

# **Countrywide surface models from historical panchromatic and true color stereo imagery – a retrospective analysis of forest structures in Switzerland**

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- Our **motivation** for this project
- What **methods** have we used
- Our **results** and plausibility checks
- What next - Conclusion / **Outlook**

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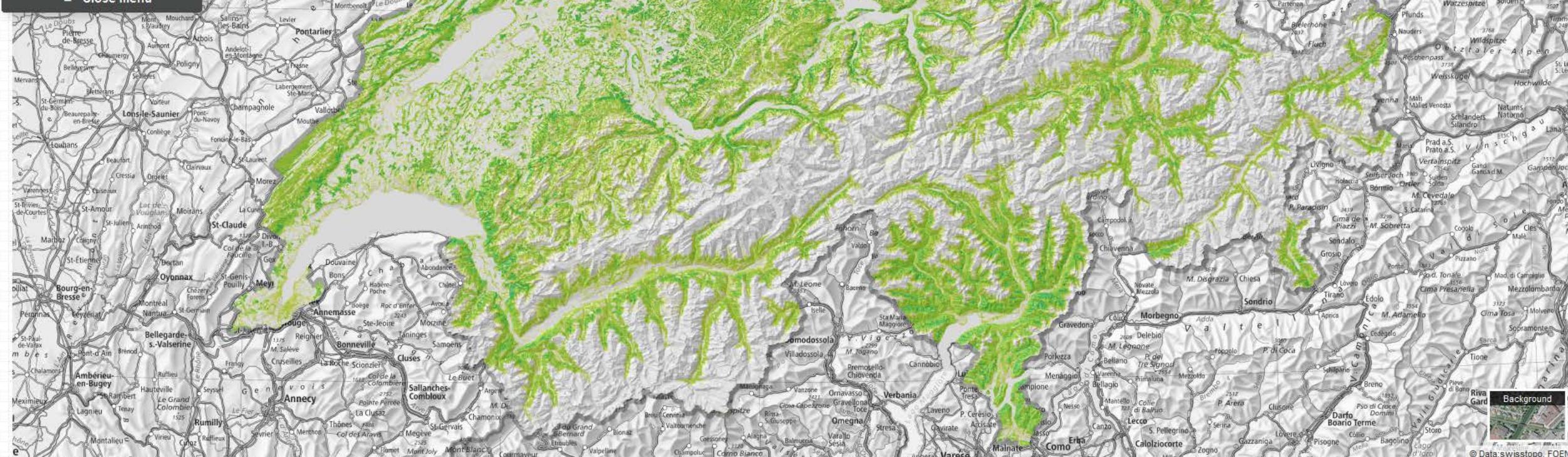
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Article

## Wall-to-Wall Forest Map Surface Models from In a NFI Forest Definition

Lars T. Waser<sup>1,\*</sup>, Christoph Fischer<sup>2,†</sup>, Zuy

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**Abstract:** Forest mapping is an important source of information for assessing woodland resources and a key issue for any National Forest Inventory (NFI). In the present study, a detailed wall-to-wall forest cover map was generated for all of Switzerland, which meets the requirement of the Swiss NFI forest definition. The workflow is highly automated and based on digital surface models from image-based point clouds of airborne digital sensor data. It fully takes into account the four key criteria of minimum tree height, crown coverage, width, and land use. The forest cover map was validated using almost 10,000 terrestrial and stereo-interpreted NFI plots, which verified 97% agreement overall. This validation implies different categories such as five production regions, altitude, tree type, and distance to the forest border. Overall accuracy was lower at forest borders



Remote Sensing of Environment 213 (2018) 182–194

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# Remote Sensing of Environment

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## Stereo-imagery-based post-stratification by regression-tree modelling in Swiss National Forest Inventory

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### ARTICLE INFO

#### Keywords:

Double sampling for stratification  
Forest area  
Growing-stock volume  
Vegetation height model

### ABSTRACT

Swiss National Forest Inventory (NFI) produces estimates of characteristics related to the state and change of the forest resources in the whole country as well as in smaller regions and domains. The estimates are based on measurements on permanent field plots placed on a systematic grid over the country. Digital stereo aerial images are an important source of auxiliary information that can be used with post-stratified estimation to increase the precision of the estimates. We examined post-stratification based on stereo image information, available on a much denser grid than the field plots, for the estimation of forest area, total growing-stock volume and growing-stock volume per unit of accessible forest area. We considered 31 post-stratification schemes that consisted of (1) forest/non-forest stratification by four alternative methods based on manual or semi-automated stereo image

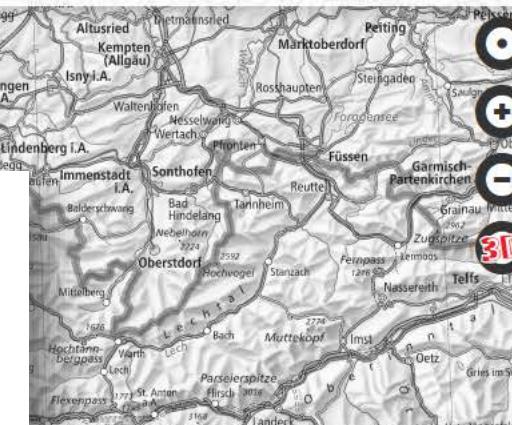
The Author(s) 2017. This article is published with open access at Springerlink.com

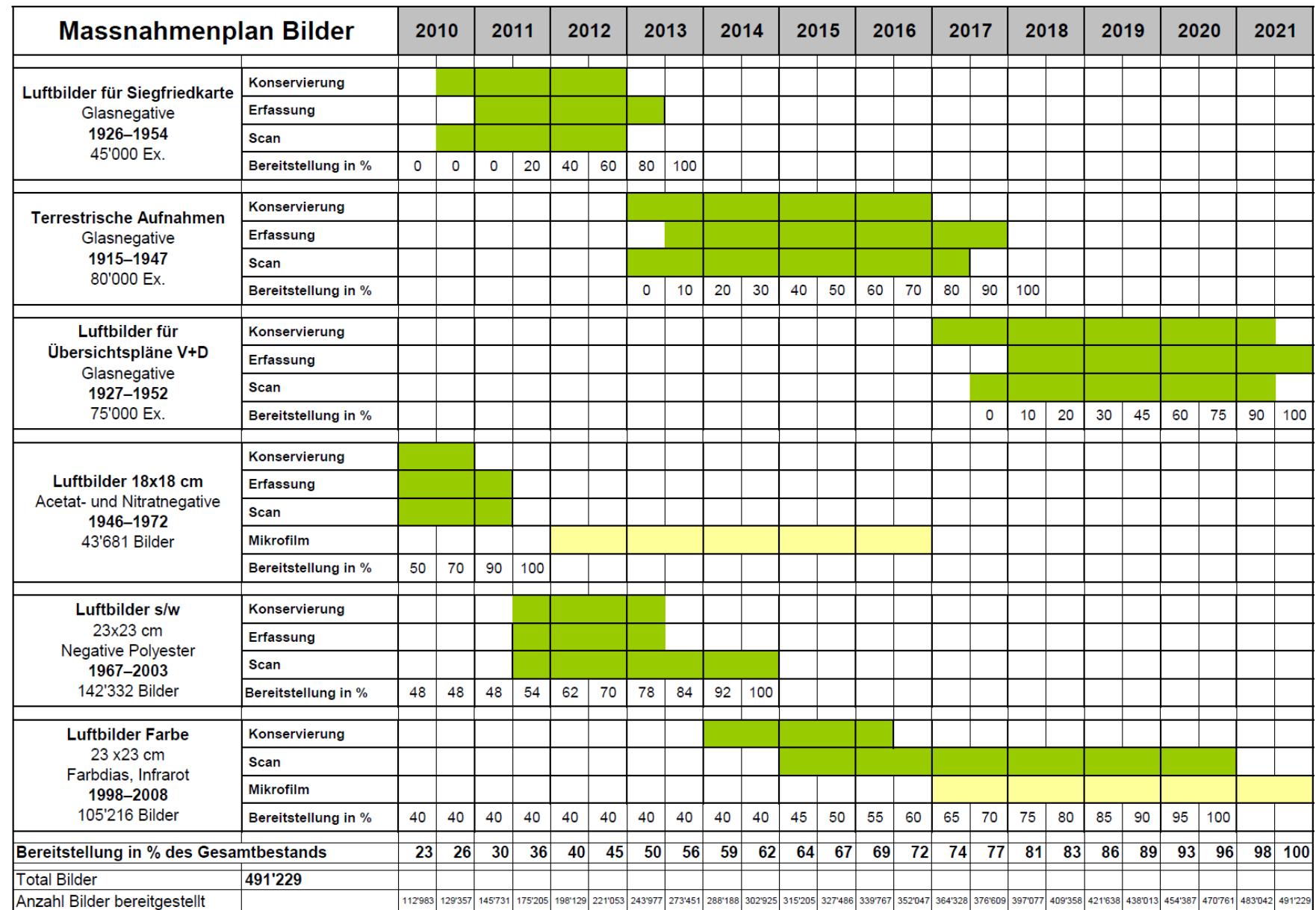


**Abstract** Trees outside forest (TOF) can perform a variety of social, economic and ecological functions including carbon sequestration. However, detailed quantification of tree biomass is usually limited to forest areas. Taking advantage of structural information avail-

able from stereo aerial imagery and airborne laser scanning (ALS), this research models tree biomass using national forest inventory data and linear least-square regression and applies the model both inside and outside of forest to create a nationwide model for tree biomass

