The Habitat Map of Switzerland v1.1: Data description

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1 Overview

1.1 Objectives

The FOEN funded project 'Developing a Habitat Map of Switzerland' conducted at the WSL, has produced a map of Swiss habitats according to the TypoCH classification (Delarze et al. 2015) wall-to-wall across the whole of Switzerland, to at least the classification's 2nd level of detail (where possible to the 3rd level of detail). Version 1.0 was published online through the WSL's Virtual Data Centre (VDC) in October 2021. Methodological details can be found in Price et al. (2023). Over 2022 and 2023 various improvements and update were integrated into the data set. This documentation refers to the version 1.1 of the habitat map, completed in March 2024.

The implementation of the Habitat Map of Switzerland is a vector data set, where each polygon of the dataset is classified to one habitat type only.

1.2 Method overview

Habitats are mapped through a variety of approaches that can be grouped as either:

1: Derived from the existing Swiss-wide datasets a) the high quality landcover mapping from Swisstopo's Topographical Landscape Model (TLM), and b) the harmonized mapping of agricultural fields area from the 'Landwirtschaftliche Nutzfläche' (LWN) mapping.

2: Modelled within the project using Random Forest or Ensemble Modelling techniques to model the spatial distribution of individual habitat types (further detail below),

3: Combining existing species distribution models to determine habitat types, or

4: Classification with relatively simple rule-sets based on auxiliary spatial datasets, i.e. vegetation height models (based on digital aerial photogrammetry and/or SwissSurface3D aerial laser scanning (ALS) data), the digital terrain model, the normalised difference vegetation index (NDVI) derived from aerial imagery and/or time-series of growing season Sentinel-2 or Planet satellite imagery.

(9: Not included)

Table 1: TypoCH habitat types at the second level and the method used in the Habitat Map of Switzerland project to determine their distribution. Habitats highlighted in light grey were modelled to the 3rd level with the same methodology as indicated in the column Method. Habitats in italics and a '9' indicated in the Methods column were not modelled in this version of the Habitat Map.

TypoCH	TypoCH_DE	TypoCH_FR	TypoCH_IT	Method
1	Gewässer	Eaux libres	Ambienti acquatici	1
1.1	Stehende Gewässer	Eaux calmes	Acque ferme	1
1.2	Fliessgewässer	Eaux courantes	Acque correnti	1
1.3	*Quellen und Quellfluren*	*Sources et suintements*	*Sorgenti e stillicidi*	*9*
1.4	*Unterirdische Gewässer*	*Eaux souterraines*	*Acque sotterranee*	*9*
2	Ufer und der Feuchtgebiete	Rivages et lieux humides	Rive e luoghi umidi	1
2.0	*Künstliche Ufer*	*Rives artificielles*	*Rive artficiali*	*9*
2.1	Ufer mit Vegetation	Rivages avec végétation	Rive con copertura vegetale	1
2.2	Flachmoore	Bas-marais	Paludi (torbiere basse)	2
2.3	Feuchtwiesen	Prairies humides	Prati acquitrinosi	2
2.4	Hochmoore	Tourbière bomées	Torbiere alte	2
2.5	*Wechselfeuchte Pionierfluren*	*Végétation annuelle temporairement inondée*	*Luoghi temporaneamente inondati con vegetazione annuale*	*9*
3	Gletscher, Fels, Schutt und Geröll	Glaciers, rochers, éboulis et moraines	Ghiacciai, rocce, ghiaioni, depositi fluviali e glaciali	1
3.1	Gletscher, Firn- und Schneefelder	Glaciers, névés	Ghiacciai e nevai	1
3.2	Alluvionen und Moränen	Alluvions et moraines	Suoli alluvionali e morene	1
3.3	Steinschutt- und Geröllfluren	Eboulis	Ghiaioni	1
3.4	Felsen	Parois rocheuses	Pareti rocciose	1
3.5	*Höhlen*	*Grottes et cavernes obscures*	*Grotte, caverne e cunicoli*	*9*
4	Grünland (Naturrasen, Wiesen und Weiden)	Pelouses et prairies	Praterie	2
4.0	Kunstrasen	Gazons et prairies artificielles	Tappeti erbosi e prati artificiali	1,2, 4
4.1	Pionierfluren auf Felsböden (Felsgrusfluren)	Dalles rocheuses et lapiez	Tavolati e campi solcati	4
4.2	Wärmeliebende Trockenrasen	Pelouses sèches thermophiles	Praterie termofile aride e semiaride	2
4.3	Gebirgs-Magerrasen	Pelouses et pâturages maigres d'altitude	Praterie e pascoli magri d'altitudine	2
4.4	Schneetälchen	Combes à neige	Vallette nivali	2
4.5	Fettwiesen und -weiden	Prairies grasses	Praterie e pascoli pingui	2
4.6	Grasbrachen	Friches à graminées	Aree abbandonate erbose	2
5	Krautsäume, Hochstaudenfluren und Gebüsche	Landes, lisières et mégaphorbiaies	Margini di bosco, radure, aggregati di alte erbe, cespuglieti e brughiere	1, 4

