Keeping an Eye on Green: Detecting Mountain Grasslands Responses to Climate and Land Use Changes from Imagery

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Introduction: The Vital Role of Mountain Grasslands

- **Ecosystem Services:** Biodiversity, water regulation, soil protection.
- **Economic Importance:** Livestock farming, high-quality dairy products, tourism.
- **Cultural Heritage:** Shaping mountain landscapes and traditions.

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Challenge: Sustainable management requires accurate and timely information on grassland status.

Challenges in Mountain Grassland Monitoring

- **Accessibility:** Rugged terrain makes field surveys difficult, time-consuming, and costly.
- **Spatial Heterogeneity:** Rapid changes in altitude, aspect, and soil lead to diverse vegetation.
- **Climate Change:** Shifting phenology, species distribution, and water availability.
- **Land Abandonment:** Balancing ecological preservation with economic viability.

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Need: Efficient, non-invasive methods for monitoring vast and complex areas.

Remote Sensing: A Powerful Tool for Spatio-Temporal Monitoring

- **Definition:** Science and art of obtaining information about an object or phenomenon without making physical contact.
- **Principle:** Measuring reflected or emitted electromagnetic radiation from the Earth's surface.
- **Advantages:**
  - Wide-area coverage
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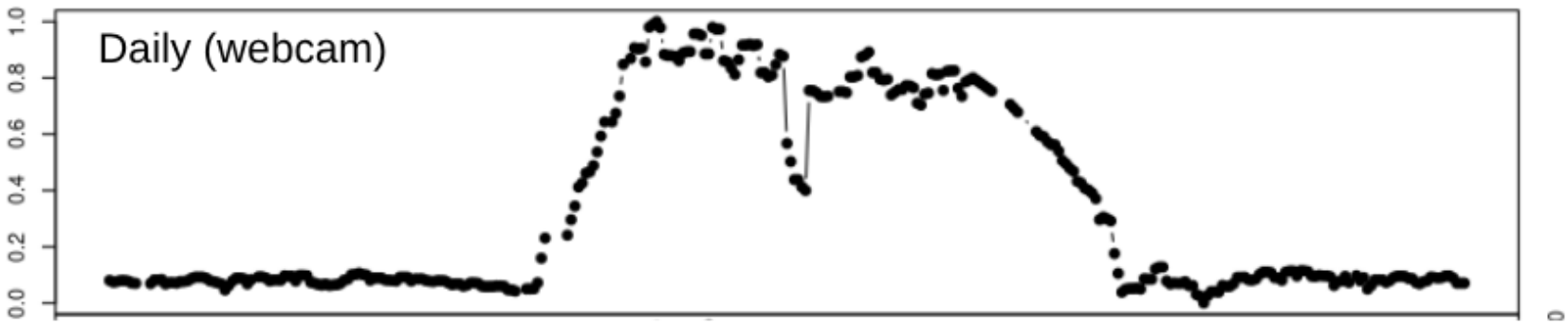
Application: Ideal for monitoring dynamic and extensive landscapes like mountain grasslands.

Resolution in time: detect a grass cut



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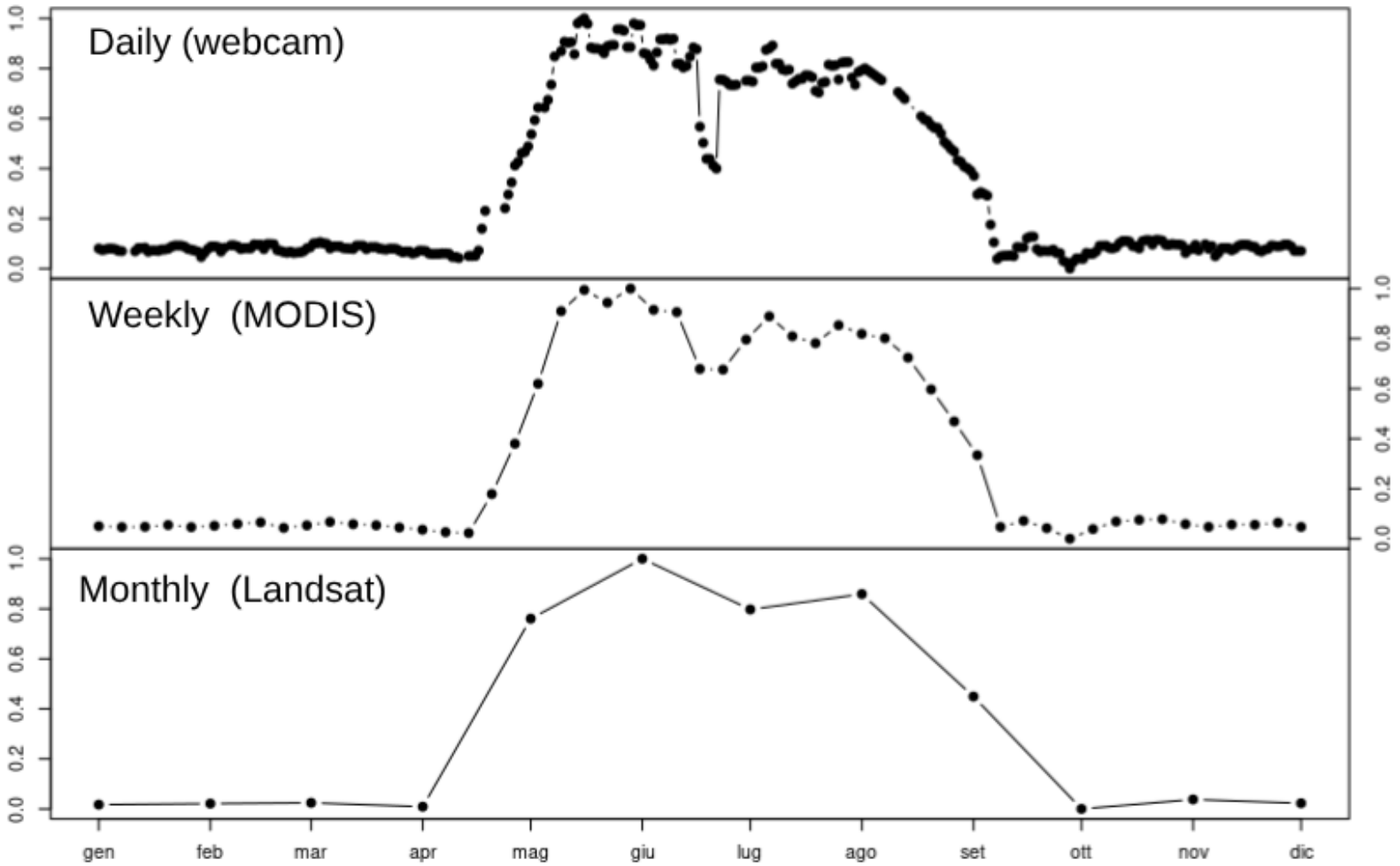

