Modelling Grassland LAI

From S1 and S2 using spatial gap-filling

Caroline Göhner[1], Mohammad Hussein Alasawedah[1], Abraham Mejia-Aguilar[2], Giovanni Peratoner[3], Alexander Dovas[3], Gabriel Sicher[3,4], Laura Stendardi[1], Paulina Bartkowiak[1], Michele Claus[1], Giovanni Cuozzo[1], and Mariapina Castelli[1]

[1] Eurac Research, Institute for Earth Observation, 39100 Bolzano, Italy
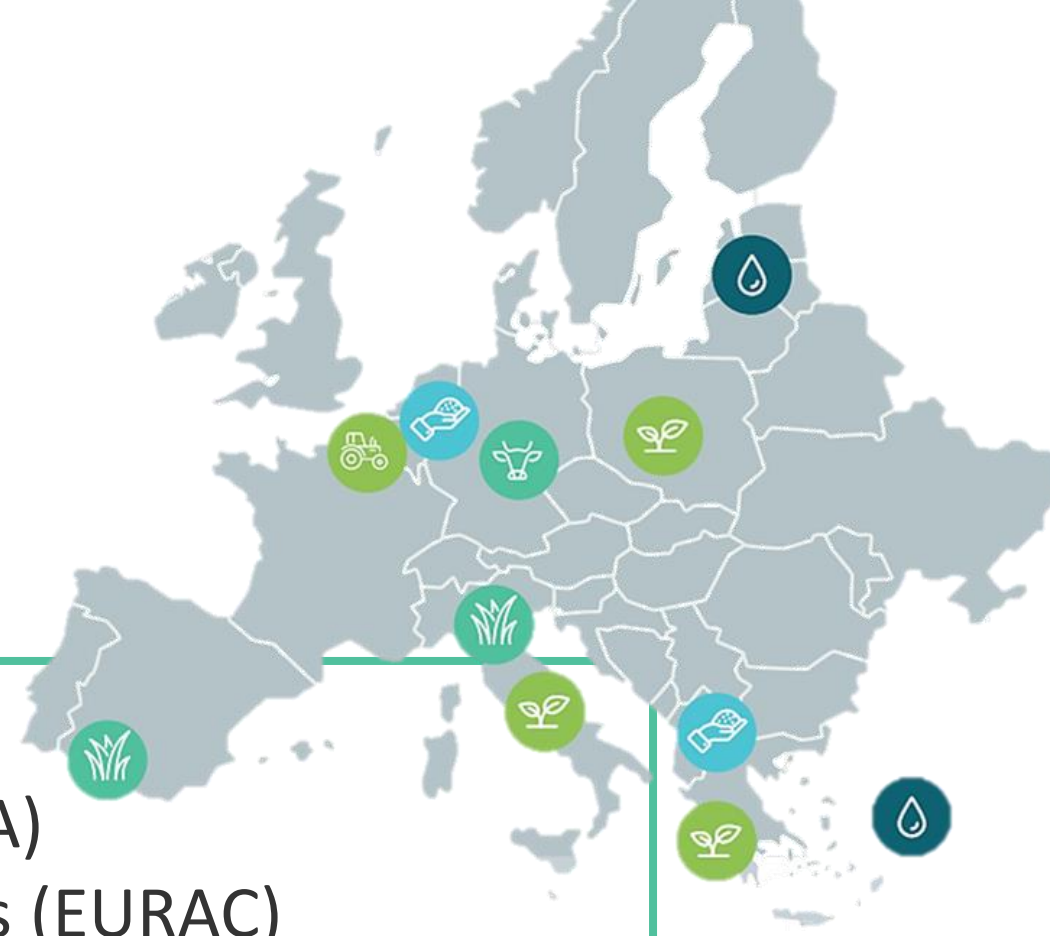[2] Eurac Research, Center for Sensing Solutions, 39100 Bolzano, Italy
[3] Laimburg Research Centre, Research Area Mountain Agriculture, Ora, 39040 Bolzano, Italy
[4] Hagelschutzkonsortium—Condifesa Bolzano, 39100 Bolzano, Italy

BioGeoSAR-2023, 16.11.2023

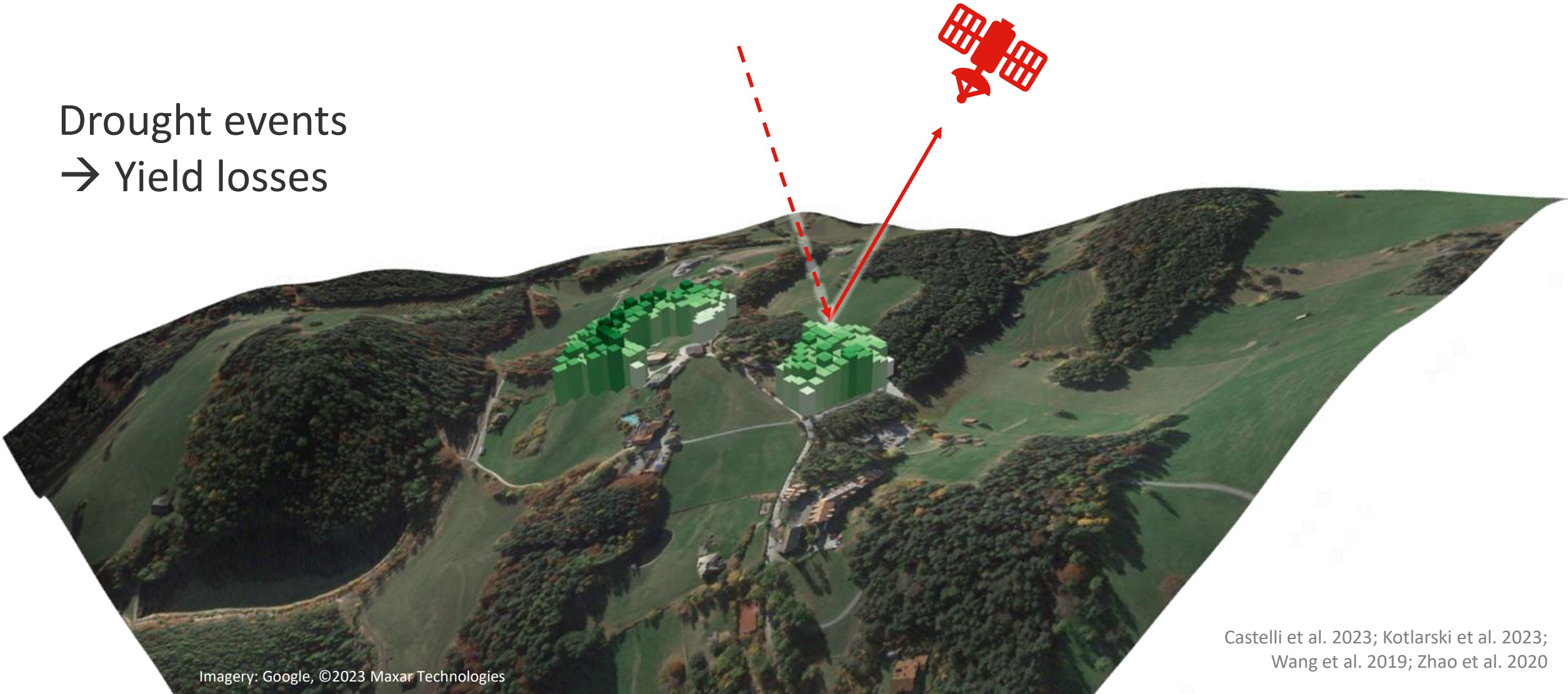→ sustainable, data-driven agriculture

Mediterranean (IFAPA)
and Alpine grasslands (EURAC)

