New opportunities for high-resolution countrywide tree type mapping

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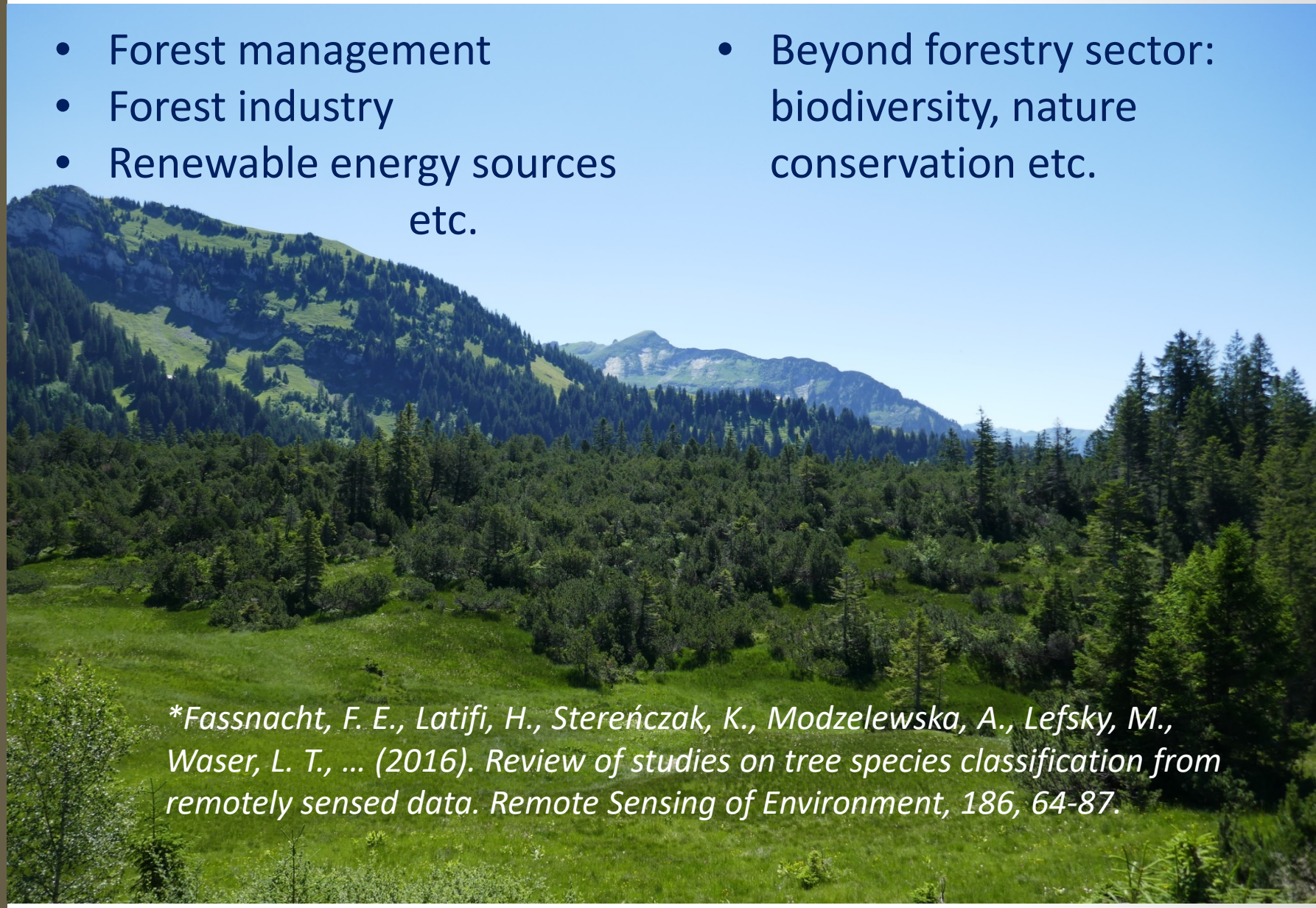
Increasing demand on countrywide tree species information

- Forest management
- Forest industry
- Renewable energy sources

etc.

- Beyond forestry sector: biodiversity, nature conservation etc.