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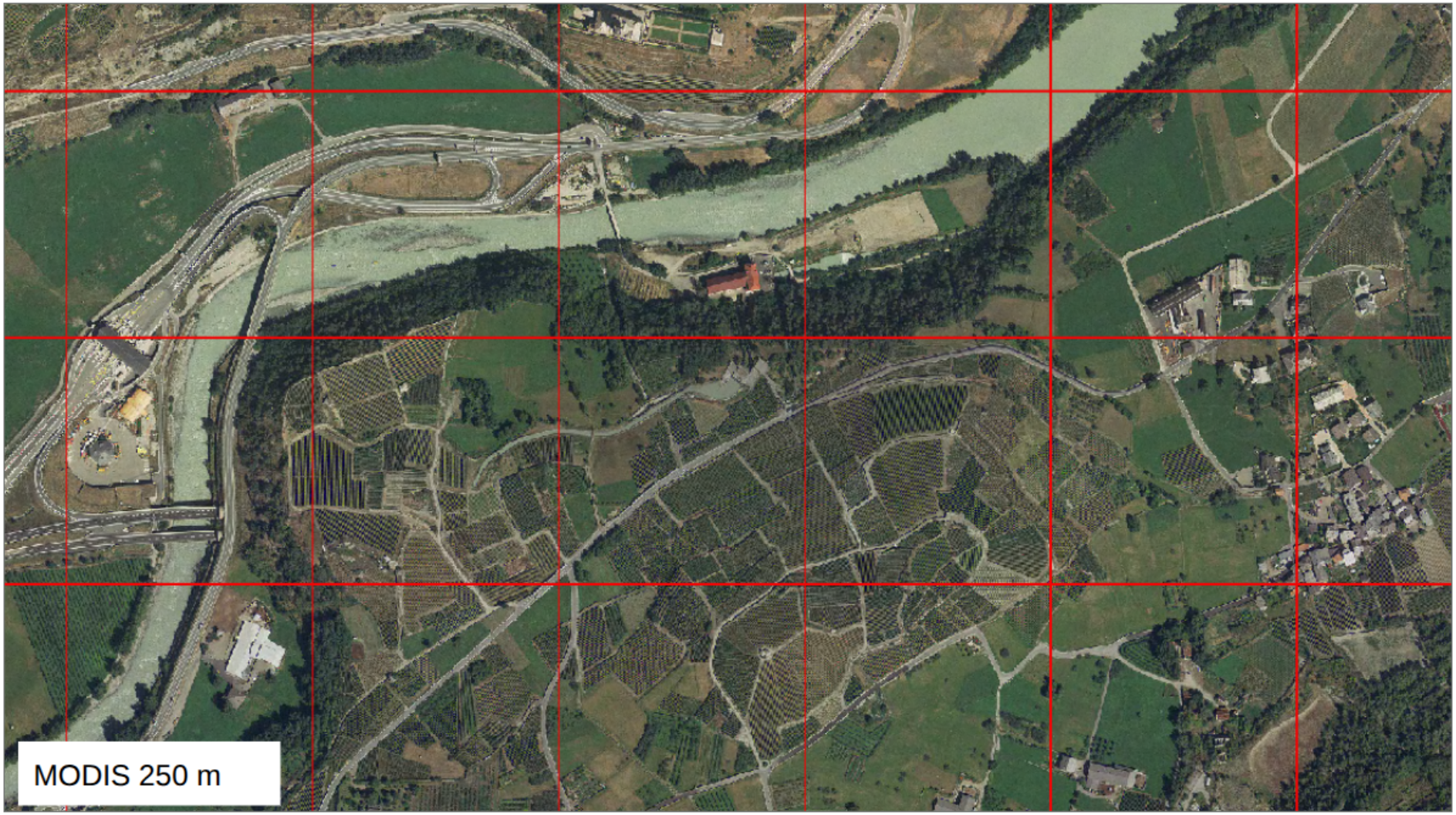

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Key Remote Sensing Sensors for Grassland Assessment

Sentinel-2

- 10 m spatial resolution (agricultural mapping) ↑
- 5 days revisiting time (S2A & S2B in tandem) ↑
- 13 spectral bands (many indices, ML training) ↑
- Free, open access, highly supported (e.g. Copernicus high res layers) ↑
- Cloud cover is a major issue in mountains. ↓