5.1	*Krautsäume*	*Lisières herbacées (ourlets)*	*Margini di bosco erbacei*	*9*
5.2	Hochstauden- und Schlagfluren	Mégaphorbiaies, coupes forestières	Tagli rasi, radure e luoghi con alte erbe	4
5.3	Gebüsche	Formations buissonnantes (manteau, fourrés, haies)	Cespuglieti (mantelli, spessine, siepi)	1,4
5.4	Zwergstrauchheiden	Landes	Brughiere	2
6	Wälder	Forêts	Ambienti boscati	1
6.0	Forstpflanzungen	Plantations	Piantagioni	4
6.1	Bruch- und Auenwälder	Forêts inondables	Boschi innondabili, alluvionali	3
6.2	Buchenwälder	Hêtraies	Faggete	3
6.3	Andere Laubwälder	Autres forêts de feuillus	Altri boschi di latifoglie	3
6.4	Wärmeliebende Föhrenwälder	Pinèdes thermophiles	Pinete termofile	3
6.5	Hochmoorwälder	Forêts de tourbières	Boschi di torbiera	3
6.6	Gebirgsnadelwälder	Forêts de cônifères d'altitude	Boschi di conifere d'altitudine	3
7	Pioniervegetation gestörter Plätze (Ruderalstandorte)	Végétation pionnière des endroits perturbés par l'homme	Ambienti ruderali e perturbati dall'uomo	4
7.1	Trittrasen und Ruderalfluren	Terrains piétinés et rudéraux	Terreni calpestati e ruderali	4
7.2	*Anthropogene Steinfluren*	*Milieux rocheux anthropogènes*	*Manufatti in sasso, muri e selciati*	*9*
8	Pflanzungen, Äcker und Kulturen	Plantations, champs et cultures	Ambienti coltivati	2
8.1	Baumschulen, Obstgärten, Rebberge	Cultures de plantes ligneuses	Colture di piante legnose	1
8.2	Feldkulturen (Äcker)	Cultures de plantes herbacées	Colture di piante erbacee	1
9	Bauten, Anlagen	Milieux construits	Ambienti edificati e infrastrutture	1
9.1	Lagerplätze, Deponien	Décharges, dépôts	Discariche, depositi di materiale vario	1
9.2	Bauten	Bâtiment	Edifici	1
9.3	Verkehrswege	Voies de communication	Vie di communicazione	1
9.4	Versiegelter Sportplatz, Parkplatz etc.	Terrain de sport revêtu, place de parc	Campi sportivi, parcheggi pavimentati ecc.	1

1.3 Improvements and updates from version 1 to version 1.1

Over 2022 and 2023 improvements were made in the mapping of several habitat types as follows.
The image segmentation and classification processes in the eCognition software were re-run with some updates to the ruleset, as described in the following and using the latest versions of the Swiss aerial imagery, image year is shown in Figure 1.

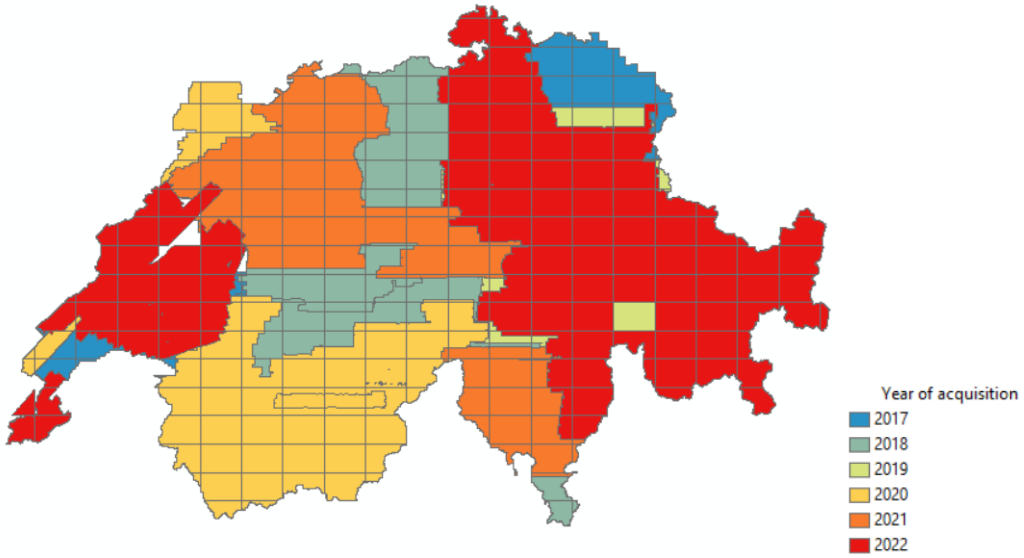

Figure 1: Acquisition year of aerial imagery

1.3.1 Cliffs, exposed rocks, screes (TypoCH 3.3, 3.4) and Pioneer vegetation on rocky surfaces (TypoCH 4.1)

In response to feedback from expert data users, the rules for determining cliffs and exposed rocks (3.4) were adjusted slightly to require a slope of >45°. Areas of lower slopes but classified as rocky surfaces in the TLM were then further classified as either screes (3.3) if both median and p95 NDVI was less than 0.2, Pioneer vegetation on rocky surface (4.1) if median NDVI was between 0.2 and 0.45 and otherwise grassland, with classification to a particular grassland type dependant on the grassland modelling (section 2.2.2).

1.3.2 Snowbeds (TypoCH 4.4)

While mapping of snowbeds for version 1 of the Habitat Map used Planet satellite imagery from only one year, for version 1.1 Planet data from six summer seasons was used, 2016-2022. Snowbeds were mapped as the intersection of areas where snow was present in June but not present in July across all data years, and where the SDM modelling (Approach 2, see section 2.2.2) indicated the presence of snowbed communities was highly probable. Snow detection was based on a threshold of 200 of the blue band.

