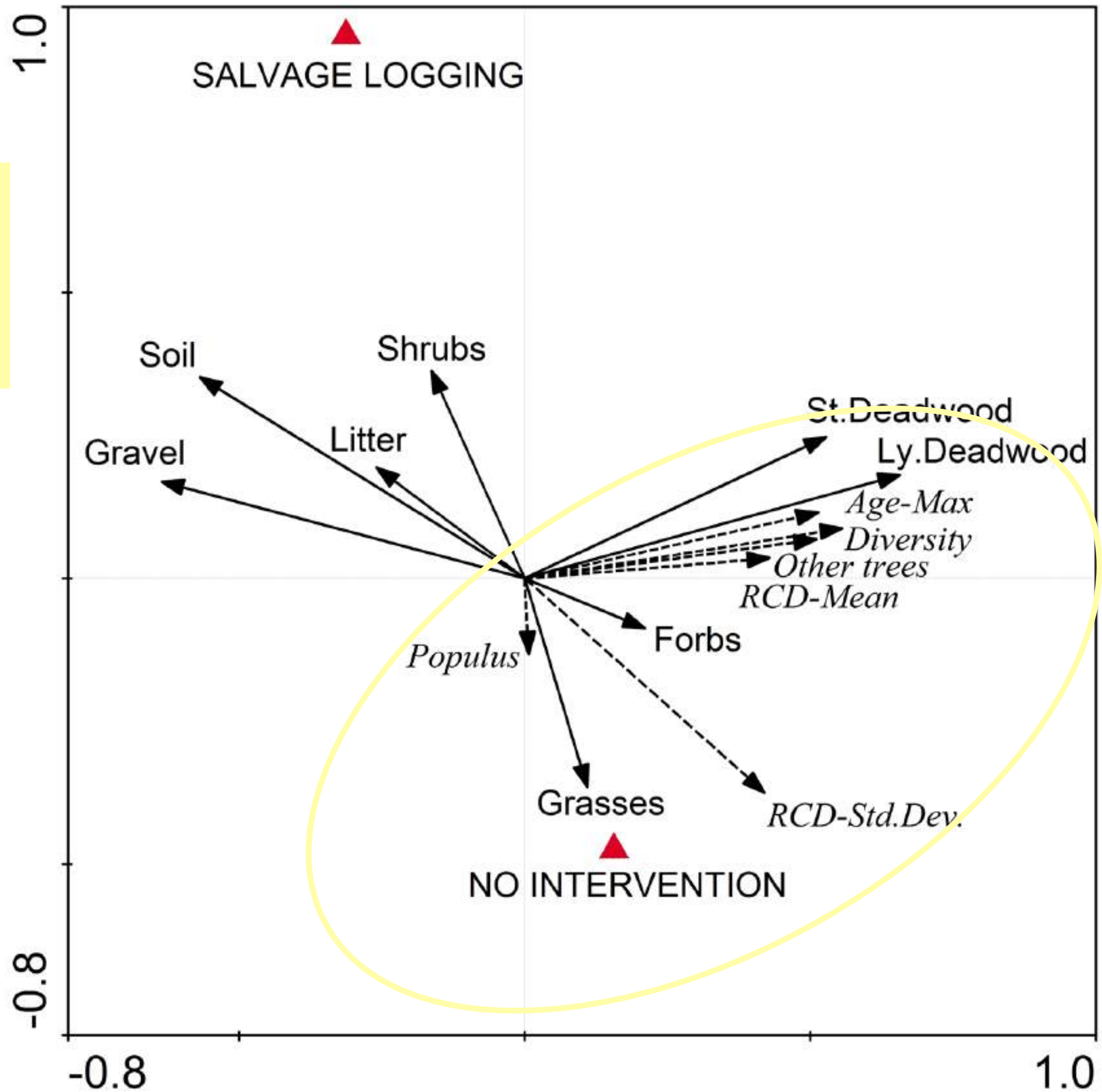
**Post-fire treatments site-scale plots:**