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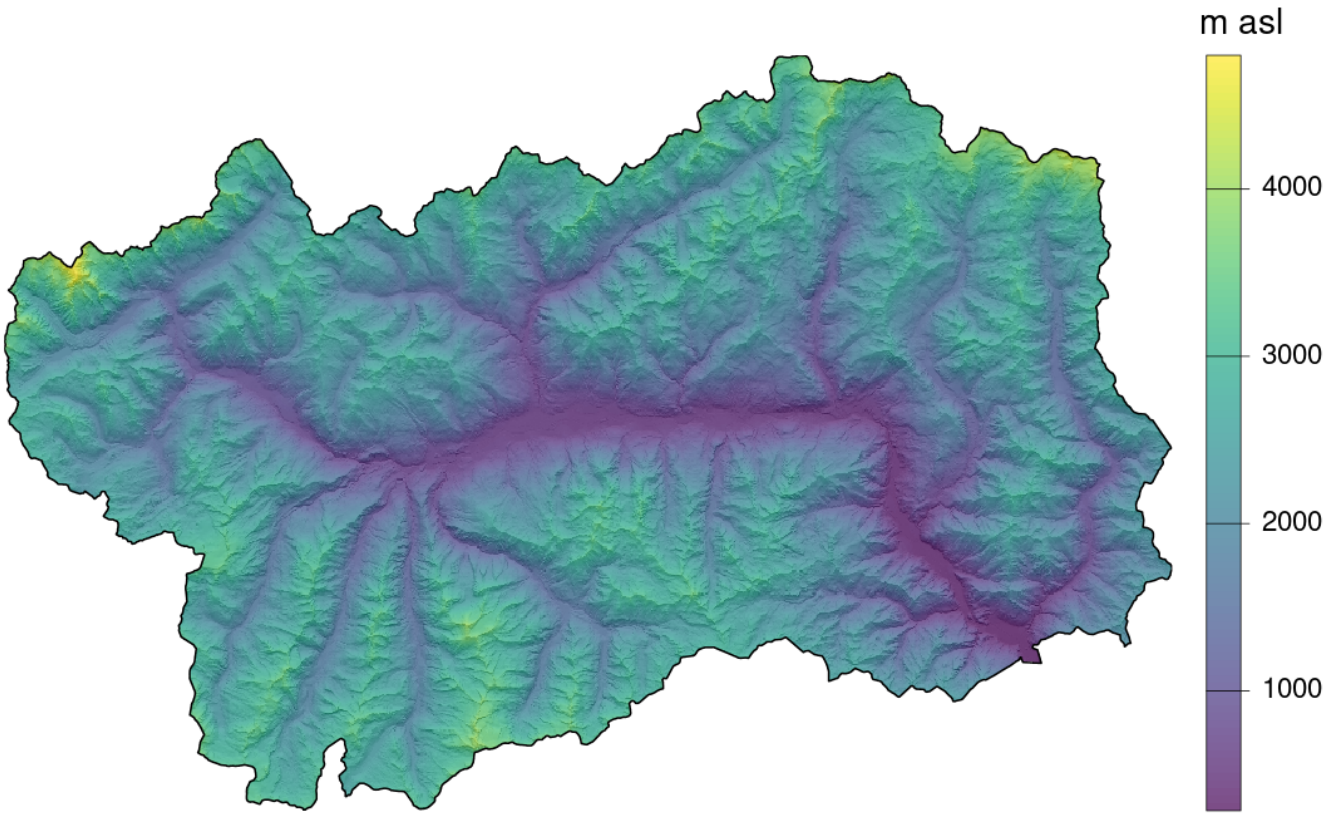
A 10-years cooperation with local agriculture department, addressing:

- **Resource assessment:** Grassland extent & productivity
- **Regulation & management:** Actual usage of the surfaces
- **Early warning:** Quasi-realtime tools for monitoring the impact of extreme events

The rationale behind the whole process is the **co-construction**

Aosta Valley, a 3200 km^2 inner-alpine, continental Valley

Elevation: 300-4800 m ASL (mean: 2100 m)
T: 14°C (300 m), -3°C (3000 m)
P: 500 - 1800 mm/yr (40-50% as snow)



Grassland Area: Supervised Machine-Learning based mapping (90% accuracy in grassland detection)

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Productivity: In-situ biomass measurements + RS + regression models

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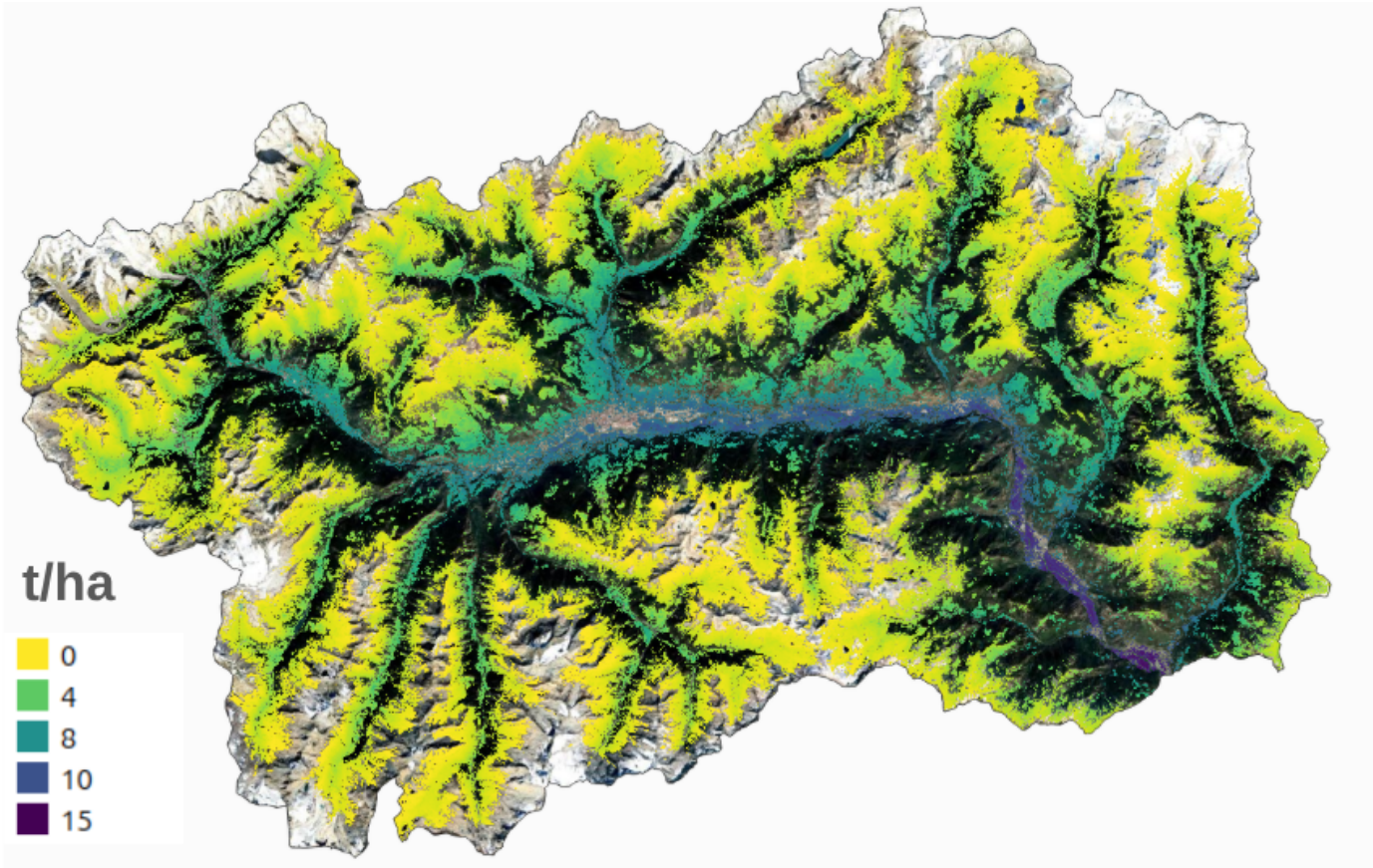
- $\approx$ 900 km^2 of grasslands
- $\approx$ 600 km^2 of used **pastures** and meadows
- Productivity: 0.3 - 15 t/ha/yr