1.3.3 Trees and hedges/shrubs outside of forest (TypoCH 5, 6.0)

SwissSurface3D aerial laser scanning (ALS) data was used, where available (see Figure 2), to determine the presence of trees and shrubs outside of forests (defined by the NFI Forest mask) and urban areas (defined as the TLM settlement boundaries for areas with a population greater than 100). The ALS data points classified as vegetation were rasterised using LAStools software (https://lastools.github.io/) into 1m spatial resolution vegetation metrics, including mean and maximum vegetation height. Raster cells with maximum height over 3m were classified as trees (TypoCH 6.0), and maximum height between 50cm and 3m as shrubs (TypoCH 5), below 50cm as grass. The shrub and tree classification were then separately converted to polygons and cleaned by eliminating (using the ArcGIS Pro function eliminate) small polygons of less than 6m^2 area.

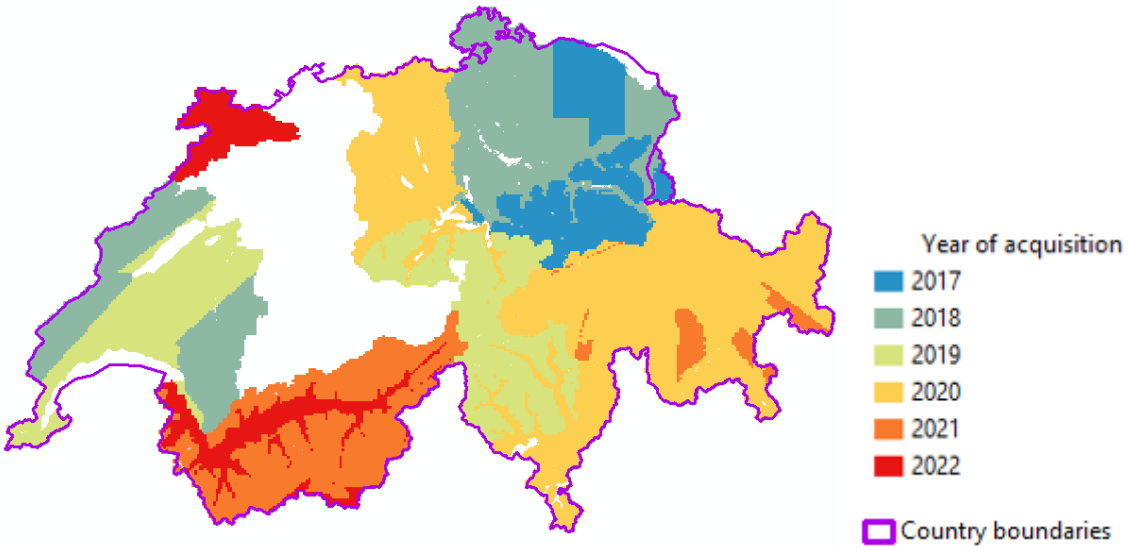

Figure 2: Area and year of acquisition of SwissSurface3D aerial laser scanning data

1.3.4 Juniperus sabina Dwarf shrubs (TypoCH 5.4.2)

Using field observation training data from InfoFlora, a random forest modelling approach was employed to identify image segments (from the eCognition ortho-image segmentation) that were likely to have presence of *juniperus sabina* dwarf shrubs.

The random forest models used the following predictors: all bands of the aerial imagery (R, G, B, NIR), NDVI, NDWI, vegetation height, soil moisture, northness, elevation, slope, and median NDVI in Spring derived from Sentinel-2 time series (2017-2022). Following the random forest modelling there was also some post-processing to limit the segments classified as *juniperus sabina* to those where: vegetation height is less than 3m; the modelled probability of grass is low (<= 0.1); the modelled probability of the '*juniperus sabina* absence' class is low (>=0.33); NDVI for the segment is greater than the mean value of all NDVI values of the surrounding segments that were not classified as *juniperus sabina*; and the segment falls within an area of the Delarze et al.(2015) coarse distribution maps where the presence of *juniperus sabina* is considered very likely (>0.75).

1.3.5 Forests (TypoCH 6)

In response to feedback from expert data users, some simple rules were applied to the forest classification to remedy some common misclassifications of forest types.

Swamp forest of the group 6.1 are now only able to occur in wet areas identified by the TLM and the national and region wetland inventories. Forests within this group are only further differentiated into types when the types are mapped in the national and region wetland inventories, with the exception of type 6.1.2 (Riverine Salix woodland). This type (6.1.2) has a distinctive colouring and is now identified using the blue (>= 75) and red (>= 85) bands of the aerial imagery and with a minimum mean height of 5m from the vegetation height model.

Beech forests of group 6.2 are identified as forests dominated by *fagus sylvatica* (according to the MoGLI distribution models, see section 2.2.3). Type 6.2.3 can only occur at elevations below 900m, 6.2.4 below 1200m and 6.2.5 above 1100m.

Mixed *tilia* forests (type 6.3.2) are now limited to slopes greater than 30° where *euonymus latifolius* occurs (MoGLI modelling).

Inner alpine steppe forest (type 6.4.3) are now limited to elevations below 1000m.

All areas with presence *larix decidua* (MoGLI modelling) and above 1000m elevation are classified to group 6.6 high-altitude coniferous forests. Also within this group, types 6.6.1, 6.6.2 and 6.6.3 are limited to elevations over 1100m where 6.6.1 has presence of *abies alba*, and 6.6.3 *pinus cembra*. The upper elevation limit for 6.6.4 is 900m while type 6.6.5 is now limited to areas with presence of *pinus mugo* below 1700m and with vegetation height greater than 3m.

1.3.6 Crops (TypoCH 4.0.1, 8.2)

For version 1.1 of the Habitat Map, the previous machine learning modelling differentiating cropland from permanent grassland used in version 1 was replaced with newly available harmonized nationwide mapping of cropland from the 'Landwirtschaftlichen Nutzflächen'. This data is gathered by cantonal authorities and covers agriculturally used areas in accordance with the Agricultural Terminology Ordinance (LBV), the Direct Payments Ordinance and the definitions of uses derived from these by the Confederation and the cantons.