- FB - 10 plots
- RD - 10 plots
- PM - 20 plots
- SL - 20 plots

Fire 2005 – First survey 2011 – Second survey 2016

# RDA: natural regeneration structure in relation to environmental variables and management options

Natural regeneration positively related with no intervention areas



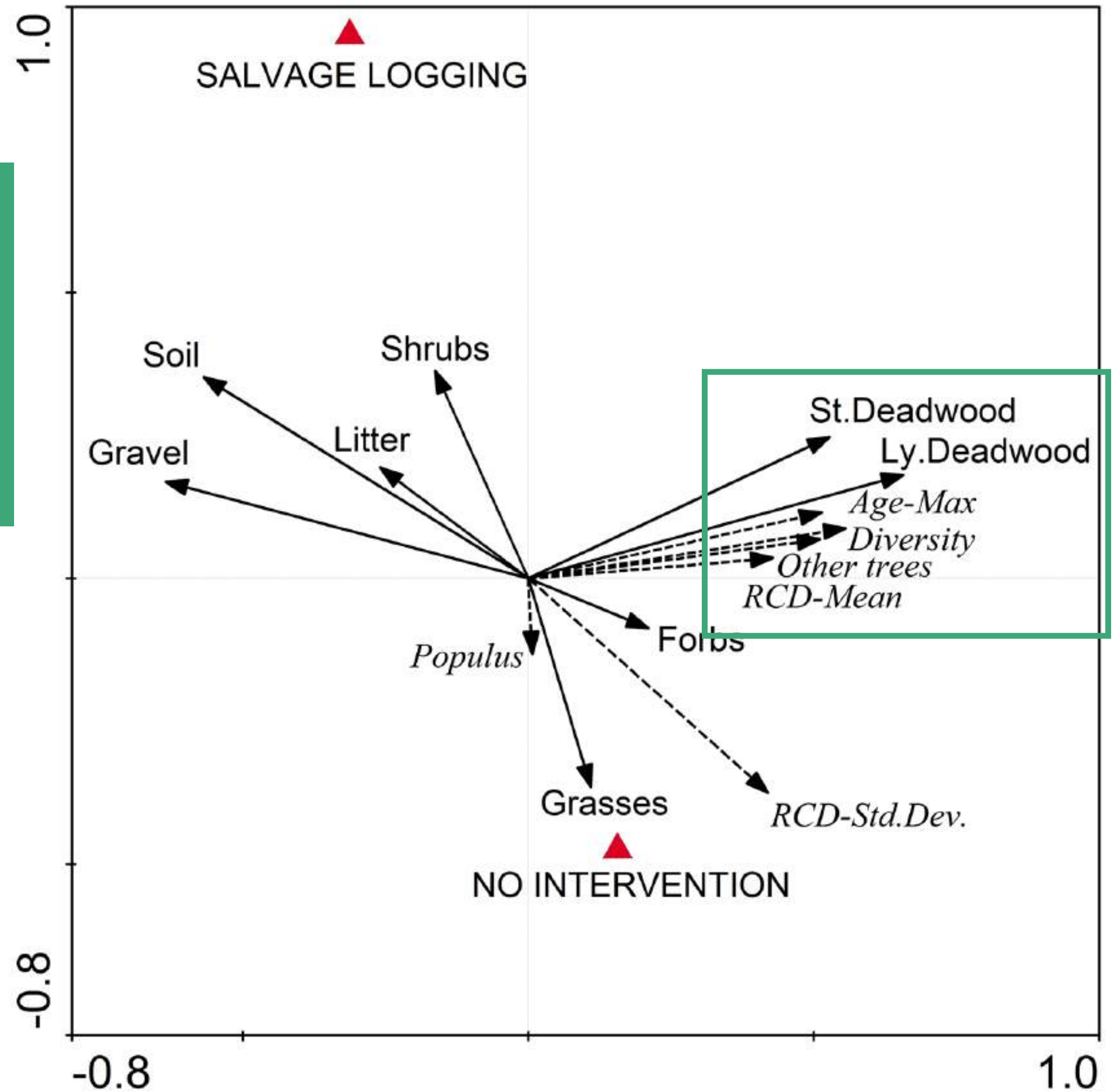

——— Environmental variables

- - - - - Regeneration

| | |
|---|---|
| Variance 1° axis | 19.9 % |
| Variance 2° axis | 3.1 % |
| P-value (Monte Carlo test) | 0.001 |

# RDA: natural regeneration structure in relation to environmental variables and management options

Natural regeneration positively associated (higher density and diversity) with standing and lying deadwood




—— Environmental variables

- - - - - Regeneration

| | |
|---|---|
| Variance 1° axis | 19.9 % |
| Variance 2° axis | 3.1 % |
| P-value (Monte Carlo test) | 0.001 |

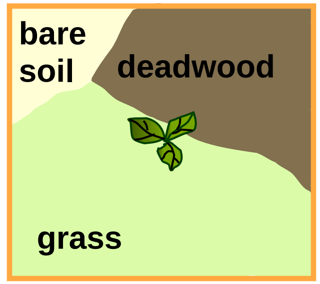
# Main results

Higher regeneration density, specific and structural diversity within no intervention areas.

Response and timing depending on:

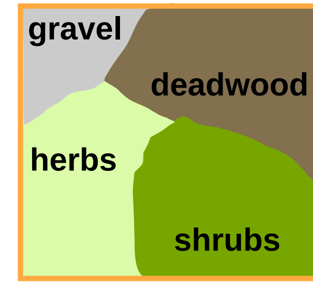
- Fire severity
- Site conditions
- Post-disturbance management

## Microsites with seedling




20 cm

## Microsites without seedling




20 cm

1 m E

Seedling
(species, diameter, height, age, coordinates)

Soil cover classes

Presence of deadwood and/or rocks
(less than 1m distance)

Soil cover classes

Presence of deadwood and/or rocks
(less than 1m distance)

# Microsite results

**2011**

| Explanatory variable | *Beta* | S.E. | *p*-Value | Odds ratio | 95% Confidence interval for odds ratio |
|---|---|---|---|---|---|
| Proximity to | | | | | |
| Deadwood_W | 1.281 | 0.279 | 0.000 | 3.600 | 2.084–6.221 |
| Deadwood_S | 0.957 | 0.260 | 0.000 | 2.605 | 1.566–4.334 |
| Deadwood_E | 0.937 | 0.236 | 0.000 | 2.553 | 1.607–4.057 |
| Deadwood_N | 0.612 | 0.254 | 0.016 | 1.844 | 1.122–3.033 |
| Rocks_N | 0.608 | 0.603 | 0.313 | 1.837 | 0.563–5.99 |
| Rocks_W | 0.390 | 0.846 | 0.645 | 1.477 | 0.281–7.753 |
| Rocks_S | 0.387 | 0.800 | 0.628 | 1.473 | 0.307–7.064 |

*Marzano et al.2013*

**2016**

Increase in odds ratio, re-arrangement of anisotropic relationships.

Microsite cover changed towards bare soil reduction (25 to 7 %)

# Main results

Regeneration established close to deadwood.

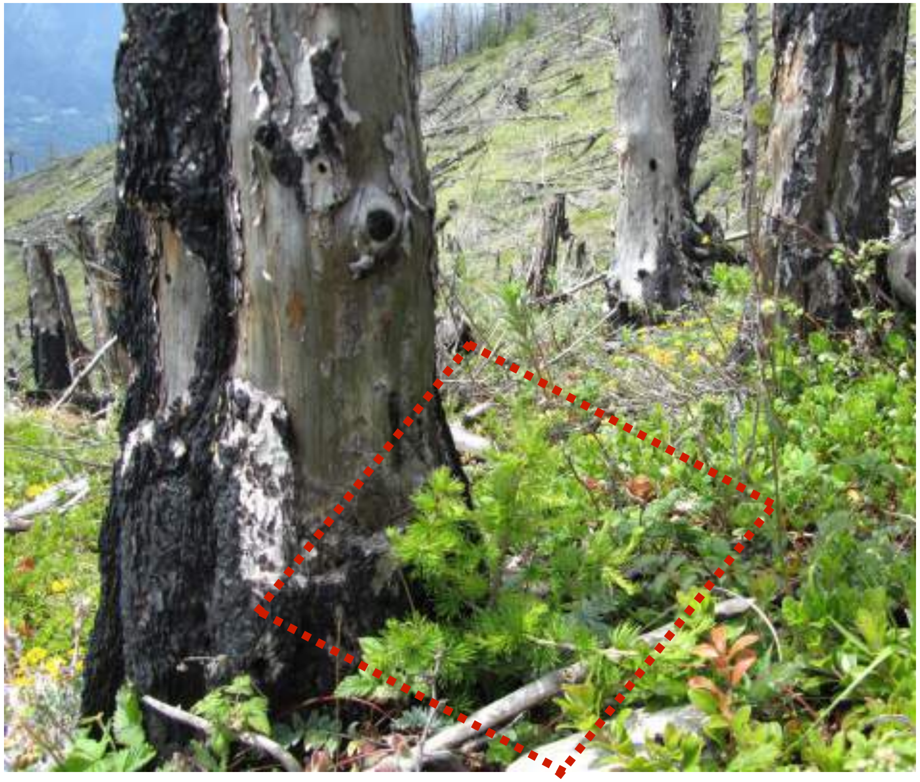
Deadwood enhances the probability of seedling establishment and survivorship (‘safe sites’).

Establishment probability up to 4 times higher (particularly for *P.sylvestris*).