... improve grassland monitoring

GRASSLANDS

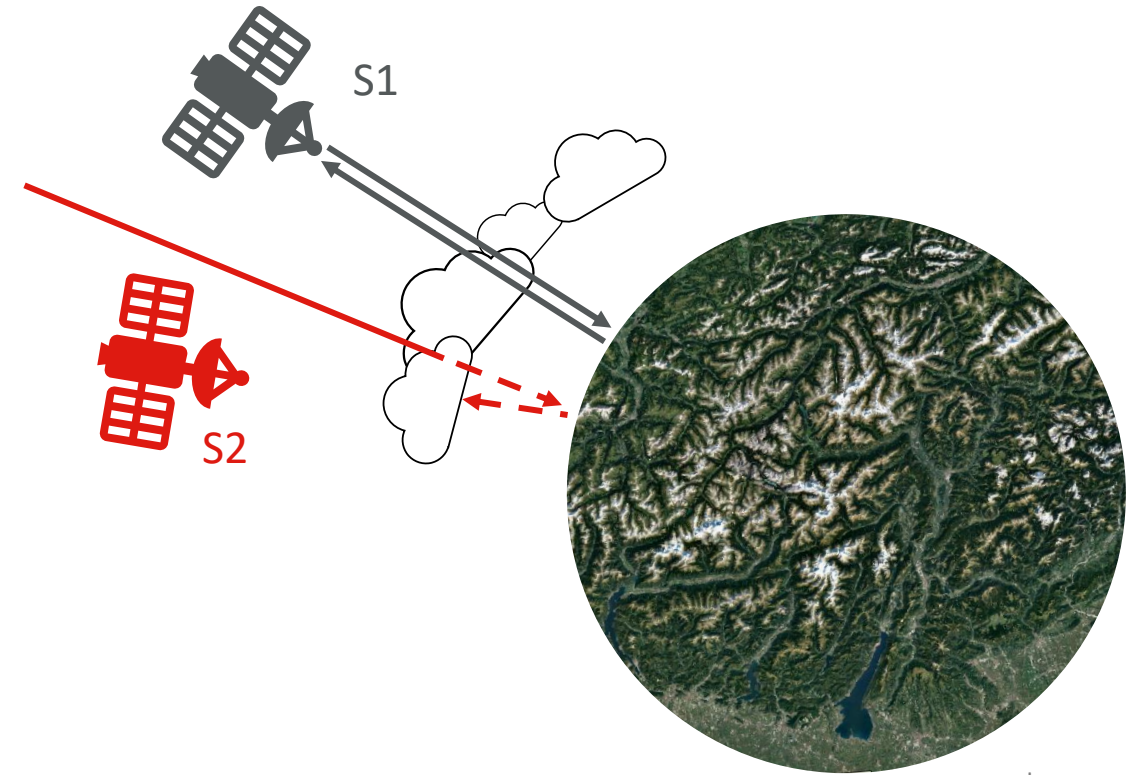# Grassland monitoring

Drought events
→ Yield losses
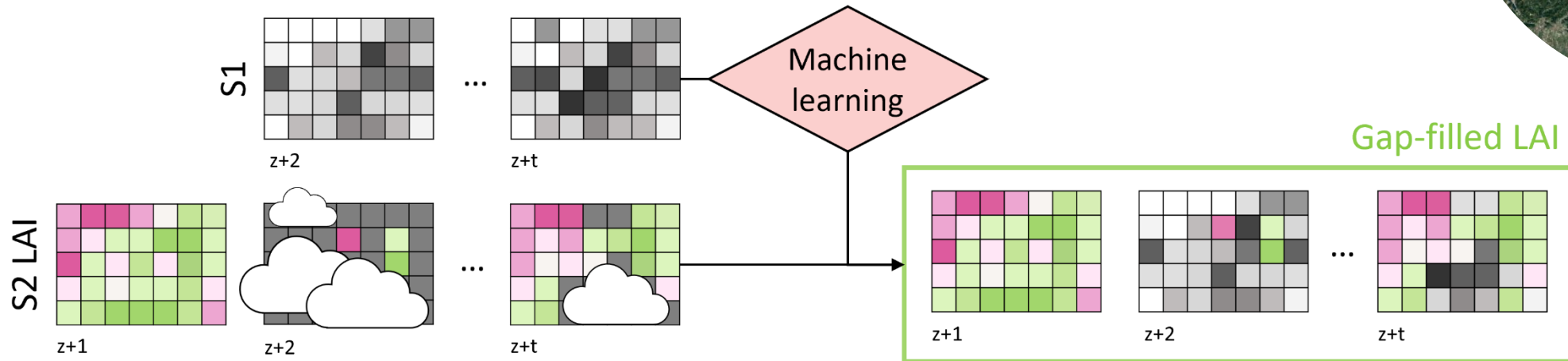

Imagery: Google, ©2023 Maxar Technologies

Castelli et al. 2023; Kotlarski et al. 2023; Wang et al. 2019; Zhao et al. 2020

Sentinel-1 SAR

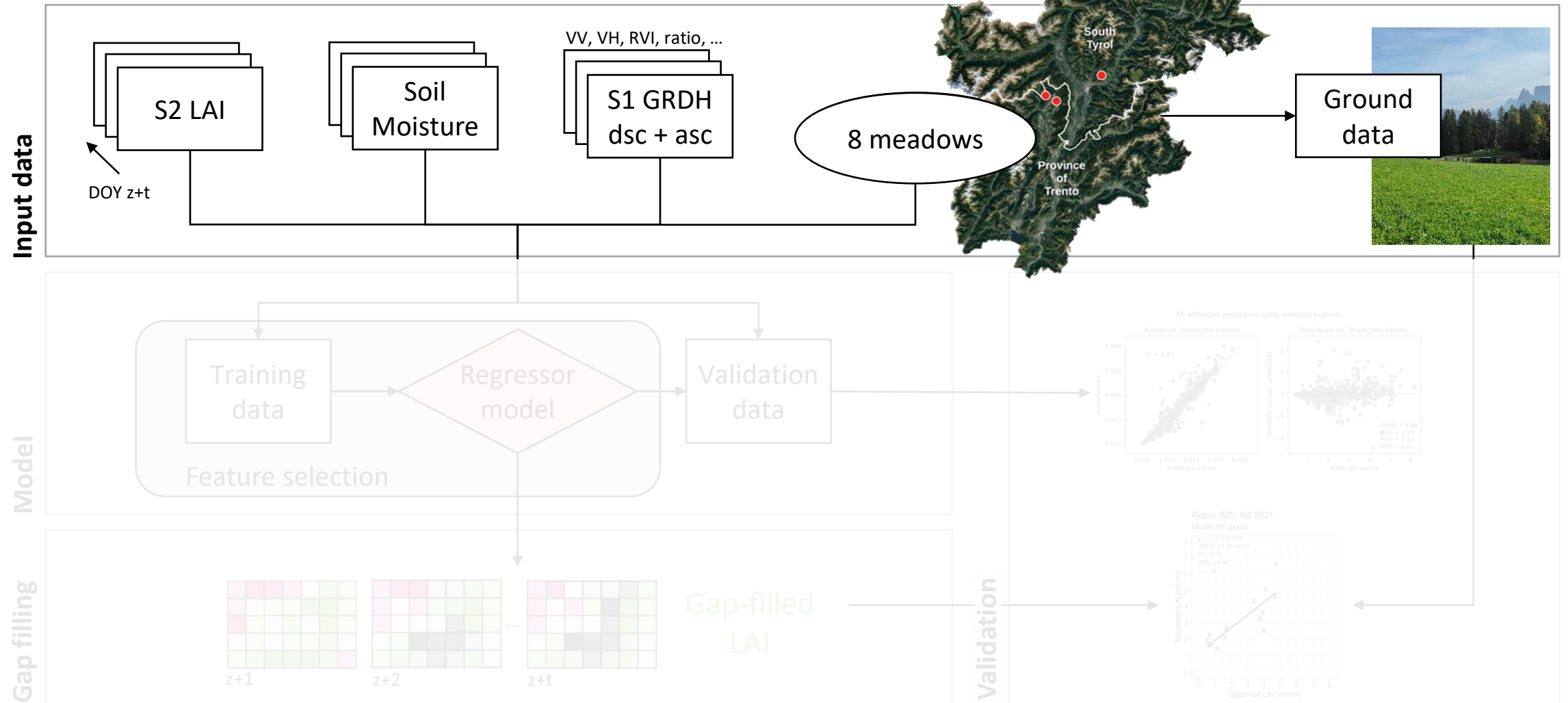Frequent cloud coverage in the alps...

S1

S2

Imagery:
Google, ©2023 TerraMetrics

S1

z+2 ... z+t

Machine learning

S2 LAI

z+1 z+2 ... z+t

Gap-filled LAI

z+1 z+2 ... z+t

Castelli et al. 2023; Wang et al. 2019; Ali et al. 2016

Methodology

Sentinel-2 LAI and SMC data

Sentinel-2 LAI

25.06.2021

LAI [m²/m²]