1.3.7 Urban areas

As with version 1 of the Habitat Map, urban areas are identified using the TLM urban areas (Siedlungsgebiete) boundaries as locations with a population greater than 100 inhabitants. These areas are subject to significant human modification and made up of fine-scale mosaics of sealed and built-up areas interspersed with small patches of open land and therefore considered unsuitable for the SDM based modelling used elsewhere within the project to identify natural habitats. In these urban areas, plus a 50m buffer, and where SwissSurface3D data was available (Figure 2), the LiDAR data, aerial images (1m resolution) and time series of Planet satellite data were classified to 8 different urban habitat types: temporally dynamic grass; partially dynamic grass; non-dynamic grass; shrubs, hedges, bushes; structurally complex trees; non-complex trees; green roofs; and non-green surfaces.

A mosaic of 4-band (red, green, blue, near infrared) orthoimages captured in leaf-on conditions was derived from the most recent available aerial images (Figure 1) at 1m spatial resolution, from which the normalised difference vegetation index (NDVI) metric was calculated. As urban areas include significant shaded areas, a single NDVI threshold could not be used to consistently identify green areas. Therefore, four categories of 1) shaded vegetation, 2) non-shaded vegetation, 3) shaded non-vegetation and 4) non-shaded non-vegetation, were mapped with the assistance of visual interpretation and a random forest classification model using the 4 raster bands, NDVI and the normalised saturation-value difference index (NSVDI) following Ma et al. (2008). The four categories were then merged in two, namely: vegetation and non-vegetation (referred to as green mask).

The ALS data were rasterised using LAStools software (https://lastools.github.io/), into 1m spatial resolution vegetation metrics representing horizontal and vertical distribution of vegetation, i.e., maximum vegetation height and the vertical complexity index (VCI). The VCI quantifies the variation in vertical distribution of points in the point cloud, measuring the abundance of lidar returns in height bin (voxel of 1m x 1m x 1m size) as a proportion of the total number of lidar returns. Only points from the vegetation classes (3, 4, 5) were used.

Based on the Planet satellite imagery, the Swiss-wide median NDVI rasters (3 m spatial resolution) were calculated for April, July and October 2021. The standard deviation of the three rasters allowed to capture the temporal variability in NDVI over the growing season.

The detection of green roofs was based on the number of flat pixels and mean NDVI. These measures were calculated for each building using the TLM3D building models and the orthoimagery, respectively.

1.4 Data structure

The dataset has the following attributes (Table 2). The methodology used to derive the attributes 'Probability' and 'Cover' is described in section xx of this document.

Table 2: Dataset attributes

Attribute	Attribute_DE	Attribute_FR	Type	Examples	Explanation
TypoCH	TypoCH	TypoCH	Int	1, 65, 451	Integer code representing the TypoCH number code at the highest level available
Class	Bereich	Zone	Int	1,2,3,4…9	Code for the top level of the TypoCH system, Class
Group	Gruppe	Groupe	Int	12, 21, 34, 45…	Code for the 2nd level of the TypoCH system, Group. Class code when no 2nd level classification is available
Type	Typ	Type	Int	232, 451, 633	Code for the 3rd level of the TypoCH system, Type. Group/Class code when no 3rd level classification is available
TypoCH_DE	TypoCH_DE	TypoCH_DE	text	1.1 Stehende Gewässer	Name of TypoCH number in German
TypoCH_FR	TypoCH_FR	TypoCH_FR	text	1.1 Eaux calmes	Name of TypoCH number in French
TypoCH_IT	TypoCH_IT	TypoCH_IT	text	1.1 Acque ferme	Name of TypoCH number in Italian
TypoCH_Sci	TypoCH_Sci	TypoCH_Sci	text	Carpinion	Latin name of Habitat type, when available
Source	Quelle	Source	Int	1, 2, 3, 4	code for data source 1: TLM, 2: WSL Modelling, 3: Combination of existing models, 4: Ruleset
Prob	Wahrscheinlichkeit	Probabilité	Int	1, 2, 3, 9999	Code for model probability 1: low probability, 2: medium probability, 3: high probability. Only for wetland, grassland, shrub forest (539, 54), arable land (8.2) and forest classes, all others have 9999 unknown
Cover	Anteil	Proportion	float	0.67, 0.82	Percentage area of polygon covered by this class according to the models. Only for wetland, grassland, shrub forest (539, 54), arable land (8.2) and forest classes, all others have 9999 unknown

2 Methods

2.1 Overall approach

The base data for the habitat map of Switzerland is the 1m resolution airborne orthoimagery. The overall general workflow for producing the Habitat Map is show in Figure 1. Within the software eCognition, the orthoimagery is segmented into 'image primitives' on the basis of the reflectance in the RGB and NIR bands, and values of the metric NDVI. In a rule-based approach, habitat types are assigned to segments based on the input data and distribution models, which, depending on habitat types, come from one of the four approaches listed above in section 1.2. If multiple habitat types could be potentially present within an image segment (according to the different distribution models), the assignment to a habitat class is in general based on majority coverage by area.