# Main results

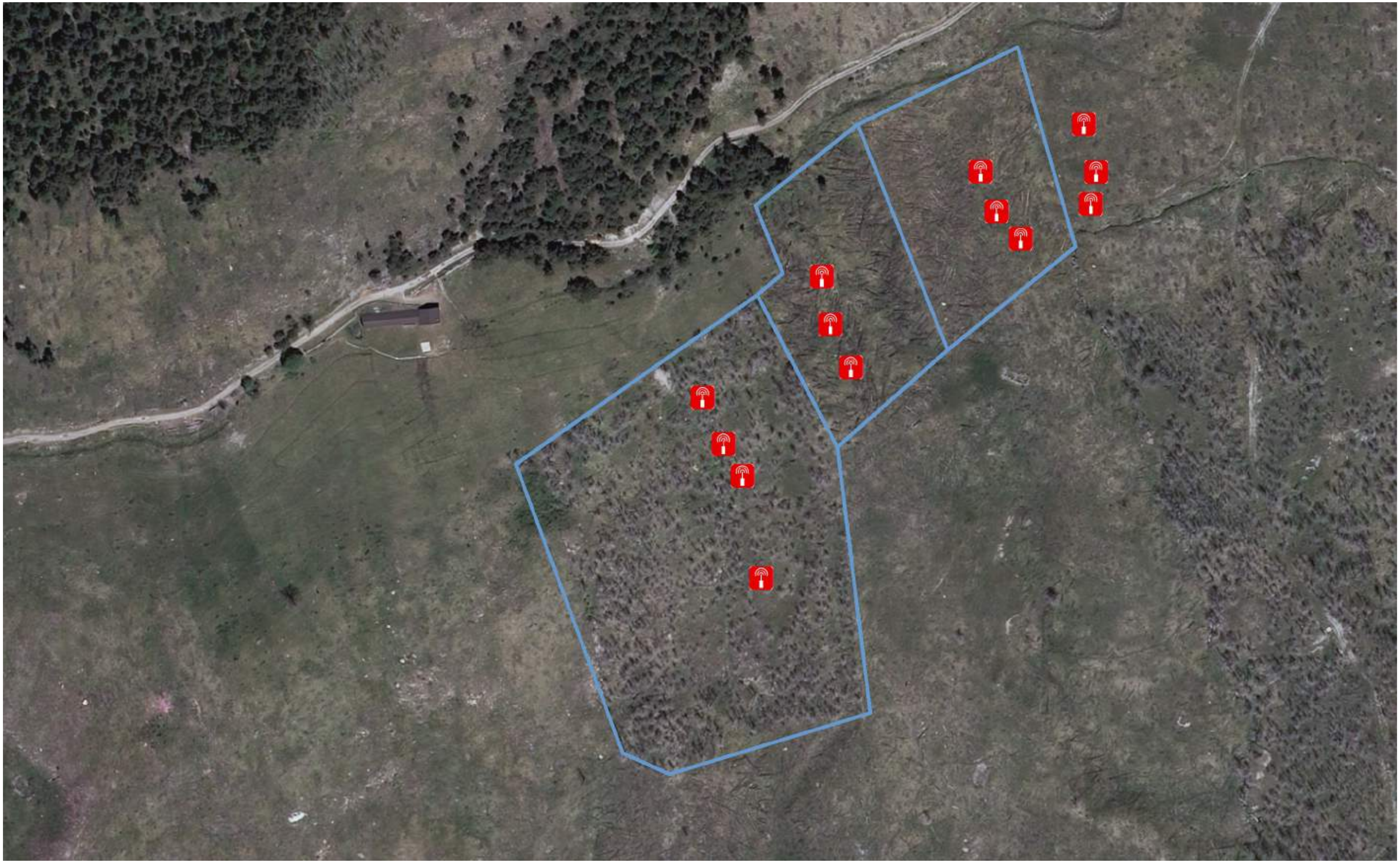
Positive anisotropic spatial interactions (attraction) were found between deadwood and natural regeneration.

Shelter objects to south significantly increased odds of regeneration. Stronger in early post-fire environment.



# Post-fire regeneration in the Alps

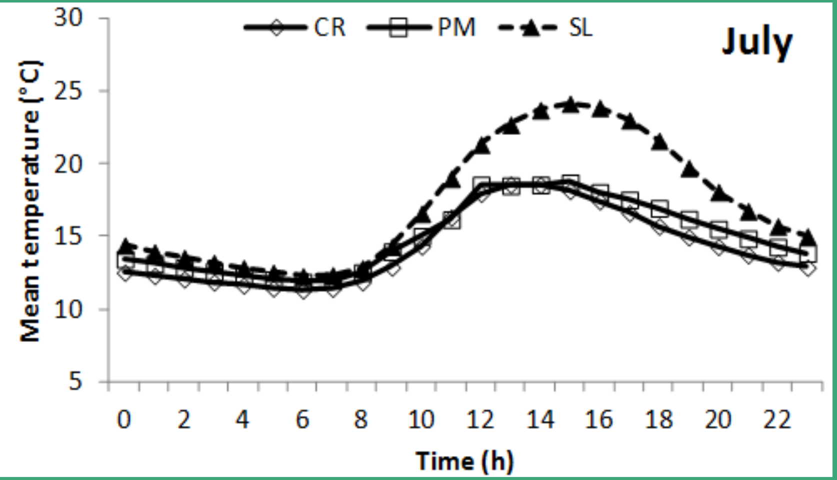


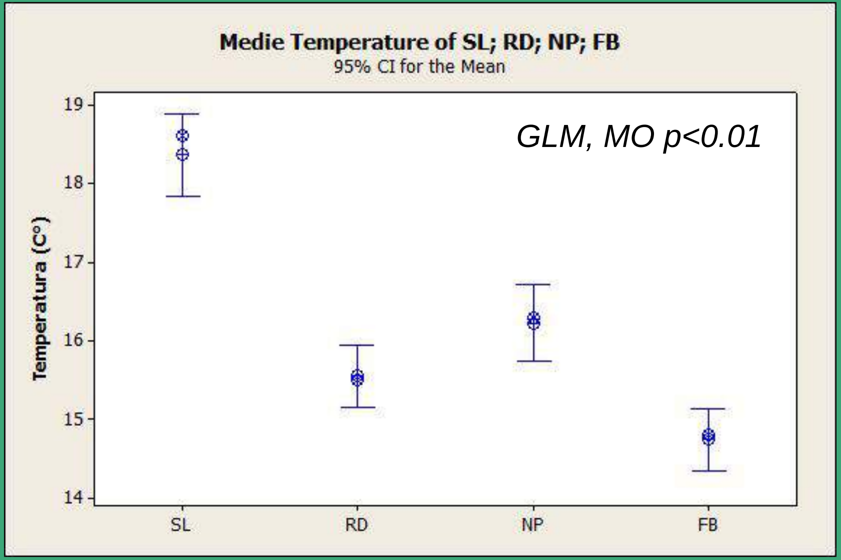


Salvaged sites were dryer than the other treatments:

- significantly higher mean soil temperature and near-ground solar radiation
- lower soil moisture
- higher daily and seasonal variability (highest extreme values)

Deadwood elements provide shadow and wind protection to seedlings.



