Cartography M.Sc.

Precision Mapping for Pest Identification in Mediterranean Pine Forest. Case study: Pine Processionary

Alexandros Theofanidis

Presentation Outline

- **Introduction and Motivation**
- **Research Objective – Research Questions**
- **State of the Art**
  - The Pine Processionary Moth (PPM)
  - Map making principles
- **Methodology**
  - Study area
  - Data Collection
  - Image Processing for Nest Identification
  - User Study
  - Visualization Methods Testing
- **Results and Discussion and Discussion**
- **Conclusion and Outlook**

Introduction and Motivation

"*Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*"

- 1.6 Billion people depend on forests
- Forests are home for more than 80% of all terrestrial species (animals, plants, and insects)
- Mountain regions provide 60-80% of the earth's fresh water
- **Forest pest** is one of the most common factors affecting forests' health (Yuan & Hu, 2016)
- Forest Monitoring and protection is time and resources consuming
- High demand in personnel

United Nations

Introduction and Motivation

Cartography's contribution with the use of Unmanned Aerial Vehicles (UAV):

- Identify
- Localize
- Manage
- Predict
- Anticipate propagation

Research Objective

RO.1: To develop a method that identifies infested trees with the use of multiband aerial imagery obtained by UAVs.
RO.2: To explore and test different visualization aspects of the pests' location, behaviour and the size of the threat that causes their outnumber existence.
RO.3: To evaluate and finally establish a visualization pattern for the use and benefit of forestry applications (Mapping technique to produce precision maps)

Research Questions

RQ1: In what degree and in what manner can cartography improve the management and protection of forests that are threatened by the existence of malicious pests when outnumbered?
RQ2: How can UAV imagery data contribute in monitoring pests?
RQ3: Are 3D maps more suitable for the specific case study compared to 2D maps?
RQ4: What colours should be used to emphasize to the user an imminent threat?

State of Art

The Pine Processionary Moth (PPM)

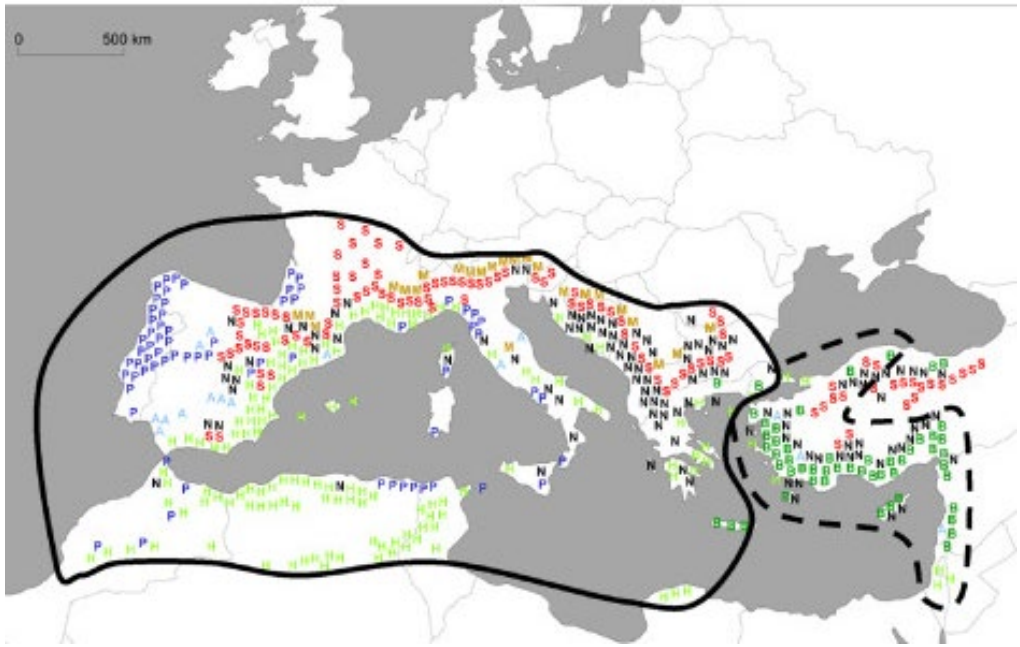
Get to know with the Pest

State of Art

The Pine Processionary Moth (PPM)

Distribution of the PPM

- Southern Europe
- Western Mediterranean
- **Higher Altitude and Latidute**



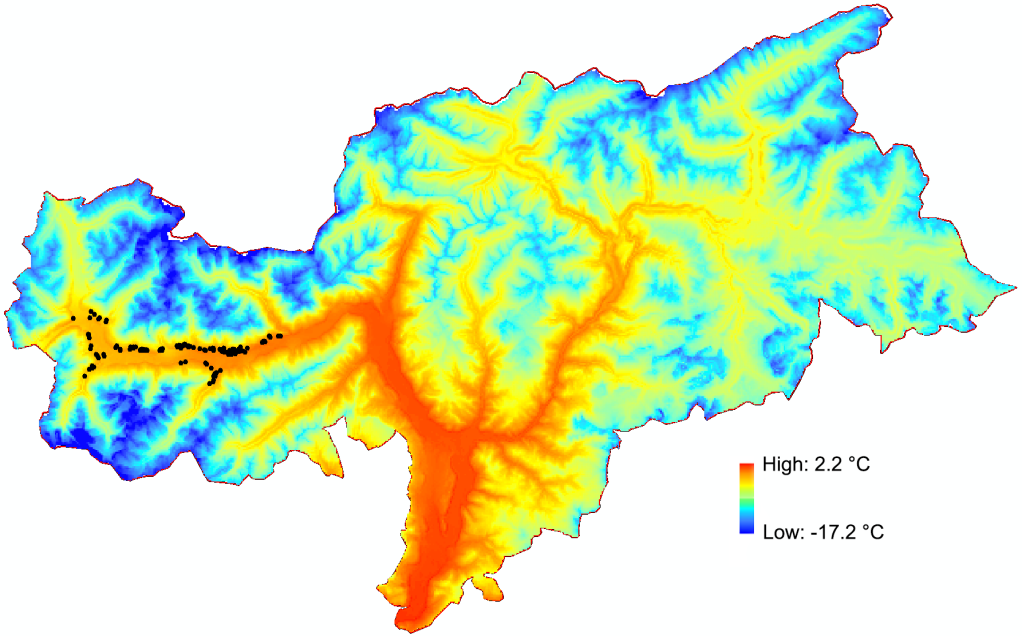
https://www.researchgate.net/figure/Ranges-of-the-pine-processionary-moths-indicating-the-occurrence-of-native-Pinus_fig1_26791539

State of Art

The Pine Processionary Moth (PPM)

Conditions that foster the expansion

- Food presence (Vulnerable trees)
- Absence of natural enemies (Fauna)
- survival of PPM is strongly affected by the **temperature** of the environment (-16 °C lethal)



Monthly mean temperature 1981 - 2010 (Crespi et al., 2020)
Black dots on the western part of the map represent the spatial distribution where PPM is present. PPM Locations were provided by the Forest Service of Bolzano.

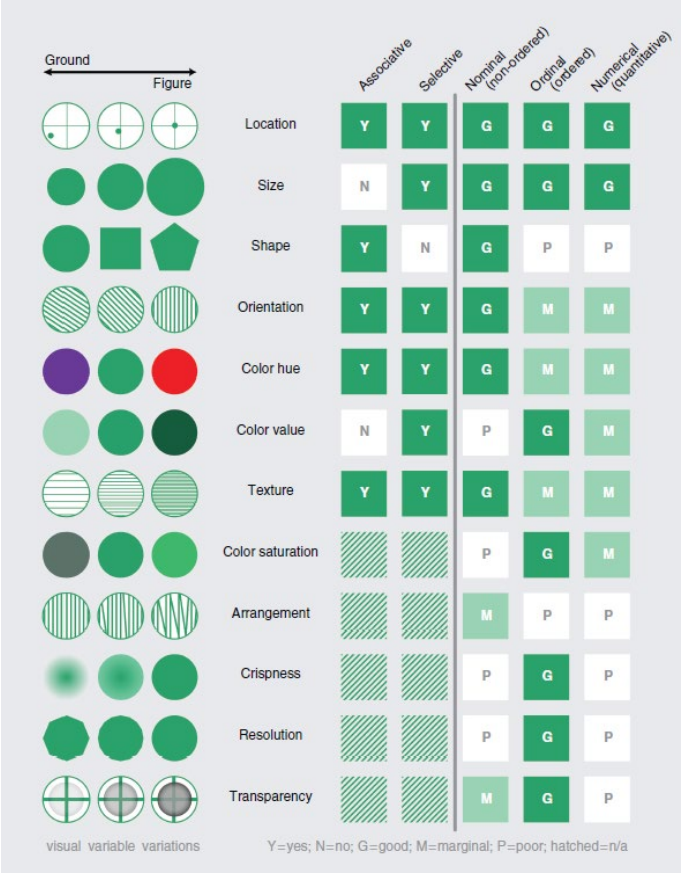
State of Art

Visualization and map making principles

Visual Variables

Used to encode information about line, point and area features

- Location
- Size
- Shape
- Orientation
- Color Hue
- Color Value
- Texture
- Arrangement
- Crispness
- Resolution
- Transparency



Bertin (1967/1983), MacEachren (1995), and MacEachren et. al. (2012)

State of Art

Visualization and map making principles

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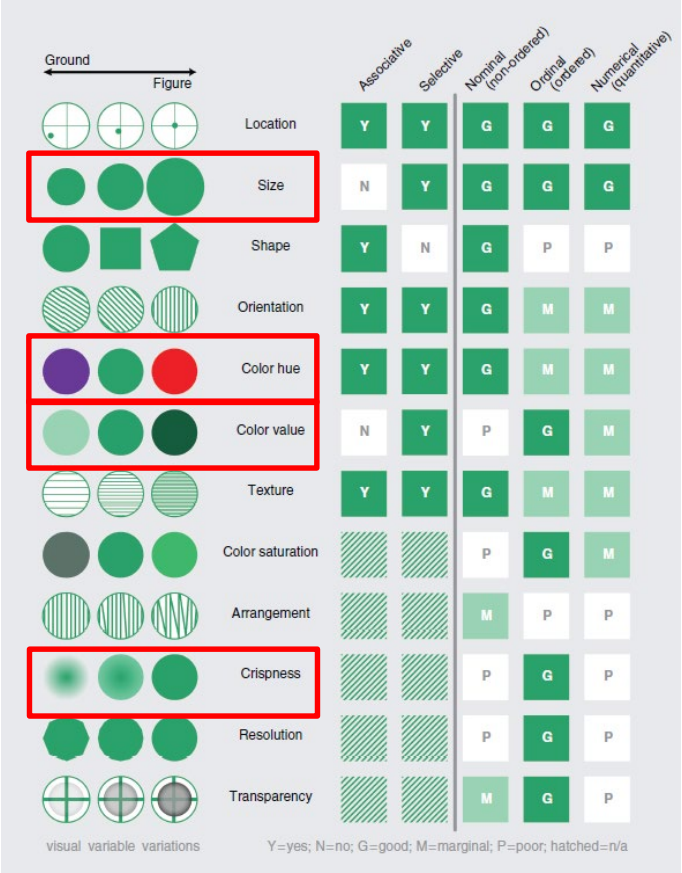
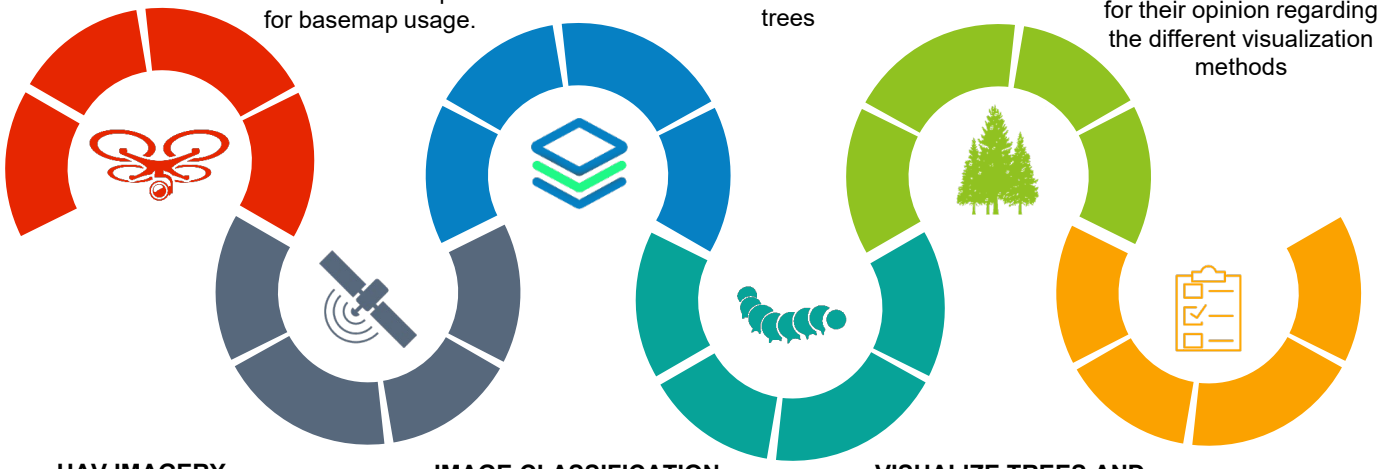


Bertin (1967/1983), MacEachren (1995), and MacEachren et. al. (2012)

Methodology
Overview workflow



SATELITE IMAGERY

Imagery obtained by Satellites and Orthophotos for basemap usage.