Once each image segment is assigned a habitat class within the eCognition software, segments are dissolved according to habitat type. Then, the segments are exported to ArcGIS for smoothing and cleaning. Finally, the

dataset is overlaid with small and detailed features, these are:

- TLM features of roads, buildings, railways, smaller river features (with a constant 1m buffer),
- Small scale land use features from TLM, see Table 3 for details
- Trees outside forest and shrubs and hedges identified from the SwissSurface3D data (see section 1.3.3)
- Urban area mapping using the SwissSurface3D data and aerial imagery, (see section 1.3.7)

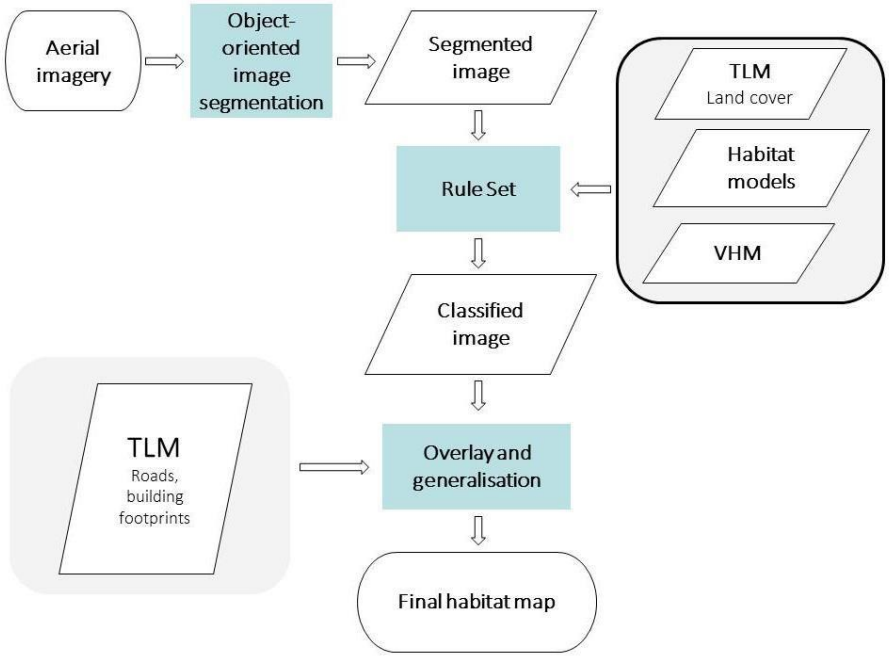

Figure 1: Overview of the methodological workflow for producing the Habitat Map of Switzerland

2.2 Method details

2.2.1 Approach 1: Nationwide existant datasets (TLM and LNF)

Table 3 details the habitat groups and types that are adopted directly from existant nationwide datasets, specifically the Topographic Landscape Model (TLM) and the harmonised crop datasets Landwirtschaftlichen Nutzflächen (LWN) and lists the source TLM datasets. The LWN data from 2021, 2022 and 2023 were combined by union into one dataset before being incorporated into the Habitat Map.

2.2.2 Approach 2: WSL Modelling

2.2.2.1 Wetlands (2.2, 2.3, 2.4), Grasslands (4.0, 4.2, 4.3, 4.4, 4.5, 4.6) and Dwarf Shrubs (5.4)

An ensemble modelling approach was used to model the distribution of wetland and grassland habitat types at the level of the habitat type (3rd level). Training data samples were compiled from various data sources, predominantly vegetation surveys. Sentinel 1 backscatter products and Sentinel-2 indices as well as variables describing climate, soil properties and topography were used as predictors. For inclusion into the Habitat Map, the maps of the individual habitat types (with the exception of snow bed communities, 4.4) were combined into an overall grassland and wetland habitat map differentiating 20 habitat types at a 10x10 m resolution. Full details can be found in Huber et al. (2023).

For the snow bed communities (4.4), the ensemble distribution maps were combined with polygons featuring long snow cover detected in the years 2016-2022 with high temporal resolution satellite imagery (Planet).

For dwarf shrubs (5.4), the same modelling procedure was applied as for the wetland and grassland habitat types. The training samples were provided from aerial image interpretation. As additional predictors, texture variables derived from the 1m resolution airborne ortho imagery were used. The models cover only the TypoCH types 5.4.3, 5.4.4 and 5.4.5, and are mapped as the group 5.4. In version 1.1 of the Habitat Map, *Juniperus sabina* dwarf shrub forest 5.4.2 was modelled separately and integrated into the map, see description below.

Table 3a: Included TLM data with source dataset and how each is translated to TypoCH. The dataset TLM_BODENBEDECKUNG is used in an initial coarse eCognition segmentation. Asterisked* classes are then further classified using the Methodological approaches 2, 3 or 4. All other TLM datasets indicated in the table are incorporated as an overlay, post eCognition processing.