0   7
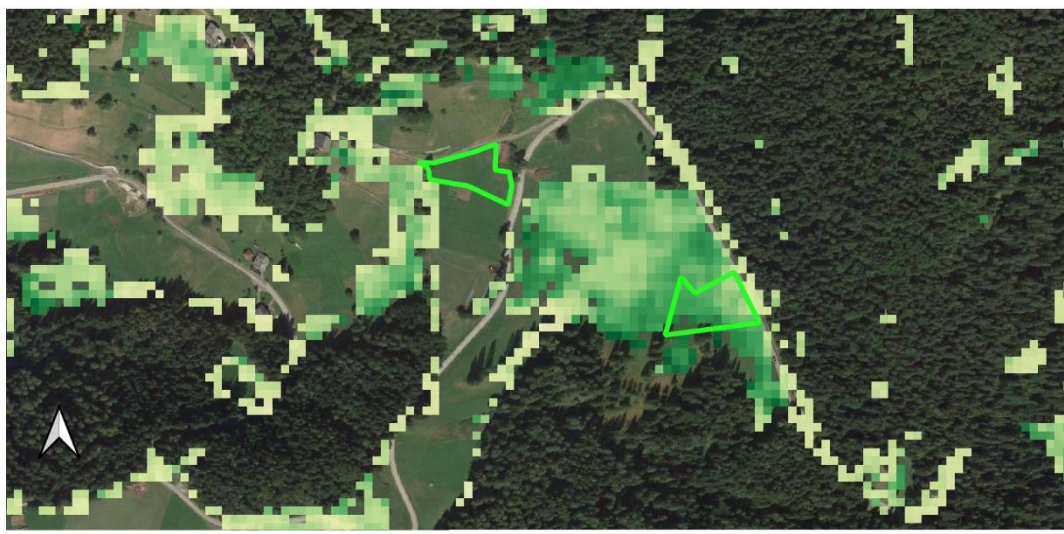
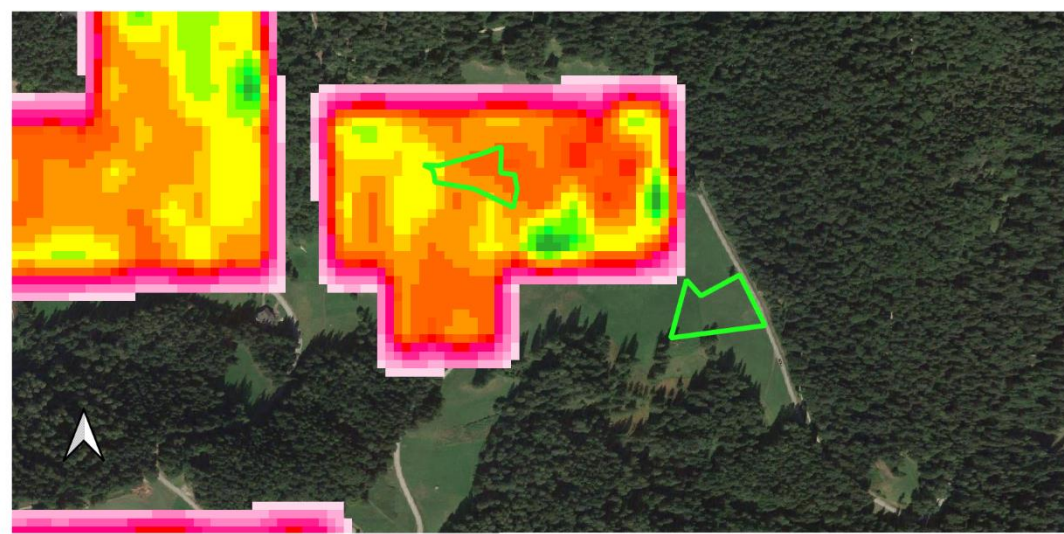**Soil Moisture Content**
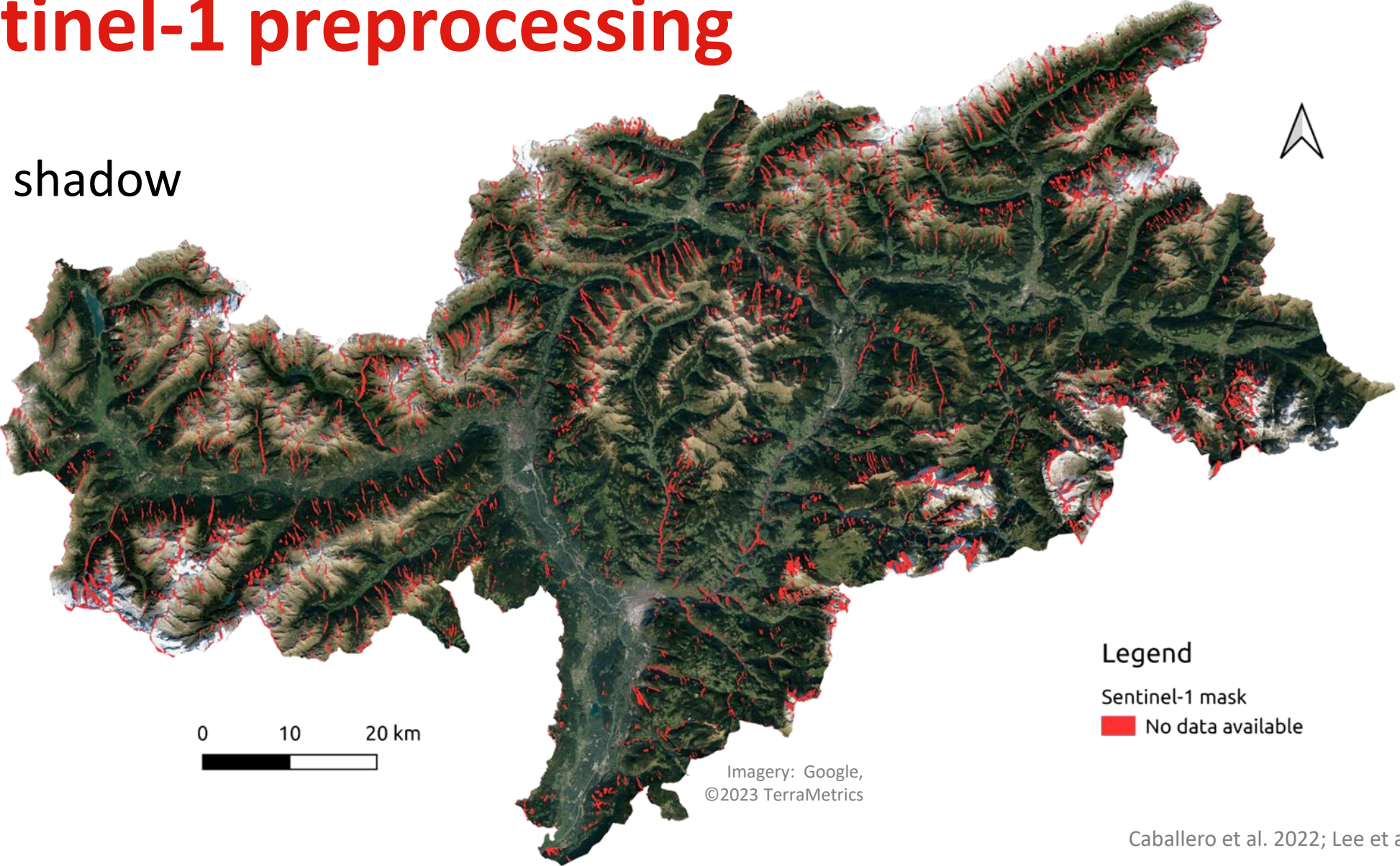
25.06.2021

SMC [%]

0   43

Imagery: Google, ©2023 CNES / Airbus, Maxar Technologies

Soil Moisture data: Greifeneder et al. 2021; Weiss et al. 2020
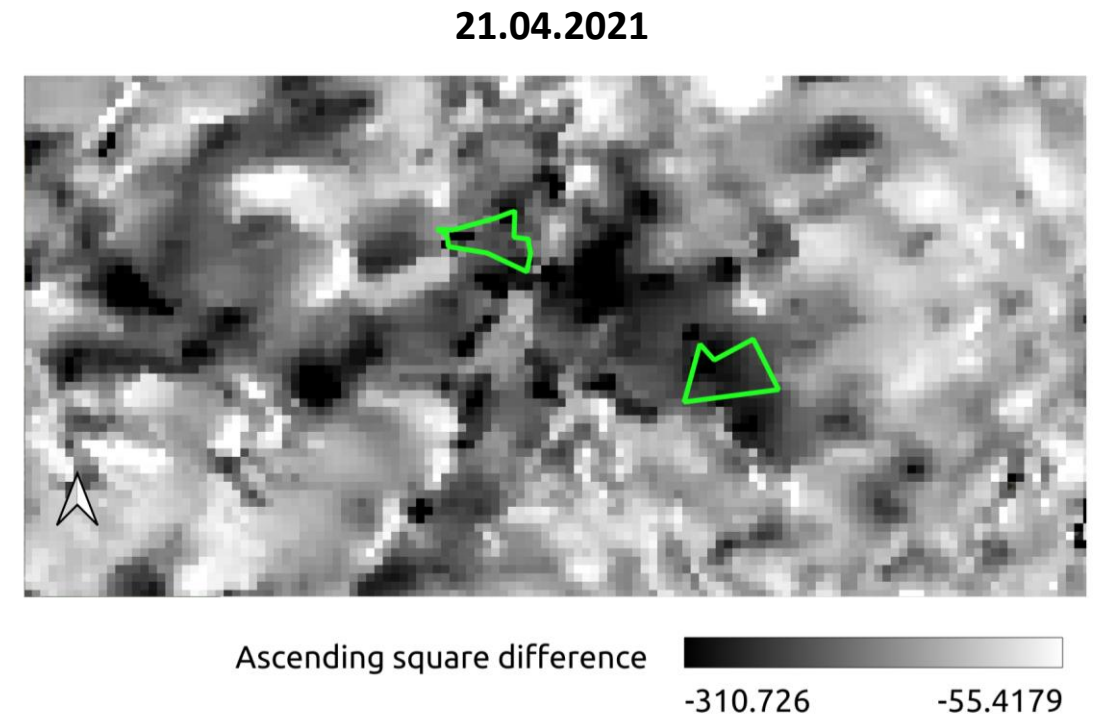
Sentinel-1 preprocessing