(biovolume and basal area). Validation of the tree







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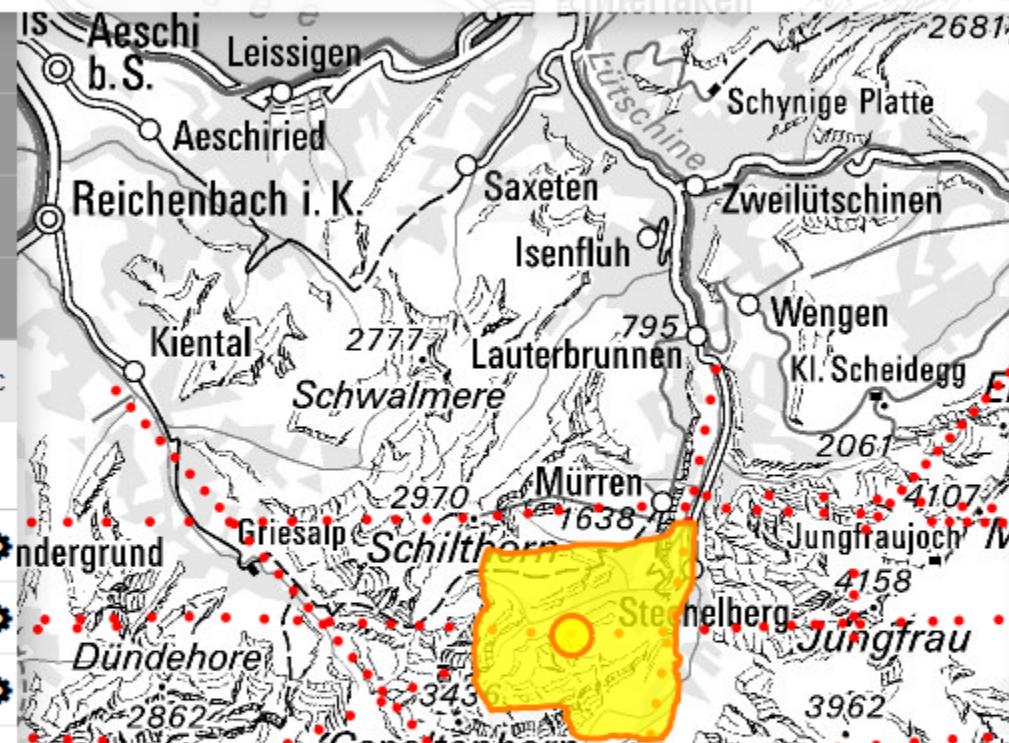
1980

Vegetation height model NFI

Surface model NFI

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Object information

Aerial Images swisstopo b / w (Federal Office of Topography swisstopo)

Picture number

19801530034525

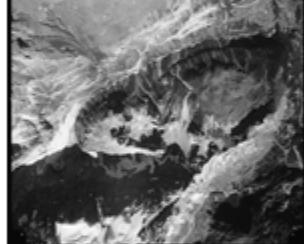
Flight date

03-09-1980

Film type

bw

Quickview



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Order (CHF 91.55)

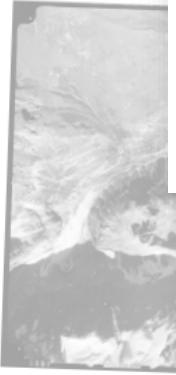


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Picture number	19801530034525
Inventory number	241984
Flight date	03-09-1980
Flying height [m]	5200
Scale	1:19000
Centre coordinate Y	632621
Centre coordinate X	153395
Film type	bw
Dimensions of original image [cm]	23 x 23
File size [MB]	277
Image path	lubis\frame
Ortho image path	lubis\ortho
Orientation elements	True
Rotation [°]	2
Link Online Shop	<a href="#">Online Shop</a>



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## Aerial Images swisstopo b / w (Federal Office of Topography swisstopo)

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<b>Inventory number</b>	241984
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<b>Orientation elements</b>	True
<b>Rotation [°]</b>	2
<b>Link Online Shop</b>	<a href="#">Online Shop</a>