LOCATING PPM NESTS

Identify the exact location of nests found on infected trees

SURVEY

We conducted a survey asking 10 forestry experts for their opinion regarding the different visualization methods

UAV IMAGERY

4 Flights to obtain high resolution imagery for locating PPM nests on the trees.

IMAGE CLASSIFICATION

Image analysis to separate the trees from anything else on the UAV images.

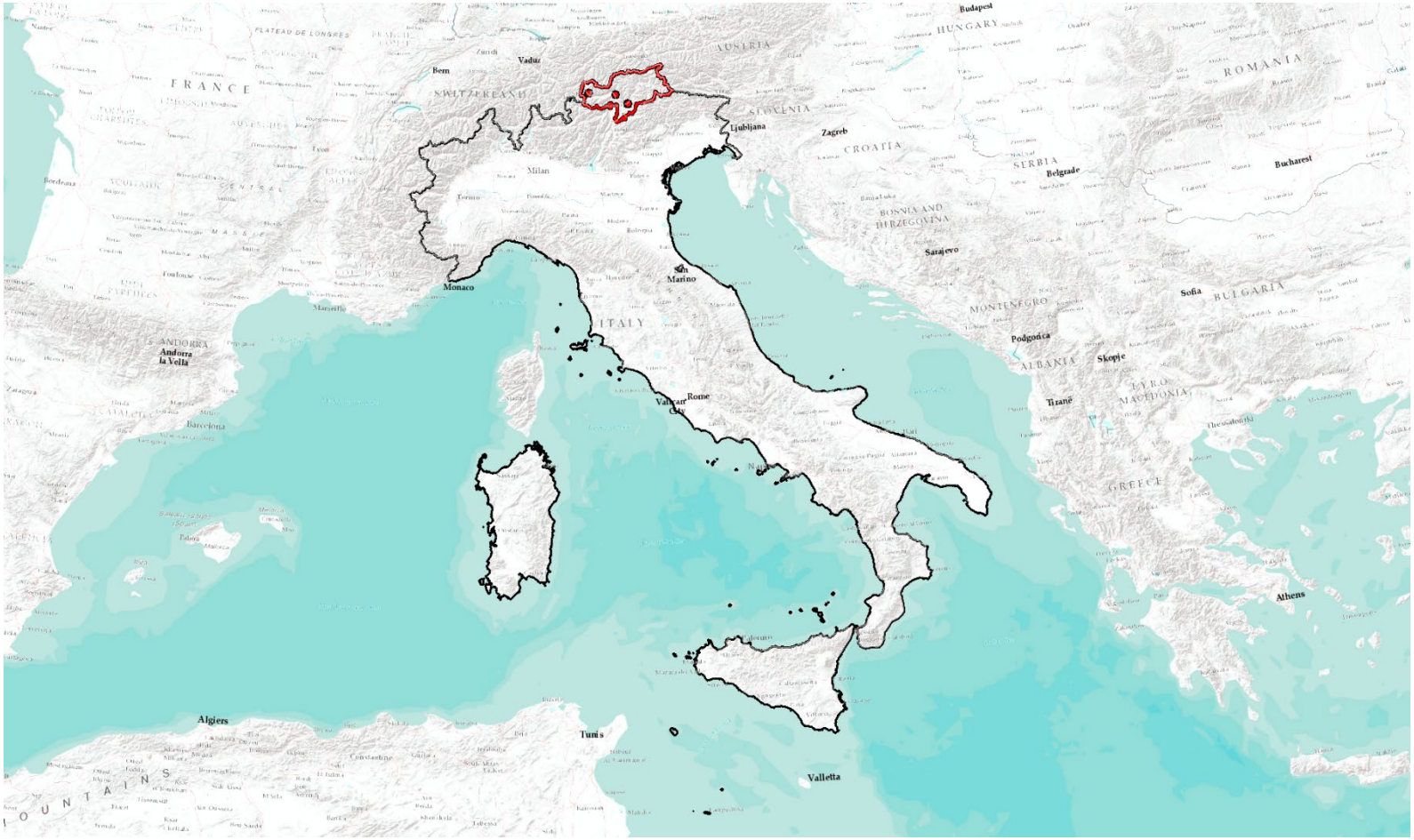
VISUALIZE TREES AND NESTS

We explore and propose different types of visualizing the PPM nests.

Methodology

Study Area

Autonomous Province of Bolzano



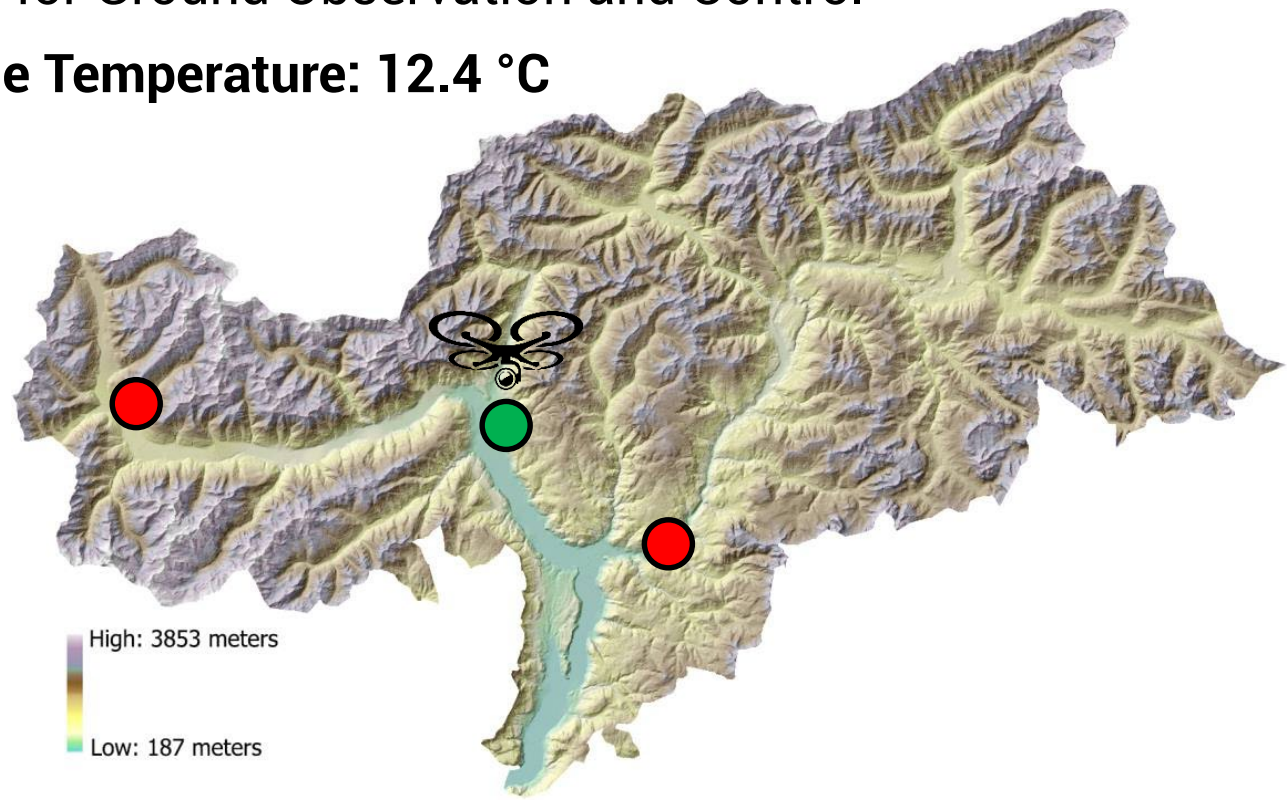
Base-map: Topographic by ESRI

Methodology

Study Area

Autonomous Province of Bolzano

- 3 Cites of 1270m 700m 360m Elevation
- 2 Cites for Ground Observation and Control
- **Average Temperature: 12.4 °C**



Methodology
Data Collection

UAV Flights

- Soleon Octocopter
- Multispectral lens: **Red Edge Micasense** (5 bands; RGB, NIR, RedEdge)
- Flights: 17/12/2021 - 23/06/2022
- 3 Total Ground Control for Outbreak Checking (June and July 2022)
- Height of the flight: approx.. 40m (15-**20** m from the crown)

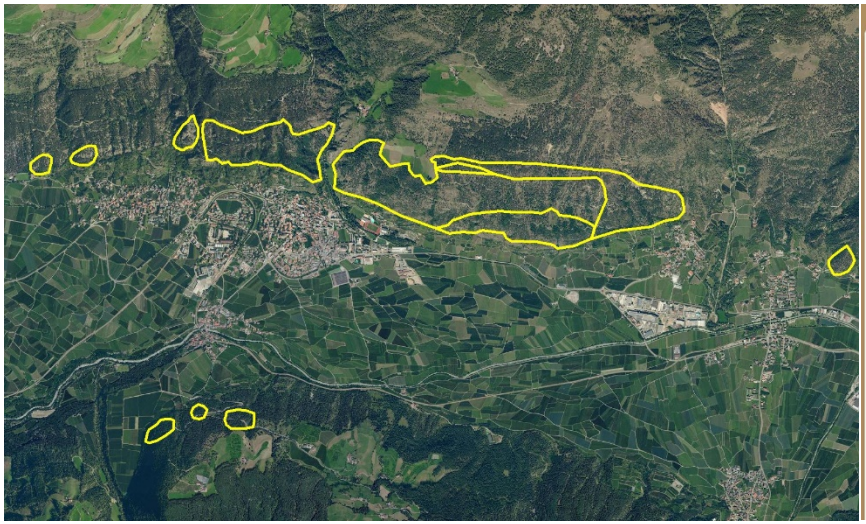
https://www.soleon.it

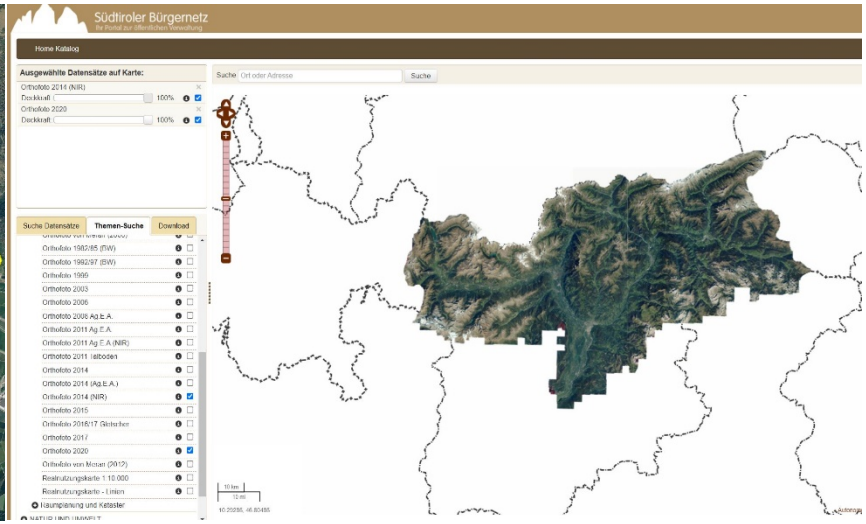
https://www.aeromotus.com/product/rededge-m/

Methodology

Data Collection

- Forest Agency of Autonomous Province of Bolzano
- geoportal.buergernetz.bz.it
- Eurac research
- Copernicus