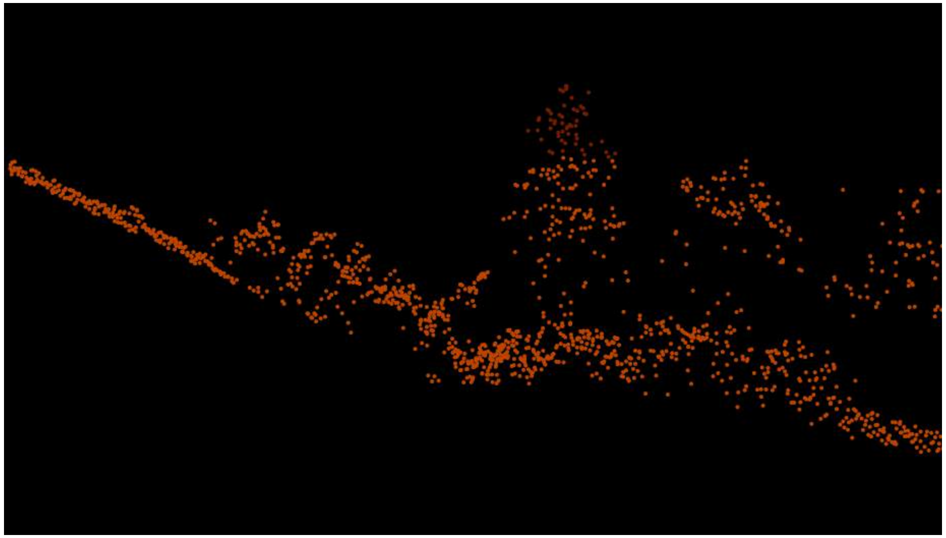



# Main results

Salvage logging altered and/or slowed down natural dynamics (particularly in limiting conditions).

Post-fire management should take into account the ecological role of deadwood.

# LiDAR data



- 2008
Aosta Valley Region Administration

- 2011
PR.AT.2009

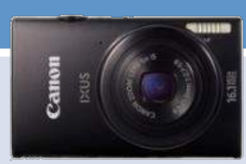
| Characteristic | Value |
|---|---|
| Vehicle | Helicopter |
| Sensor | Optech ALTM 3100 |
| Date of survey | June 20 2011 |
| Mean relative flight height | ~525 m above ground |
| Scan angle | ± 21.5° |
| Scan frequency | 71.5 KHz |
| Output Datum | ETRS2000 (2008) – WGS84 |

# UAV-Photogrammetric data

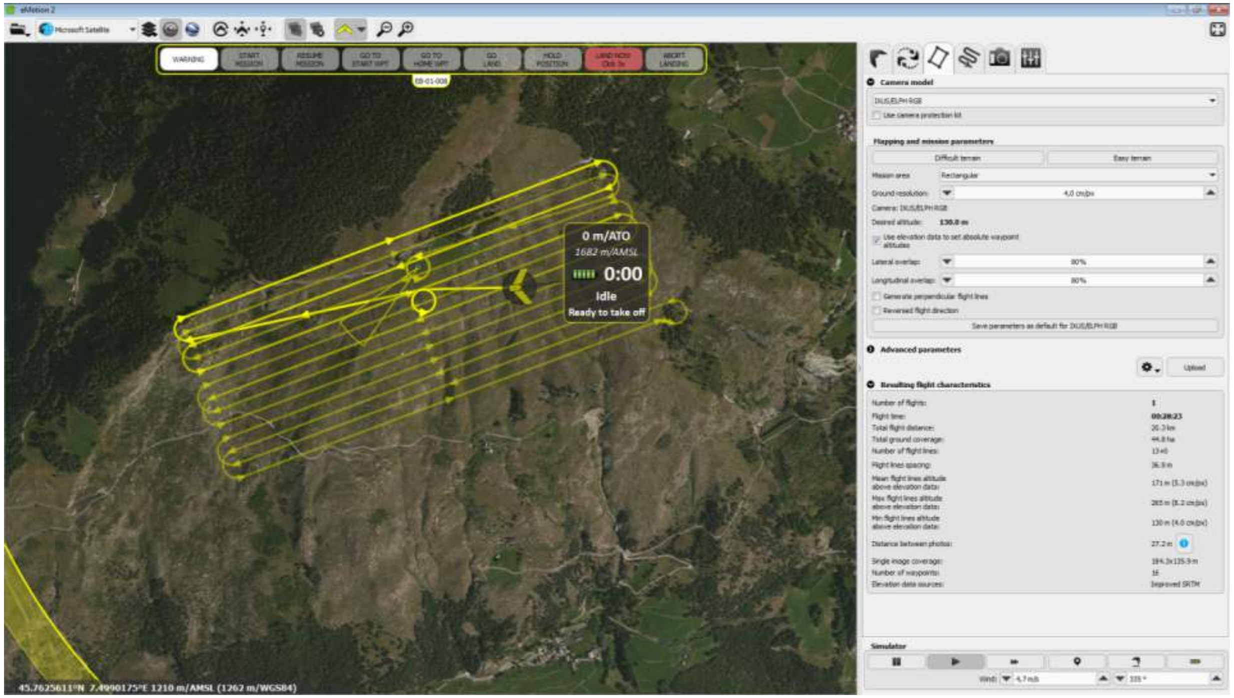
- 2015
NEWFOR

*UAV: eBee SenseFly*

| Technical aspects | |
|---|---|
| **Weight (including the camera)** | 0.69 Kg |
| **Dimension** | 55 x 45 x 25 cm |
| **Wingspan** | 96 cm |
| **Propulsion** | Electric, DC motors 160 W brushless |
| **Battery** | 11.1 V, 2150 mAh |
| **Operative aspects** | |
| **Maximum flight time** | 50 minutes |
| **Flight velocity** | 50 – 90 Km/h |
| **Radiolink range** | 3 Km |
| **Maximum surface detectable** | 12 $Km^2$ at 974 m of altitude |
| **GSD at 100 m** | 0.03 m |
| **Landing accuracy** | ~ 5 m |

| | | Model | Resolution | Pixel size | Bands | Images size |
|---|---|---|---|---|---|---|
| **RGB camera** |  | Canon IXUS 110 HS | 16 Mp | 1.33 µm | Green Red Blue | 4608 x 3456 |
| **NIR camera** |  | Canon S110 NIR | 12 Mp | 1.86 µm | Green Red NIR | 4000 x 3000 |