# 10'800 stereo models cover Switzerland

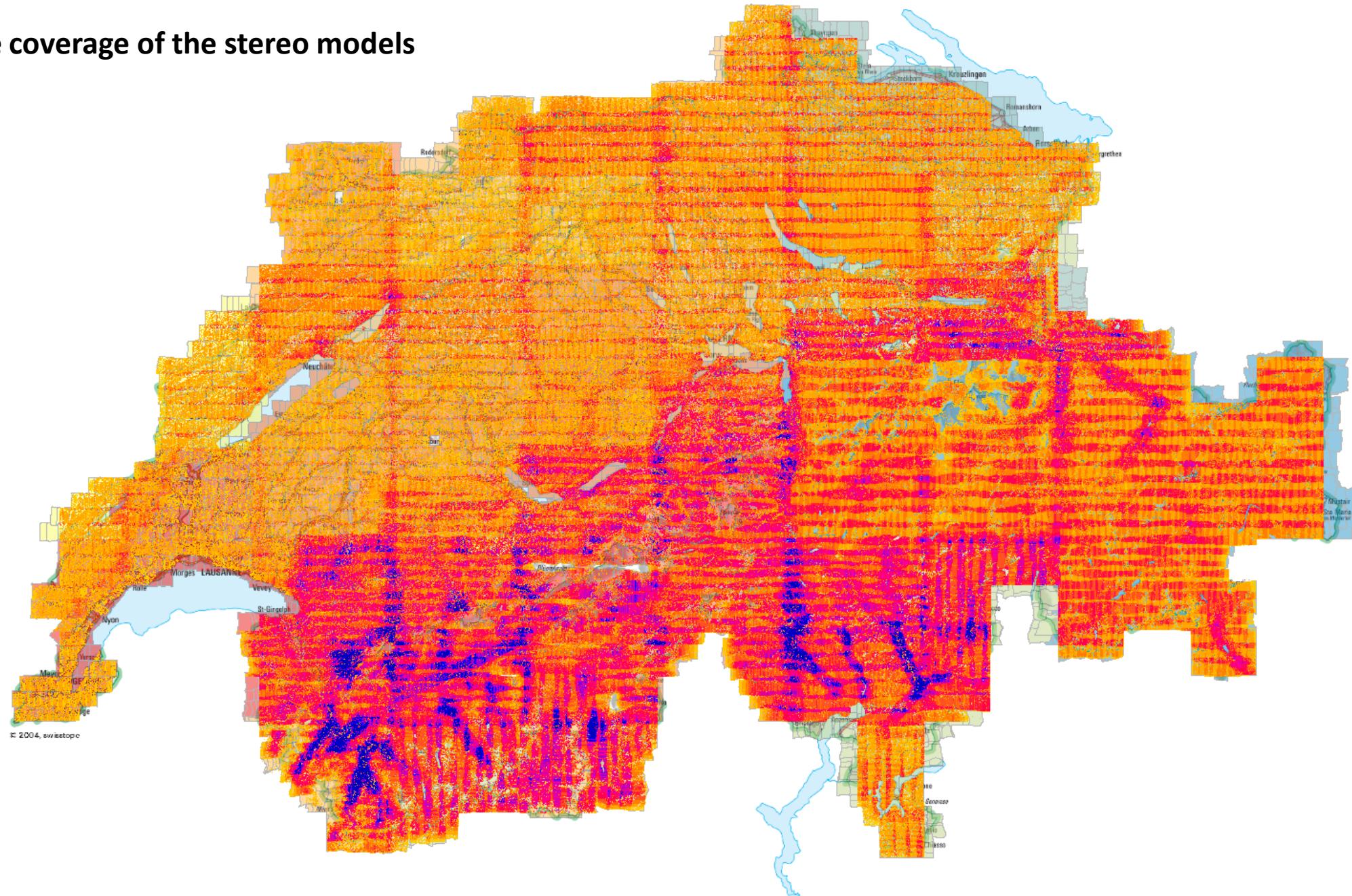
Year of image acquisition

- 1979
- 1980
- 1981
- 1982
- 1983
- 1984
- 1985



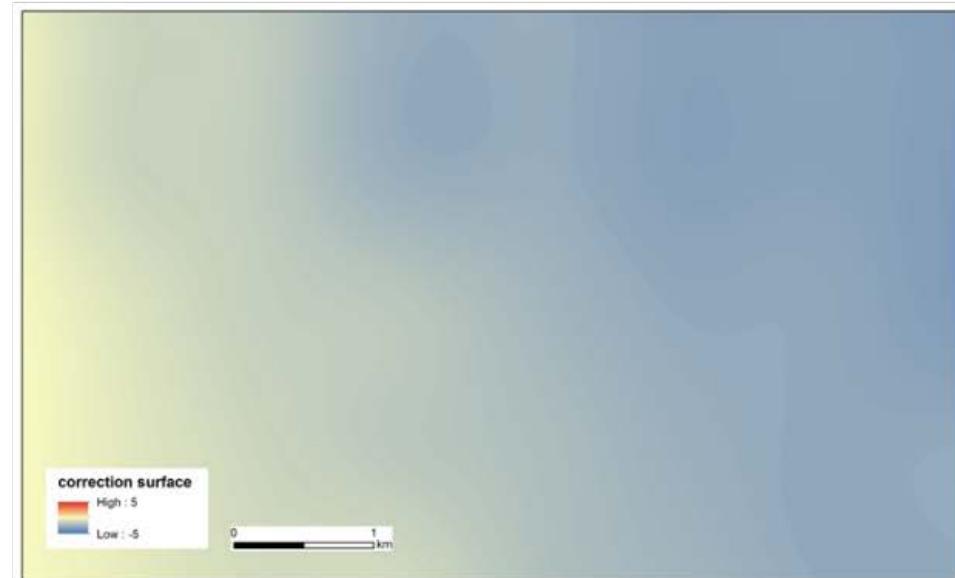
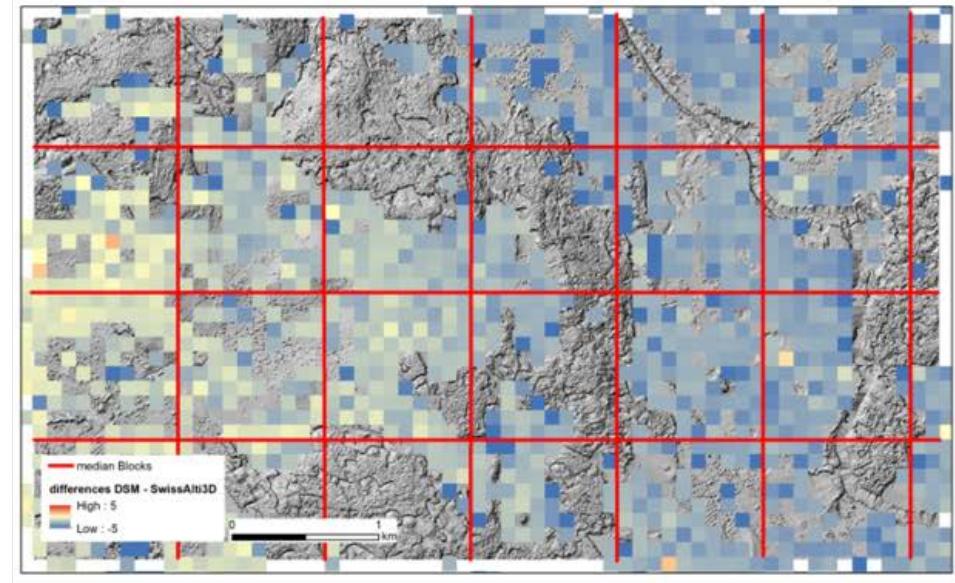
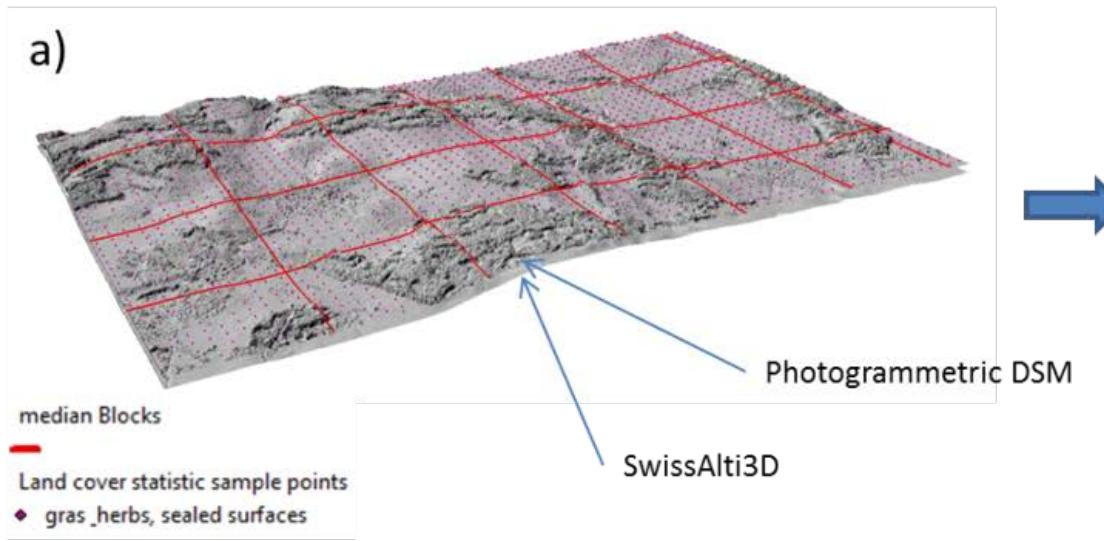
## Multiple coverage of the stereo models

- █ 1
- █ 2
- █ 3
- █ 4
- █ 5
- █ 6
- █ 7
- █ 8
- █ 9
- █ 10
- █ 11



## Surface model 1 m x 1 m





Interpretationskategorien Arealstatistik LC21

21 Gras-, Krautvegetation LC

**Definition**  
Vorwiegend mit Gräsern und Kräutern bewachsene Flächen.

**Erfüllungskriterien**

- Für Landwirtschaftsflächen und unproduktive Flächen:  
Das SP-Punkt liegt auf einer homogenen Gras-, Krautfläche von mindestens 625m<sup>2</sup> oder die heterogene Bedeckung innerhalb der Referenzfläche muss zu >50% mit Gras-, Krautvegetation bedeckt sein  
(d.h. sie muss mit weniger als 50% Sand, Geröll, Humus, Gebüsch bedeckt sein).
- Im Siedlungsbereich (d.h. in Verbindung mit einem LU aus dem Bereich Siedlung):  
SP-Punkt auf homogener Gras- und Krautvegetation (keine Mindestfläche)

**Zugehörigkeiten**

- Ackerland (mit und ohne Vegetation)
- Wiesen und Weiden
- Gras- und Krautvegetation ohne landwirtschaftliche Nutzung
- Gras- und Krautvegetation im Siedlungsbereich
- Naturwiesen mit einzelnen Rebreihen oder Doppelreihen in Abständen >3m
- Gras-, Krautvegetation innerhalb des Rebareals, aber außerhalb der Maximalabstände der Rebreihen
- Extensiv bewirtschaftete Wiesen im Gebäudeumschwung
- teils Umschwing von Ferienhäusern im Maiensässgebiet (siehe *Grenzfälle, Spezielles*)
- Gras- und Krautvegetation unter dem Kronendach von (Obst-)bäumen außerhalb der WBL
- Bodenebene Abdækungen mit Plastik oder Folies auf Wies- und Ackerland
- Blumen zum selber Pflücken ohne Einrichtungen

- Artenarm, intensiv gepflegte Räsen ohne landwirtschaftliche Nutzung → 15 Rasen
- Zu 50-80% verbuschte Flächen → 32 Verbuschte Flächen
- Zu 50-80% versteinte (und verbuschte) Flächen → 53 Versteinte Flächen
- Chinaschiff → 64 SchiffBestände (siehe *Grenzfälle, Spezielles*)
- In einem BUWAL-Inventar (Hoch-, Flachmoor, Amphibienlaichgebiete) liegende und/oder auf der Landkarte mit der Sumpf-Signatur gekennzeichnete Flächen → 63 Nassstandorte
- Begruñte Flachdächer → 12 Gebäude

Interpretationskategorien Arealstatistik LC11

11 Befestigte Flächen LC

**Definition**  
Künstlich angelegte, ganz oder teilweise versiegelte Flächen, insbesondere asphaltierte, betonierte, bekieste, gemergelte sowie mit Steinen oder Platten belegte Böden.

**Erfüllungskriterien**

- SP-Punkt auf befestigter Fläche (keine Mindestflächen)

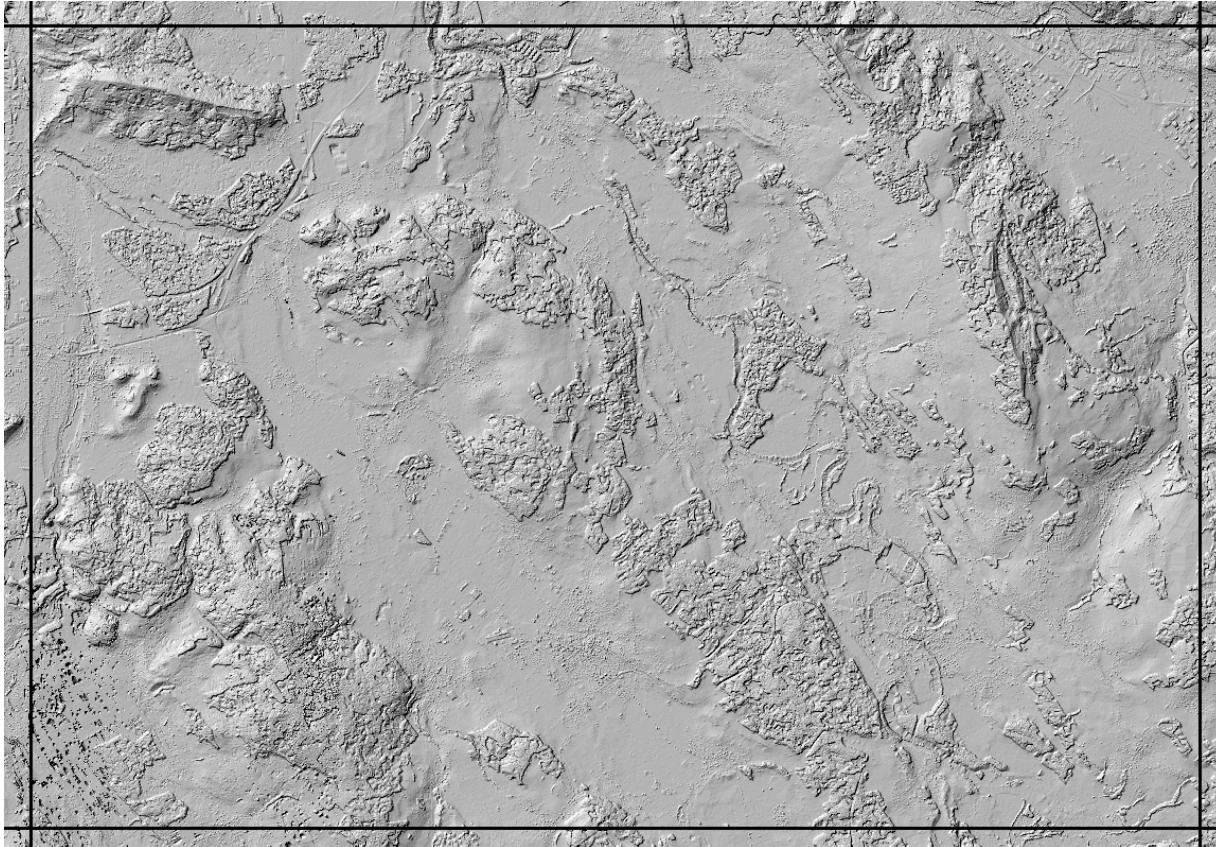
**Zugehörigkeiten**

- Durch bauliche Massnahmen ganz oder teilweise versiegelte Flächen
- Stark verdichtete natürliche Böden (Park-, Wende-, Lagerplätze)
- Strassen, Wege, Trottors, Plätze
- Brücken
- Gesamte Gleisanlagen bis zum Übergang zu einer anderen Bedeckung
- Befestigte Pisten auf Flugplätzen
- frei stehende Unterstände an Haltestellen
- Mäststöcke, offene Gullysilos, Fahrsilos
- Betonerte Wasserbecken von Schwimmbecken, Parkanlagen, Kläranlagen, Fischzuchten
- Betonerte Ausgleichsbecken von Kraftwerken, Löschweihern
- Befestigte Flächen von Baustellen (siehe auch *Grenzfälle, Spezielles*)
- Befestigte Flächen unter Bäumen
- Wege, Umschlag-, Lagerplätze in Kies-, Lehmgruben etc., sofern sie nicht mit Fremdmaterial befestigt sind → 52 Geröll, Sand, Humus
- Häuser, Garagen, Lagerhallen, Ställe, Tanks und Silos → 12 Gebäude
- Gewächshäuser → 13 Treibhäuser
- Gelwege von kleinräumigen Gartenstrukturen → 14 Gartenstrukturen
- Felsböschungen bei Strassen- und Bahnanlagen → 51 Felsen
- Mit Folien ausgelegte Biotope, meist mit einem Schilfbaum → 61 Wasser, 64 Schilfbestand