Radar shadow
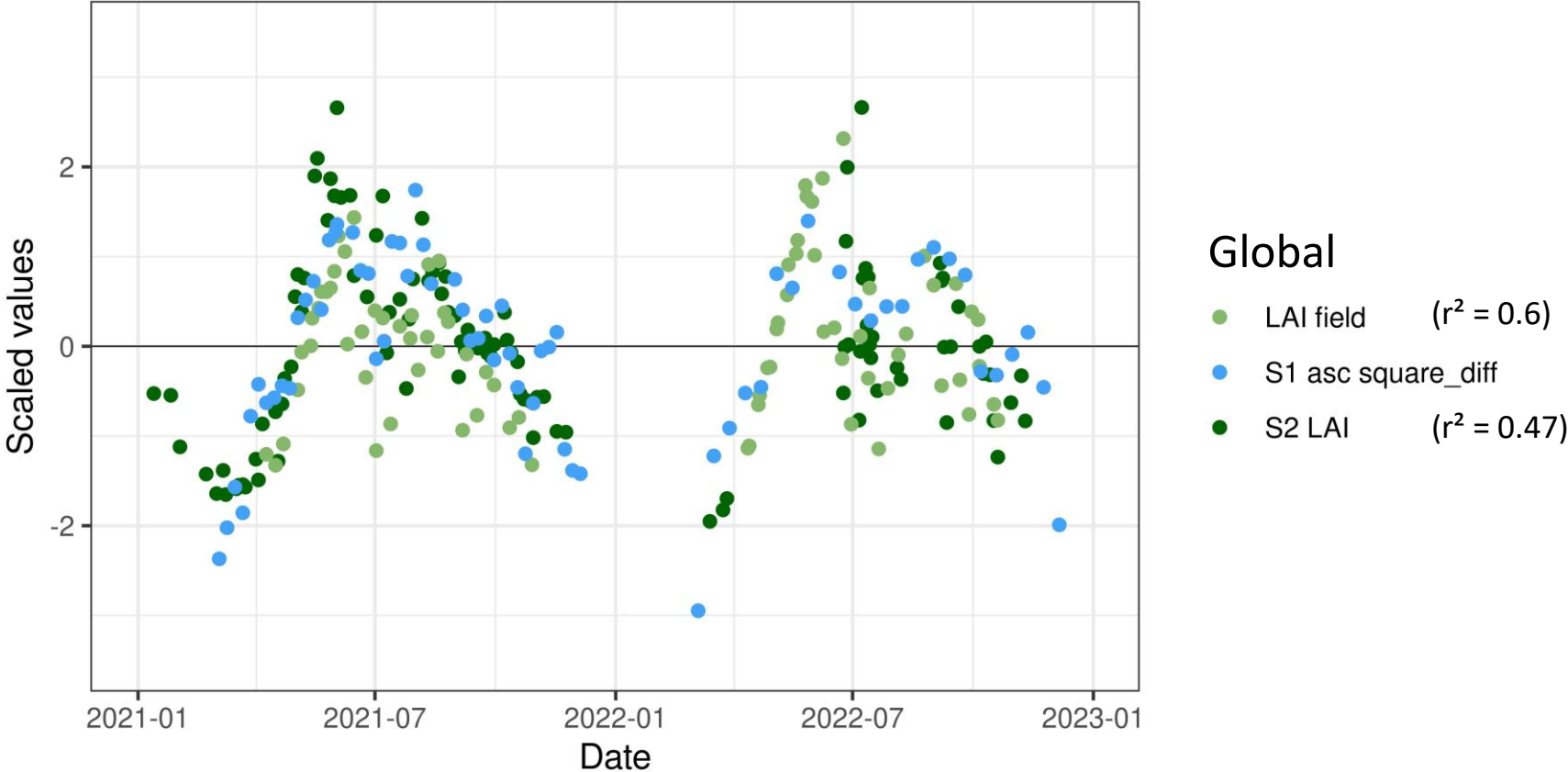

Imagery: Google, ©2023 TerraMetrics

Legend

Sentinel-1 mask

No data available

0   10   20 km

Caballero et al. 2022; Lee et al. 2009; openeo.org

Sentinel-1 features

Band/Feature	Formula	Reference
VV	$-$	
VH	$-$	
ratio	$\dfrac{VH}{VV}$	
RVI	$\dfrac{4 * VH}{VV + VH}$	Yunjin Kim et van Zyl 2009 / Trudel et al. 2012
sum	$VV + VH$	Laurin et al. 2018
difference	$VV - VH$	
product	$VV * VH$	
VH/product	$\dfrac{VH}{VV * VH}$	Xu et al. 2022
sum/product	$\dfrac{VV + VH}{VV * VH}$	
square difference	$VV^2 - VH^2$	

21.04.2021

Ascending square difference

-310.726   -55.4179

Caroline Göhner | Grassland LAI   16.11.2023

Sentinel-1 and LAI

Global

- ● LAI field (r² = 0.6)
- ● S1 asc square_diff
- ● S2 LAI (r² = 0.47)

Ground data 2021-2022 by Laimburg Research Centre

Ground data

Ritten (R) 1230-1290 m a.s.l.
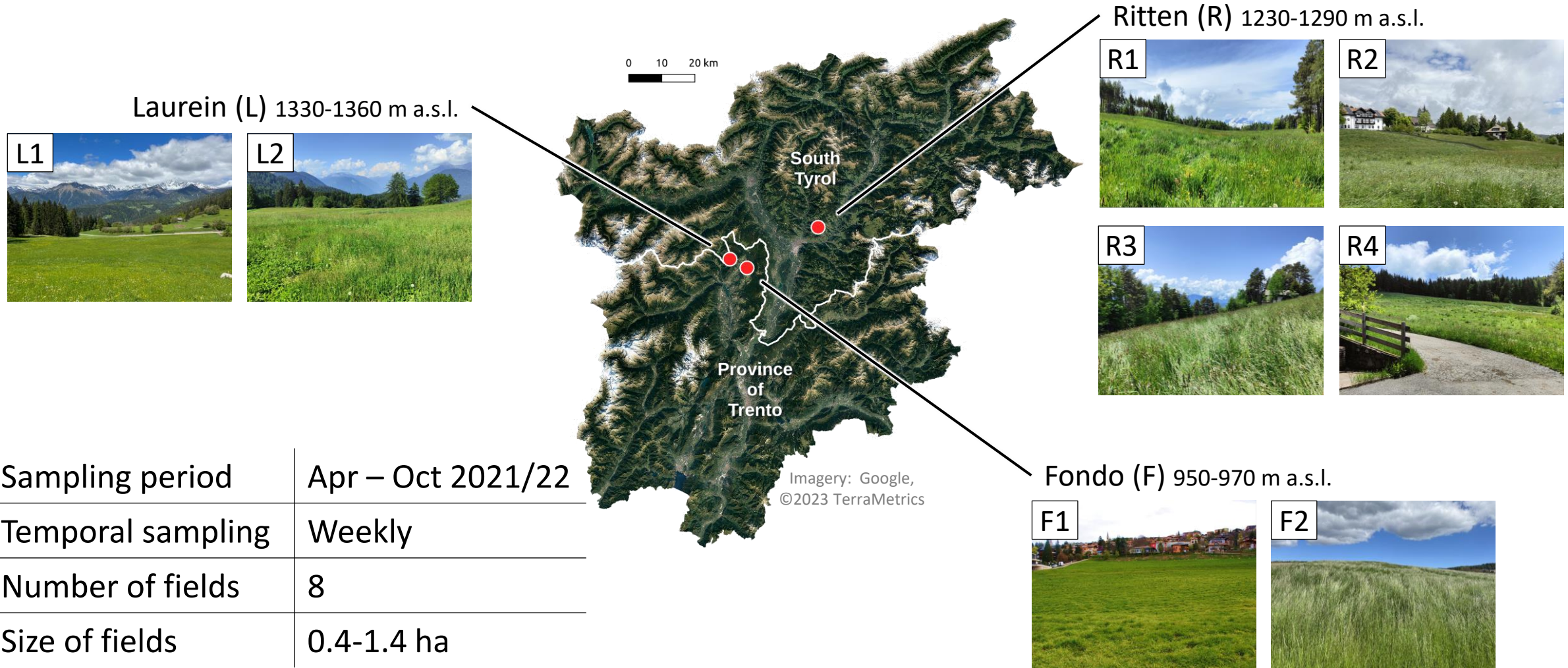
Laurein (L) 1330-1360 m a.s.l.

Imagery: Google,
©2023 TerraMetrics
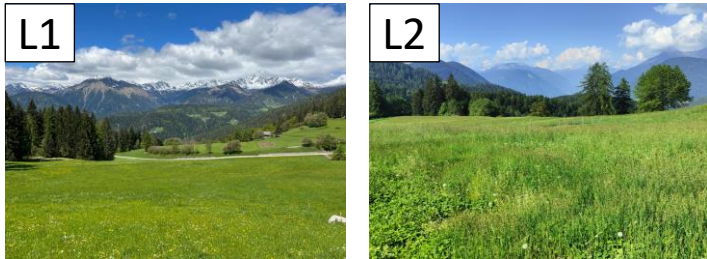
Fondo (F) 950-970 m a.s.l.

Sampling period	Apr – Oct 2021/22
Temporal sampling	Weekly
Number of fields	8
Size of fields	0.4-1.4 ha