Case study at subregional scale:

Focus: meadows & pastures below treeline (1000-2000 m asl)

Potential livestock rate: Modelled from biomass, slope and elevation

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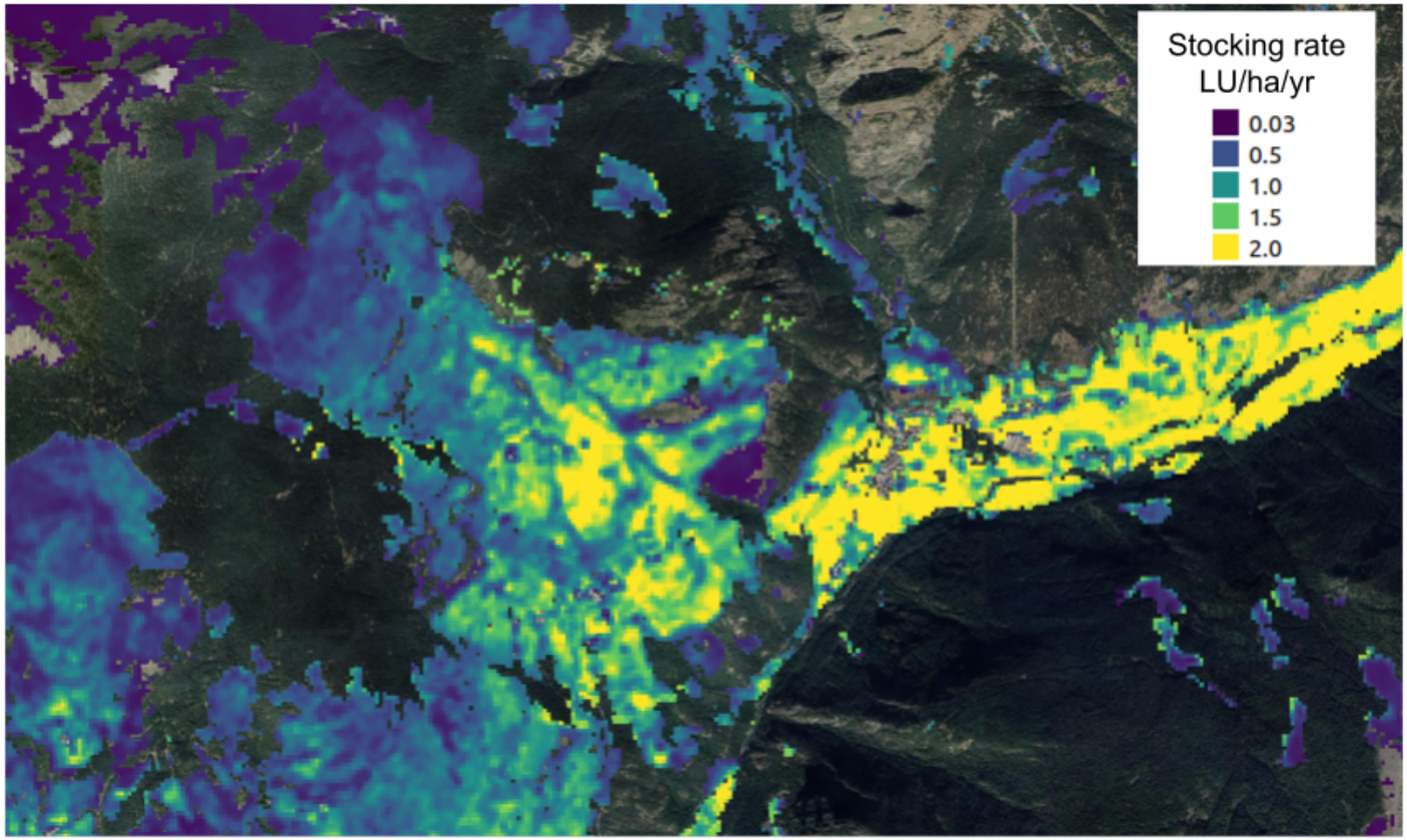

Aggregated at the agricultural parcel level → A true management tool

Utilization of the surfaces: CAP Subsides are given based on farmer's declaration + information at the national and EU level (e.g. sen4CAP)