# *Flight planning: eMotion* flight planning software




## *Flight parameters*

Ground resolution: 4 cm/px

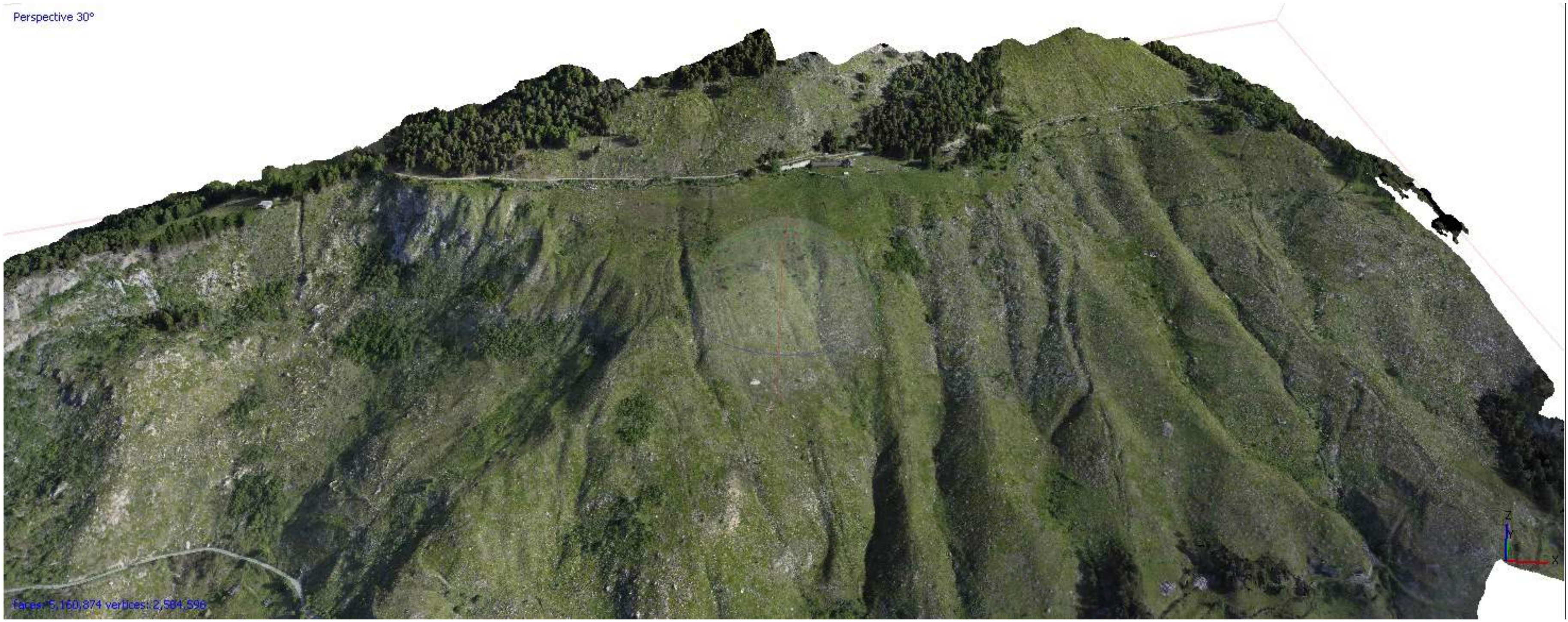
Lateral and longitudinal coverage: 80%

Flight altitude: 130 m

Time of flight: 28 minutes

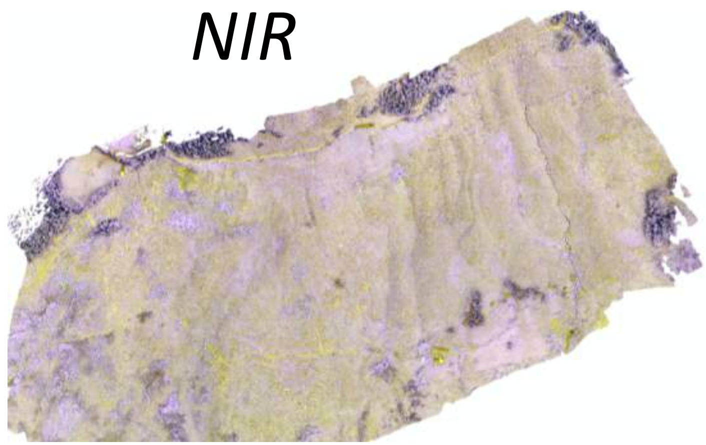
Total ground coverage: 45 ha

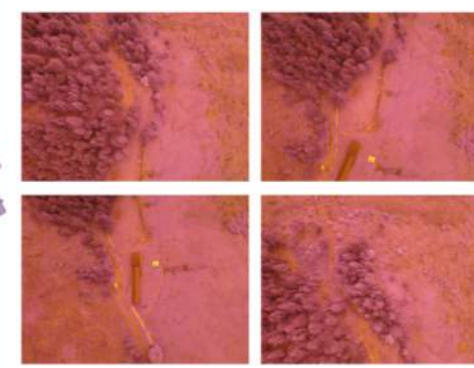
Distance between photos: 27 m



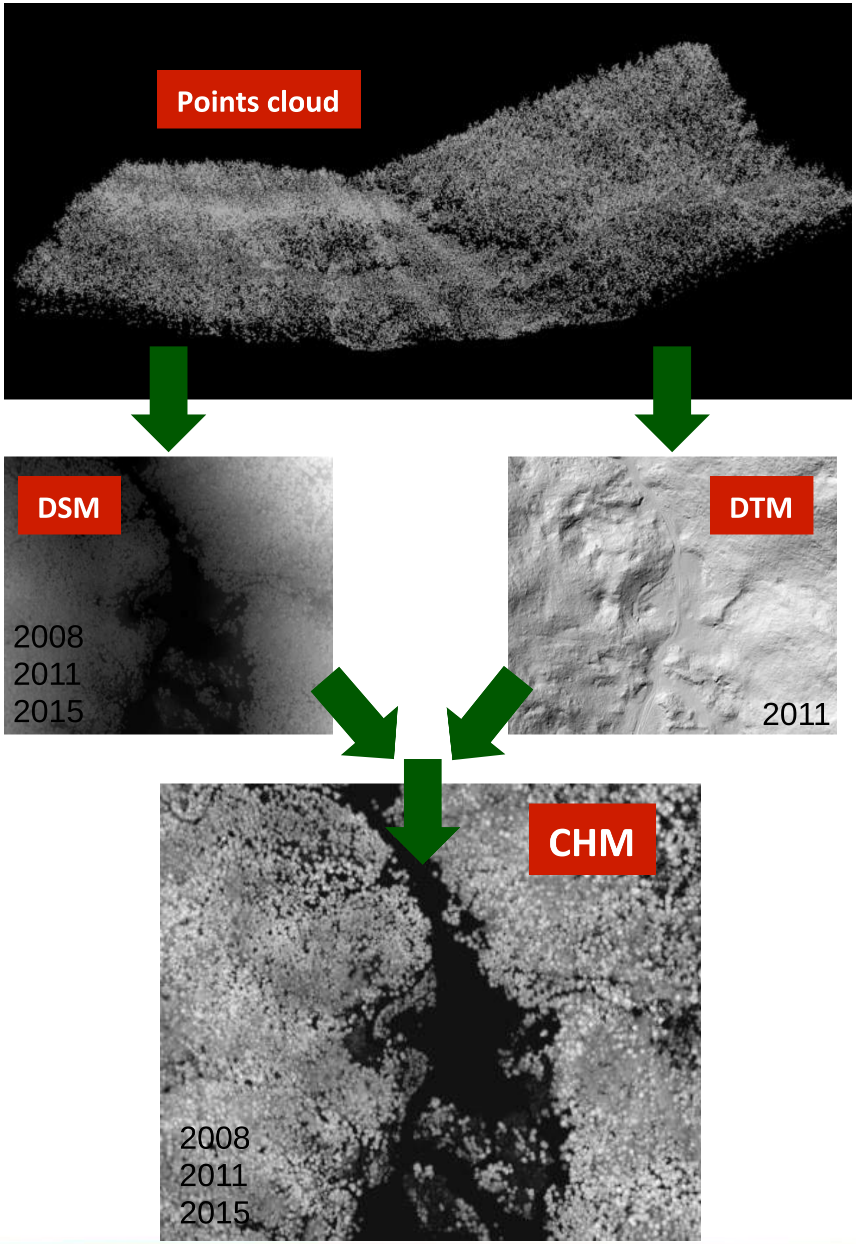

| 3D RGB model | |
|---|---|
| **Sparse point cloud** | ~ 765000 |
| **Dense point cloud** | ~ 26000000 |
| **Mesh vertices** | ~ 2600000 |
| **Mesh faces** | ~ 5200000 |