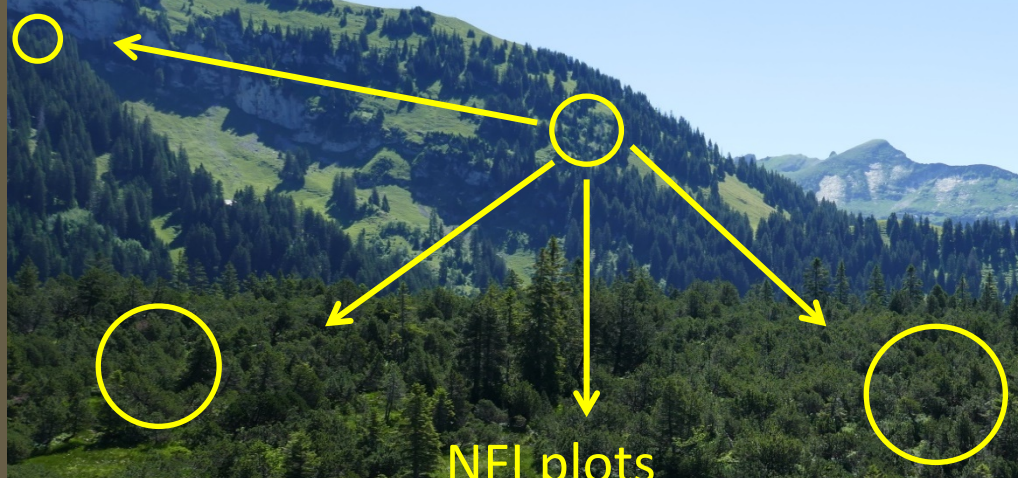


**Fassnacht, F. E., Latifi, H., Stereńczak, K., Modzelewska, A., Lefsky, M., Waser, L. T., … (2016). Review of studies on tree species classification from remotely sensed data. Remote Sensing of Environment, 186, 64-87.*

Why do we spatially estimate forest attributes?

- Lack of spatial information beyond National Forest Inventory (NFI) sample plots*

  -> Spatial products needed for operational NFI applications



- **Tree types**
- **Tree species**
- Volume
- Health
- etc.

**Barrett, F., McRoberts, R.E., Tomppo, E., Cienciala, E., and Waser, L.T., 2016. A questionnaire-based review of the operational use of remotely sensed data by NFIs. Remote Sensing of Environment 174: 279-289.*

Is countrywide mapping of tree types feasible?




What is needed by the user?