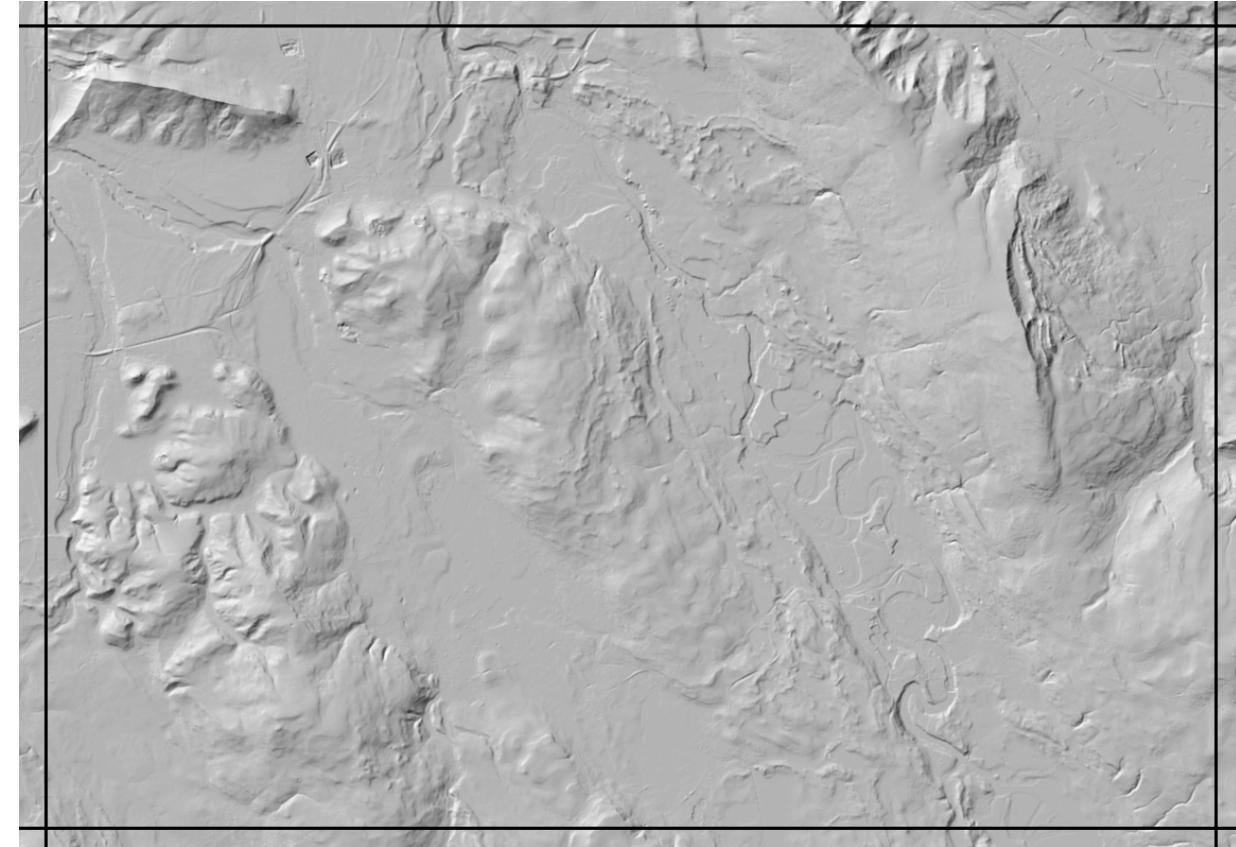
**Hinweise, Beispiele**

Plätze in Anlagen mit permanenter Nutzung sind in der Regel mit einer Siedlungsnutzung kombiniert und als befestigt anzusehen (Kompostanlagen, Industrielager, LKW-Abstellplätze etc.). Vorrübergehend zur Lagerung benutzte Flächen sind in der Regel nicht befestigt (Holzlager, Materialdepots von Baustellen etc.).

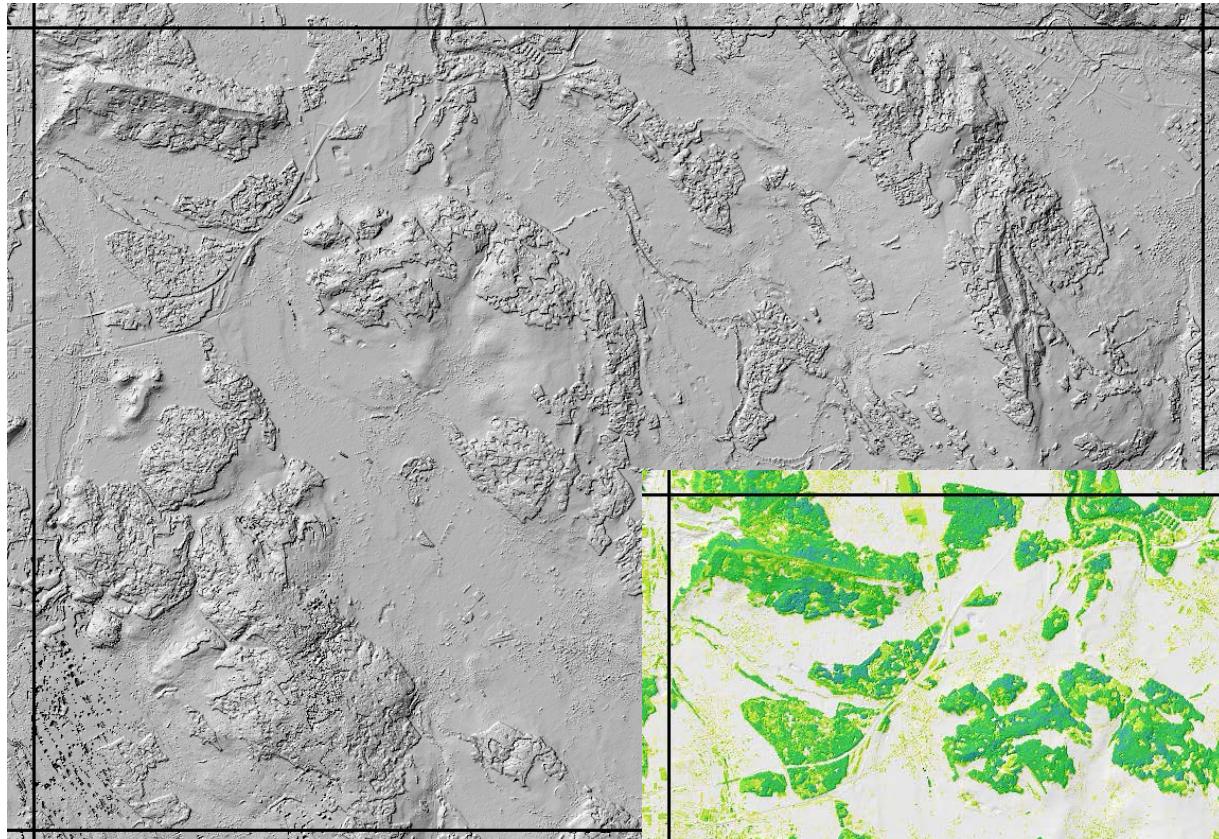
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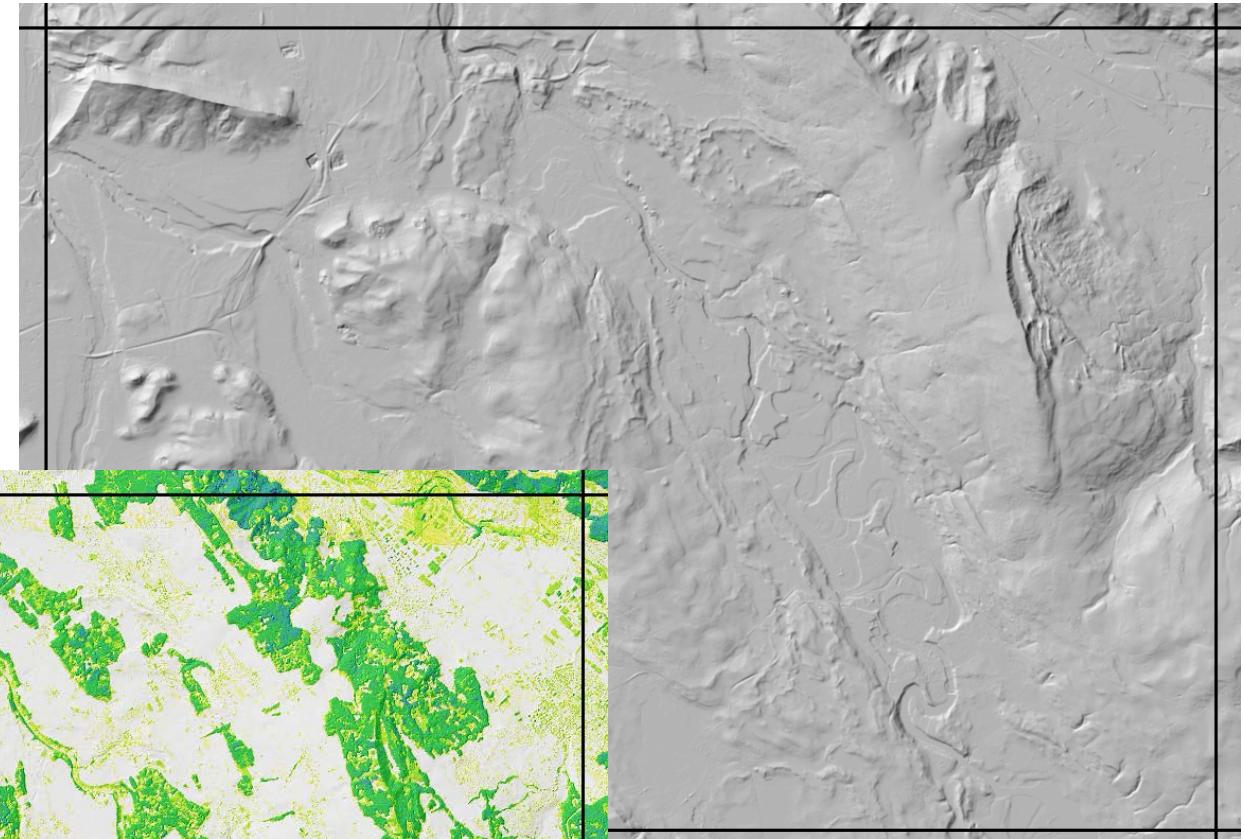
**Surface model (DSM) 1 m x 1 m**