*NIR*





*Processing time:* 5-6 hours with Windows7, 16 GB RAM, Intel i7

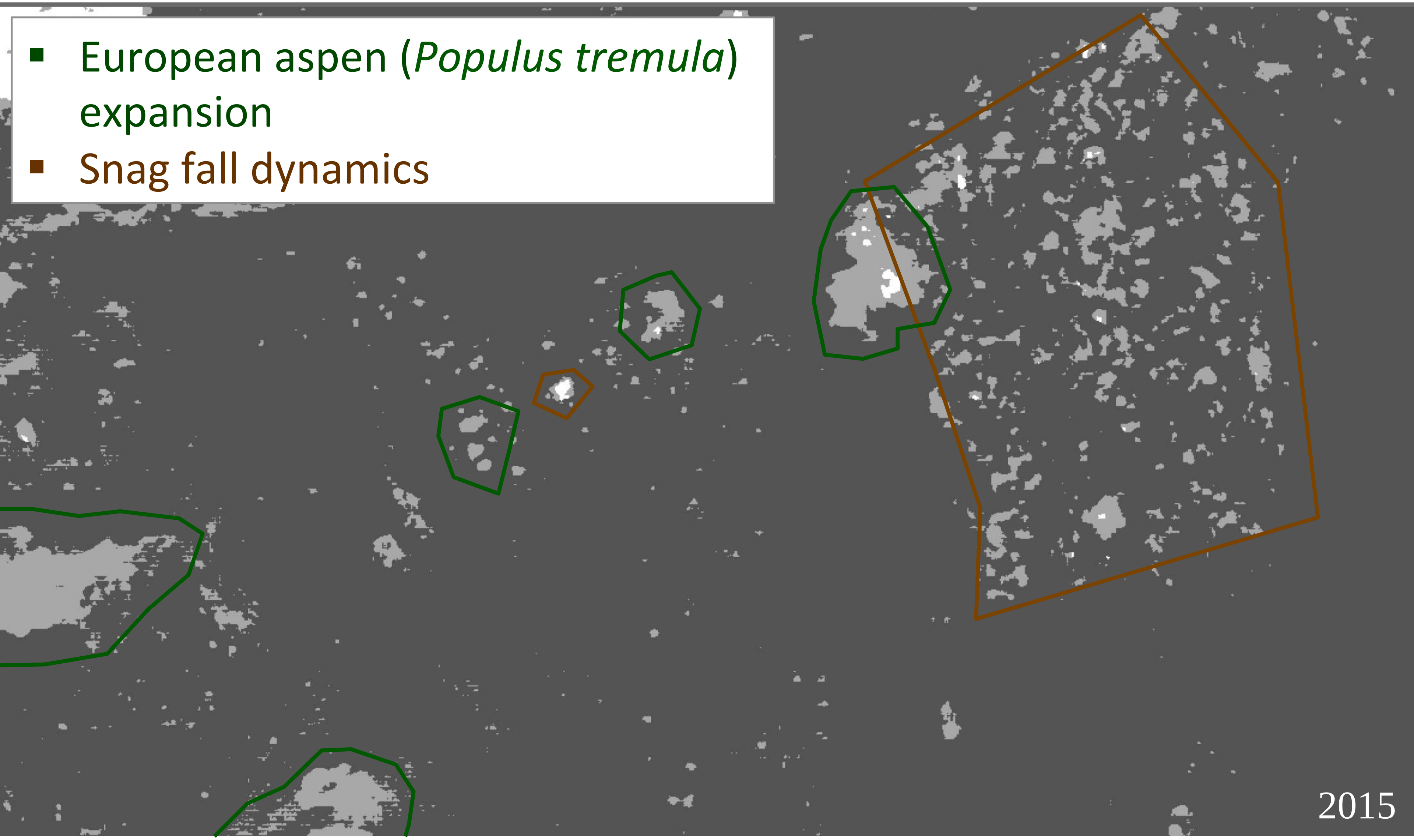


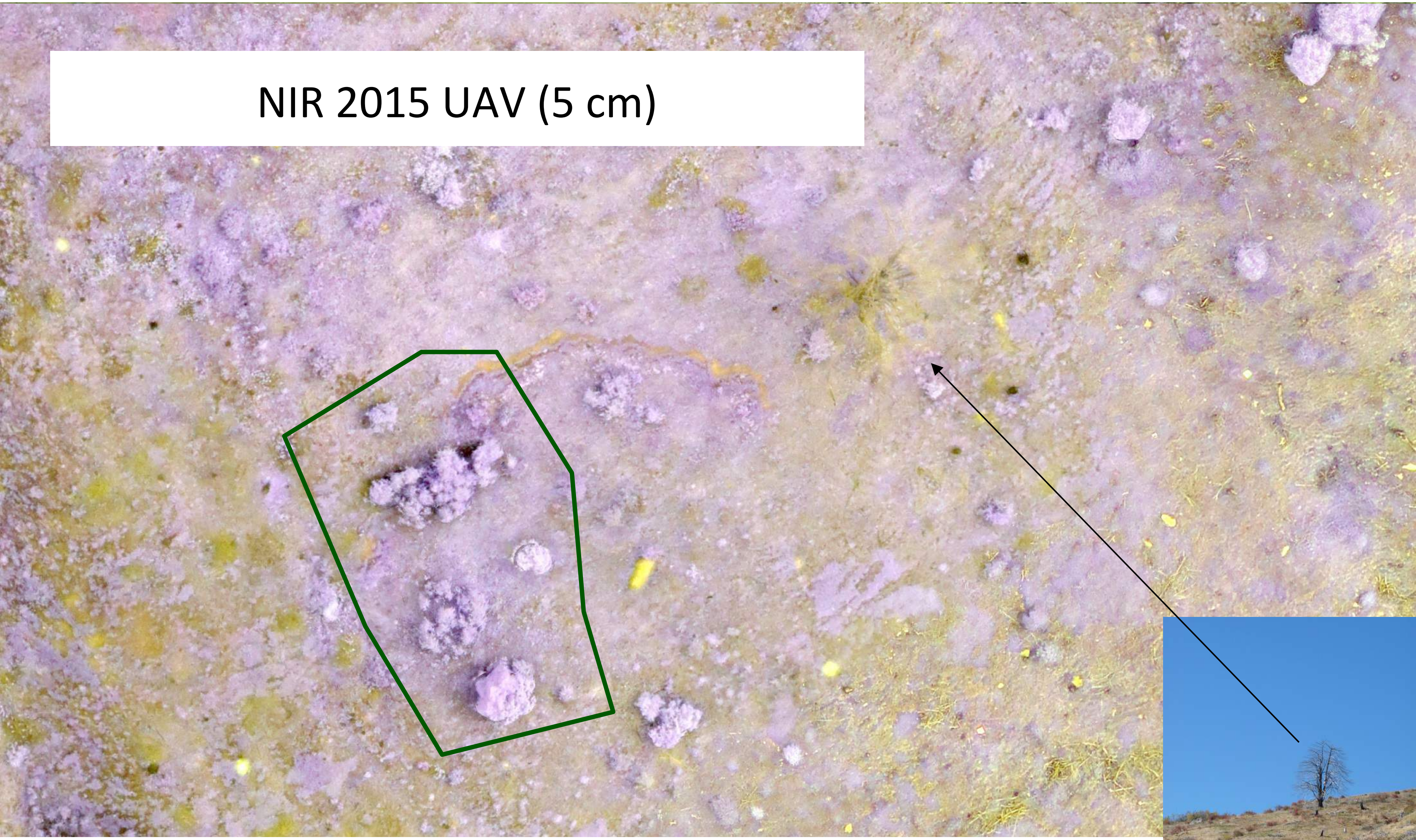

# Change detection

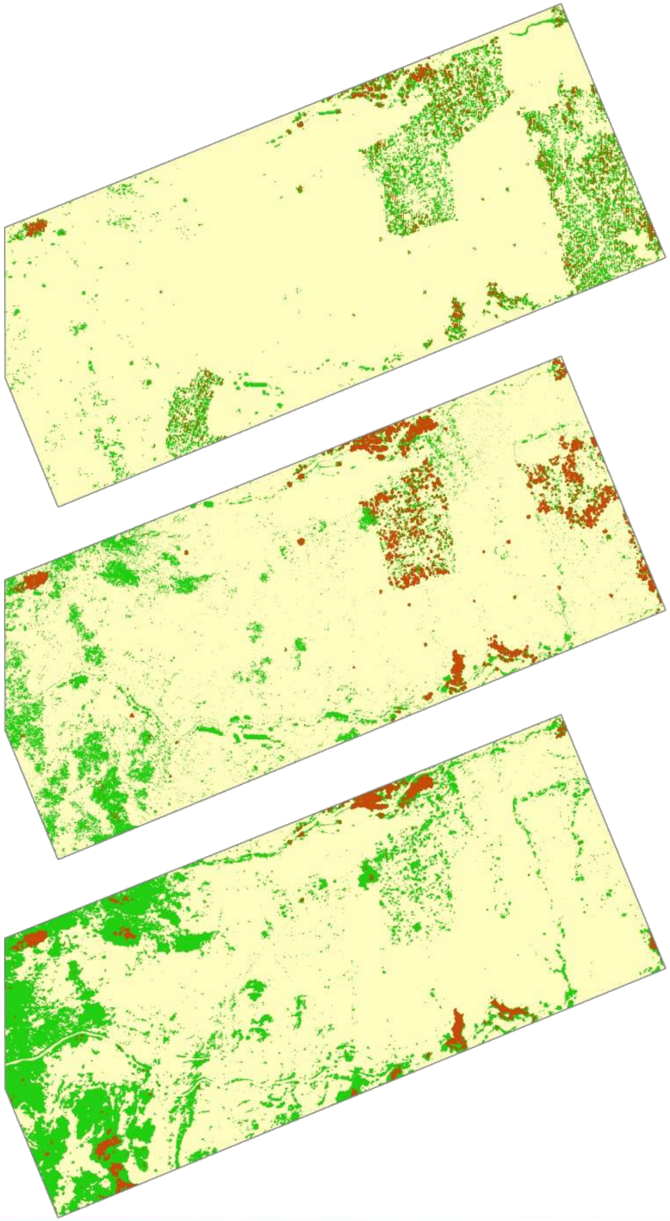
Canopy Height Model (CHM) chronosequence

2008, 2011, 2015

- European aspen (*Populus tremula*) expansion
- Snag fall dynamics