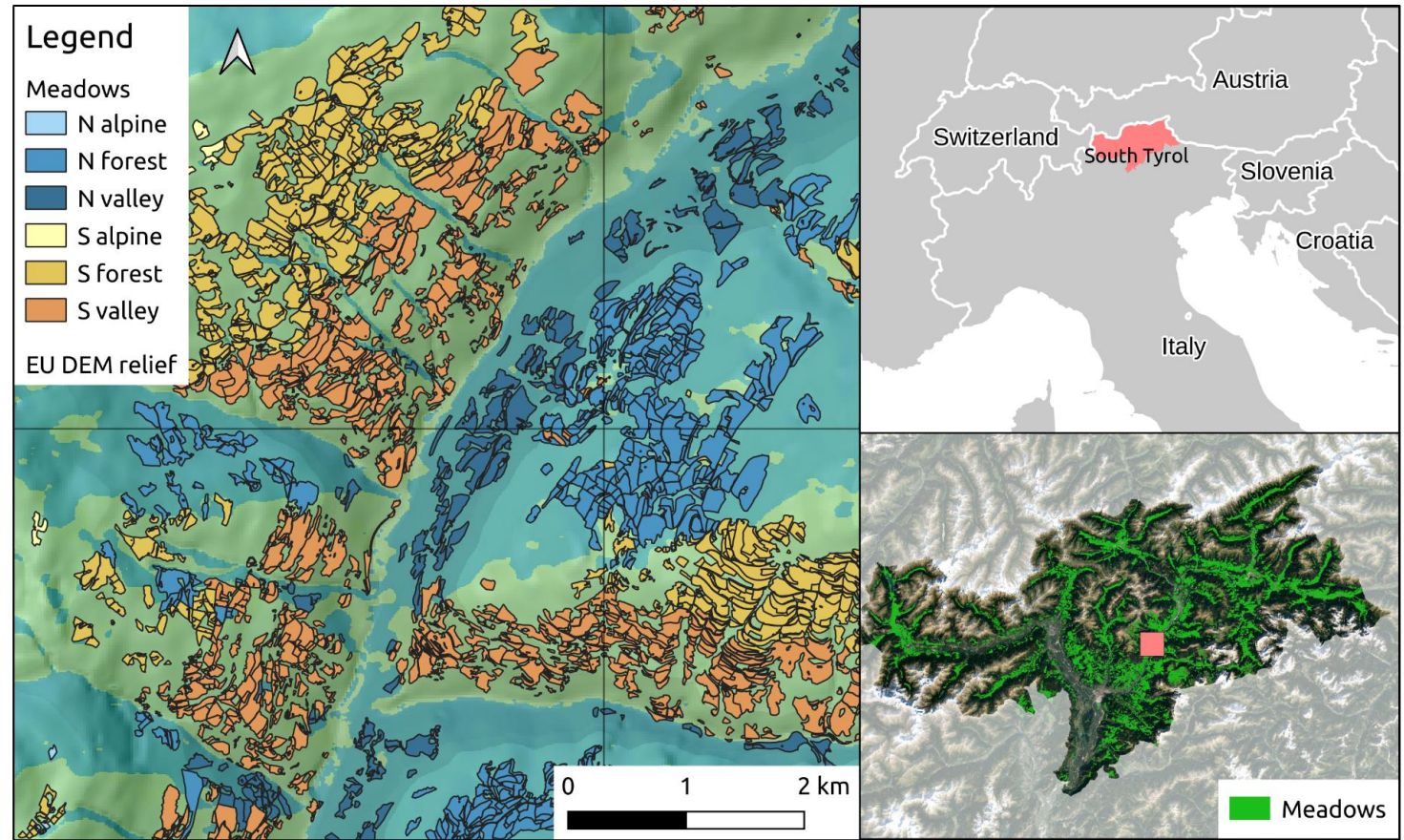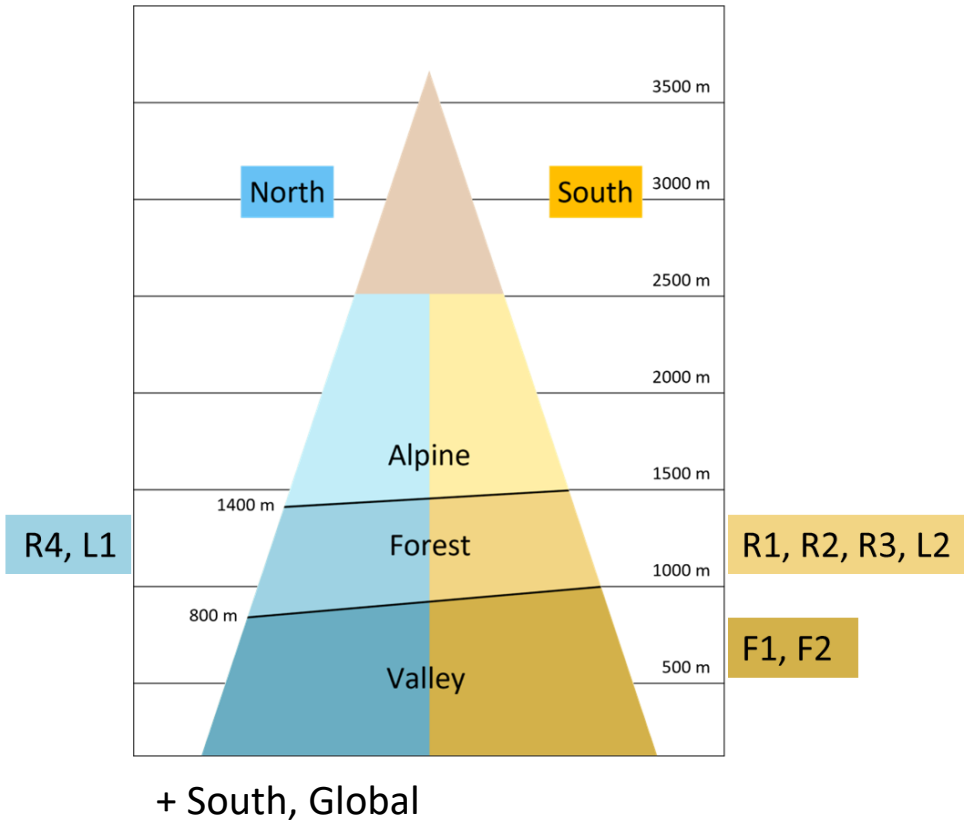Ground data 2021-2022 by Laimburg Research Centre

Ground data

- Leaf Area Index (LAI)
- Photosynthetically Active Radiation (PAR)
- Vegetation composition
- Soil moisture
- Sward height
- Yield
- Lodging
- Mowing events

Sampling scheme

2 weeks

cut

Growing period
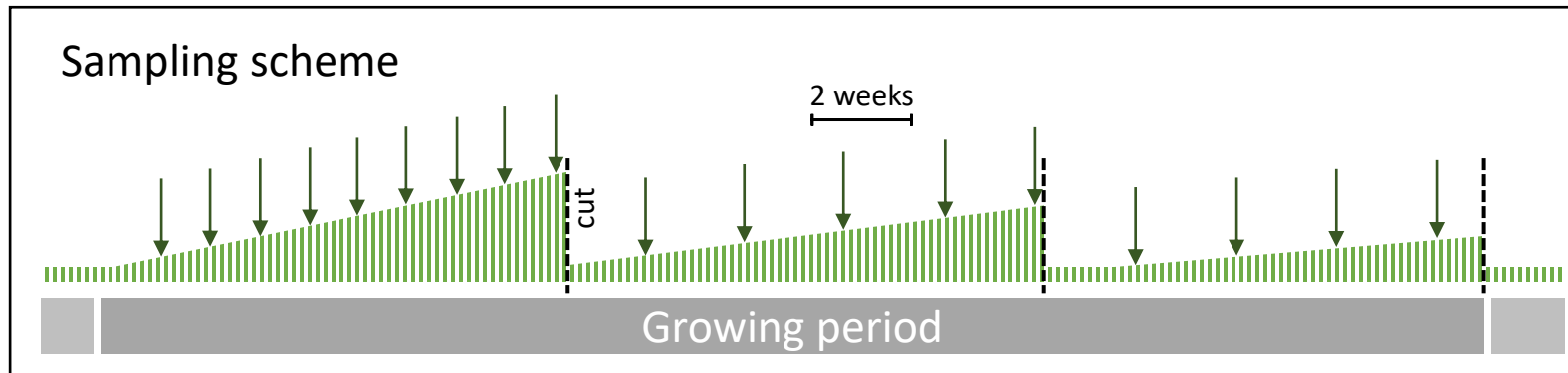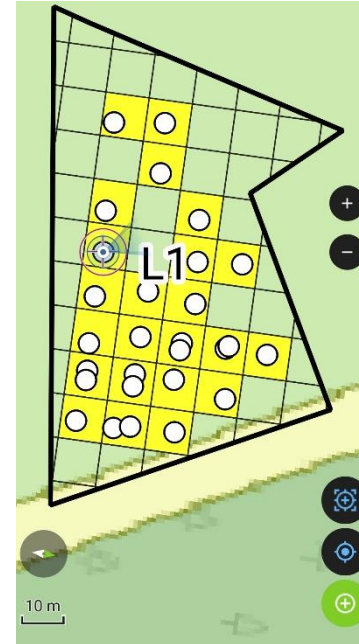
LI-COR LAI-2200C Plant Canopy Analyzer; Apogee Instruments MQ-301X Line Quantum