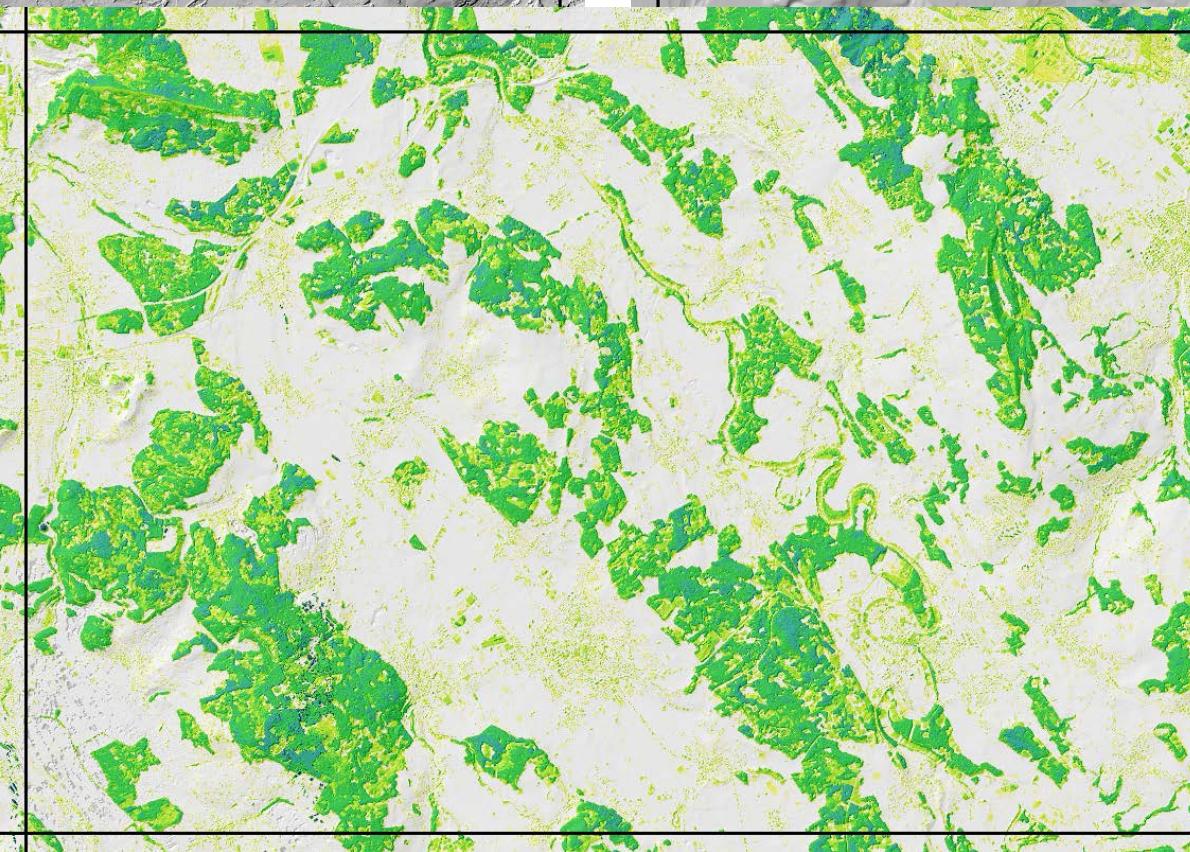
**SwissAlti3D terrain model (DTM) 1 m x 1 m**