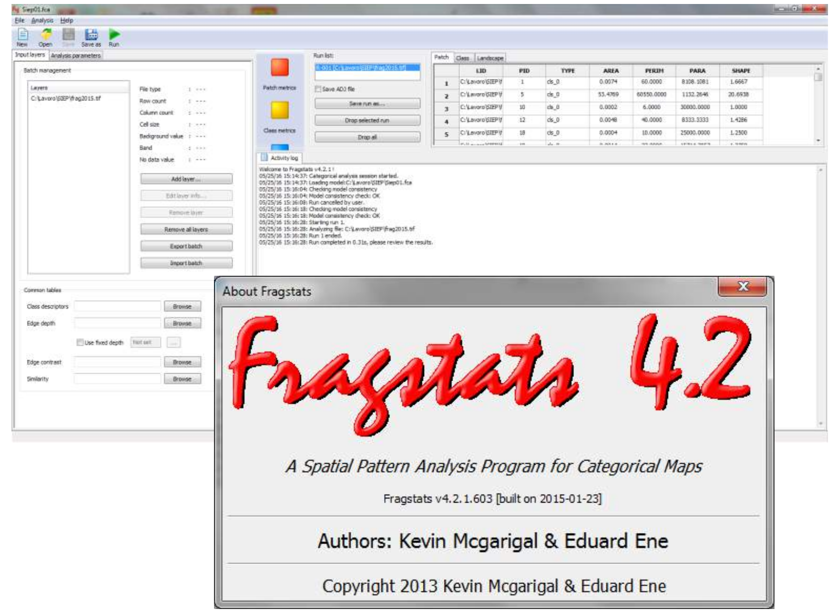

NIR 2015 UAV (5 cm)



2008

2011

2015




Landscape and class (*Populus*, snags) metrics

## Preliminary results

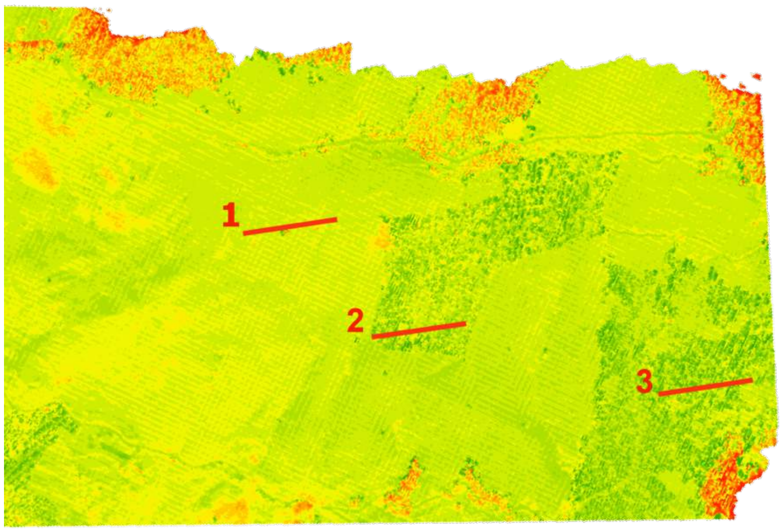
*P. tremula* patches expansion ➡ 1.03 ha $year^{-1}$ (from 8.4% in 2008 to 18.9% in 2015). Higher connectivity and patch dimension.