Cluster meadows

+ South, Global

Legend

Meadows
- N alpine
- N forest
- N valley
- S alpine
- S forest
- S valley

EU DEM relief

0   1   2 km

R4, L1

North   South

3500 m
3000 m
2500 m
2000 m
1500 m
1000 m
500 m

1400 m
800 m

Alpine
Forest
Valley

R1, R2, R3, L2

F1, F2

Austria
Switzerland
South Tyrol
Slovenia
Croatia
Italy

Meadows

Methodology

Feature Selection

Random Forest Regressor

Gaussian Process Regressor

1. Testing every feature + all together

2. Recursive Feature Elimination

2. Permutation Importance

3. Prediction using selected features
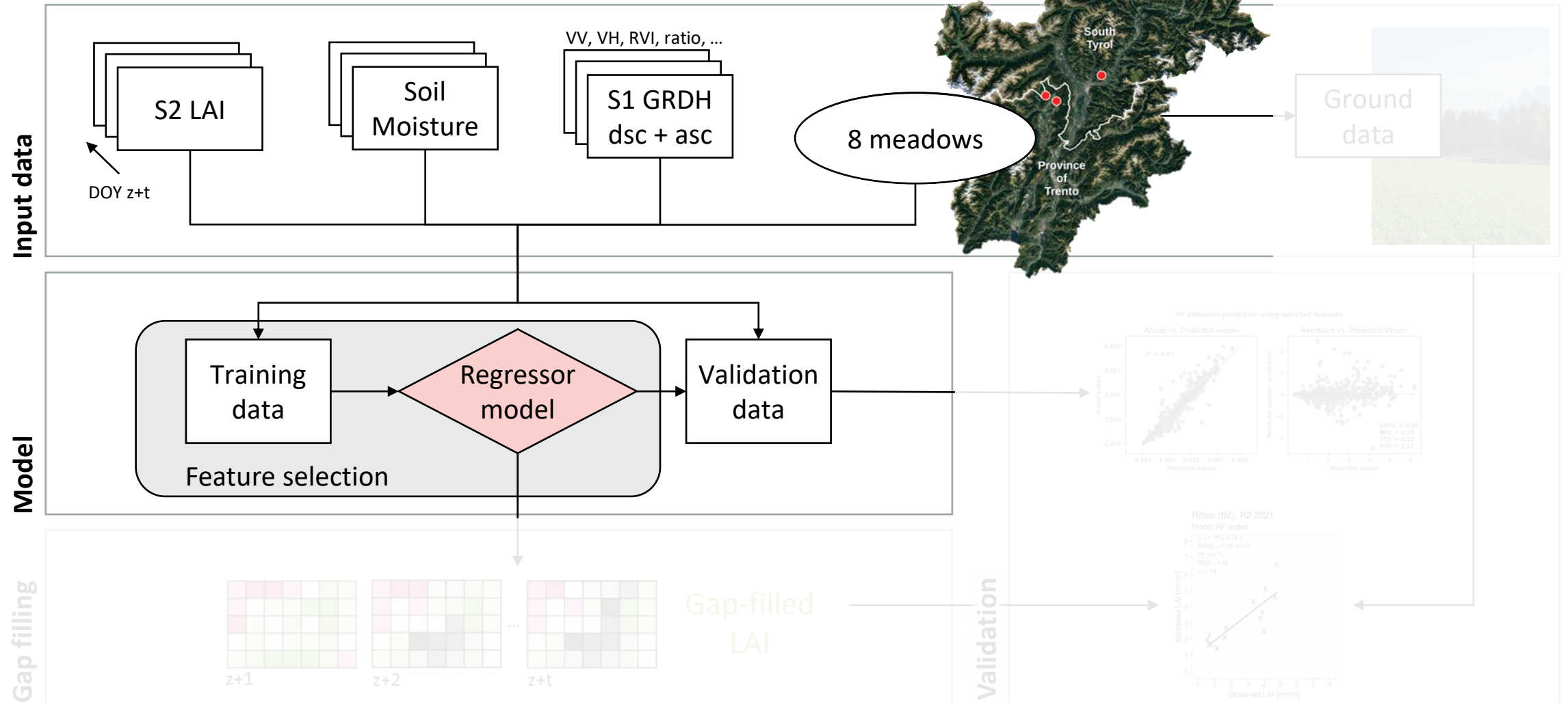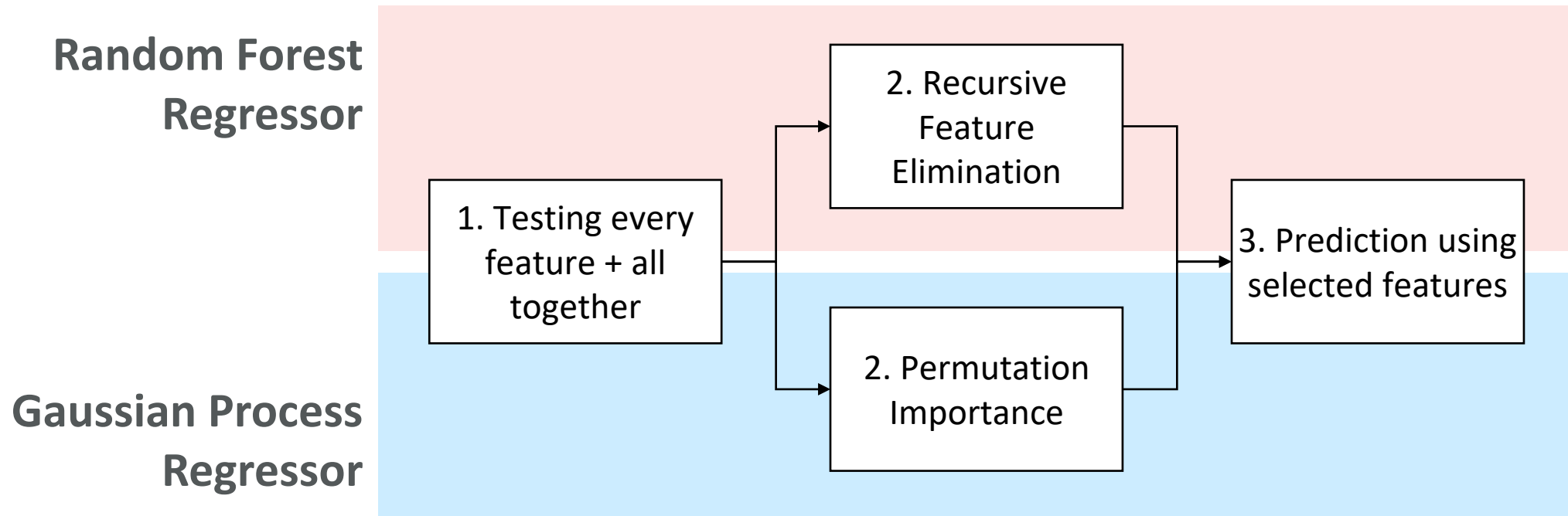
Feature selection method based on Xu et al. 2022; Raab et al. 2020
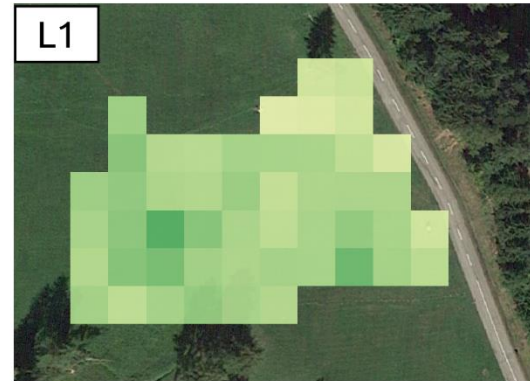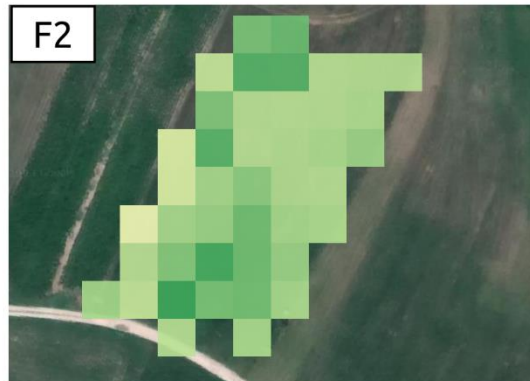
Methodology

Feature Selection

Gap-filled LAI

01.07.2021

Gap-filled LAI

LAI
0   7
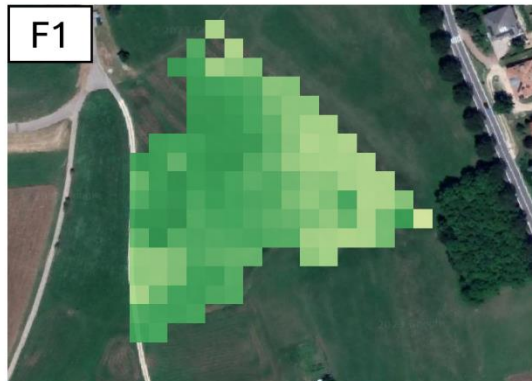
Imagery: Google, ©2023 Maxar Technologies

Gap-filled LAI

01.07.2021

R3

Sentinel-2 LAI
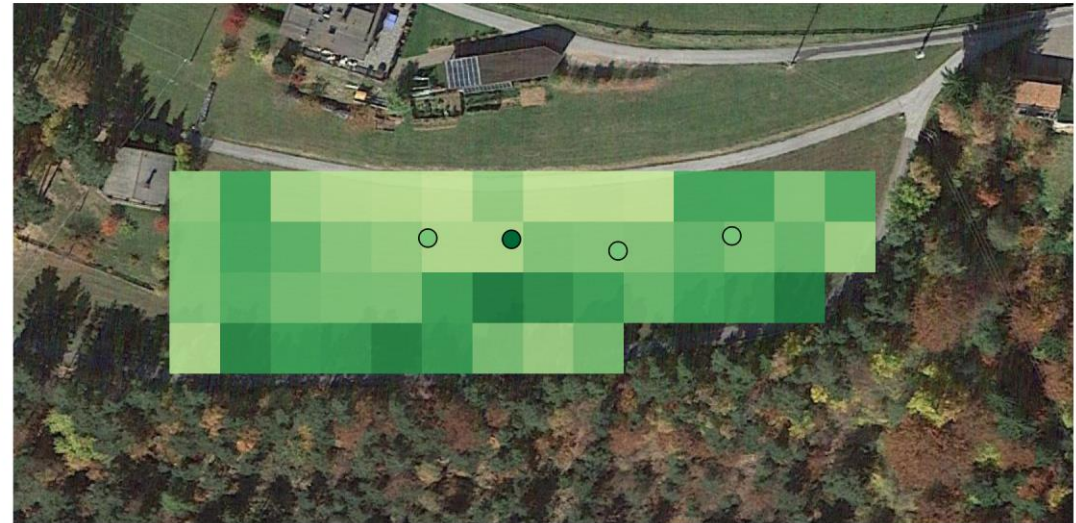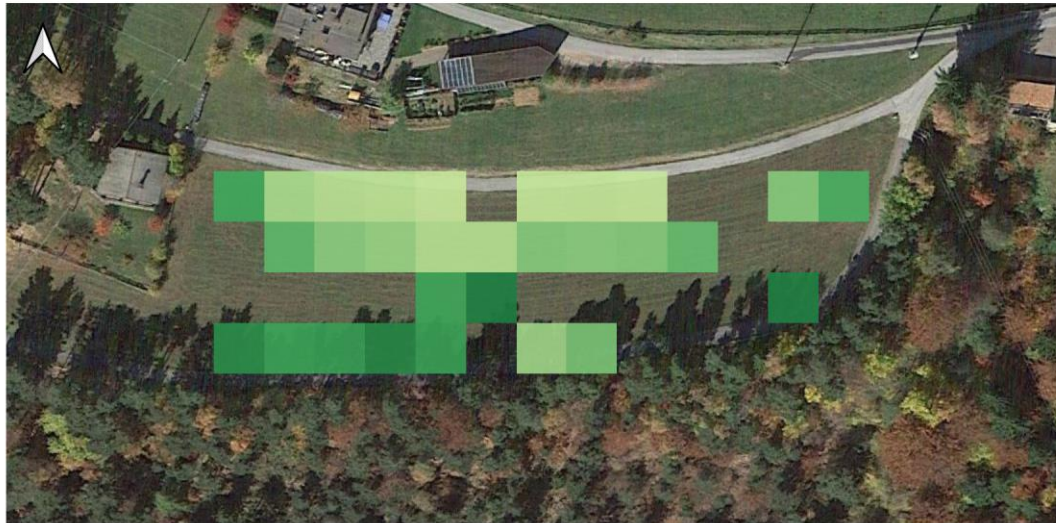
Gap-filled LAI

Imagery: Google, ©2023 Maxar Technologies

Field data 01.07.2021.