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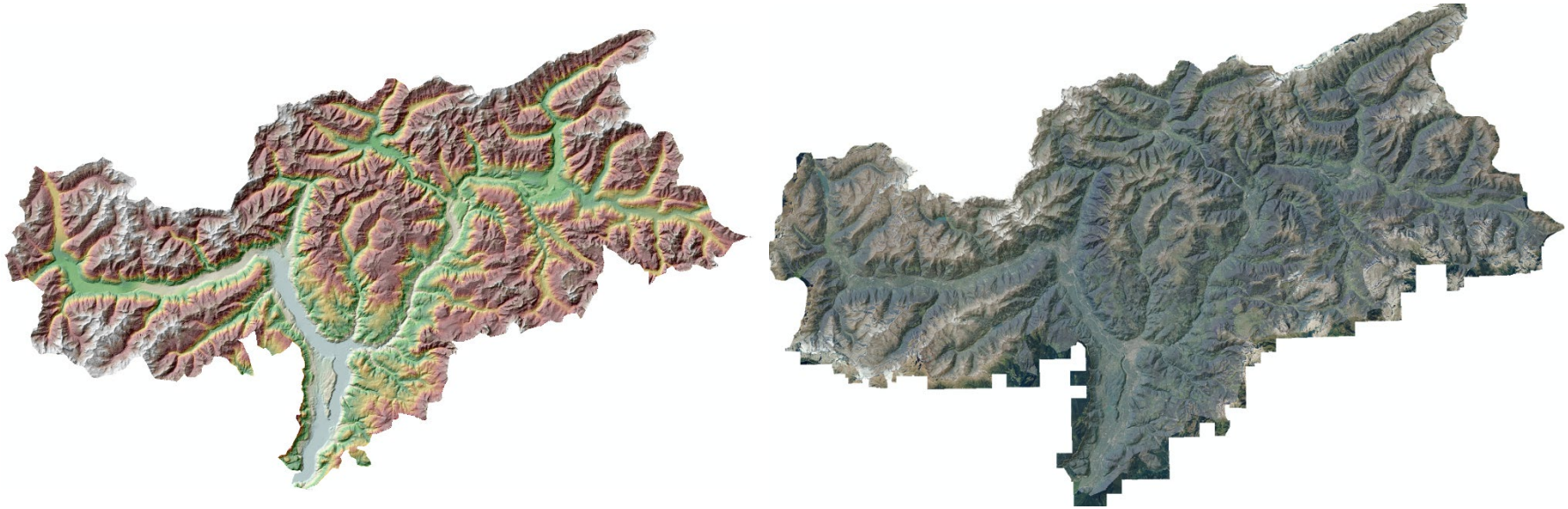
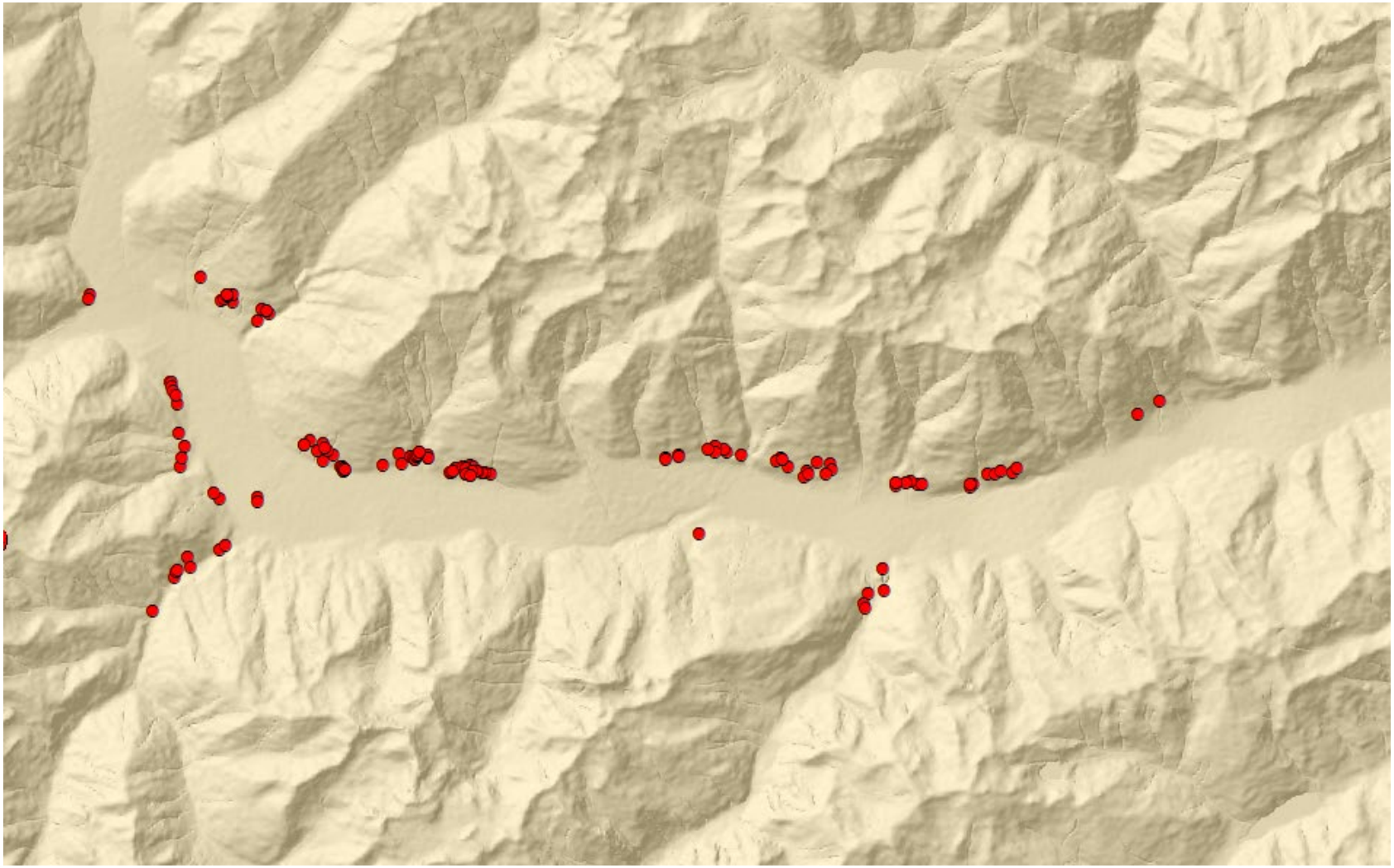


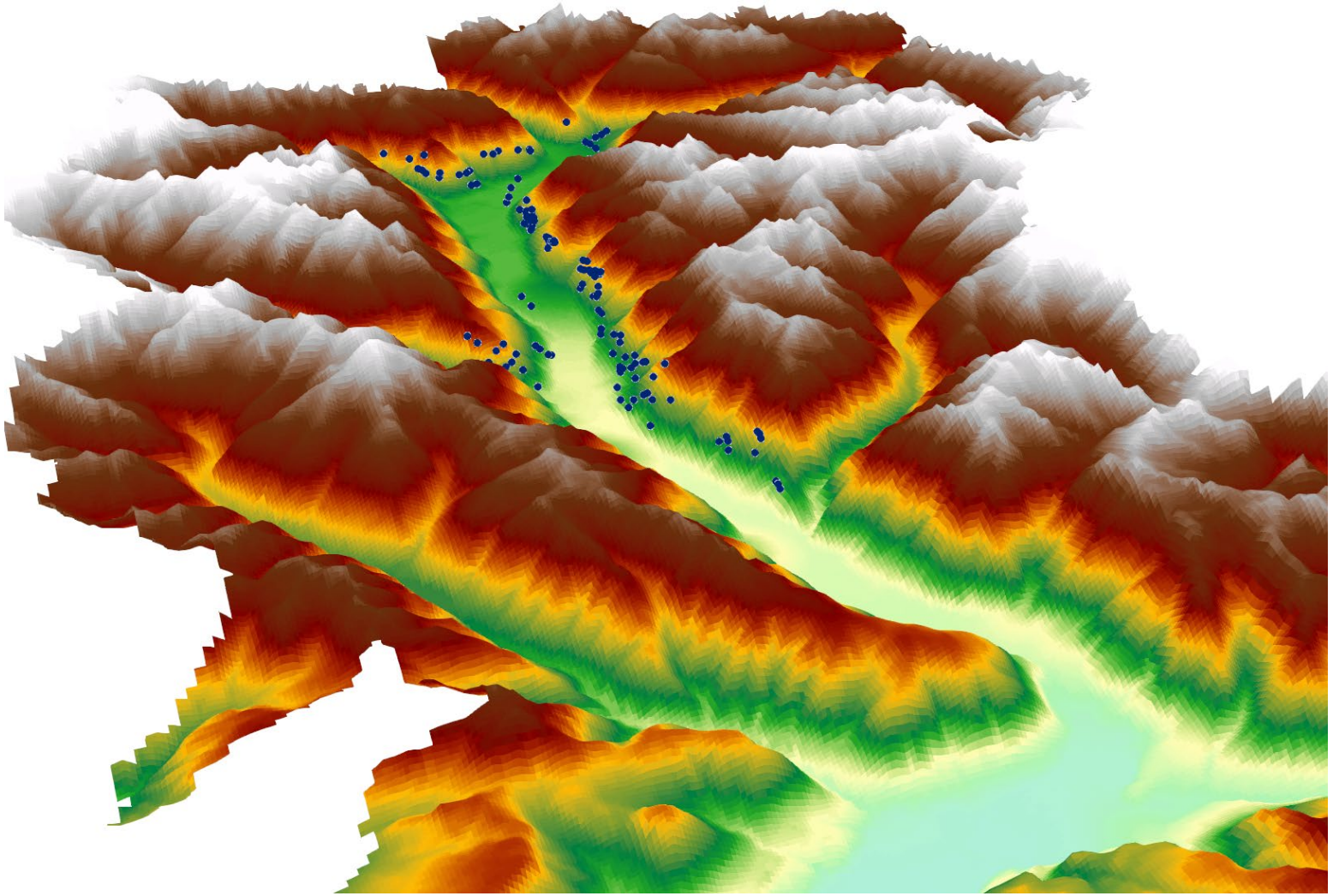
Methodology

Data Construction



Methodology

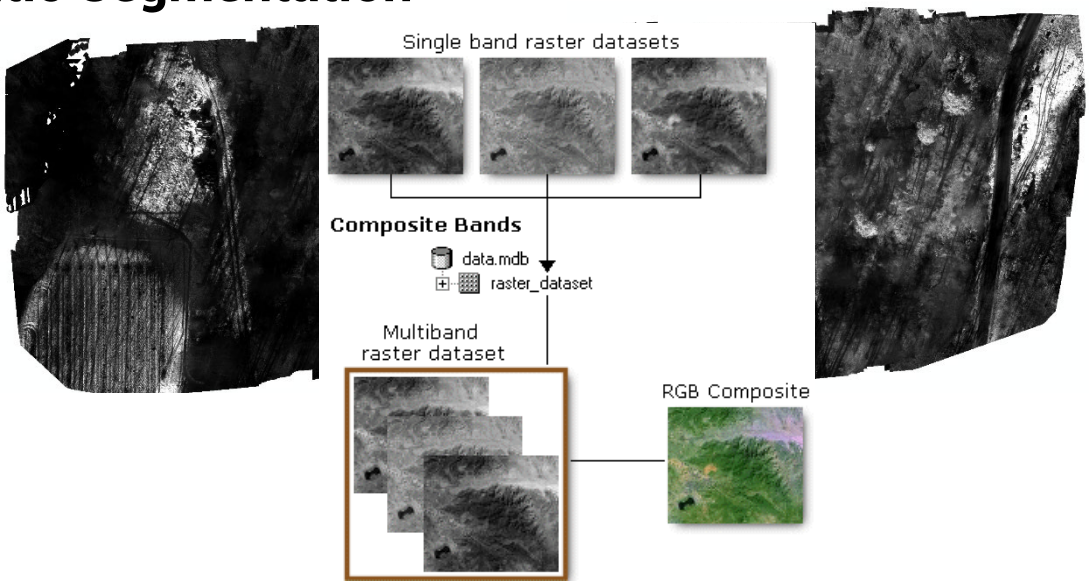
Data Construction

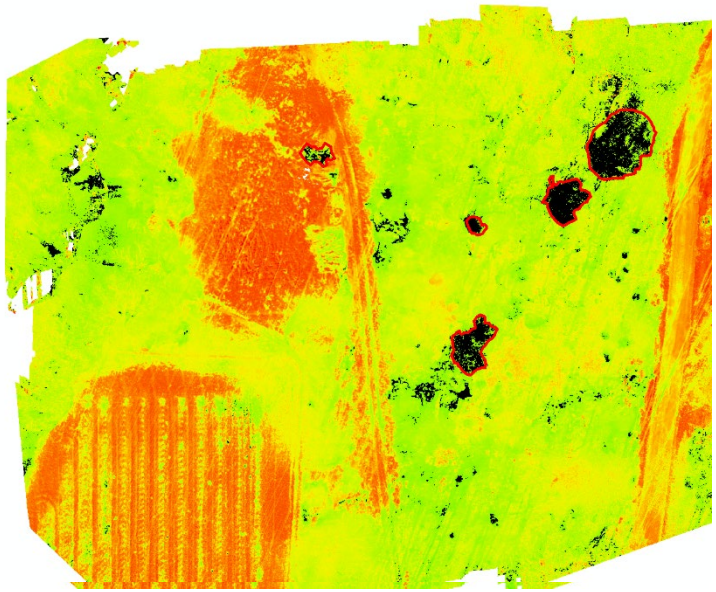


Methodology

Image Processing – Semantic Segmentation

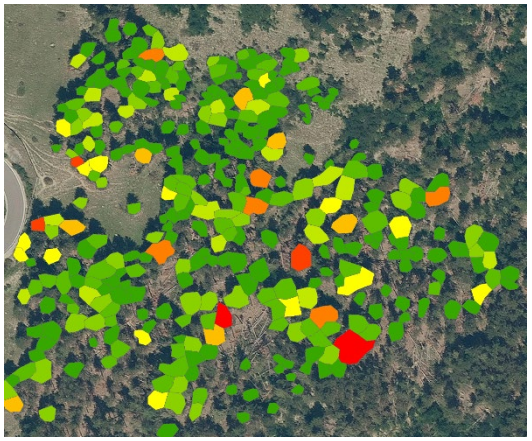
- Airborne – Satellite Imagery
- UAV Imagery Acquisition
- Multispectral Image Processing
- NDVI Calculation
- NDVI Raster files filtering
- Predict individual tree's area
- Optical control
- Nest identification