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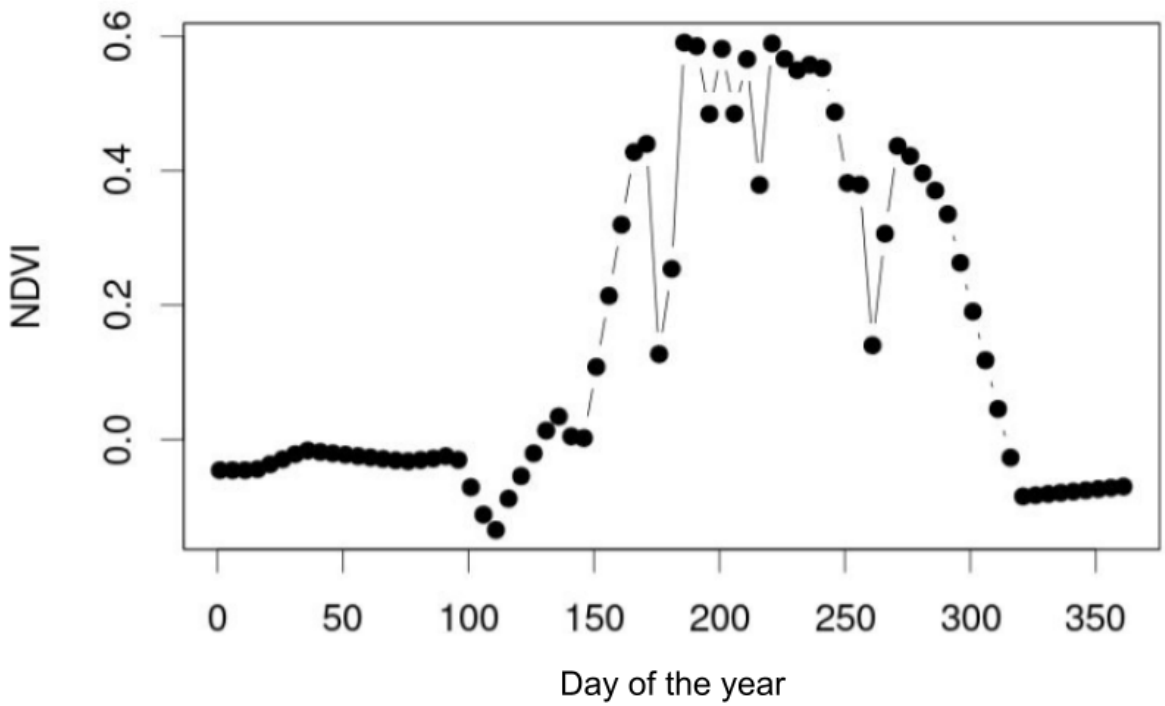
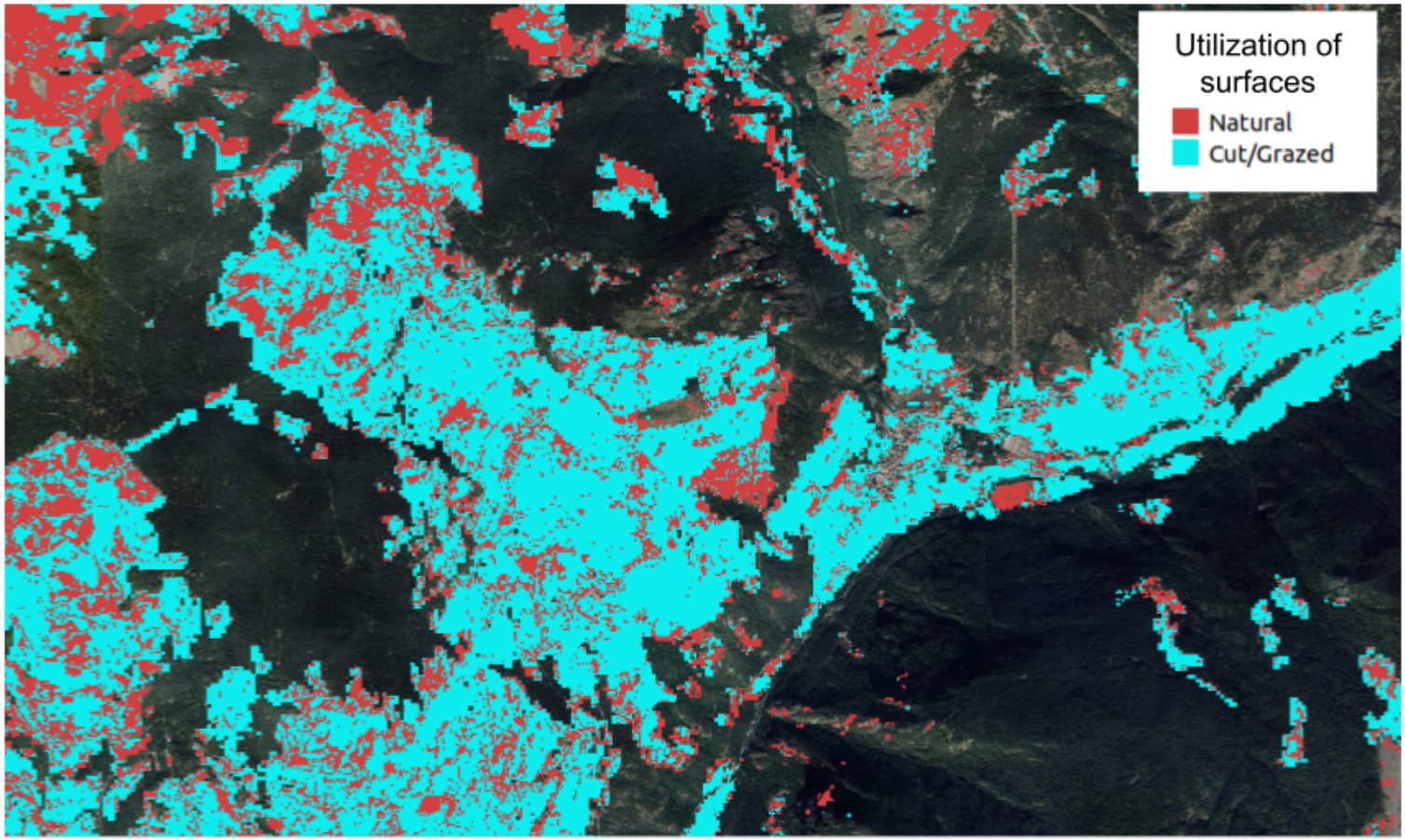
An algorithm for the pixel-by-pixel detection of:

- Utilization (i.e. natural vs cut/grazed)
- Number of utilizations
- Time (day of year) of utilizations