Surface model (DSM) 1 m x 1 m



terrain model (DTM) 1 m x 1 m



nDSM (~Vegetation height model) 1 m x 1 m

Objekthöhe [m]
0 - 1
1 - 2
2 - 3
3 - 5
5 - 15
15 - 20
20 - 30
30 - 40
40 - 60

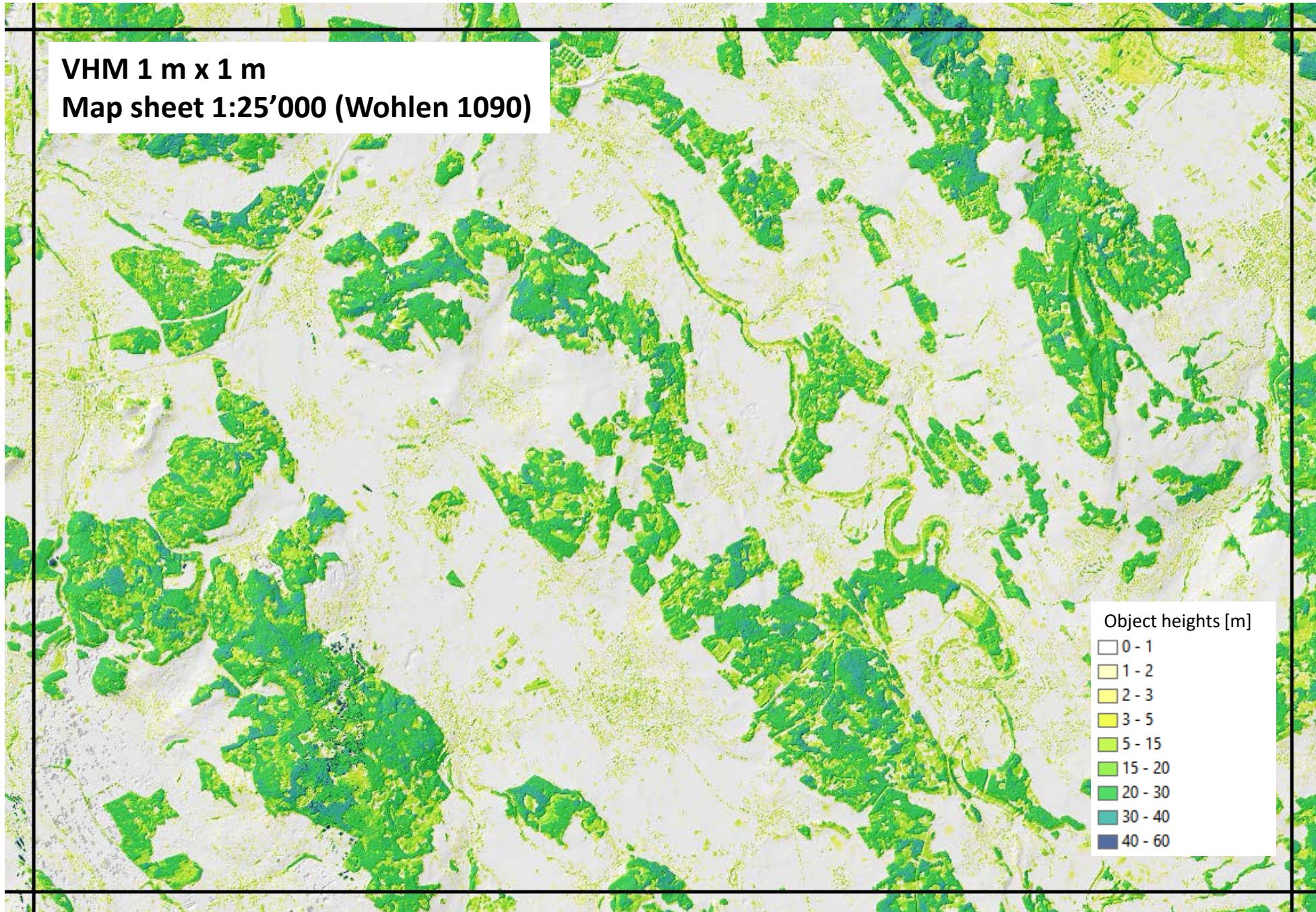
## DSMs 1 m x 1 m



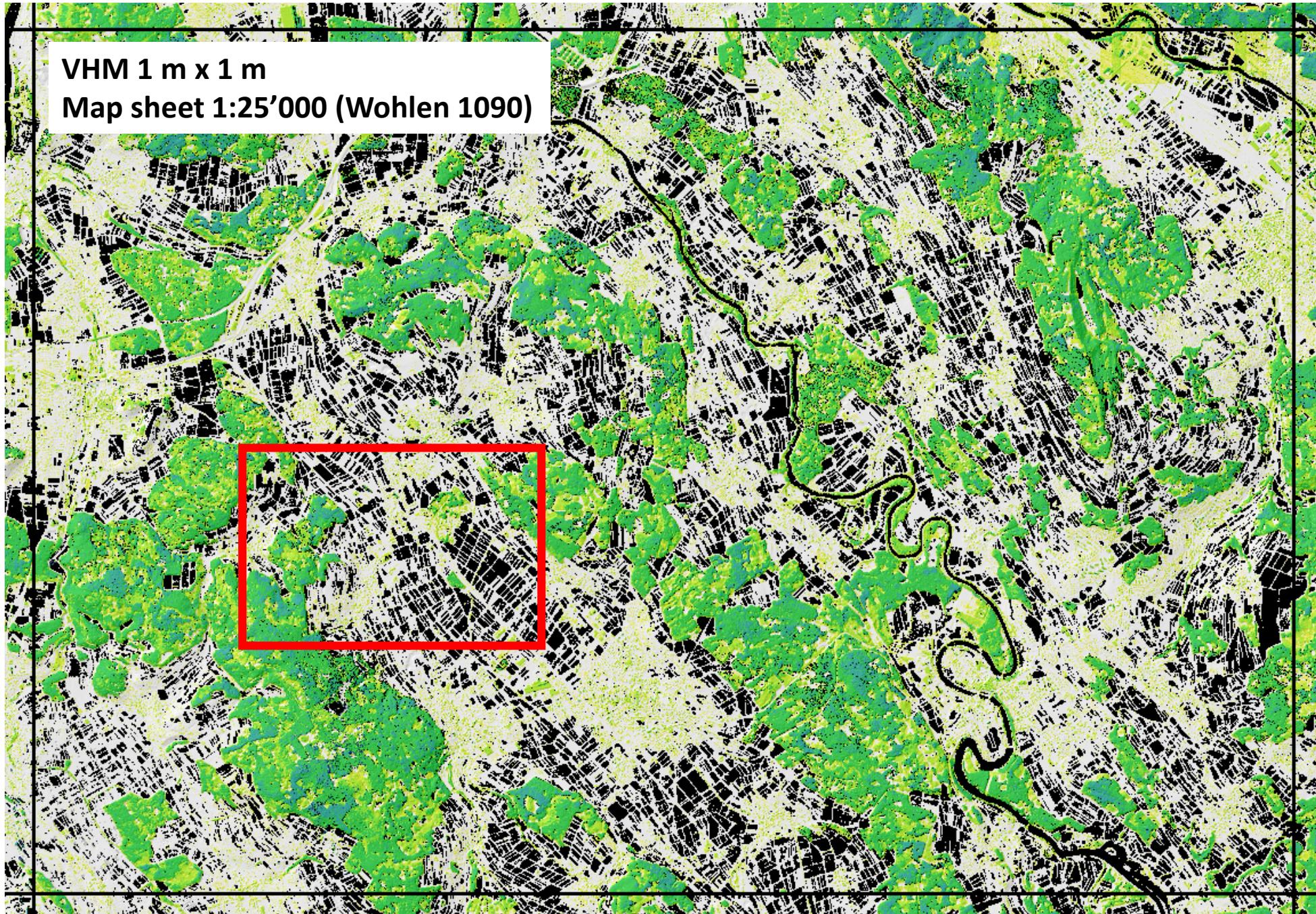
VHM 1 m x 1 m



**VHM 1 m x 1 m**  
**Map sheet 1:25'000 (Wohlen 1090)**

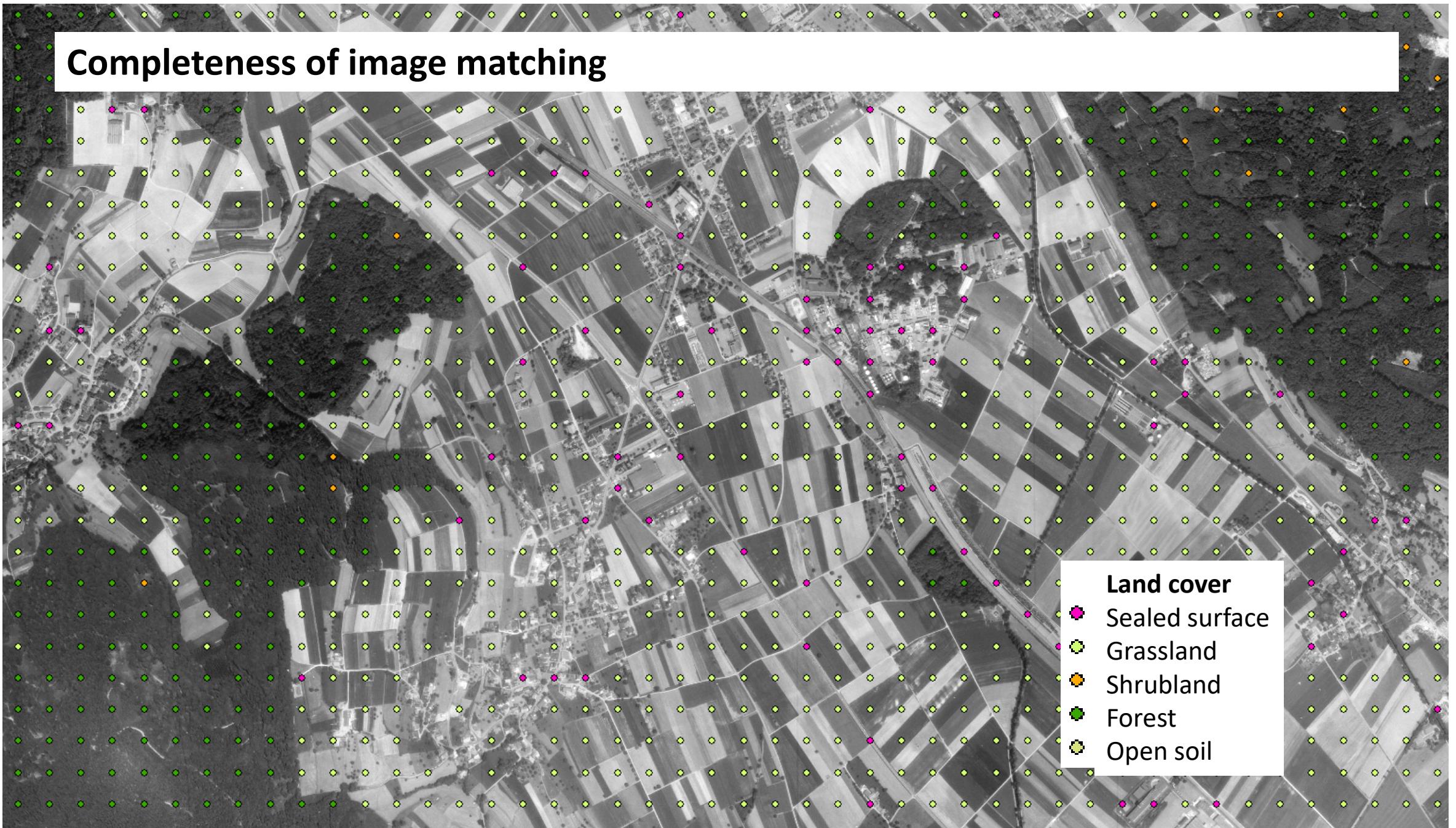


**VHM 1 m x 1 m**  
**Map sheet 1:25'000 (Wohlen 1090)**



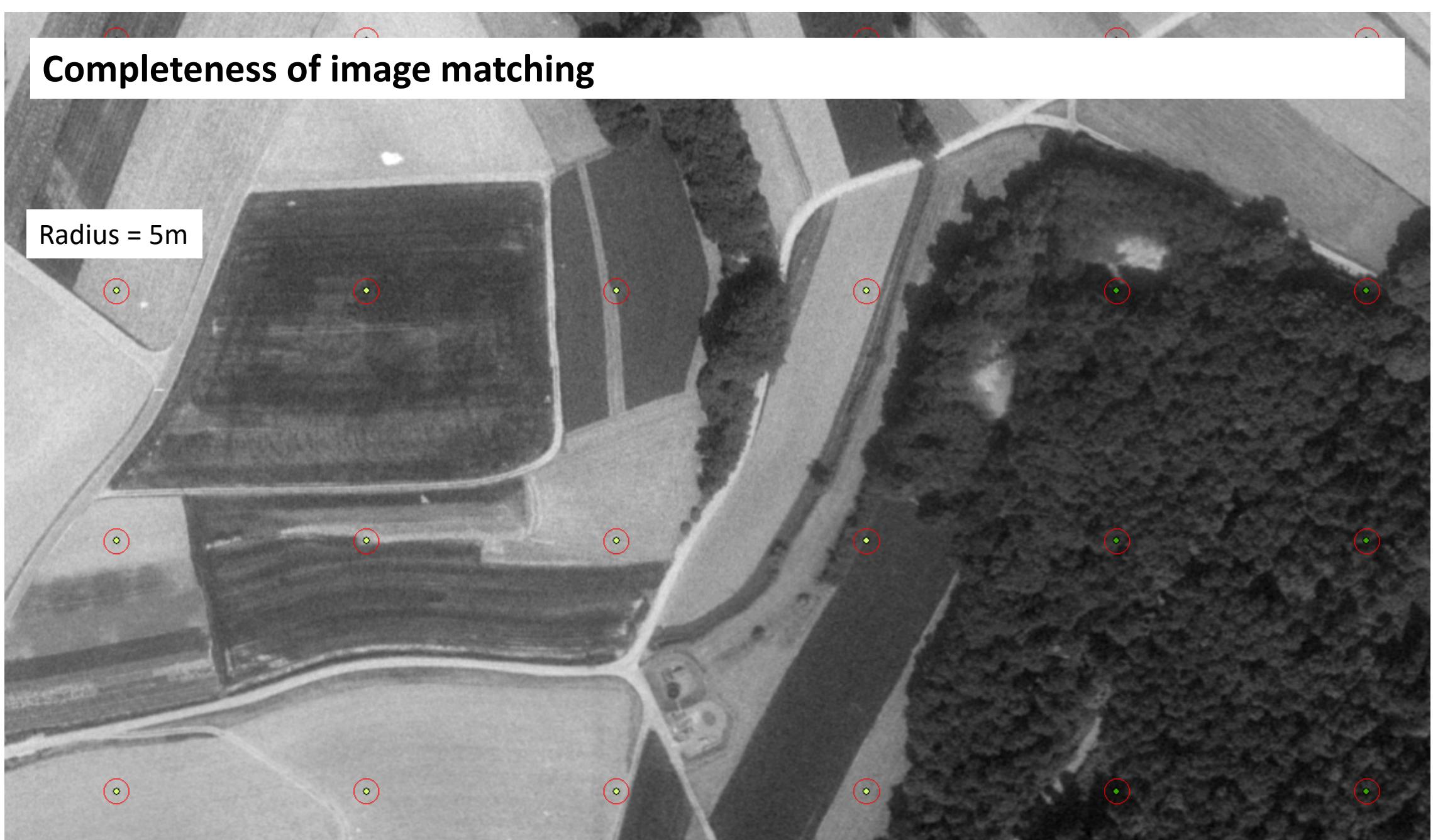