Snag fall dynamics and salvage logging activities ➡ decrease in standing dead trees patch size, higher aggregation indices.

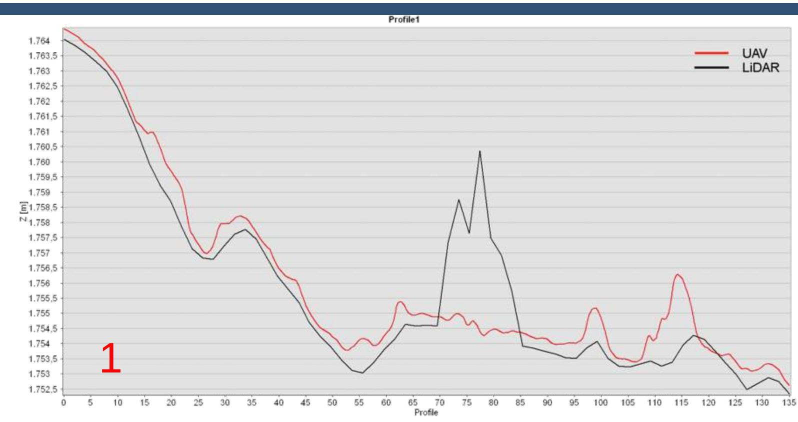
Post-fire management ➡ simplification of landscape structure, (Vegetation recovery increased landscape heterogeneity)

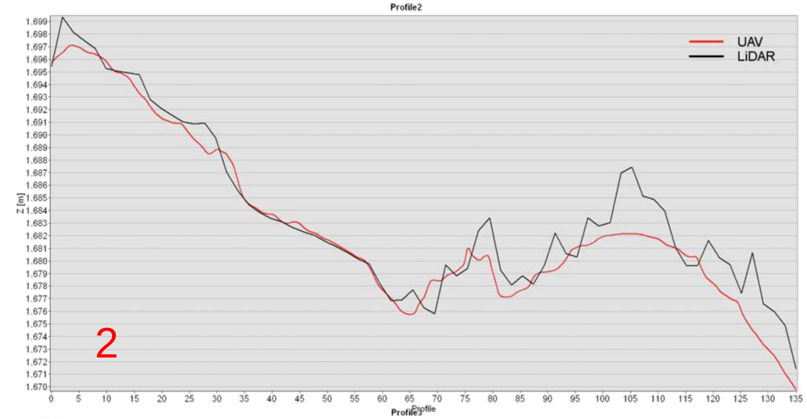
# *Preliminary results*

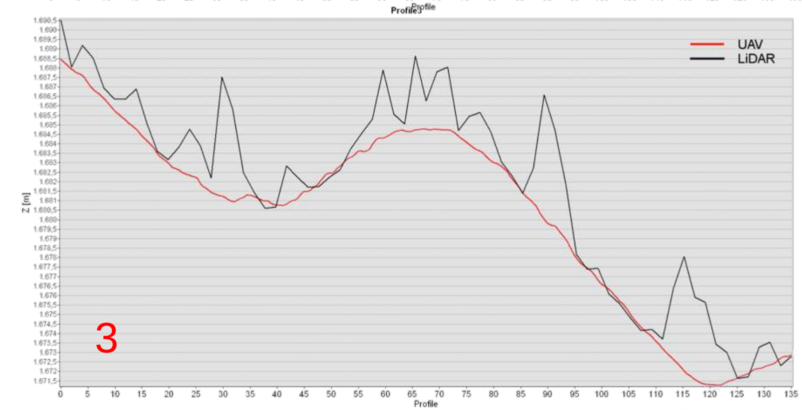
3D change detection




2011-2015



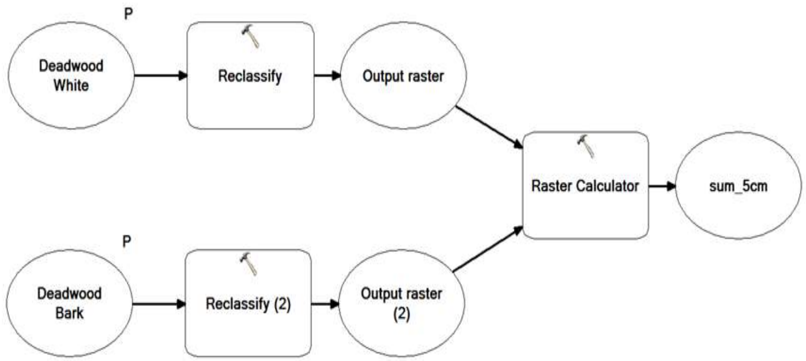



# *Preliminary results*

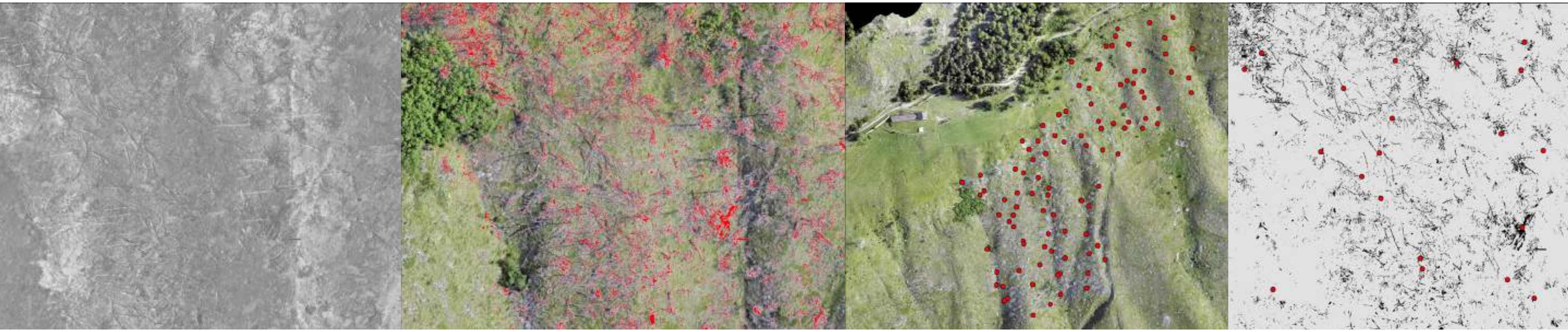
Automatic CWD detection

- High resolution imagery from UAV
- Vegetation indexes (i.e. NDVI, SAVI)

$$Ratio\ GR = \frac{(Float(\text{Green Band\%}) - Float(\text{"\%}Red\ Band\text{\%"}))}{(Float(\text{"\%}Green\ Band\text{\%"}) + Float(\text{"\%}Red\ Band\text{\%"}))}$$




Overall accuracy: 77%
Kappa Index: 57%



# Conclusions

- Taking advantage of natural restoration processes may be a preferred strategy to salvage logging and replanting in coniferous forests of the Alps
- Current restoration activities for post-disturbance management altered natural forest structure and delayed its development
- Salvage logging and no intervention are not the only options!
- UAV systems and LiDAR data demonstrated their high potential in post-disturbance monitoring studies

*Special thanks to*:

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.

Photo Shannon

# Thanks for your attention!

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