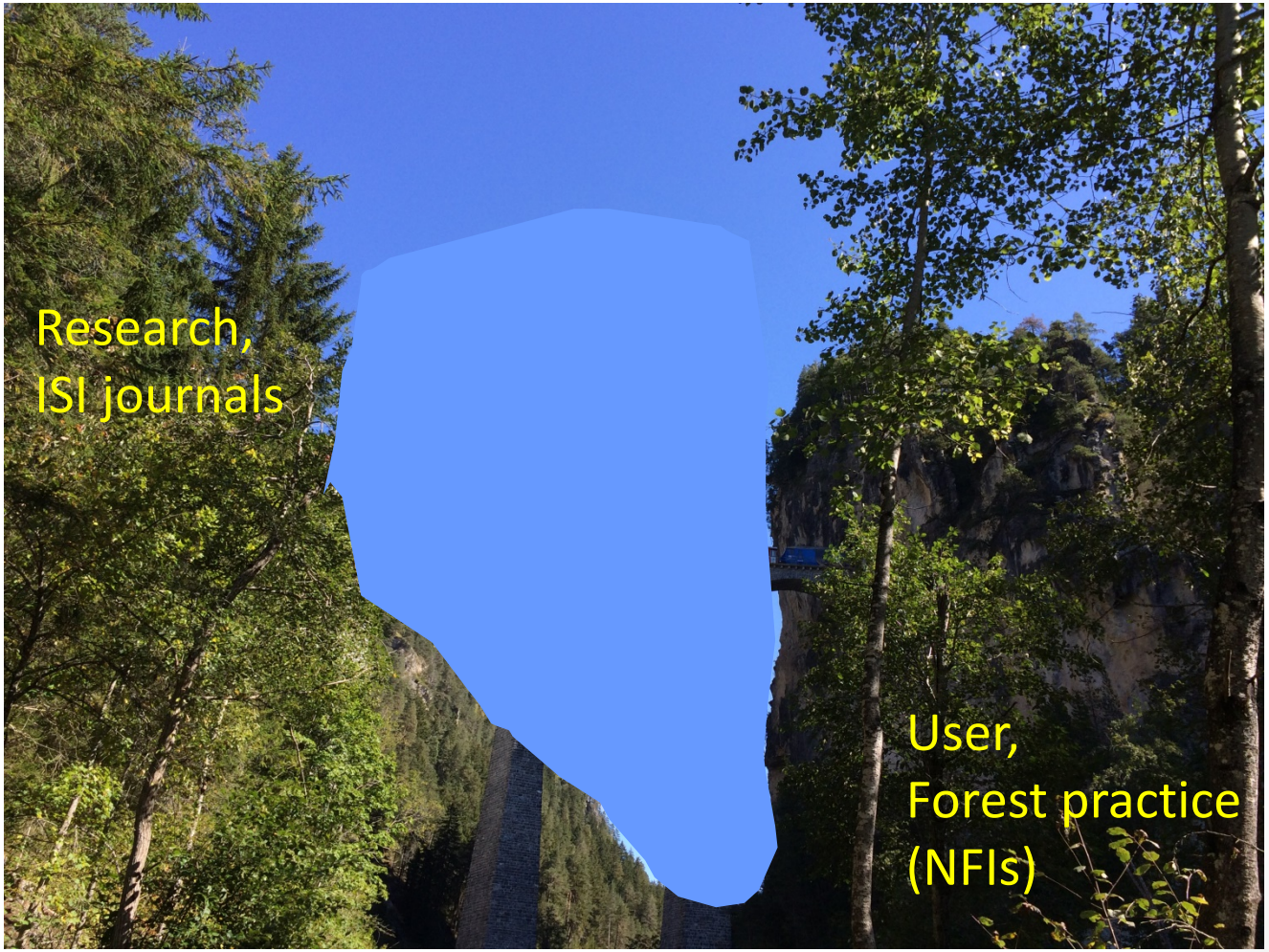
User demands

- **(high) expectations** on tree species maps
- What input data are available (remote sensing data, reference data)
- Continuity of these data sets (regular updating?)
- What level of detail? (e.g. single tree level, plot, stand level)

- In the last 40 years, **advances in remote sensing technologies** (new sensors, 3D point clouds, machine learning etc.)
- However, (only) recently from case study to countrywide level

Building a bridge

- **Gap** between **research and practice:** optimal conditions versus operational constraints => difficult to implement



UNESCO, world heritage Parc Ela

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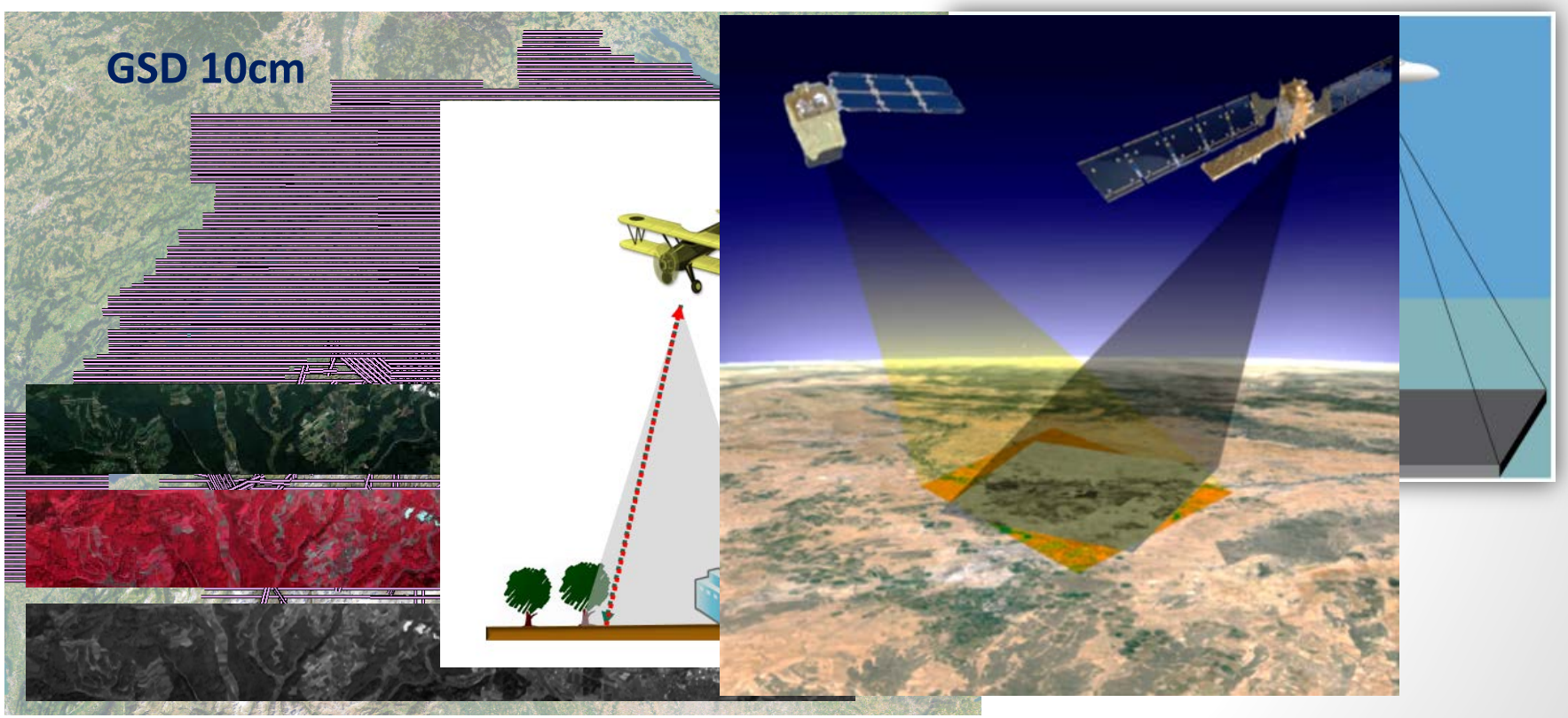
- Countrywide tree type mapping
  - Remote sensing and training data
  - Approaches, products, challenges
- Conclusions