# Completeness of image matching

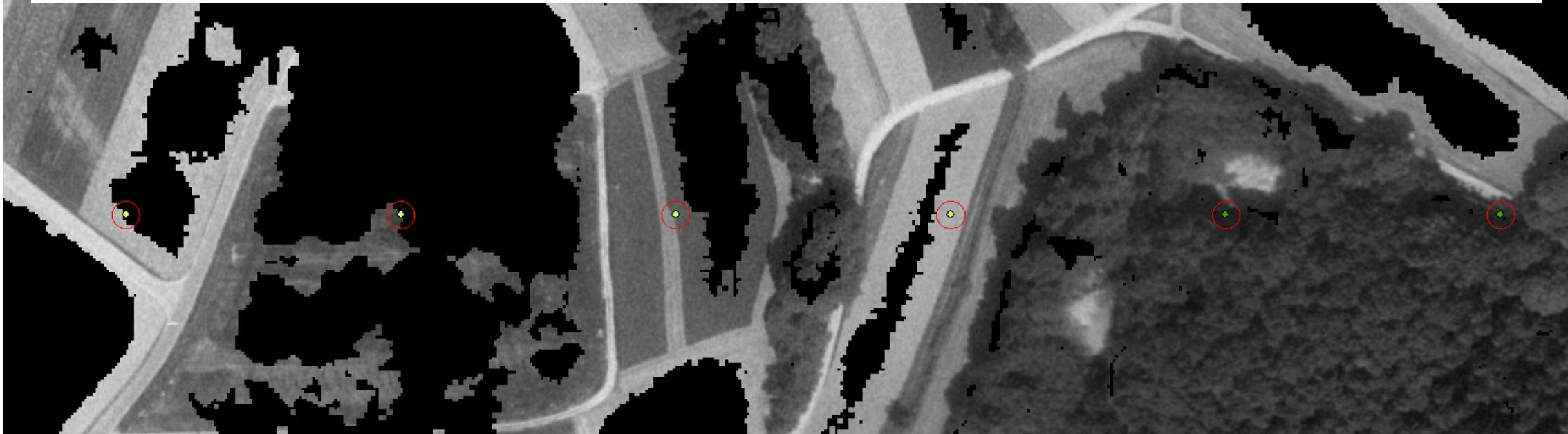


# Completeness of image matching

Radius = 5m



## Completeness of image matching



Land cover	Avg. completeness[%]	Samplesize
Forest	83	34'805
Grassland	68	36'992
Shrubland	92	6'915
Sealed surfaces	94	3'000
Open soil	91	18'973

# Comparison with stereo height measurements

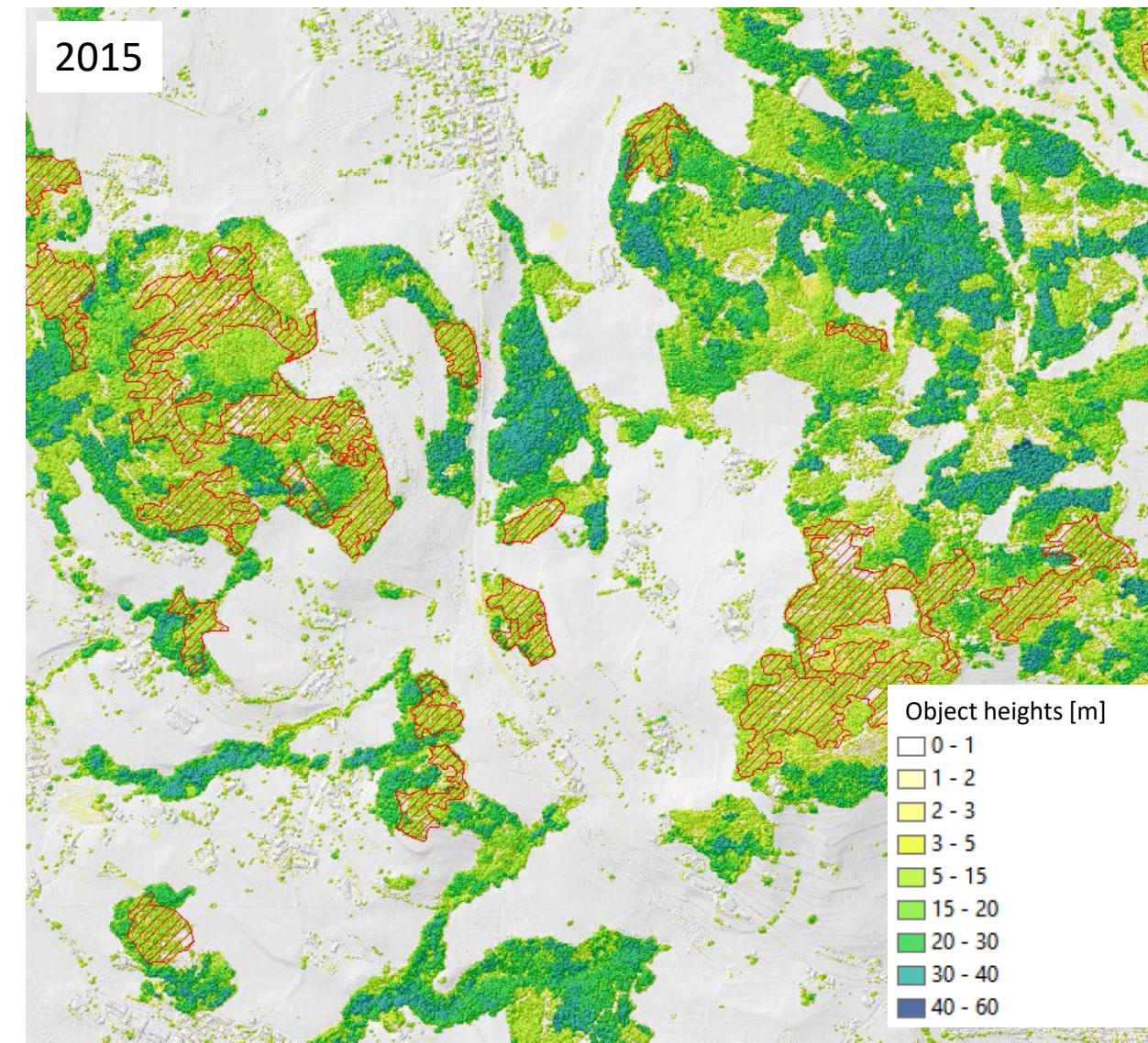
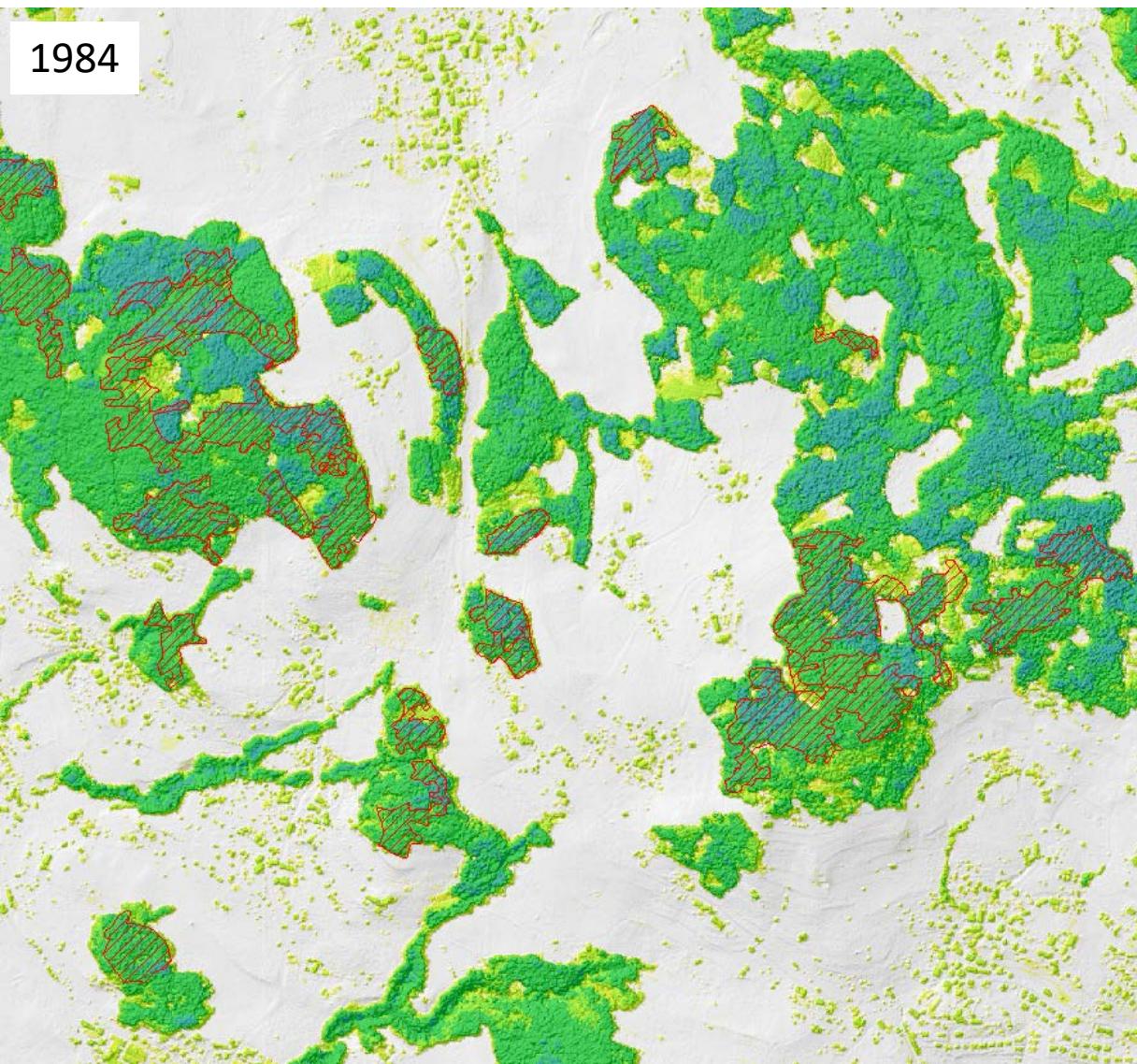