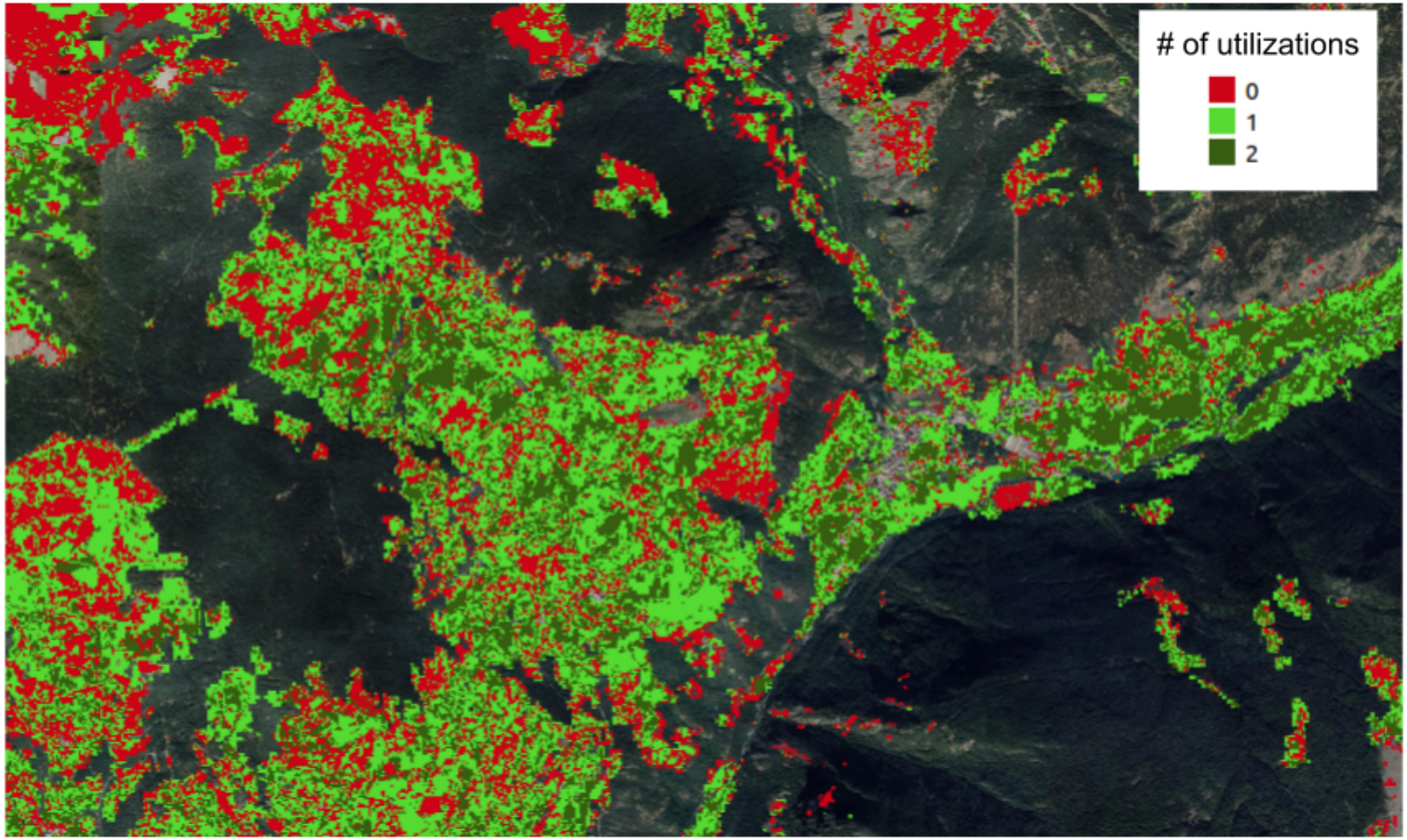
Utilization mask: Natural vs grazed/cut grasslands in 2022