Methodology

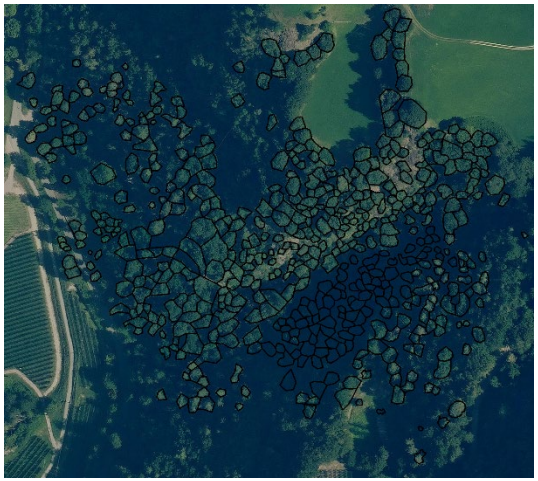
Visualization Methods Testing

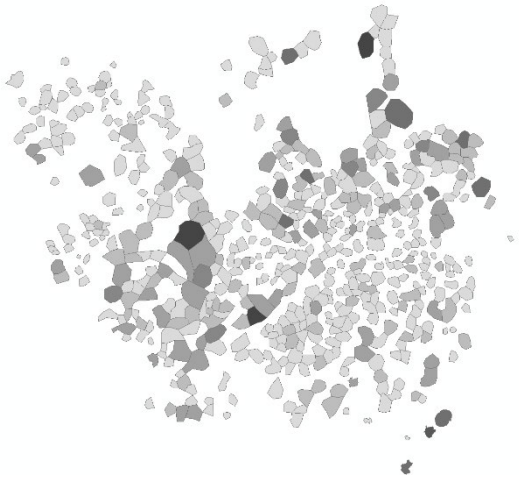


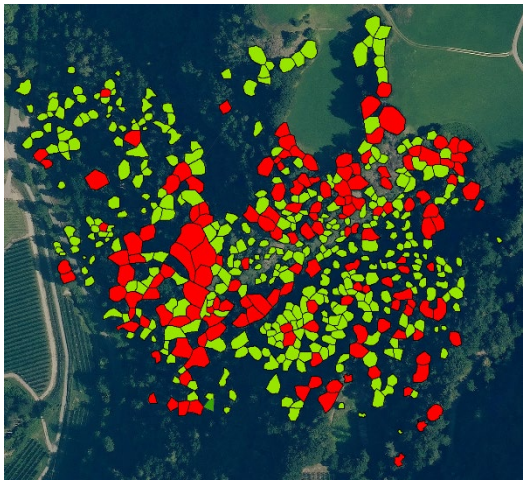
TREES

4 Main Visualization Patterns

- Polygons with no fill
- Polygons with monochromatic fill
- Polygons filled with different color that indicate vegetation's health conditions
- Polygons with two colors that indicate if the tree is infested or not







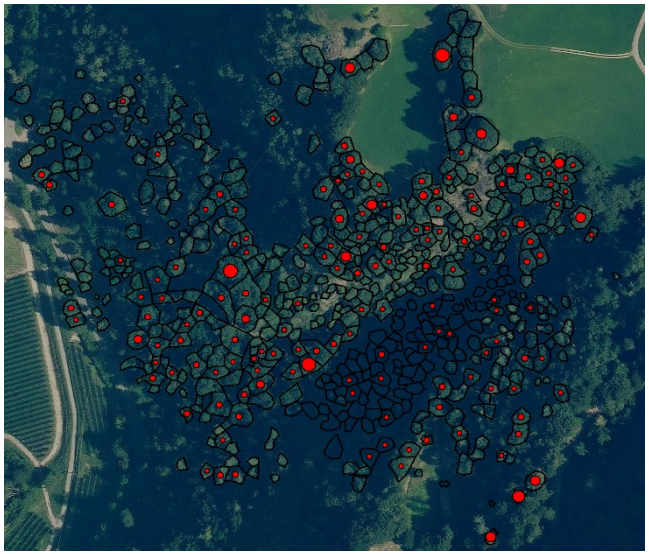
Methodology

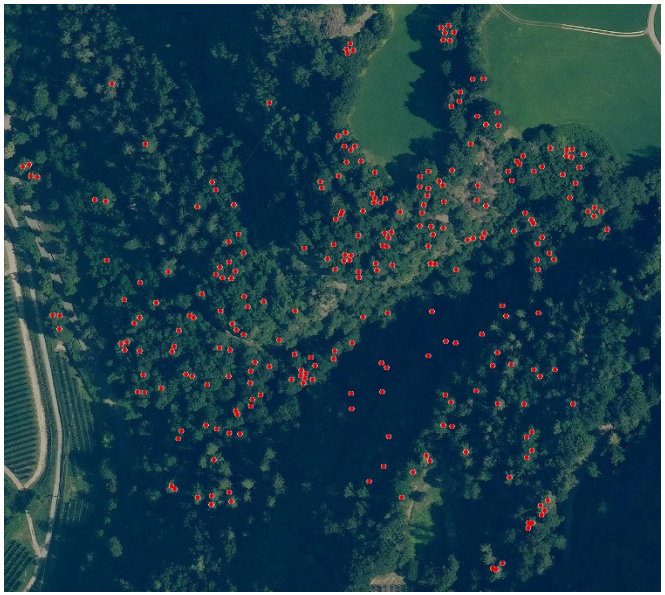
Visualization Methods Testing

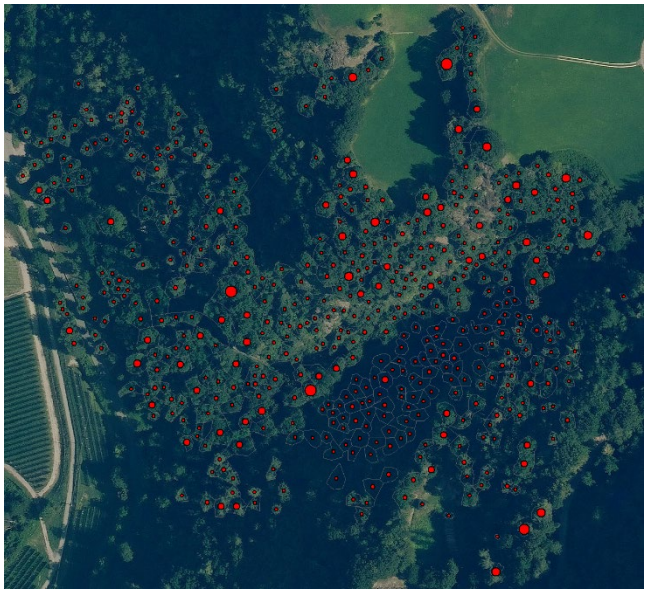
PPM NESTS

3 Main Visualization Patterns

- Dot density
- Graduated symbols
- Combined with tree polygons







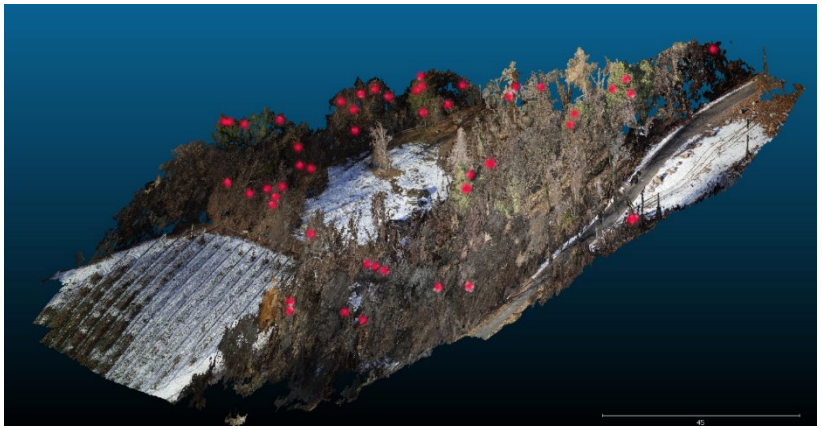
Methodology

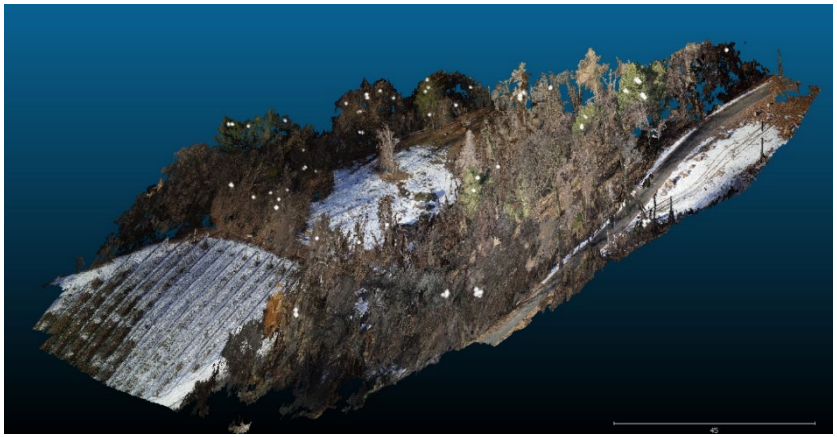
Visualization Methods Testing

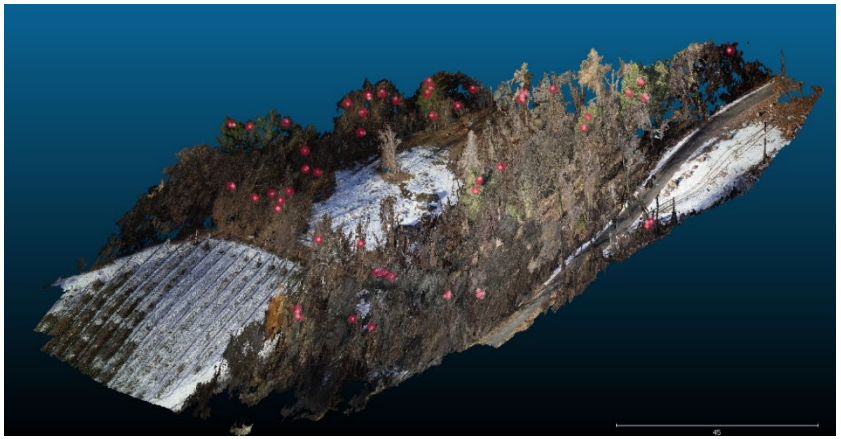
3D Representation

4 Visualization Patterns

- White emphasized nests
- Red dots
- Red dots with transparency
- Red dots with crispness







Results and Discussion

Image Processing for PPM Nest Identification

Band 1 – Blue

- pine trees are shown as darker areas on the image compared to the nests
- Snow might confuse the user
- Bare soil pretty well and separates it from the forest
- Quite proper band for locating PPM

Results and Discussion

Image Processing for PPM Nest Identification

Band 2 – Green

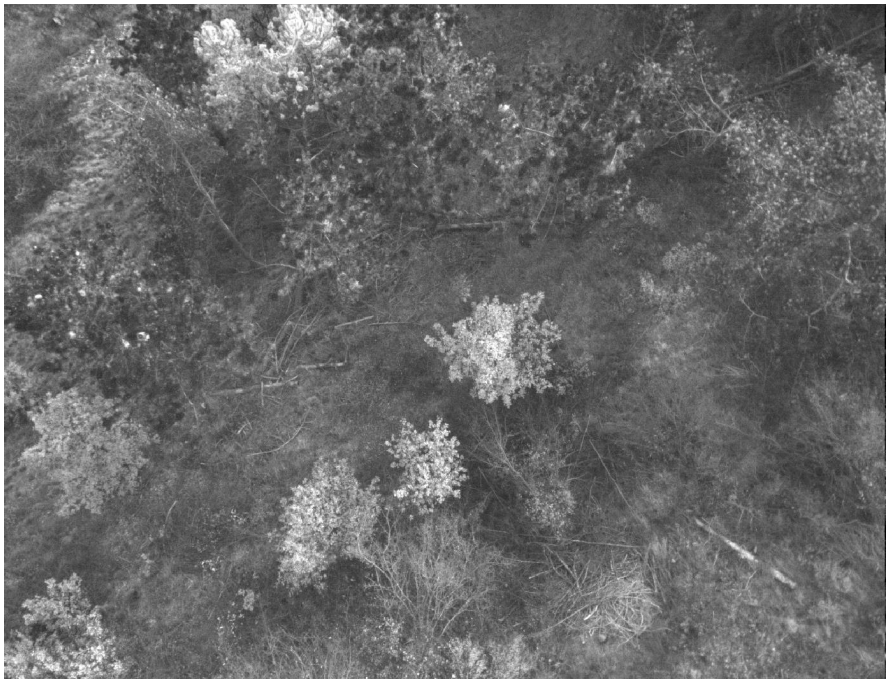
- Pine trees are easily distinguishable
- other trees are deciduous and have no leaves during the winter darker
- Trees and nests are having high values in this band and are shown as bright pixels.
- Distinguishing PPM nests is hard

Results and Discussion

Image Processing for PPM Nest Identification

Band 3 – Red

- Vegetation in red band pops and has a vibrant representation
- Healthy green colored vegetation is darker than unhealthy vegetation due to the presence of chlorophyll (green color) on the leaves.
- PPM nests can be easily spotted



Results and Discussion

Image Processing for PPM Nest Identification

Band 4 – Near Infra-Red

- Plants that have more chlorophyll tend to reflect more near-infrared energy than unhealthy plants
- Pine trees in our case good condition very high pixel values making the nest identification impossible.

Results and Discussion

Image Processing for PPM Nest Identification

Band 4 – Red Edge

- Similarly to the Red band, high chlorophyll increases absorption in the red region.
- **The result was that there was a better separation of the bare soil and the vegetation compared to the calculation with red band**.
- Although, spotting PPM nests on healthy trees is quite difficult as nests and trees are high valued pixels with reduced contrast.