TLM Dataset	OBJEKTART	Description	TYPOCH	TYPOCH_Name
TLM_BODENBEDECKUNG	1*	Fels with slope ≥ 45°	34	Felsen
TLM_BODENBEDECKUNG	1*	Fels with slope < 45°	33	Steinschutt- und Geröllfluren
TLM_BODENBEDECKUNG	2*	Fels locker	33	Steinschutt- und Geröllfluren
TLM_BODENBEDECKUNG	3*	Felsblöcke	33	Steinschutt- und Geröllfluren
TLM_BODENBEDECKUNG	4*	Felsblöcke locker	33	Steinschutt- und Geröllfluren
TLM_BODENBEDECKUNG	5	Fliessgewässer	12	Fliessgewässer
TLM_BODENBEDECKUNG	6	Gebüschwald	53	Gebüsche
TLM_BODENBEDECKUNG	7*	Lockergestein	33	Steinschutt- und Geröllfluren
TLM_BODENBEDECKUNG	8*	Lockergestein locker	33	Steinschutt- und Geröllfluren
TLM_BODENBEDECKUNG	9	Gletscher	31	Gletscher, Firn- und Schneefelder
TLM_BODENBEDECKUNG	10	Stehende Gewässer	11	Stehende Gewässer
TLM_BODENBEDECKUNG	11*	Feuchtgebiete	2	Feuchtgebiete
TLM_BODENBEDECKUNG	12*	Wald	6	Wälder
TLM_BODENBEDECKUNG	13*	Wald offen	6	Wälder
TLM_BODENBEDECKUNG	14*	Geholzfläche with VHM >3m, VHM<3m	600, 53	Nichtwaldbäume, Gebüsche
TLM_STRASSE	all	with Belegsart = 100	932	Asphalt- oder Betonstrasse
TLM_STRASSE	all	with Belegsart = 200	933	Naturstrasse, Weg
TLM_EISENBAHN	all		934	Bahngleis
TLM_GEBAEUDE_FOOTPRINT	all <> 16	Gebäude	92	Bauten
TLM_SPORTBAUTE	0 (with mean NDVI < 0.1)	Sportplatz	94	Versiegelter Sportplatz, Parkplatz usw.
TLM_SPORTBAUTE	1 (with mean NDVI > 0.1)	Sportplatz	402	Kunstrasen auf Sportplätzen, im Siedlungsraum usw.
TLM_STAUBAUTE	0	Staumauer	9	Bauten
TLM_VERKEHRSBAUTE	1	Staudamm	9	Bauten
TLM_VERKEHRSBAUTE	2	Wasserbecken	11	Stehendes Wasser
TLM_VERKEHRSBAUTE	3	Wehr	9	Bauten

TLM_VERKEHRSBAUTE	2	Graspiste	402	Kunstrasen auf Sportplätzen, im Siedlungsraum usw.
TLM_VERKEHRSBAUTE	3	Hartbelagpiste	932	Asphalt- oder Betonstrasse
TLM_VERKEHRSBAUTE	4	Perron	93	Verkehrswege
TLM_VERKEHRSBAUTE	5	Rollfeld Gras	402	Kunstrasen auf Sportplätzen, im Siedlungsraum usw.
TLM_VERKEHRSBAUTE	6	Rollfeld Hartbelag	932	Asphalt- oder Betonstrasse
TLM_VERKEHRSBAUTE	7	Schleuse	12	Fliessgewässer
TLM_NUTZUNGSAREAL	3	Baumschule	81	Baumschule, Obstgarten, Rebberge
TLM_NUTZUNGSAREAL	9	Kehrrichtverbrennungsareal	9	
TLM_NUTZUNGSAREAL	15	Obstanlage	81	Baumschule, Obstgarten, Rebberge
TLM_NUTZUNGSAREAL	17	Reben	816	Rebberge
TLM_NUTZUNGSAREAL	18	Schrebergartenareal	823	Hackfruchtacker (Sommerkultur), Garten
TLM_NUTZUNGSAREAL	23	Unterwerkareal	92	Fabrik, Halle, Lagerhaus (9243/4 Kraftwerk)
TLM_NUTZUNGSAREAL	5	Oeffentliches Parkplatzareal	94	versiegelter Sportplatz, Parkplatz, usw.
TLM_NUTZUNGSAREAL	*all others not included*			
TLM_VERKEHRSAREAL	10	Privates Parkplatzareal	94	versiegelter Sportplatz, Parkplatz, usw.
TLM_VERKEHRSAREAL	*all others not included*			
TLM_FREIZEIT_AREAL	*not included*			

Table 3b: Included LWN data and the translation to TypoCH. In Asterisked* classes only trees within these LWN polygon areas identified using swissSurface3D LiDAR data were classified to the TypoCH type, and not the entire areas.

LNF Nutzungcode	**Description**	**TYPOCH**	**TYPOCH_Name**
720*, 923*	Gepflegte Selven (Kastanienbäume), Kastanienbäume in gepflegten Selven	8.1.3	Kastanienhain (Selve, ohne Unterwuchs)
921*, 922*	Hochstamm-Feldobstbäume, Nussbäume	8.1.4	Hochstammobstgarten (Streuobstwiesen)
702, 703, 704, 730, 731	Obstanlagen (Äpfel), Obstanlagen (Birnen), Obstanlagen (Steinobst), Obstanlagen aggregiert, Andere Obstanlagen (Kiwi, Holunder usw.)	8.1.5	Niederstammobstgarten
701, 717, 722, 735	Reben, Rebflächen mit natürlicher Artenvielfalt, Baumschulen von Reben, Reben (regionsspezifische BFF)	8.1.6	Rebberg
705	Mehrjährige Beeren	8.1.7	Beerenkultur
501, 502, 504, 505, 506, 507, 508, 509, 511, 512, 513, 514, 515, 516, 519, 521, 522, 523, 524, 525, 526, 527, 528, 531, 534, 535, 536, 537, 538, 539, 541, 542, 543, 544, 545, 546,	Sommergerste, Wintergerste, Hafer, Triticale, Mischel Futtergetreide, Futterweizen, Körnermais, Reis, Emmer, Einkorn, Sommerweizen (ohne Futterweizen), Winterweizen (ohne Futterweizen), Roggen, Mischel Brotgetreide, Dinkel, Saatmais, Silo- und Grünmais, Zuckerrüben, Futterrüben, Kartoffeln, Pflanzkartoffeln, Sommerraps zur Speiseölgewinnung, Winterraps zur Speiseölgewinnung, Soja, Sonnenblumen zur Speiseölgewinnung, Lein, Hanf, Ackerbohnen zu Futterzwecken, Eiweisserbsen zu Futterzwecken, Lupinen zu Futterzwecken, Ölkürbisse, Tabak, Hirse, Getreide siliert, Leindotter, Einjährige Freilandgemüse, ohne	8.2	Feldkulturen (Äcker)