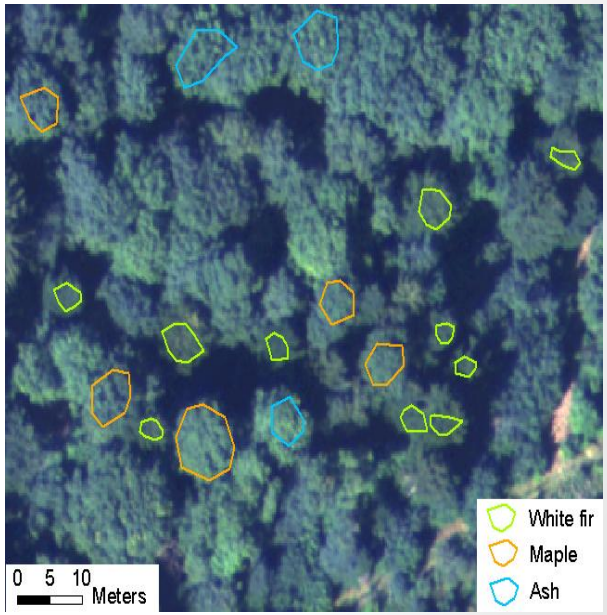
Remote sensing data of Switzerland

- ADS40/80/100 sensor with 10-50 cm RGBI aerial imagery – updated every 3 years (since 2005) by Swiss Federal Office of Topography
- LiDAR with ~0.5 – 40 points/m^2 (2001-2015), since 2017 full-waveform
- Sentinel-1 (SAR) / Sentinel-2 (1C, 8 bands), 10-20 m spatial resolution