Yearly products **can** be used as tools to check farmer's declarations



At the regional level ≈60% of the grassland surfaces are grazed/cut

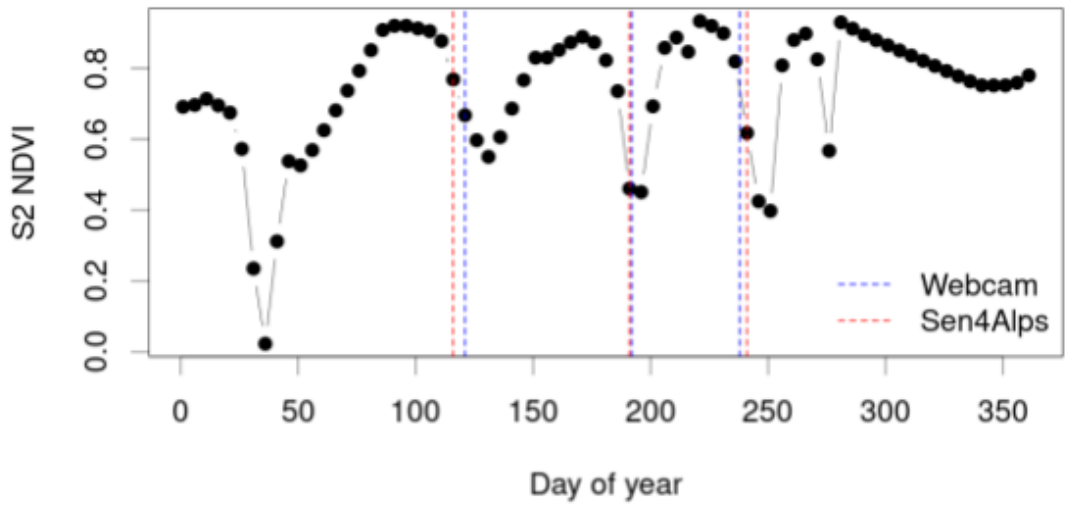
Number of cuts/grazing events



Check for spatial patterns $\rightarrow$ **Validation** required

Validation with ground truth: webcams

Accuracy assessment



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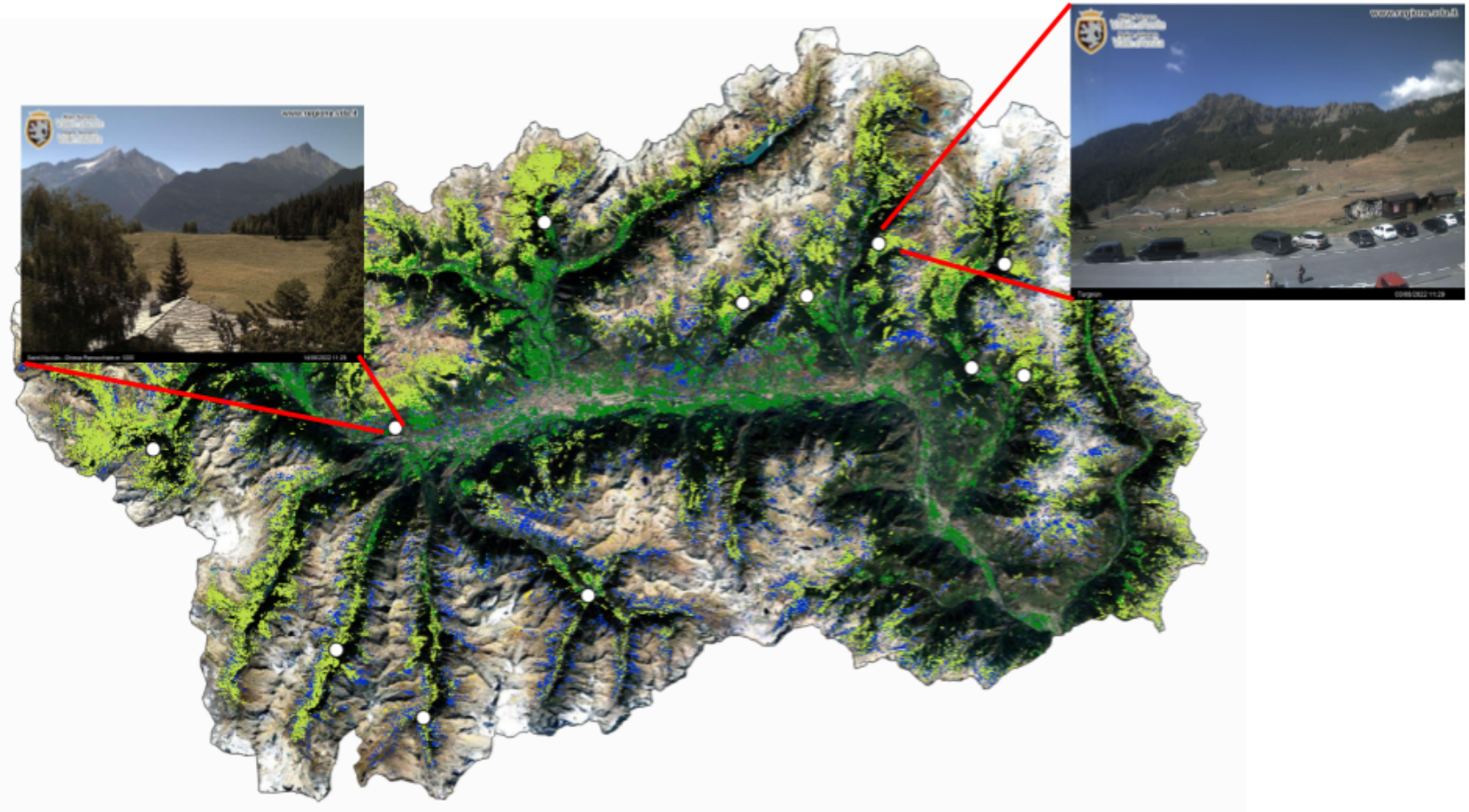

12 touristic webcams x 9 years of data (not too bad)

Estreme events are becoming every-day business

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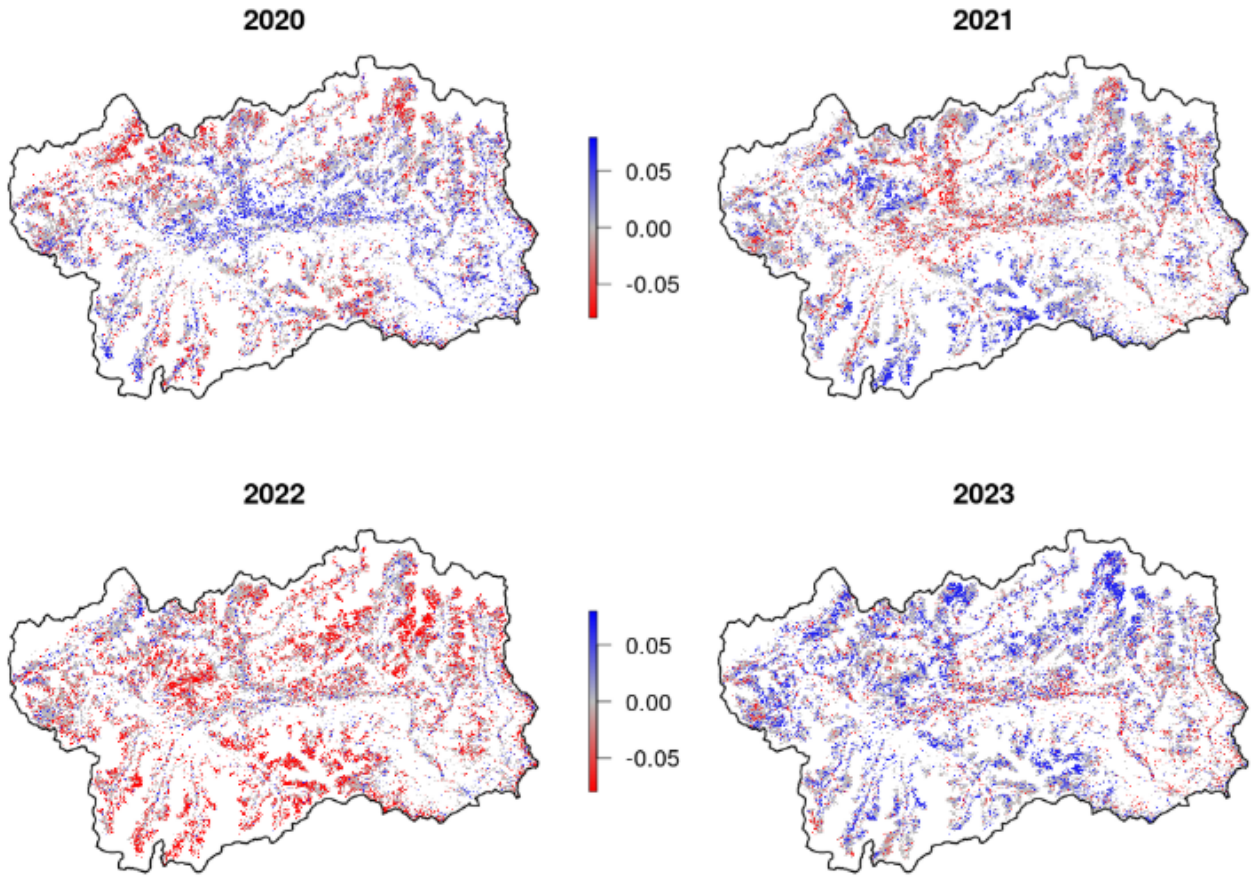
Quasi-real time monitoring of the impact of extreme events on grassland health