547, 548, 549, 550, 551, 552, 553, 554, 566, 567, 568, 569, 572, 573, 574, 590, 591, 592, 594, 595, 597, 598, 601, 602, 631, 632, 705, 706, 707, 708, 709, 710, 721, 725, 750, 797, 909	Konservengemüse, Freiland-Konservengemüse, Wurzeln der Treibzichorie, Buchweizen, Sorghum, Übrige Ackerfläche, Einjährige Beeren (z.B. Erdbeeren), Einjährige nachwachsende Rohstoffe (Kenaf, usw.), Einjährige Gewürz- und Medizinalpflanzen, Einjährige gärtnerische Freilandkulturen (Blumen, Rollrasen usw.), Mohn, Saflor, Linsen, Mischungen von Ackerbohnen, Eiweisserbsen und Lupinen mit Getreide, Blühstreifen für Bestäuber und andere Nützlinge, Senf, Quinoa, Sommerraps als nachwachsender Rohstoff, Winterraps als nachwachsender Rohstoff, Sonnenblumen als nachwachsender Rohstoff, Offene Ackerfläche, beitragsberechtigt (regionsspezifische BFF), Übrige offene Ackerfläche, nicht beitragsberechtigt (regionsspezifische BFF), Übrige offene Ackerfläche, beitragsberechtigt, Übrige offene Ackerfläche, nicht beitragsberechtigt, Kunstwiesen (ohne Weiden), Übrige Kunstwiese, beitragsberechtigt (z.B. Schweineweide, Geflügelweide), Futterleguminosen für die Samenproduktion, Futtergräser für die Samenproduktion, Mehrjährige Beeren, Mehrjährige Gewürz- und Medizinalpflanzen, Mehrjährige nachwachsende Rohstoffe (Chinaschilf, usw.), Hopfen, Rhabarber, Spargel, Mehrjährige gärtnerische Freilandkulturen (nicht im Gewächshaus), Permakultur, Übrige Dauerkulturen, beitragsberechtigt, aggregiert, Übrige Flächen mit Dauerkulturen, beitragsberechtigt, Hausgärten		
801, 802, 803, 804, 807, 808, 810, 811, 812, 813, 814, 830, 847, 848, 849	Gemüsekulturen in Gewächshäusern mit festem Fundament, Übrige Spezialkulturen in Gewächshäusern mit festem Fundament, Gärtnerische Kulturen in Gewächshäusern mit festem Fundament, Beerenkulturen in Gewächshäusern mit festem Fundament, Übrige Spezialkulturen in geschütztem Anbau ohne festes Fundament, Gärtnerische Kulturen in geschütztem Anbau ohne festes Fundament, Pilze in geschütztem Anbau mit festem Fundament, Gemüsekulturen in geschütztem Anbau ohne festes Fundament; im gewachsenen Boden, Gemüsekulturen in geschütztem Anbau ohne festes Fundament; auf Pflanztischen oder -gestellen, Beerenkulturen in geschütztem Anbau ohne festes Fundament; im gewachsenen Boden, Beerenkulturen in geschütztem Anbau ohne festes Fundament; auf Pflanztischen oder -gestellen, Kulturen in ganzjährig geschütztem Anbau, beitragsberechtigt aggregiert, Übrige Kulturen in geschütztem Anbau ohne festes Fundament, beitragsberechtigt, Übrige Kulturen in geschütztem Anbau mit festem Fundament, Übrige Kulturen in geschütztem Anbau ohne festes Fundament, nicht beitragsberechtigt	9.2.2	Gewächshäuser

2.2.2.2 Shrub forest (5.3.9, 5.4)

Models of the distribution of Green alder shrub forest (TypoCH 5.3.9) and mountain pine shrubs (*Pinus mugo* ssp. *mugo*) developed by Rüetschi et al (2021); Weber et al (2021) were integrated into the Habitat Map. Thereby, the mountain pine shrubs were added as TypoCH 5.4 to the ensemble models described in *2.2.2.1*. The shrub models are random forest models, using NFI plot and image interpretation training data, and VHM, Sentinel 1 and 2 satellite imagery explanatory data. Methodological details can be found in Rüetschi et al. (2021) and Weber et al. (2021).

2.2.3 Approach 3: Combination of existing models

Mapping of class 6 Forest habitat types relied on existing spatially explicit models of forest tree species. Within the WSL, there are a number of previous and ongoing projects mapping distributions of forest species/communities/types (e.g., Wüest and Baltensweiler 'Modellierte Verbreitungskarten für die häufigsten Gehölzarten der Schweiz' (MoGLI); Waser et al. 'Exploiting the full potential of Copernicus Sentinel data for countrywide tree species mapping'; Scherrer et al. 'Modelling of potential natural forest communities across Switzerland based on NFI-Data'). Therefore, instead of building new models within this project, we relied on the existing modelling outputs from the MoGLI project (Wüest el al. 2021), with a view to improving the mapping of forest habitats as the results of the ongoing projects are released in the coming years.

The MoGLI project modelled the 70 most common tree species of Switzerland. For each of the TypoCH forest habitat types at the second level, we identified the character and indicator species for which a MoGLI model was available. We then combined these models so that the distribution of the habitat type was defined as the areas where the distribution models of all available character and indicator species intersected one another.

2.2.4 Approach 4: Rulesets

Some habitat types are defined using a rule-based approach within the eCognition classification. Here, auxiliary datasets including the Digital Terrain Model (25m resolution), Vegetation Height Models of 2012 and 2019, and time series of growing season NDVI derived from 4 years (2017-2020) of Sentinel-2 imagery are used as input to classification rules. These rules are summarised in Table 4 for the relevant habitat classes.