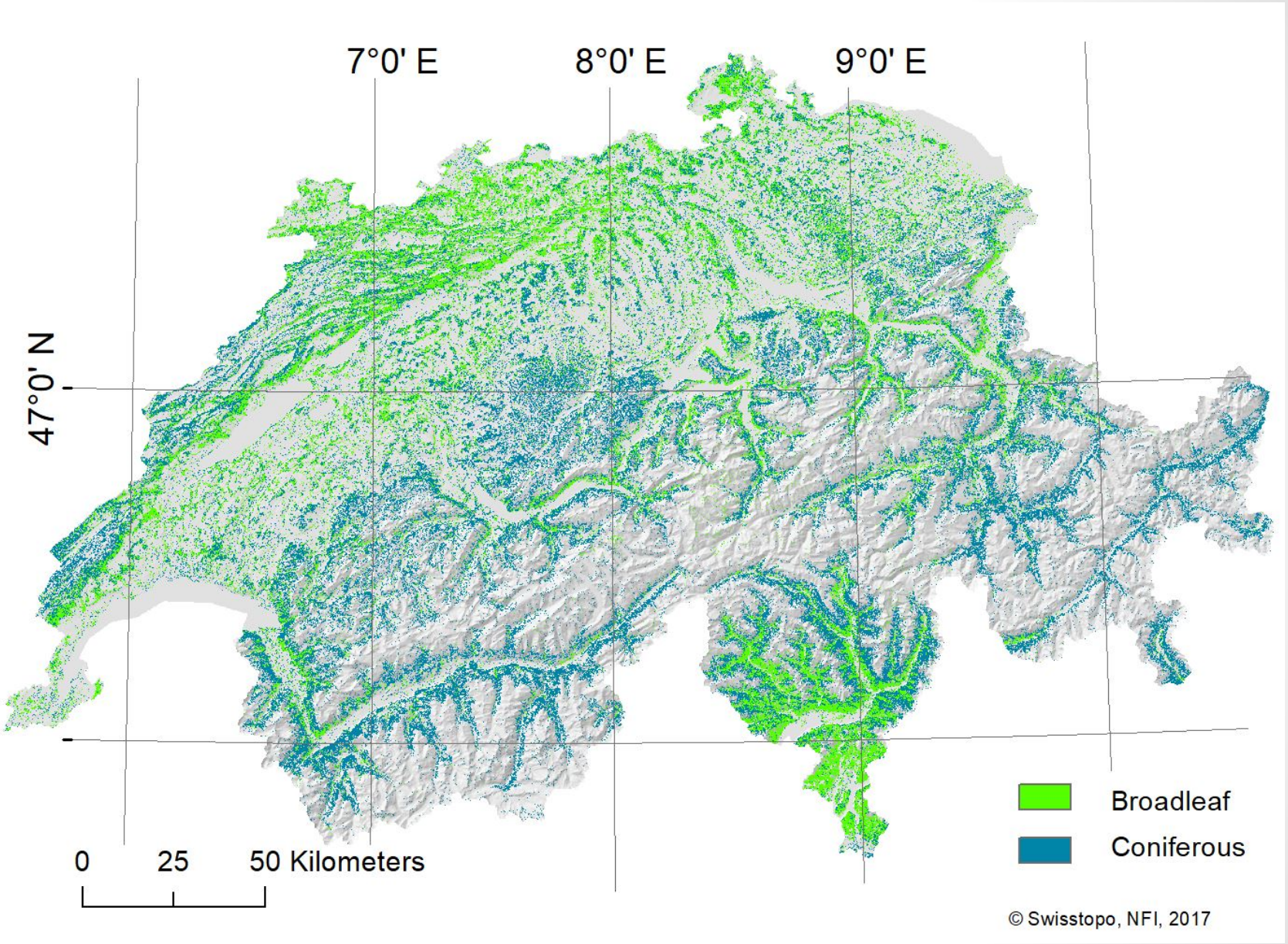


Training / reference data

- From Swiss National Forest Inventory
  - two-phases sample based survey, continuously visited (9 year circle) on a 1.4 km regular grid
  - Aerial stereo-image interpretation
  - Terrestrial survey
- From individual field mapping / image interpretation



Tree type map of Switzerland (41'285 km^2)



Lars T. Waser "New opportunities for high-resolution countrywide tree type mapping"
Remote Sensing for forest applications, EGU General Assembly, 9 April 2018, Vienna

Tree type map of Switzerland (41'285 km^2)

- Distinction of broadleaved / coniferous trees at 3 m spatial resolution
- Input: RGBI ADS80 aerial images, remote sensing indices, digital terrain model from ALS data
- Training data: Digitized tree polygons
- Highly automated workflow using Random Forest (RF) in *R*

Model accuracies: **95-99.9%**, *Kappa* 0.85-0.99 (5 *10-fold CV)

=> Overestimation of coniferous tree fraction

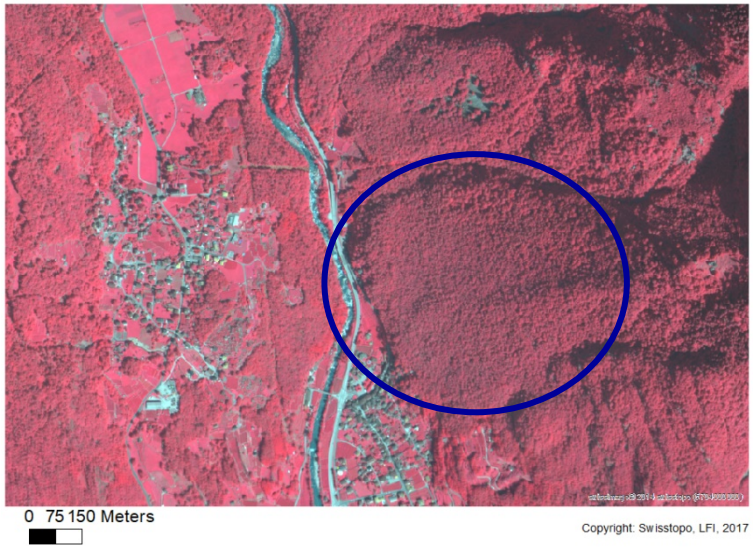
*Waser, L.T.; Ginzler, C.; Rehush, N., 2017. Wall-to-Wall Tree Type Mapping from Countrywide Airborne Remote Sensing Surveys. Remote Sensing, 9, 766

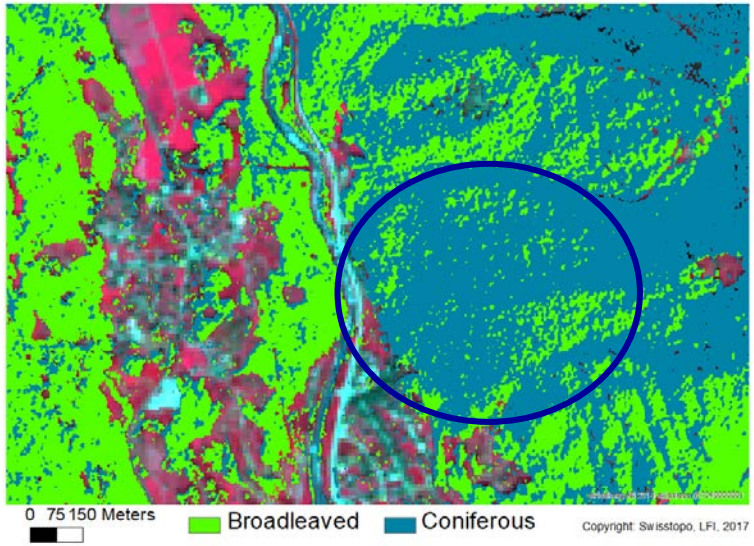
*Waser, L.T. et al., 2014. Remote Sensing, 6, 4515–4545