Anomaly (current vs average year) of selected parameters: **Foliar water content** in July



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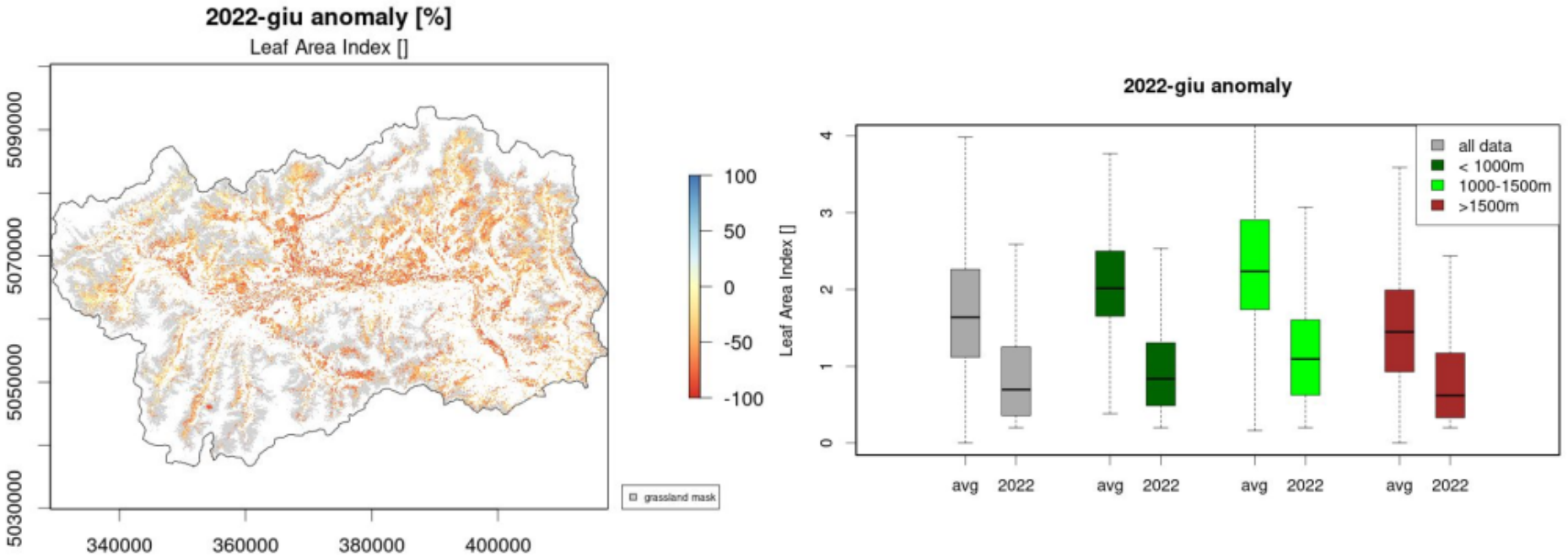
Leaf area index across elevation belts indicates stronger impact at lower elevation



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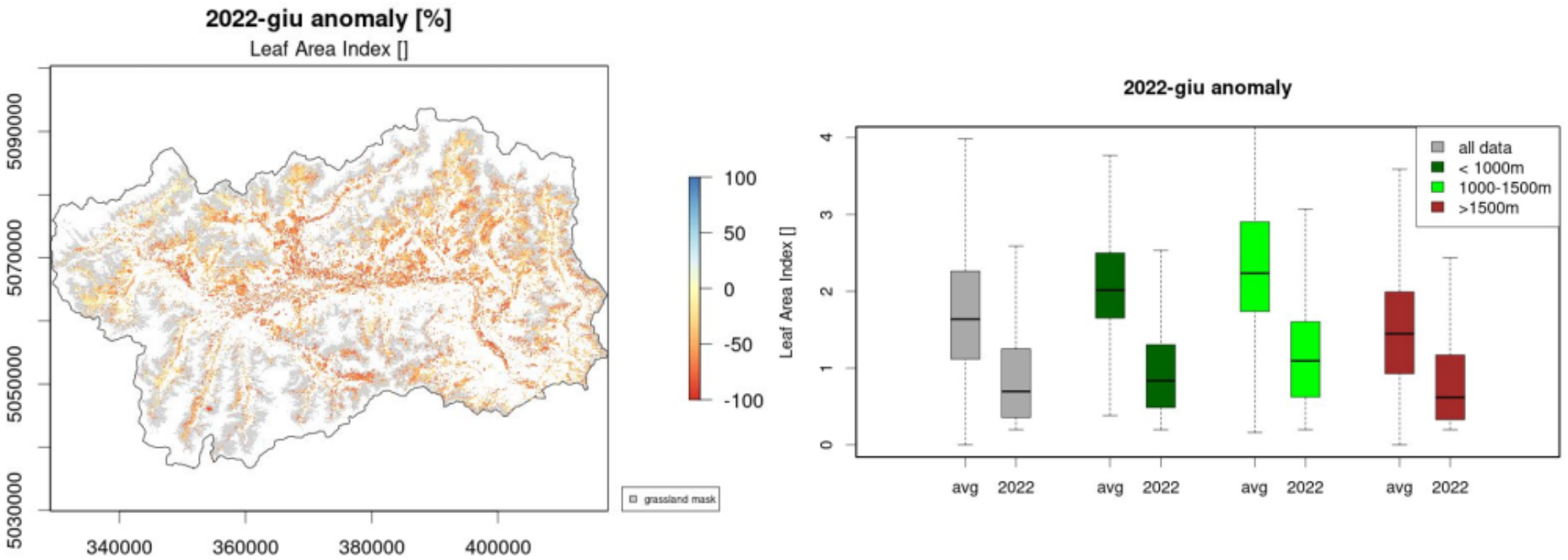

Taken together, these indicators provided the basis for a derogation order permitting the early withdrawal of livestock from pastureland in 2022.

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- An updatable, scalable tool for the prompt quantification of grassland resources.
- A support for **local** regulation on CAP (careful negotiation required).
- A quasi-realtime support for decision-making in case of extreme meteorological conditions.

Thank You!

Questions?

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