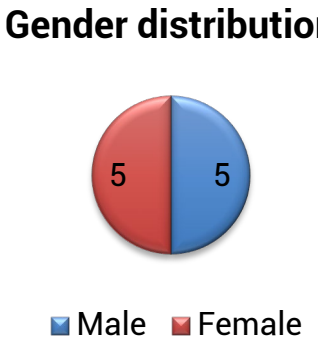
	BAD	AVERAGE	GOOD
BLUE			X
GREEN		X	
RED			X
NIR	X		
RED EDGE	X		
RGB			X

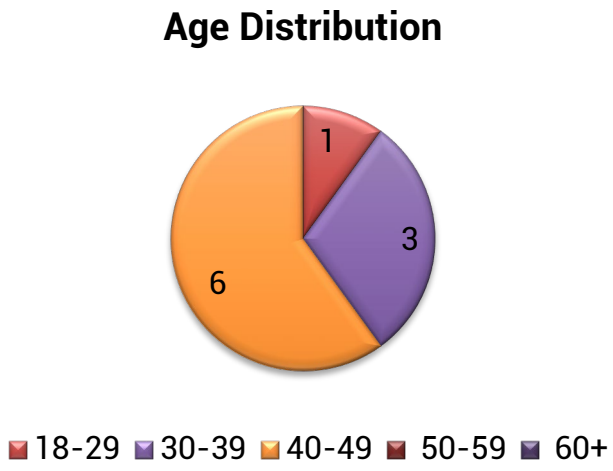
Results and Discussion

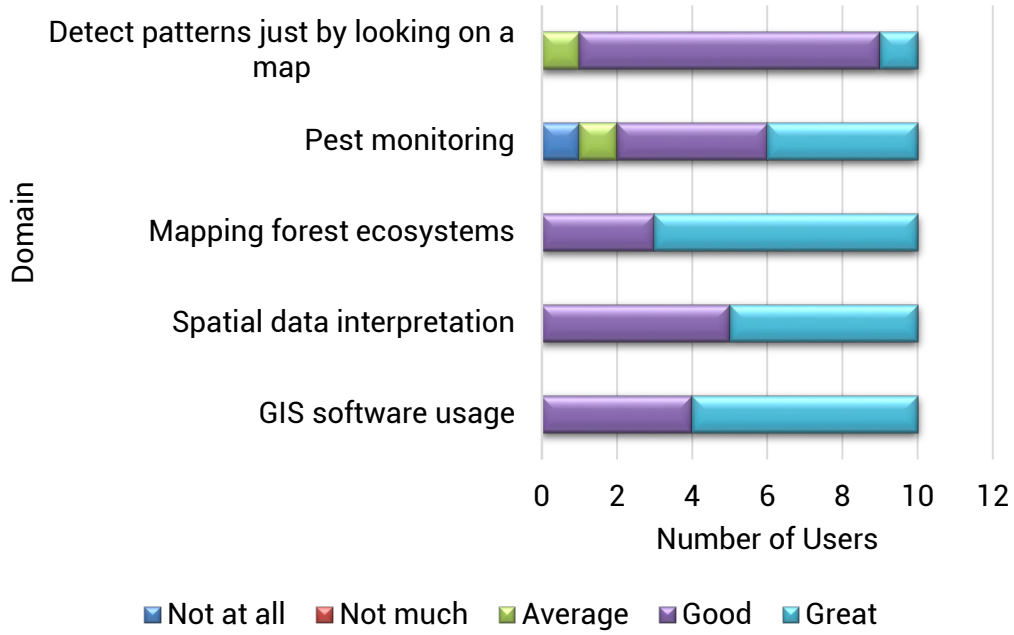
User study

Users' Overview

- 10 Participants
- Forestry Experts



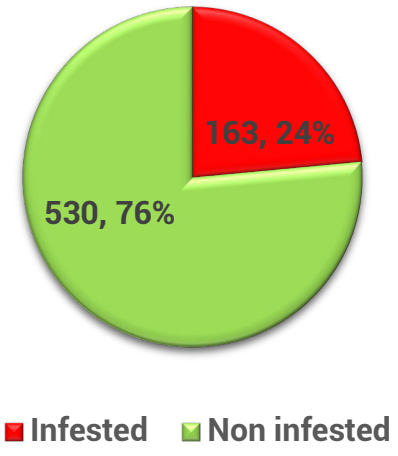




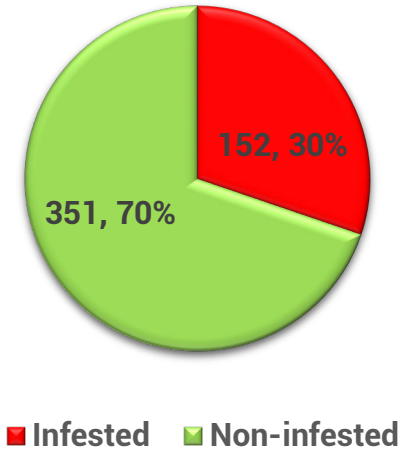
Results and Discussion

User study - Monochromatic Representation of Vegetation

Comparing areas through visualization



Area 1

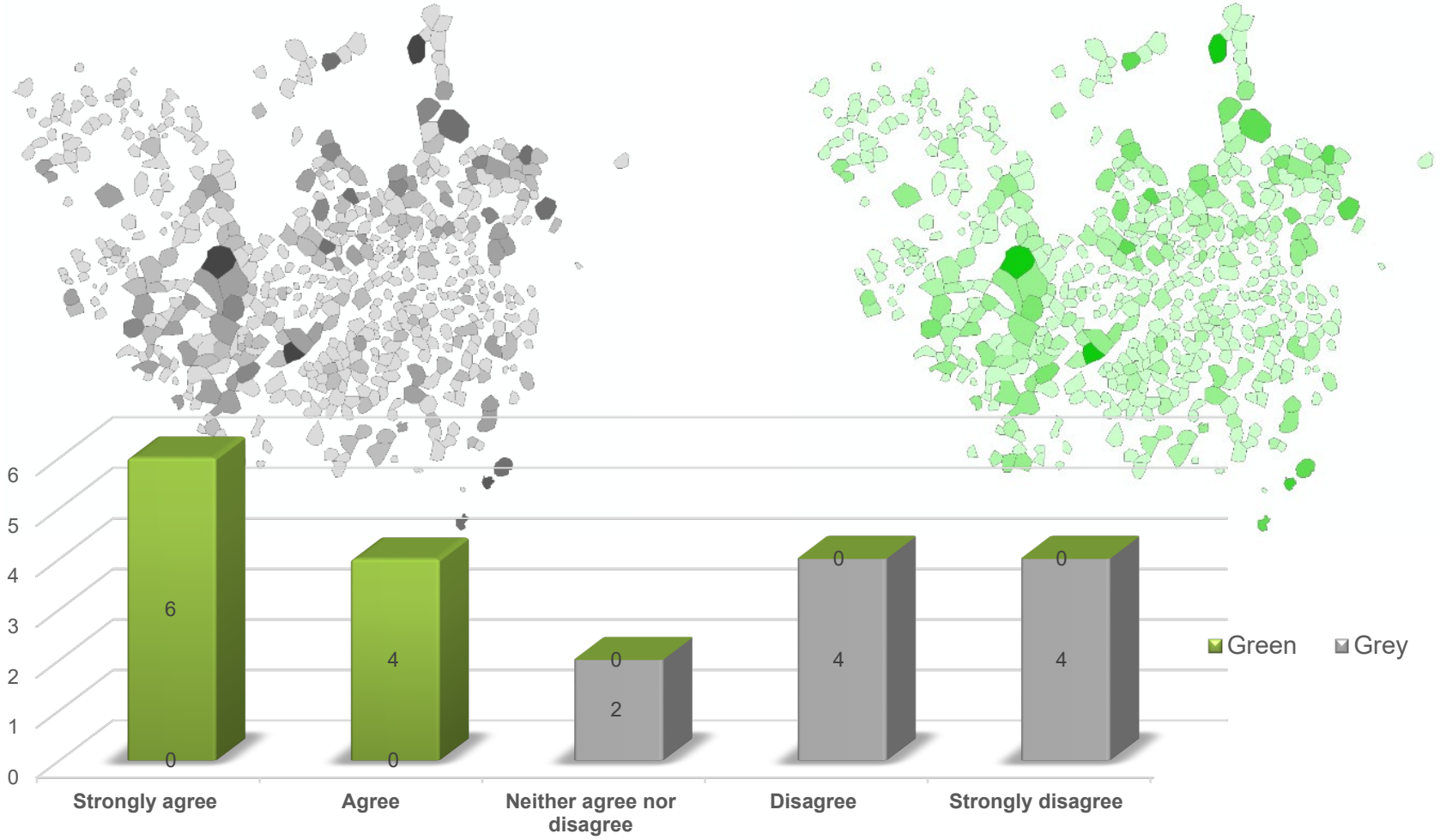


Area 2

Results and Discussion

User study - Monochromatic Representation of Vegetation

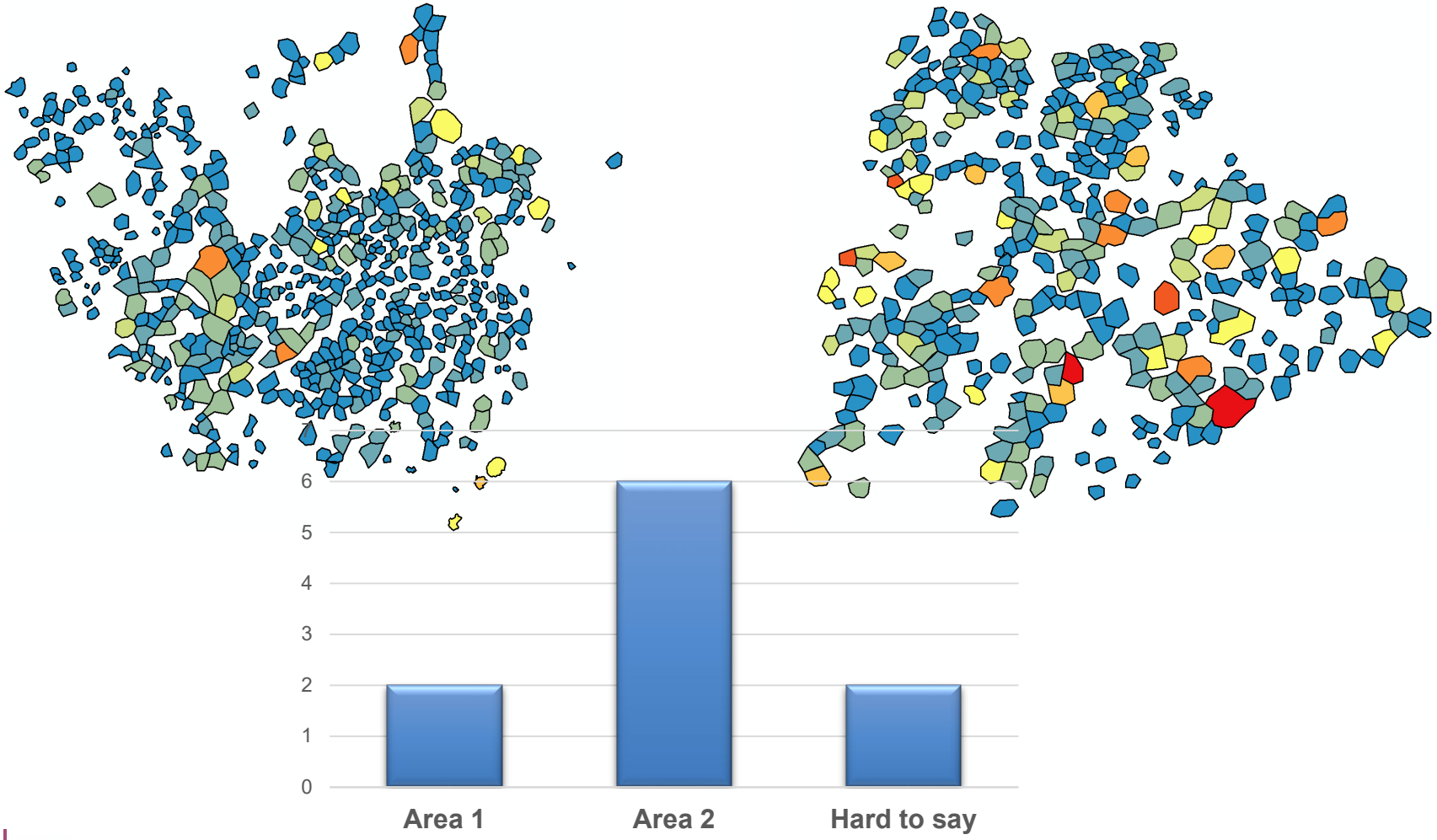
Darker polygons represent trees that are healthy



Results and Discussion

User study – Multiple color representation

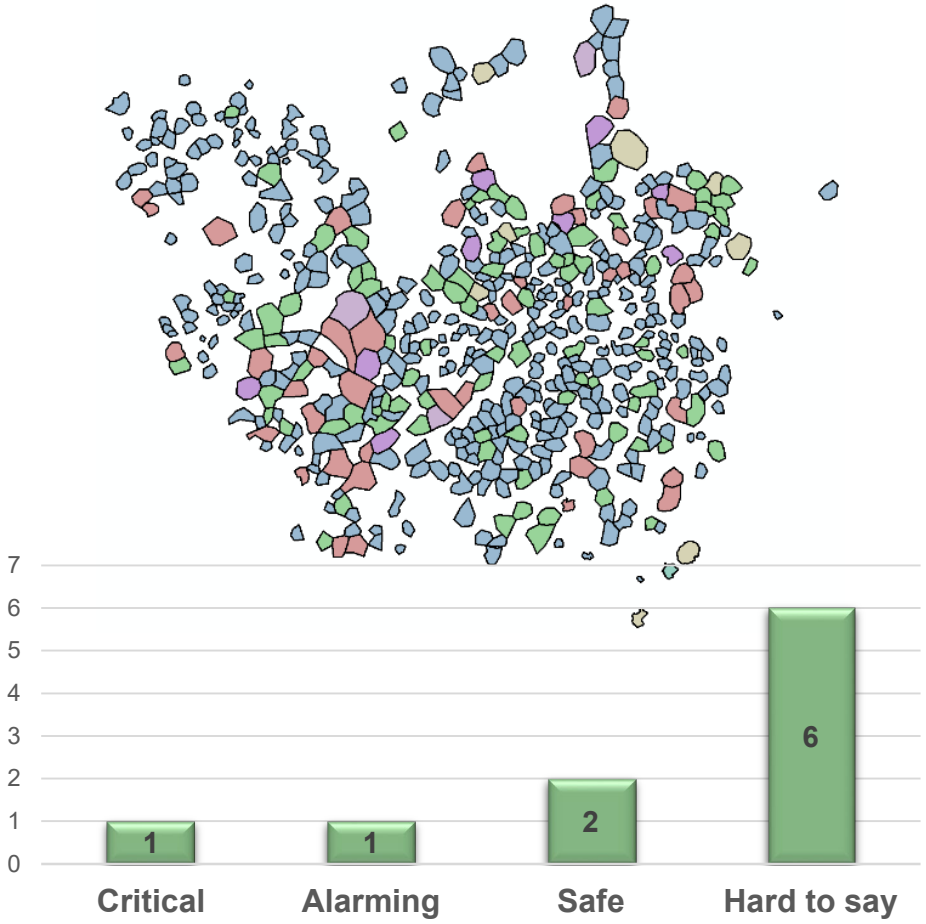
Which area is in greater risk?