*Waser, L.T. et al., 2011. Remote Sensing of Environment, 115, 76–85

Challenges

ADS80 (August 2015)





- Topography:
  Steep terrain (shaded crowns)
- Phenology:
  Date of image acquisition

=> Overestimation of coniferous trees

Broadleaved

Coniferous

Improvements and new opportunities

- Improved error estimations using ensemble modelling (RF, SVM, Logistic regression, ANN, kNN)

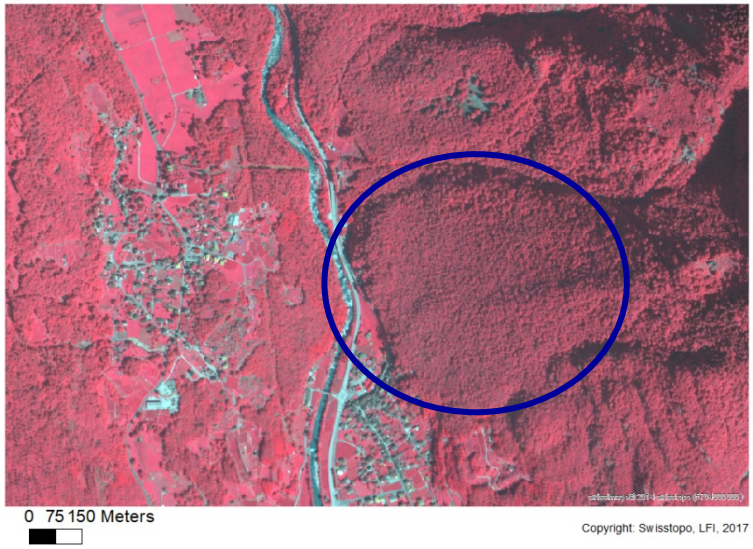
  => partly satisfactory

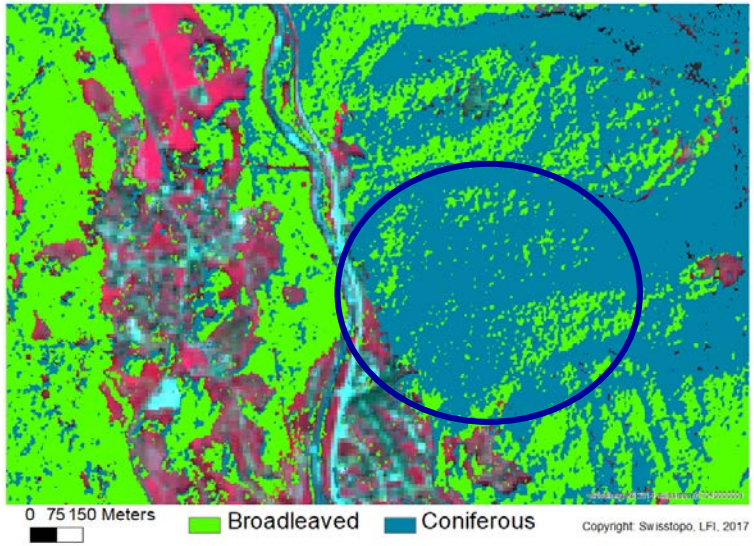
- Use of multitemporal Sentinel-2 (multispectral) data to minimize problems due to phenology, steep terrain