LAI

0   7

Ground data 2021-2022 by Laimburg Research Centre

Gap-filled LAI

07.07.2021

R3

Sentinel-2 LAI
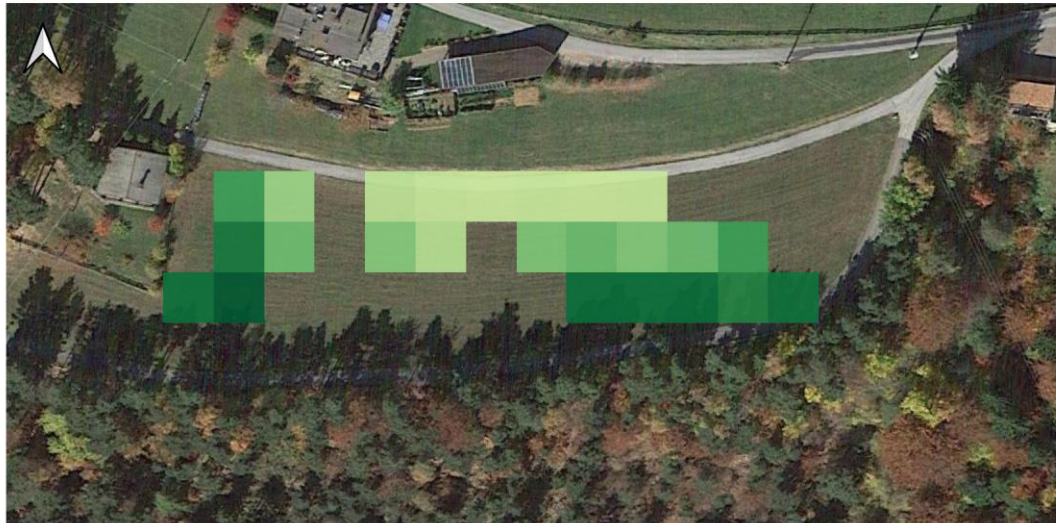
Gap-filled LAI

Imagery: Google, ©2023 Maxar Technologies

Field data 07.07.2021.

LAI

0   7

Gap-filled LAI

12.07.2021

R3

Sentinel-2 LAI

Gap-filled LAI

Imagery: Google, ©2023 Maxar Technologies

LAI

0   7

→ Mowed on 10.07.2021

Validation
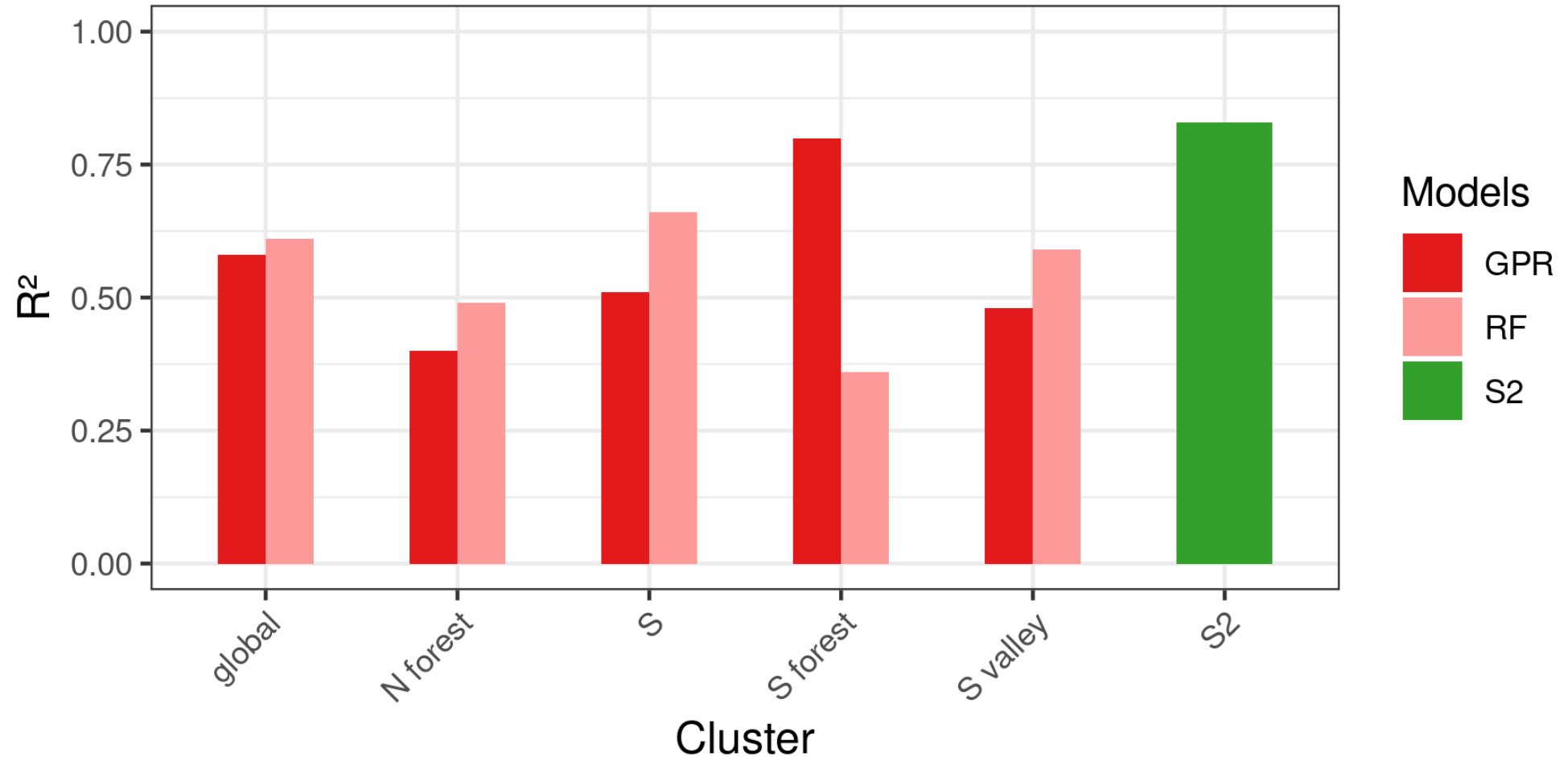
Ground data 2021-2022 by Laimburg Research Centre

Validation

Sentinel-2 LAI

Ritten (BZ), R4 2021

y = 1.17 + 0.73 x
RMSE = 0.9 m²/m²
R² = 0.87
bias = 0.46
n = 38

Gap-filled LAI

Ritten (BZ), R4 2021

Model: RF N_forest

y = 1.12 + 0.63 x
RMSE = 0.94 m²/m²
R² = 0.78
bias = 0.08
n = 68
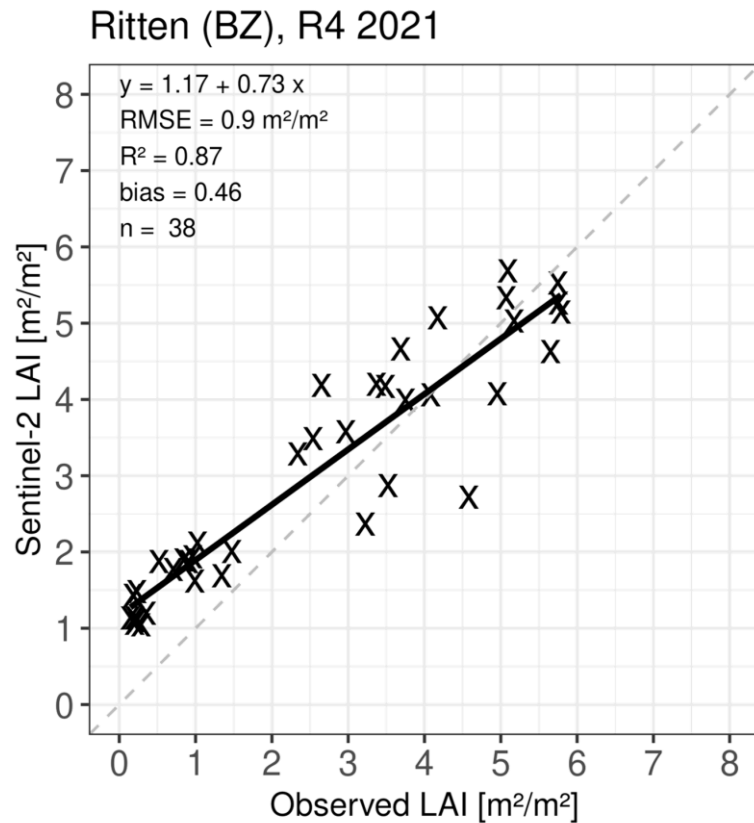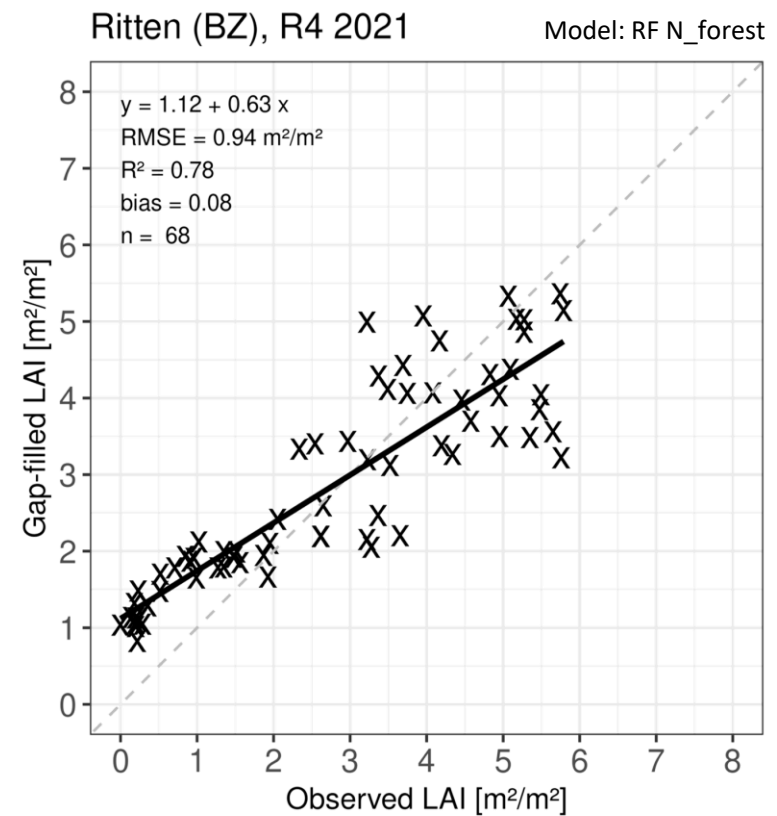
Ground data 2021-2022 by Laimburg Research Centre