Results and Discussion

User study – Multiple color representation

How would you evaluate the condition of those two areas?



Results and Discussion

User study – Multiple color representation

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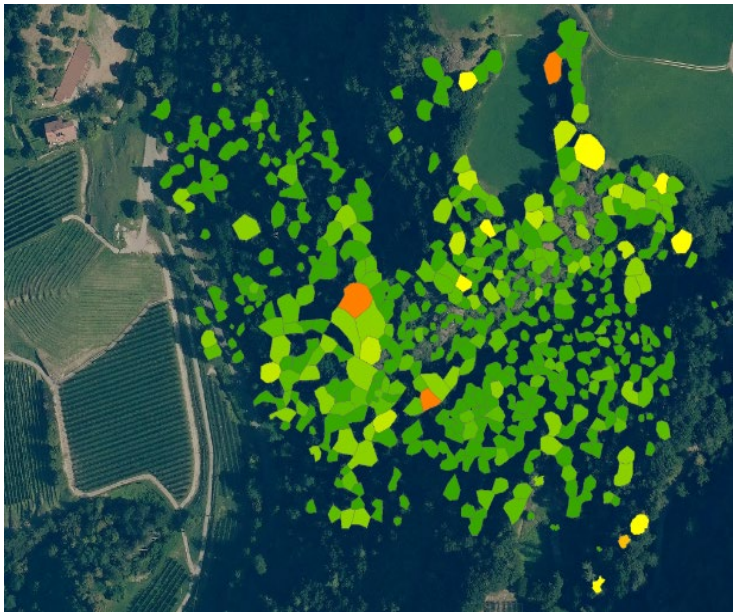
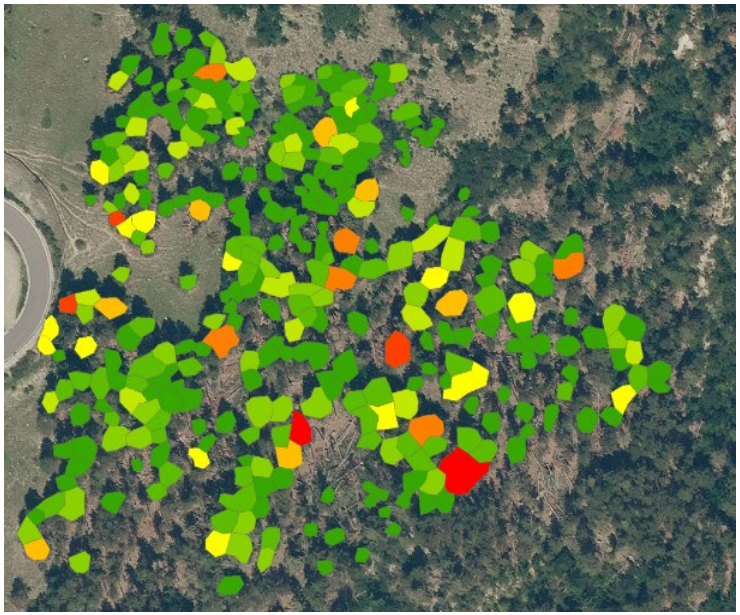
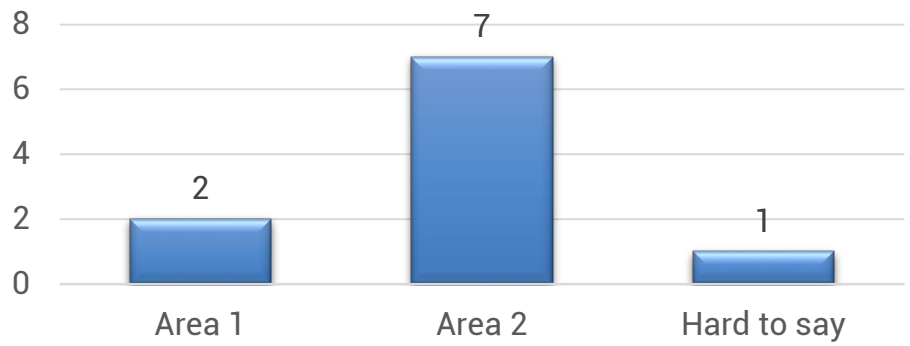


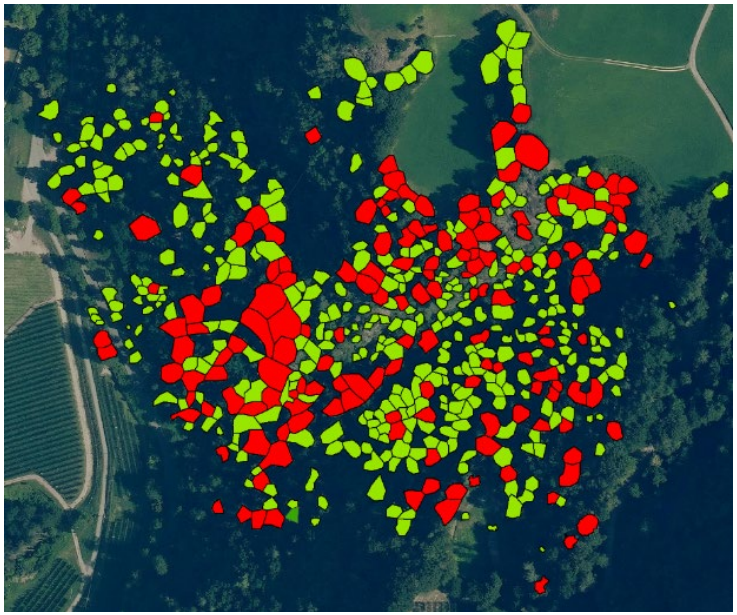


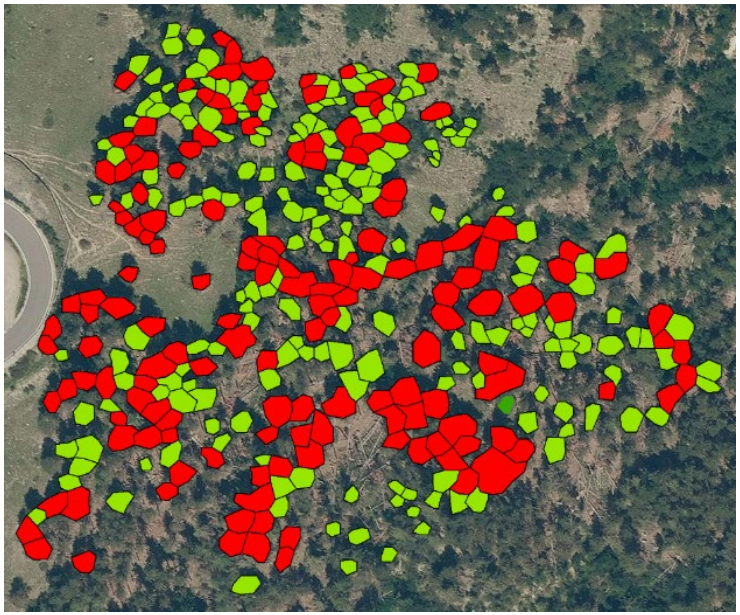


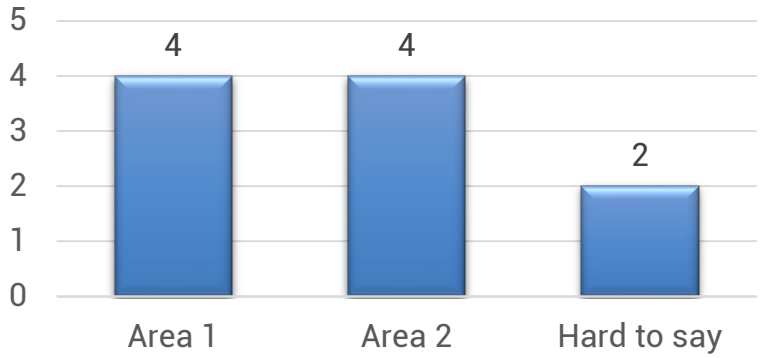
Results and Discussion

User study – Two-color representation

Which area is in greater risk?



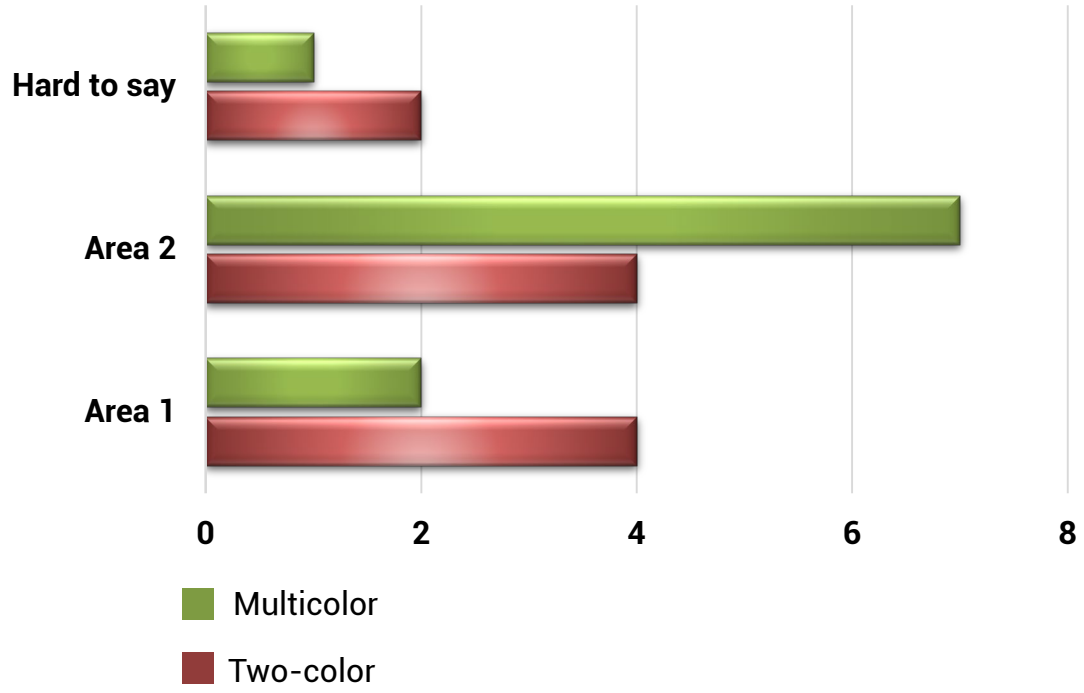




Results and Discussion

User study – Multiple color representation

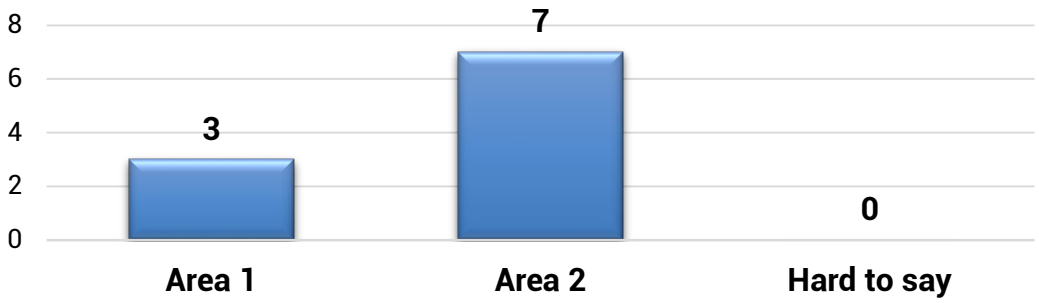
Comparing Multi- and Two-color representation



Results and Discussion

User study – Dot density

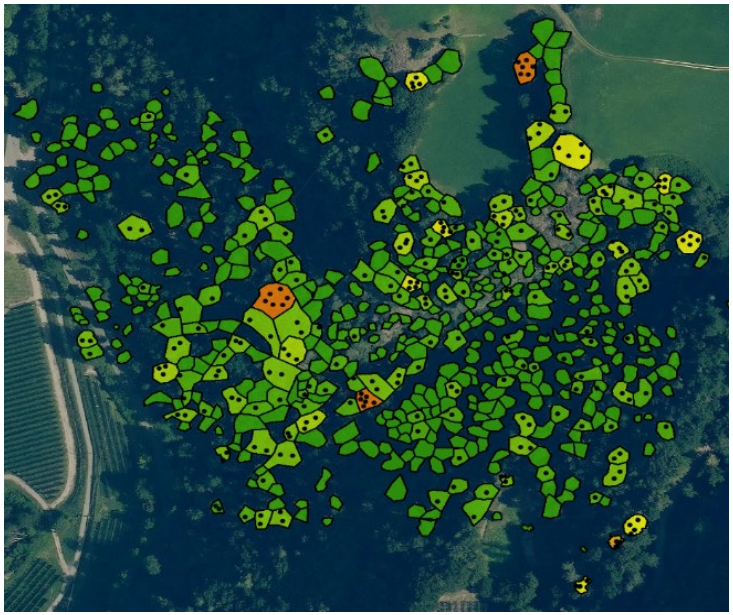
Which area is in greater risk?