  => partly satisfactory

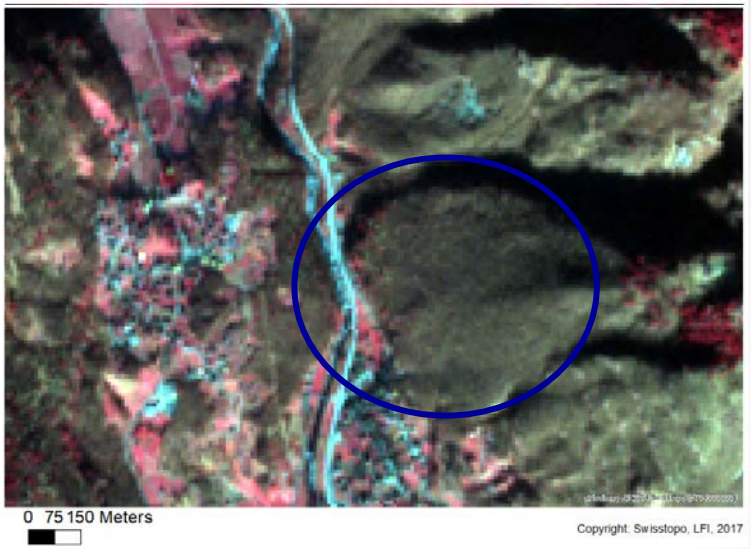
Sentinel-2 time series

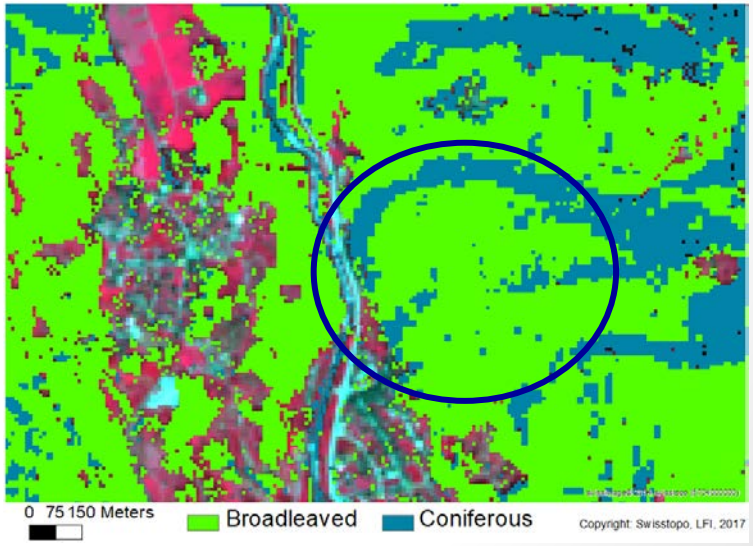
ADS80 (8/2015), 3m





Sentinel-2 (8/2016 & 2/2017), 10m





Improvements and new opportunities

- Improved error estimations using ensemble modelling (RF, SVM, Logistic regression, ANN, kNN)

  => partly satisfactory

- Use of multitemporal Sentinel-2 (multispectral) data to minimize problems due to phenology, steep terrain

  => partly satisfactory

- Sentinel-1 SAR winter / summer data
- Backscatter signals (VV, VH) from SAR
- Usage of DTM: slope classes, aspect classes

Combination of Sentinel- 1 and 2 time series

nd -2 (2016 / 2017)

=> Feasibility to seperate larches from other conifers

Accuracy assessment

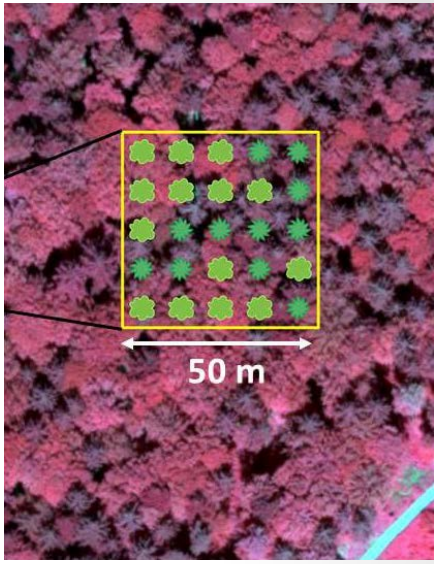
- Model accuracies

  > 96%, *Kappa* 0.89-0.92 (5 *10-fold CV)

- Map accuracies

  - Stereo-image Interpreted Areas (IAs) with 25 points

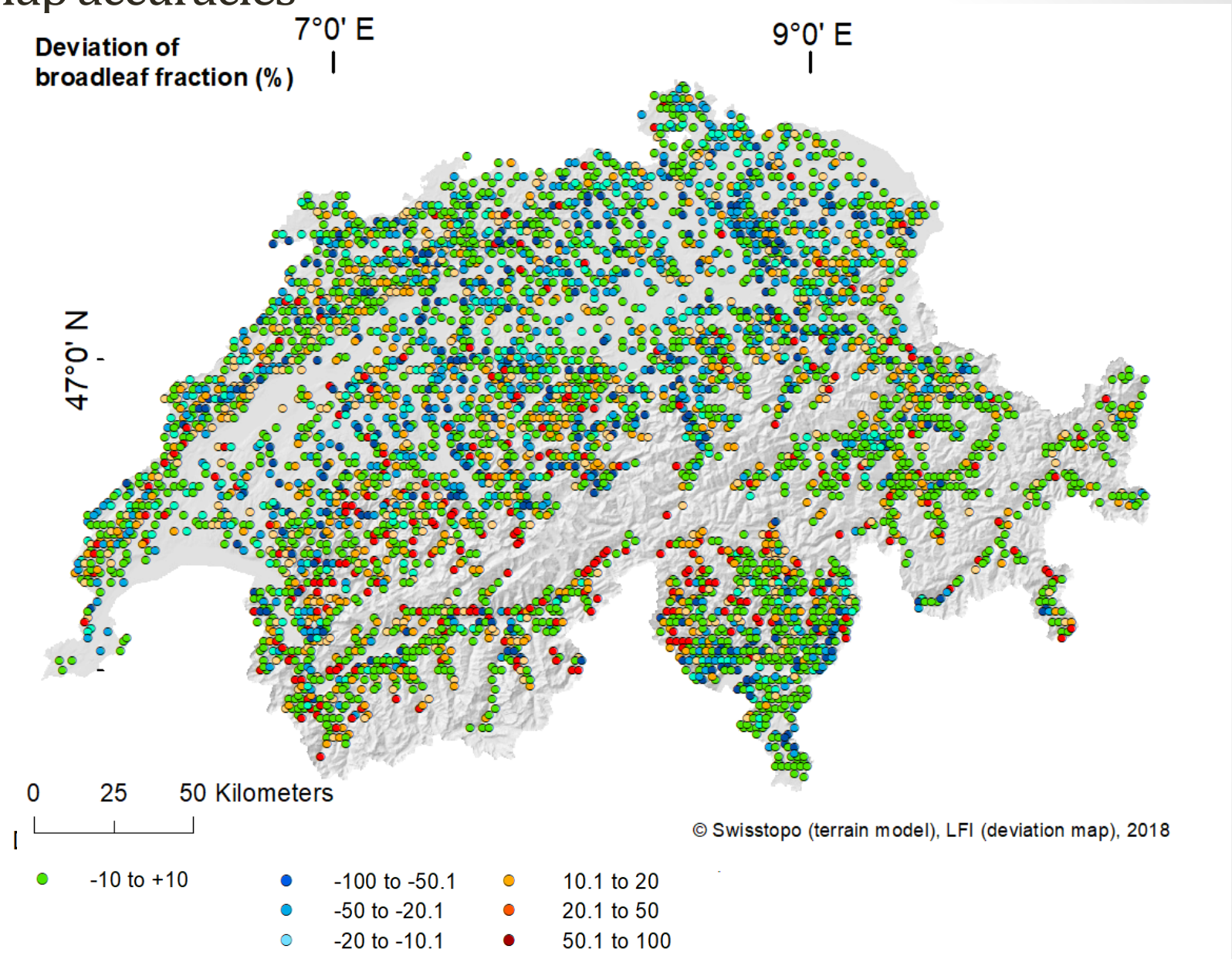
  - Agreement in predicted (tree type map) and observed (NFI) broadleaved fractions in the IAs