Validation

Ritten (BZ), R4 2021

Model: RF N_forest

$y = 1.03 + 0.66\ x$
RMSE = 0.83 m²/m²
R² = 0.83
bias = 0.08
n = 17

LAI (mean per day)
- ● Gapfilled
- ✕ Observed
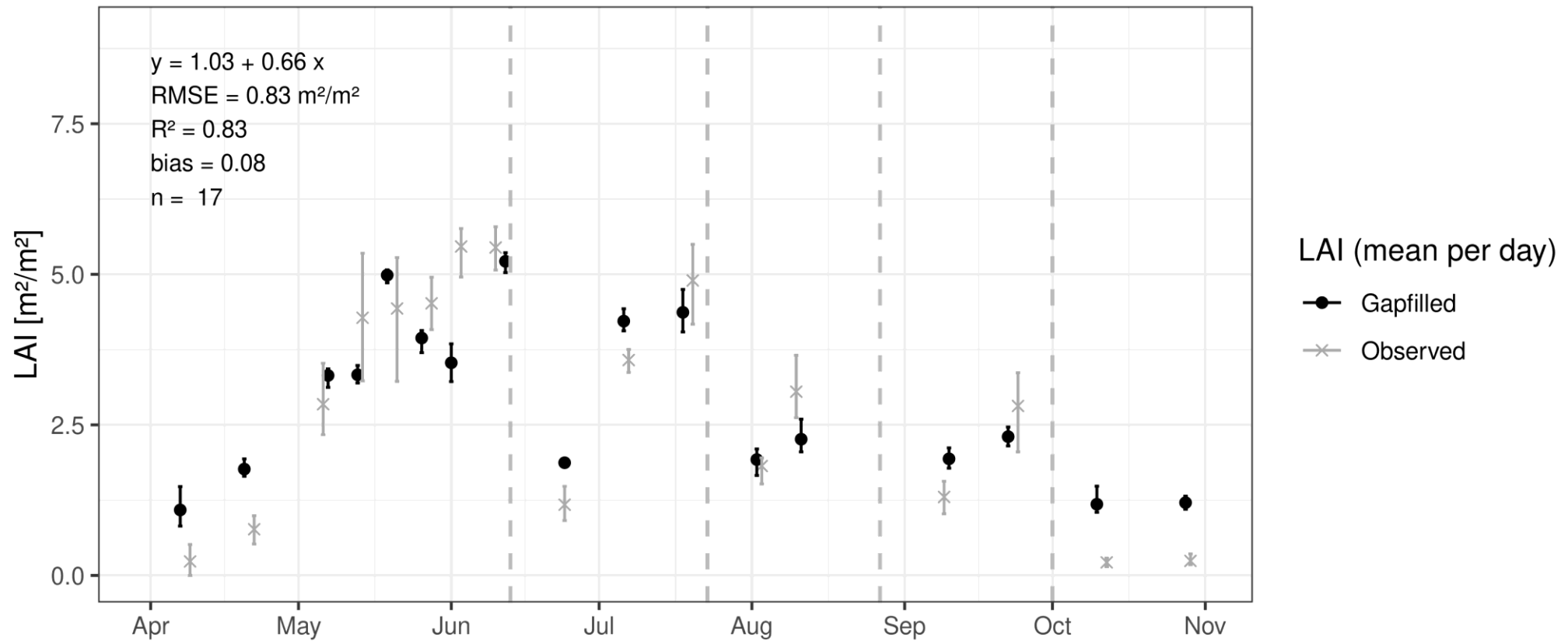
Conclusion & Outlook

- Gap-filling S2 LAI using S1
- Feature selection: S1 product & square difference
- Overestimation in early & late growing season
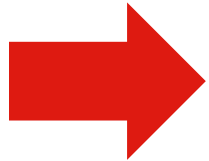
➡️ All meadows
Improved drought index

Permanent meadows
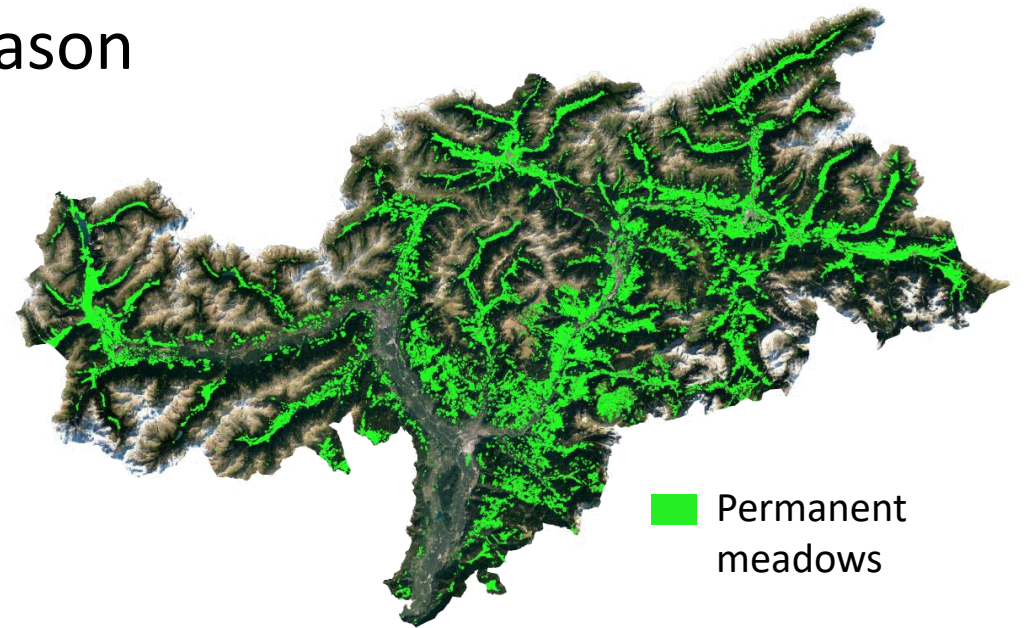
Imagery: Google, ©2023 TerraMetrics

References

Ali, I. et al. 2016. Satellite remote sensing of grasslands: from observation to management. JPECOL 9, 649–671. https://doi.org/10.1093/jpe/rtw005

Caballero, G. et al. 2022. Quantifying Irrigated Winter Wheat LAI in Argentina Using Multiple Sentinel-1 Incidence Angles. Remote Sensing 14, 5867. https://doi.org/10.3390/rs14225867

Castelli, M. et al. 2023. Insuring Alpine Grasslands against Drought-Related Yield Losses Using Sentinel-2 Satellite Data. Remote Sensing 15, 3542. https://doi.org/10.3390/rs15143542

Ellenberg, H., & C. Leuschner 2010. Vegetation Mitteleuropas mit den Alpen: in ökologischer, dynamischer und historischer Sicht. Utb, 8104.

Greifeneder, F. et al. 2021. A Machine Learning-Based Approach for Surface Soil Moisture Estimations with Google Earth Engine. Remote Sensing 13, 2099. https://doi.org/10.3390/rs13112099

Kotlarski, S. et al. 2023. 21st Century alpine climate change. Clim Dyn 60, 65–86. https://doi.org/10.1007/s00382-022-06303-3

Laurin, G.V. et al. 2018. Above-ground biomass prediction by Sentinel-1 multitemporal data in central Italy with integration of ALOS2 and Sentinel-2 data. J. Appl. Rem. Sens. 12, 1. https://doi.org/10.1117/1.JRS.12.016008

Lee, J.-S. et al. 2009. Improved Sigma Filter for Speckle Filtering of SAR Imagery. IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING 47.

openEO. URL https://openeo.org/

Raab, C. et al. 2020. Target-oriented habitat and wildlife management: estimating forage quantity and quality of semi-natural grasslands with Sentinel-1 and Sentinel-2 data. Remote Sens Ecol Conserv 6, 381–398. https://doi.org/10.1002/rse2.149

ScaleAgData. Upscaling agricultural sensor data for improved monitoring of agri-environmental conditions. URL https://scaleagdata.eu/en (accessed 11.6.23).

Trudel, M. et al. 2012. Using RADARSAT-2 polarimetric and ENVISAT-ASAR dual-polarization data for estimating soil moisture over agricultural fields. Canadian Journal of Remote Sensing, 38:4, 514-527, https://doi.org/10.5589/m12-043

Wang, J. et al. 2019. Estimating leaf area index and aboveground biomass of grazing pastures using Sentinel-1, Sentinel-2 and Landsat images. ISPRS Journal of Photogrammetry and Remote Sensing.

Weiss, M. et al. 2020. S2ToolBox Level 2 products: LAI, FAPAR, FCOVER V2.1.

Xu, C. et al. 2022. A Comprehensive Comparison of Machine Learning and Feature Selection Methods for Maize Biomass Estimation Using Sentinel-1 SAR, Sentinel-2 Vegetation Indices, and Biophysical Variables. Remote Sensing 14, 4083. https://doi.org/10.3390/rs14164083

Yunjin Kim, Van & J.J. Zyl, 2009. A Time-Series Approach to Estimate Soil Moisture Using Polarimetric Radar Data. IEEE Trans. Geosci. Remote Sensing 47, 2519–2527. https://doi.org/10.1109/TGRS.2009.2014944

Zhao, Y. et al. 2020. Grassland ecosystem services: a systematic review of research advances and future directions. Landscape Ecol 35, 793–814. https://doi.org/10.1007/s10980-020-00980-3

Thank you!

Caroline Göhner

Institute for Earth Observation
cgoehner@eurac.edu

www.eurac.edu

scaleagdata.eu