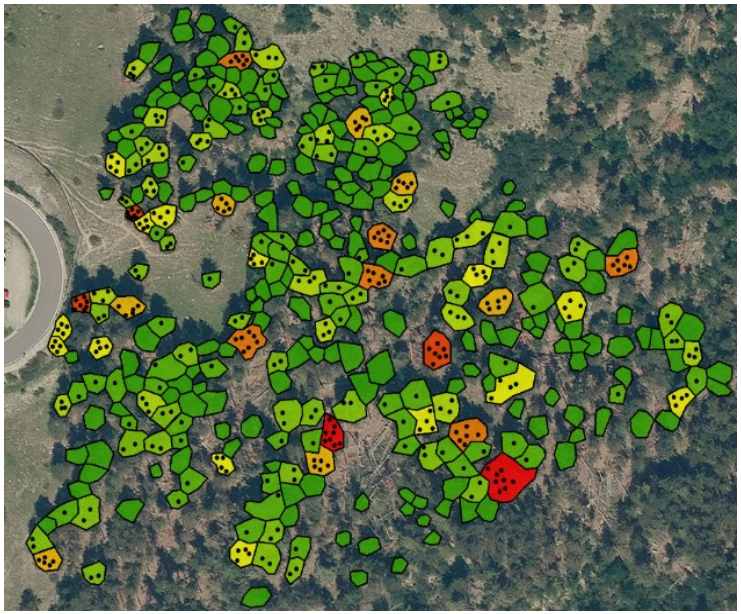


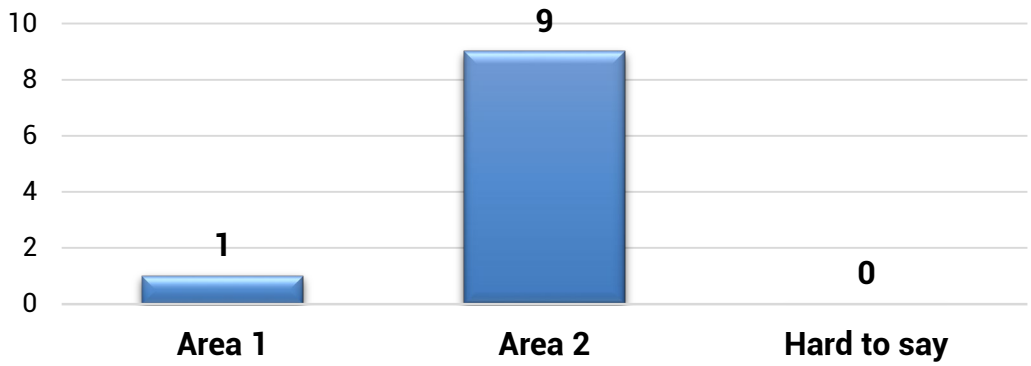
Results and Discussion

User study – Combining dots and multicolor polygons

Which area is in greater risk?



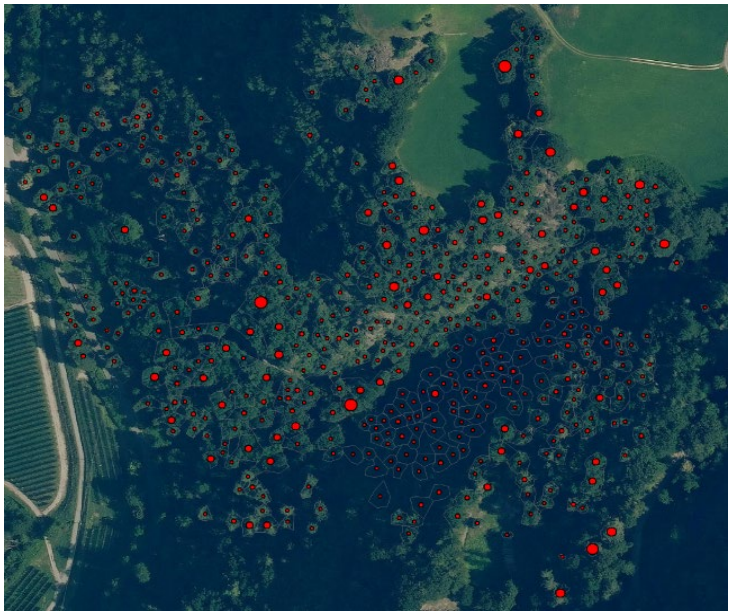


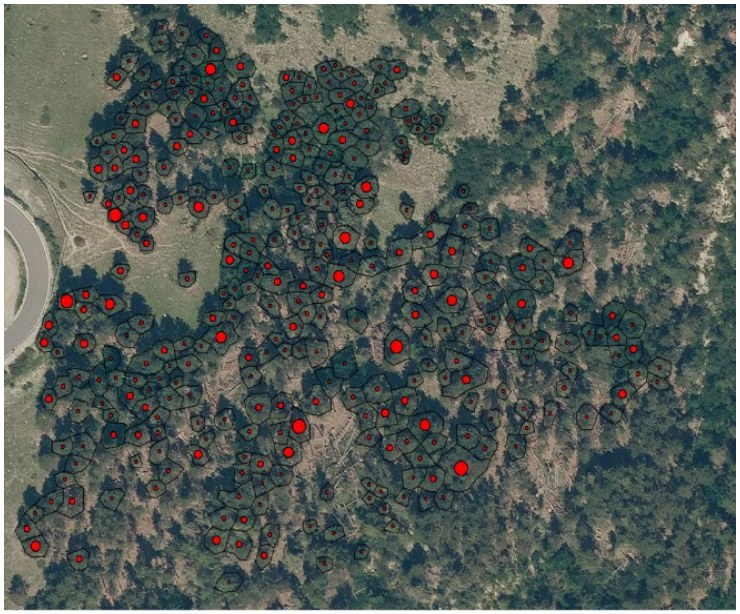


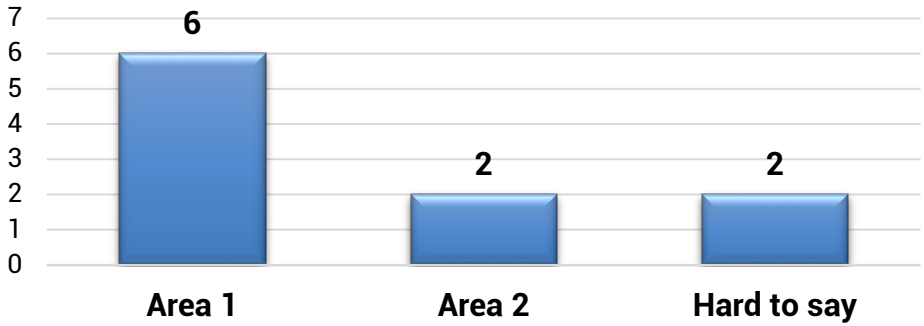
Results and Discussion

User study – Graduated symbol maps

Which area is in greater risk?



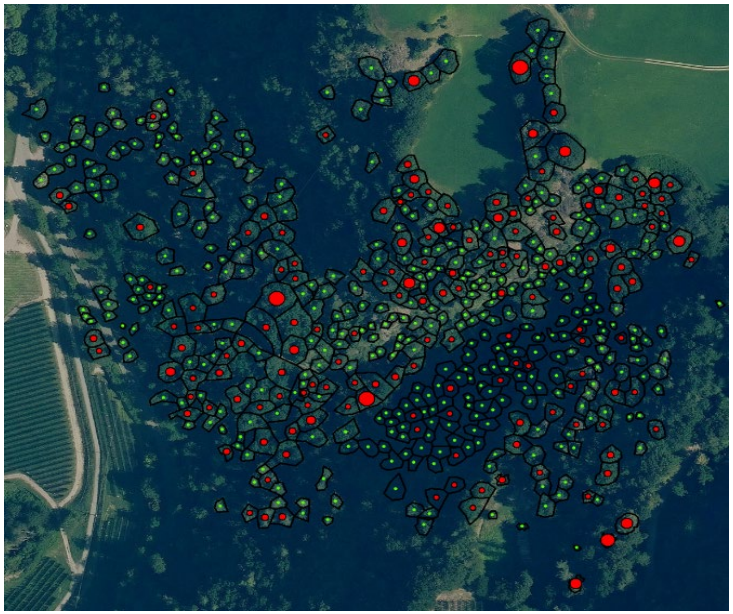


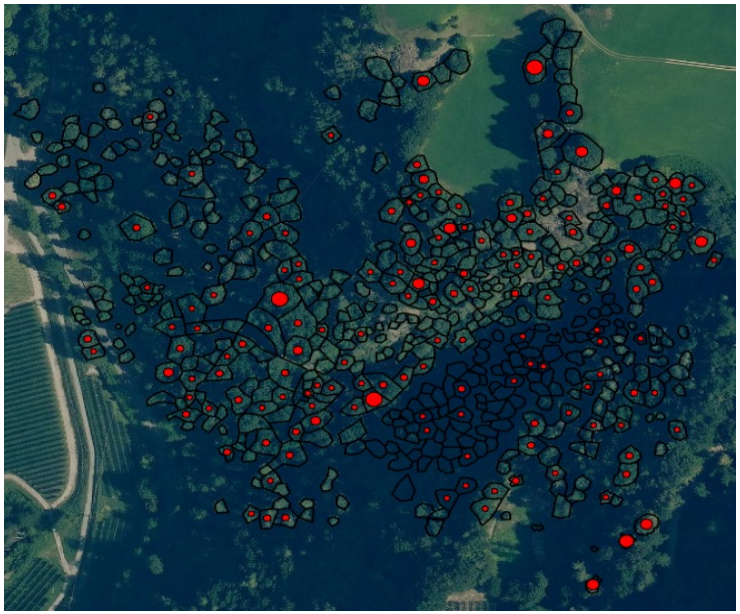


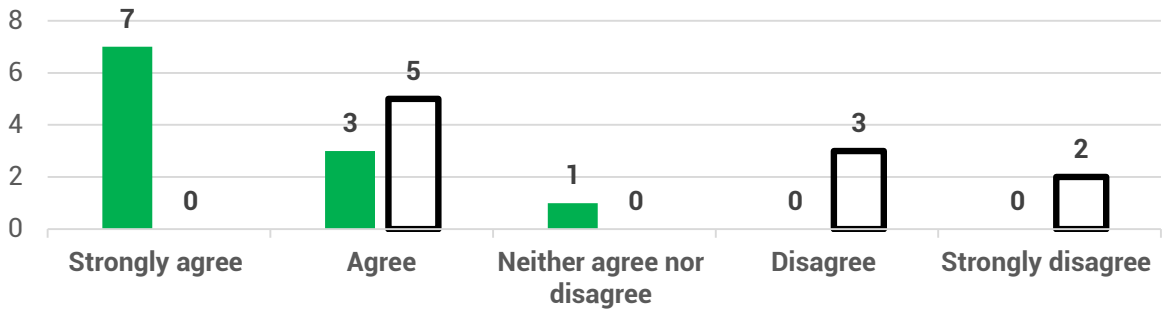
Results and Discussion

User study – Combined methods

Green dots or no dots at all for healthy vegetation?