Foto: Simon Speich

Land cover	Sample Size	Median	NMAD	Median ADS	NMAD ADS
Coniferous tree	2478	-1.77	3.77	-0.79	3.94
Deciduous tree	2917	-1.83	2.75	-0.34	2.39
Grass and herbs	6792	-0.15	1.02	-0.25	0.95
Shrubs	424	-0.41	1.62	-0.22	1.54
Sealed surfaces	408	0.19	0.63	0.05	0.77
Rock	1040	-1.40	1.70	-0.74	1.44
Sand,stones & visible earth	1231	-0.74	1.00	-0.51	0.89
Glaciars, firns & snow	567	0.17	2.15	-0.53	1.53

Ginzler & Hobi (2015)

# Plausibilisierung mit Lotharflächen (Sturm vom 26.12.1999)



# Plausibility check with yields from the National Forest Inventory

LFI2-LFI3

Jährliche Nutzung\*: Vegetationshöhenstufe · Kanton

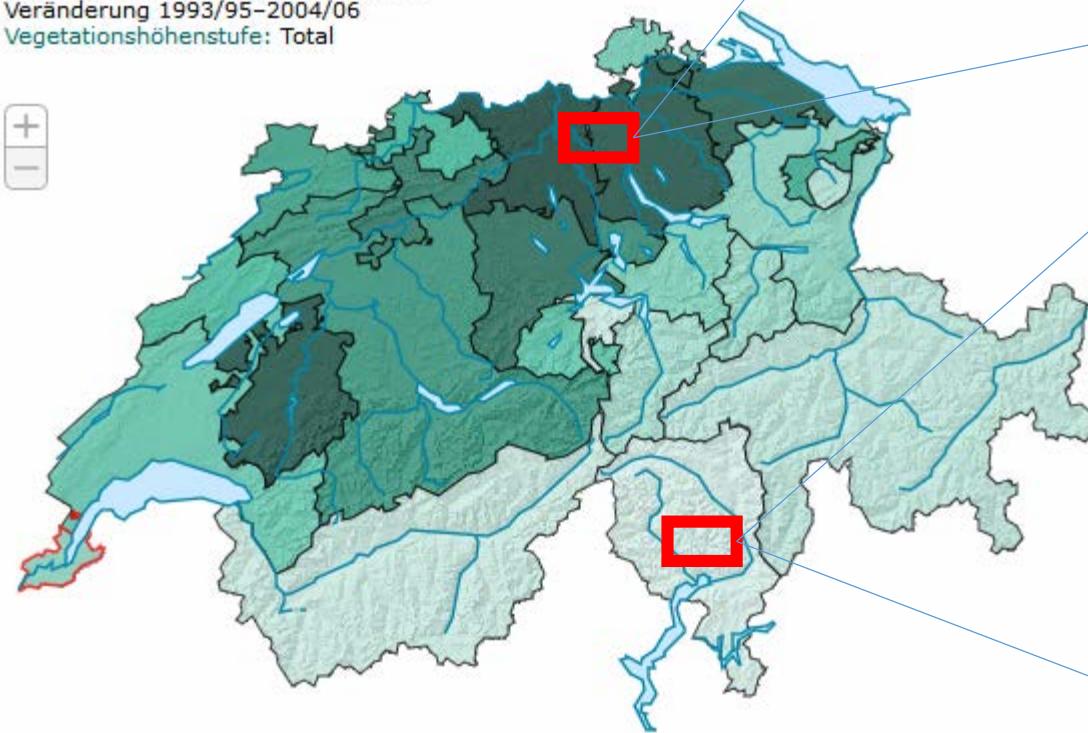
Einheit: m<sup>3</sup>/J./ha

Auswertungseinheit: gemeinsamer zugänglicher Wald ohne Gebüschwald LFI1/LFI2/LFI3/LFI4

Netz: Netz LFI4 Pensum 2009 - 2013

Veränderung 1993/95-2004/06

Vegetationshöhenstufe: Total



Height difference 2016 - 1980



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## Conclusion

- Image correlation has worked across the country.
- Surface models with  $1 \times 1\text{m}$  could be created.
- The results are plausible and the completeness of the image correlation is sufficient (for forest).

# **Outlook**

## **Creation of further periods**

- 1979 – 1985
- 1992 – 1997
- 2002 – 2007
- 2011 – 2017

**... in the framework of the National Forest Inventory**

# Outlook

Int J Appl Earth Obs Geoinformation 90 (2020) 102116

Contents lists available at ScienceDirect

Int J Appl Earth Obs Geoinformation

journal homepage: [www.elsevier.com/locate/jag](http://www.elsevier.com/locate/jag)



Predicting biomass dynamics at the national extent from digital aerial photogrammetry



Bronwyn Price\*, Lars T. Waser, Zuyuan Wang, Mauro Marty, Christian Ginzler, Florian Zellweger

Remote Sensing, Swiss Federal Research Institute WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland

B. Price, et al.

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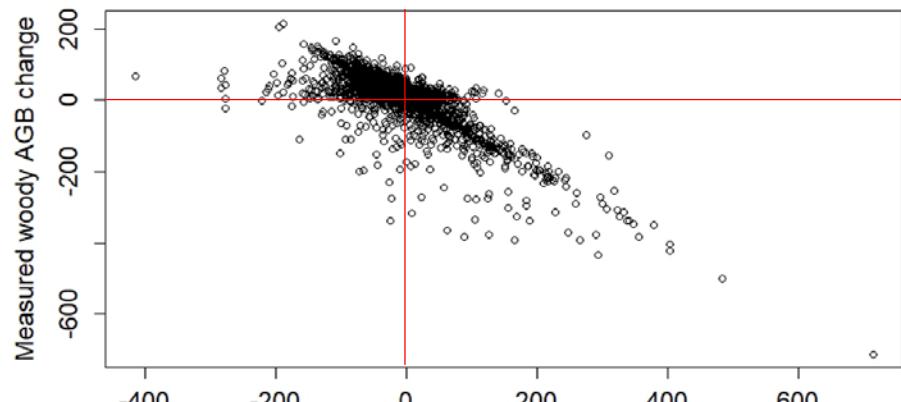


Fig. 7. Comparison between the discrepancy between predicted change and the amount of observed change in woody AGB.

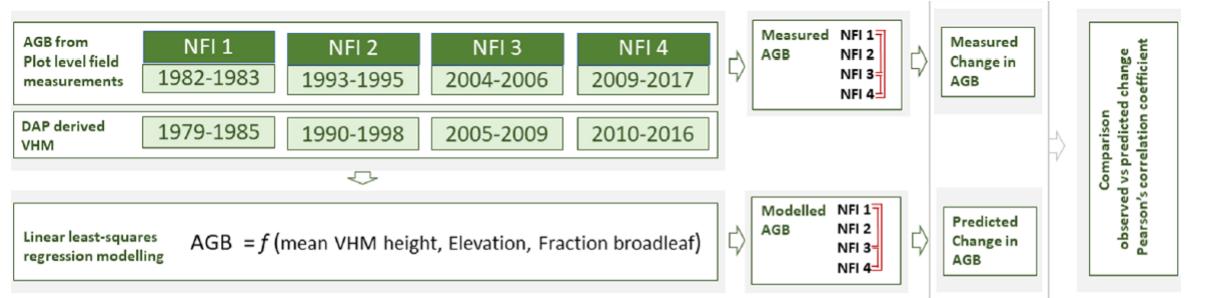


Fig. 3. Workflow for modelling process for predicting woody AGB and change over 4 time steps. Where DAP = digital aerial photogrammetry, VHM = vegetation height model, NFI = national forest inventory, AGB is woody above ground biomass.

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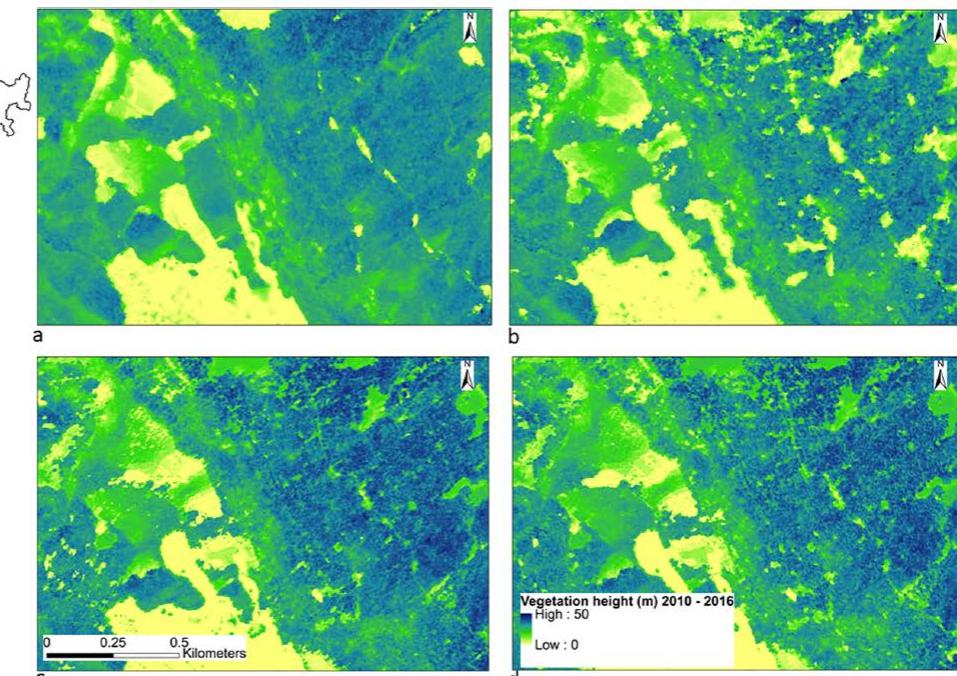


Fig. 2. Sample area from the vegetation height models (VHM) for each time step of the Swiss NFI, a) VHM for the period 1979-1985 (NFI 1), b) VHM for the period 1990-1998 (NFI 2), c) VHM for the period 2005-2009 (NFI 3) and d) VHM for the period 2010-2016 (NFI 4). Red rectangle on the outline of Switzerland indicates the sample area location. (For interpretation of the references to colour in the Figure, the reader is referred to the web version of this article).