Validation based on	IAs (n)	M (%)	M_{abs} (%)	NMAD (%)	RMSE (%)
All IAs	3385	0	11.91	17.66	30.15

=> Averaged out, no general underestimation of broadleaved tree fraction

Map accuracies



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Is countrywide mapping of tree types feasible?

YES

Conclusions

- ✓ Countrywide tree type mapping feasible
  (3-10 m spatial resolution, high accuracies)
- ✓ Restrictions (topography, shadows, phenology) minimized
  (Combination of Sentinel-1 / 2 time series)
- ✓ Remaining icreasing demand on countrywide products
- ✓ Providing spatial explicit information which is not given by NFI plots

Ongoing / future research:

- High temporal / spectral resolution of upcoming sensors
- Deep learning (CNN) to improve classifications
- **Focus on more tree species**

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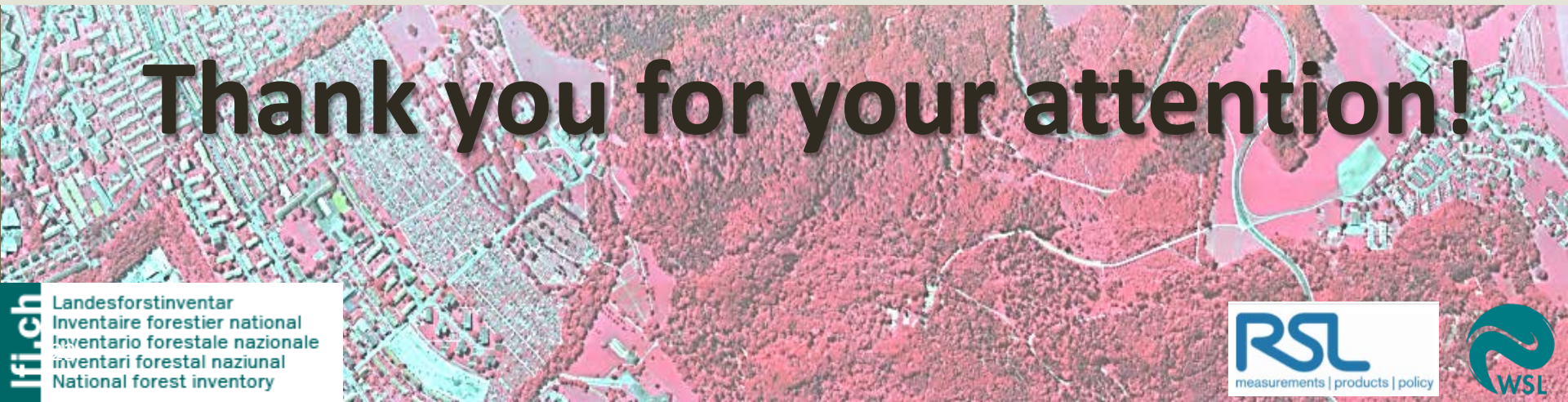

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