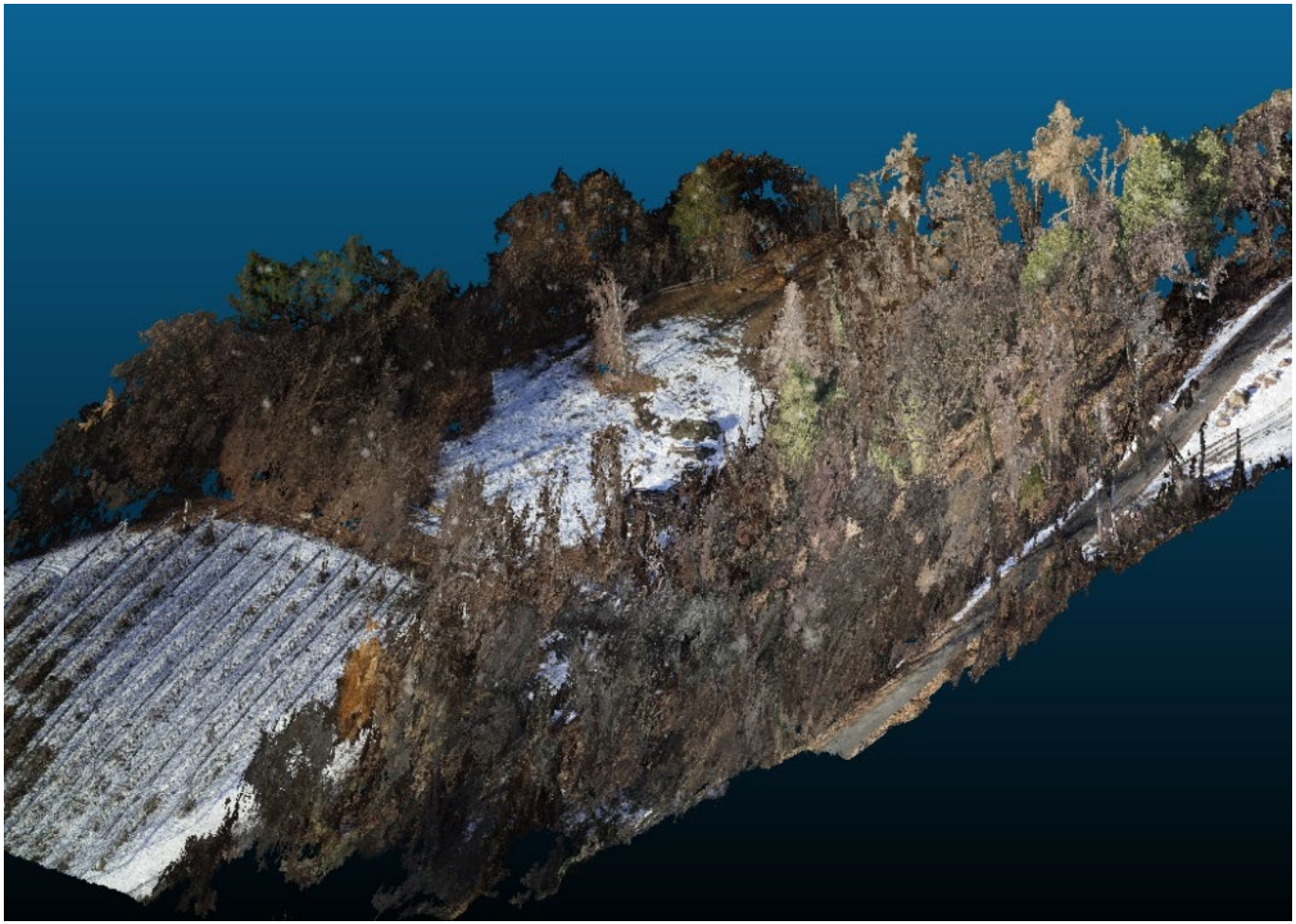




Results and Discussion

User study – Combined methods

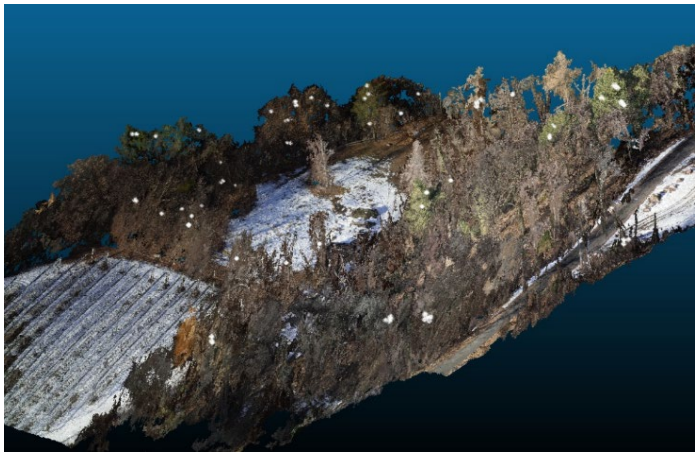
3D Representation

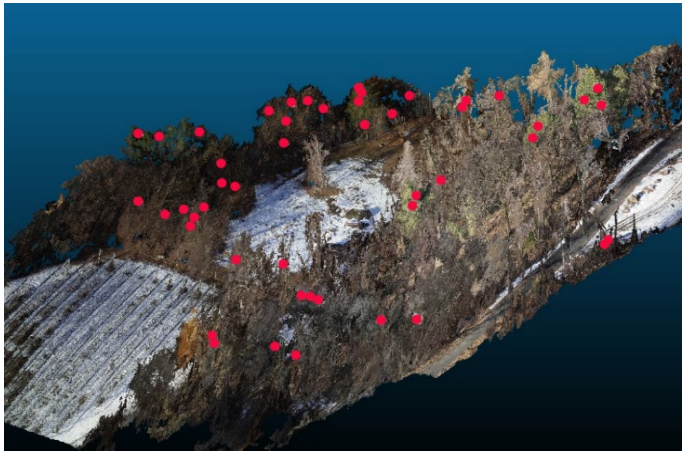


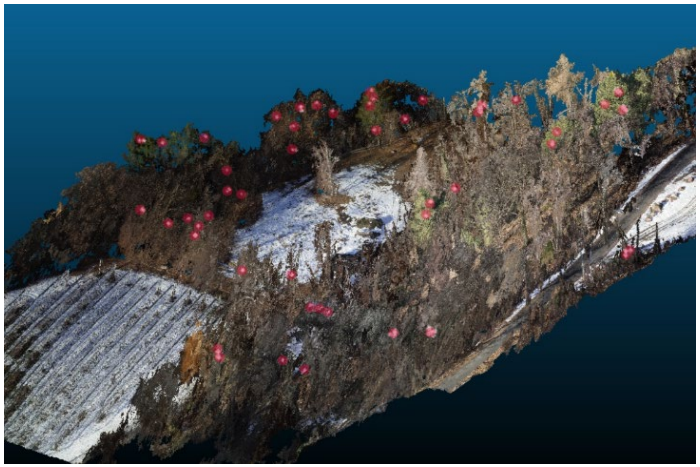
Results and Discussion

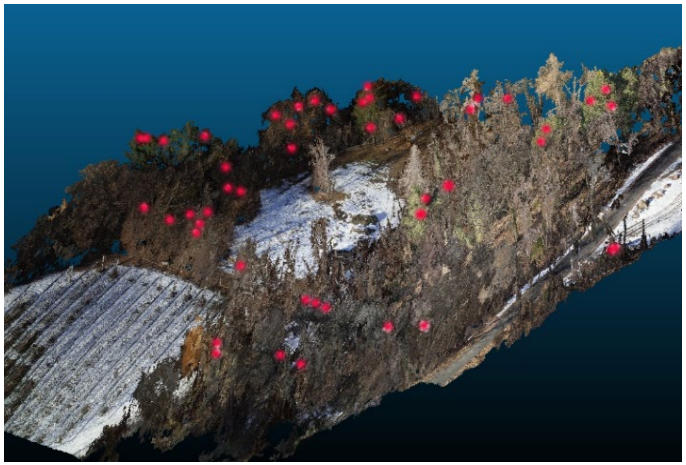
User study – Combined methods

3D Representation





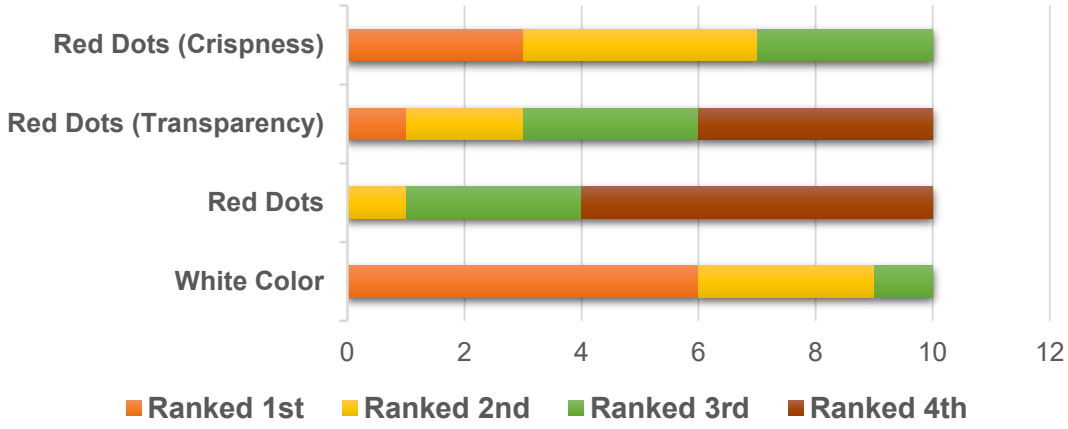




Results and Discussion

User study – Combined methods

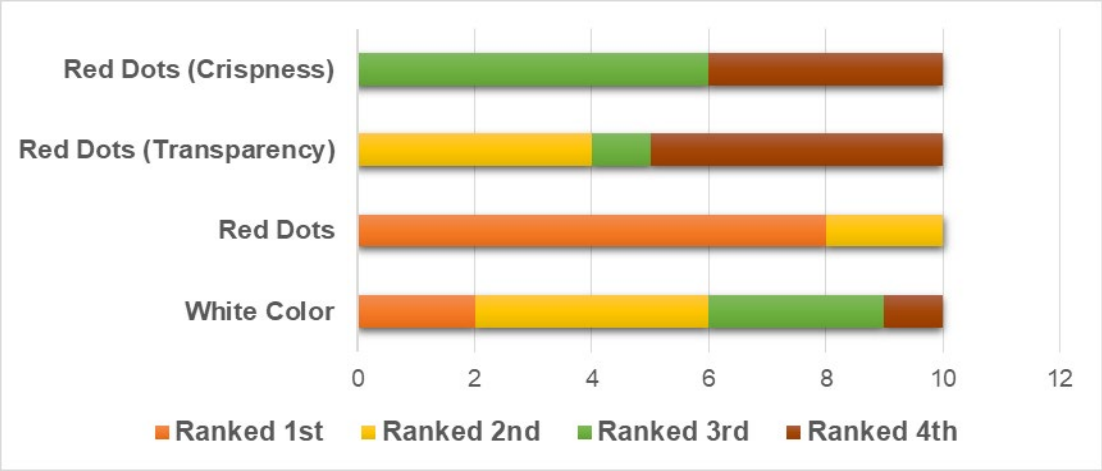
Natural result harmonized with the ecosystem



Results and Discussion

User study – Combined methods

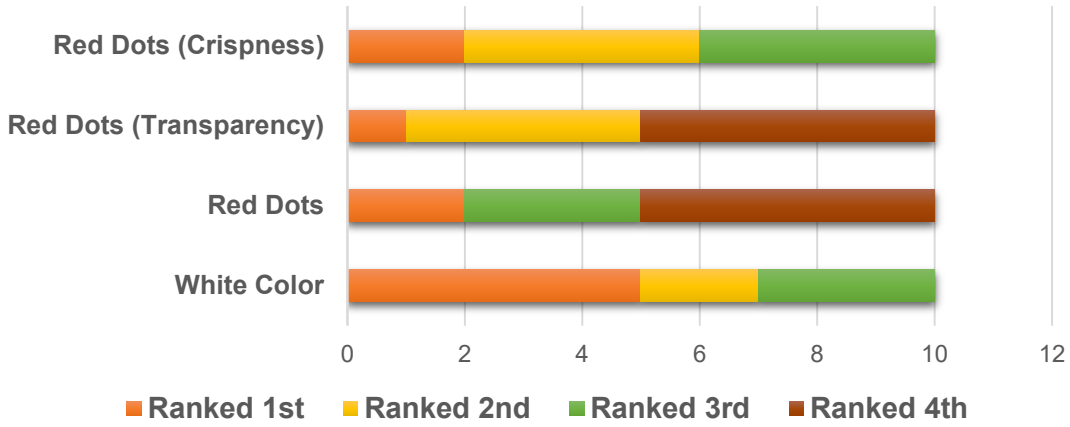
Easy to be seen



Results and Discussion

User study – Combined methods

Easy to be seen



Conclusions and Outlook

Research Question 1

Cartography's contribution in Forest management when endangered by malicious pests

- Proper visualization of spatial data
- Spread message to users
- Communication between cartographer and reader-user
- Implementation of methods that increases accuracy
- Predict trends
- Overall view of threats
- Understanding of phenomena
- Efficient Decision making

Conclusions and Outlook

Research Question 2

UAVs' contribution in pest monitoring

- Knowing the exact location of nests (high precision)
- Multispectral cameras allow us to see not only what is visible
- Fast
- Low cost
- Easy to handle

Conclusions and Outlook

Research Question 3

3D Maps compared to 2D Maps for pest monitoring

- 3D Maps great overview of area
- Good visualization tool
- Do not offer the ability for further analysis
- The simpler the better for exploring into the forest
- 2D maps more functional for forest operations

Conclusions and Outlook

Research Question 4

Proper colors for visualizing threats caused by pests in forest ecosystems

- green → positive and healthy
- red, pink and orange → something threatening is visualized
- Yellow color → neutral status when vegetation is visualized
- Polygons with multiple colors that indicate tree's condition was the most popular visualization method for visualizing vegetation's condition
- Choropleth maps that indicate the health condition of each tree looks that is the most ideal style among the proposed

Conclusions and Outlook

Limitation and Future Work

Limitation

- Flight Permission
- Weather conditions
- UAV autonomy

Future Work

- Only Trees and PPM Nests were visualized
- Further research for more important layers
- Visualization in different scales
- Developing camera sensors that detect changes in vegetation
- Application of Thermal Cameras

Thank you for your time and your attention!
Time for some questions!