Table 4: eCognition Ruleset

TypoCH	**Classification rule**
4.1 Pionierfluren auf Felsböden	TLM_BB Fels (1, 2, 3, 4) with median growing season NDVI (Sentinel-2) > 0.2 and <0.45 and slope <45 degrees
5.2 Hochstauden- und Schlagfluren	TLM_BB Forest (12,13) with mean VHM 2012 > 3m and mean VHM 2019 <3m
5.3.0 Hecken und Gebüsche ausserhalb Gebüschwald	No classification in the TLM_BB with median VHM 2019 >1.5m and median VHM2019 <3m mean NDVI (aerial imagery) > 0.2
6.0.0 Nichtwaldbäume	No classification in the TLM_BB with median VHM 2019 >3m and mean NDVI (aerial imagery) > 0.2
7.1 Trittrasen und Ruderalfluren	Areas modelled as 4.6 Grasbrachen outside of Wallis and urban areas

Separately, rulessets were also used to define habitats in urban areas, and for trees and shrubs outside forest within the available area of SwissSurface3D data. The overall approach is described in sections 1.3.3 and 1.3.7, the classification rules using SwissSurface3D, aerial imagery, and Planet data are summarised in Table 5.

Table 5: other Rulesets,. Where MaxVH = maximum vegetation height from ALS pint clouds, NDVI = normalised difference vegetation index, VCI = vegetation complexity index

TypoCH	Classification rule
Urban Areas (Siedlungsgebiete)	
4000.1 Rasen, dynamisch	Green mask areas (see section 1.3.7) AND mean NDVI > 0.25 OR ALS classification 3,4 or 5 mean MaxVH >= 0.5 m with mean standard deviation Planet NDVI > 890
4000.2 Rasen, mittel dynamisch	Green mask areas (see section 1.3.7) AND mean NDVI > 0.25 OR ALS classification 3,4 or 5 mean MaxVH >= 0.5 m with mean standard deviation Planet NDVI > 460 and NDVI <= 890
4000.3 Rasen, nicht dynamisch	Green mask areas (see section 1.3.7) AND mean NDVI > 0.25 OR ALS classification 3,4 or 5 mean MaxVH >= 0.5 m with mean standard deviation Planet NDVI <= 460
6000.0 Einzelbaum, nicht-komplexe Struktur	ALS classification 3,4 or 5 MaxVH >= 3 m and segment size >= 25 m^2 VCI <= 0.72
6000.1 Einzelbaum, komplexe Struktur	ALS classification 3,4 or 5 MaxVH >= 3 m and segment size >= 25 m^2 VCI > 0.72
5.3 Hecken und Gebüsche	Mean MaxVH >= 0.5m and <3m
9221 Gründach	Roof segment with number of flat pixels > 20 and mean NDVI > 0.2
Outside forest (NFI forest mask) and urban areas	
5 Krautsäume, Hochstaudenfluren und Gebüsche	ALS classification 3,4 or 5 Mean MaxVH >= 0.5m and <3m Area > 6 m^2
6.0 Einzelbäume und Forstpflanzungen	ALS classification 3,4 or 5 Mean MaxVH >= 3m Area > 6 m^2

2.2.5 Cover and Probability

Probability

Probability was calculated for those habitats that were modelled within the project (Methods 2 or 3).

For Cropland (Group 8.2), Wetland and Grassland (Classes 2 and 4) and shrubs (5.3.9 and 5.4), a probability of occurrence was derived directly from the Random Forest or ensemble models. In each case, a mean probability was calculated for each eCognition segment. These probabilities were reclassified to 3 classes so that probability 0-0.5 = 1, 0.5-0.75 = 2 and greater than 0.75 = 3.

For forest habitat types, probability 3 (high likelihood) is assigned to pixels where the MoGLI distribution for all available indicator and character species for the habitat type overlap. Probability class 2 is assigned to pixels that were classified to a given habitat type due to being within a segment with majority cover of that habitat type according to the combined MoGLI model, but not containing all of the indicator and character species distributions itself. All other forest pixels were assigned the low probability class (1). These are, for example, segments assigned to a given habitat type because of their neighbourhood classification.

Cover

As with Probability, the Cover variable was calculated for the habitat types that were modelled within the project. We are three combination maps: grassland and wetland, Shrub Forest and Forest, within which each pixel contains only one habitat type. Then, the Cover variable for the habitat type assigned was derived from a calculation of the percentage area of the eCognition segment polygon in which the assigned habitat type was predicted to be present.

2.2.6 Validation

For the habitat types modelled with approach 2, model validation was performed against independent data (see publications for details (Huber et al., 2023; Pazur et al. 2022; Rüetschi et al. 2021; Weber et al 2021).

In addition, plausibility analyses were performed within the project with a group of expert stakeholders. This included two expert workshops and numerous validation analyses on case areas for locations that were well known to the experts, as well as methodological discussions.

3 Discussion

3.1 Limitations

Users should be aware of the following limitations of the dataset:

- the map does not represent vegetation surveys in the field, but relies on modelled and rule based assignment of habitat types
- it is made with nation-wide available data; thus may not able to represent regional distinctions (for some regions better, for others worse)
- habitat types are not mapped completely (i.e., not all bushes/hedges included)
- not all habitats are represented; and not all with same precision
- in urban areas a limited habitat typology is mapped due to the large degree of human modification of those landscapes.
- New detailed mapping of trees and shrubs outside forest and urban areas is dependent on SwissSurface3D aerial laser scanning data which is not currently available Swisswide, thus this mapping is limited to the area of SwissSurface3D. Outside of that area the mapping has not been updated, but will be in the next version once the remainder of the SwissSurface3D data is available.
- The map is only applicable within the border of Switzerland.

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