Bern University
of Applied Sciences

OpenGeoHUB

Mastering Machine Learning for Spatial Prediction

Quick teaser and an application

OpenGeoHub Summer School
20 August 2020

Madlene Nussbaum

on myself ...

- **Geographer** with diploma and PhD in applied statistics
- Current position: **Bern University of Applied Sciences** (BFH ≠ UniBE), Section for Agronomy. Research group "soil protection and land use".

- **Focus**:
  Interdisciplinary research at the intersection of GIS, soil science and statistics. Predictive (spatial) modelling, data handling in field survey, visualisations etc.
  Moreover: foster knowledge transfer and **encourage FOSS**!
- Main language: **R**
- Further I fancy: QGis, Latex, SAGA, GRASS, OpenLayers, PostGIS, Inkscape, Git, Debian

Teaser of today's programme ...

11:00 – 13:00

Mastering machine learning for spatial prediction I

Basic concepts, an overview and introduction of widespread methods like shrinkage, generalized additive models, tree based methods, neural networks, support vector machines. Concepts like bootstrap, boosting and model averaging.

14:00 – 16:00

Mastering machine learning for spatial prediction II

Covariate selection with importance, interpretation of covariate-response relationships with partial dependence plots and maps, uncertainty of model predictions by bootstrapping

→ both: first lecture then hands-on exercises

For you inspiration...

a real world application from my current projects.

Exploit old soil maps to predict soil properties in unmapped areas

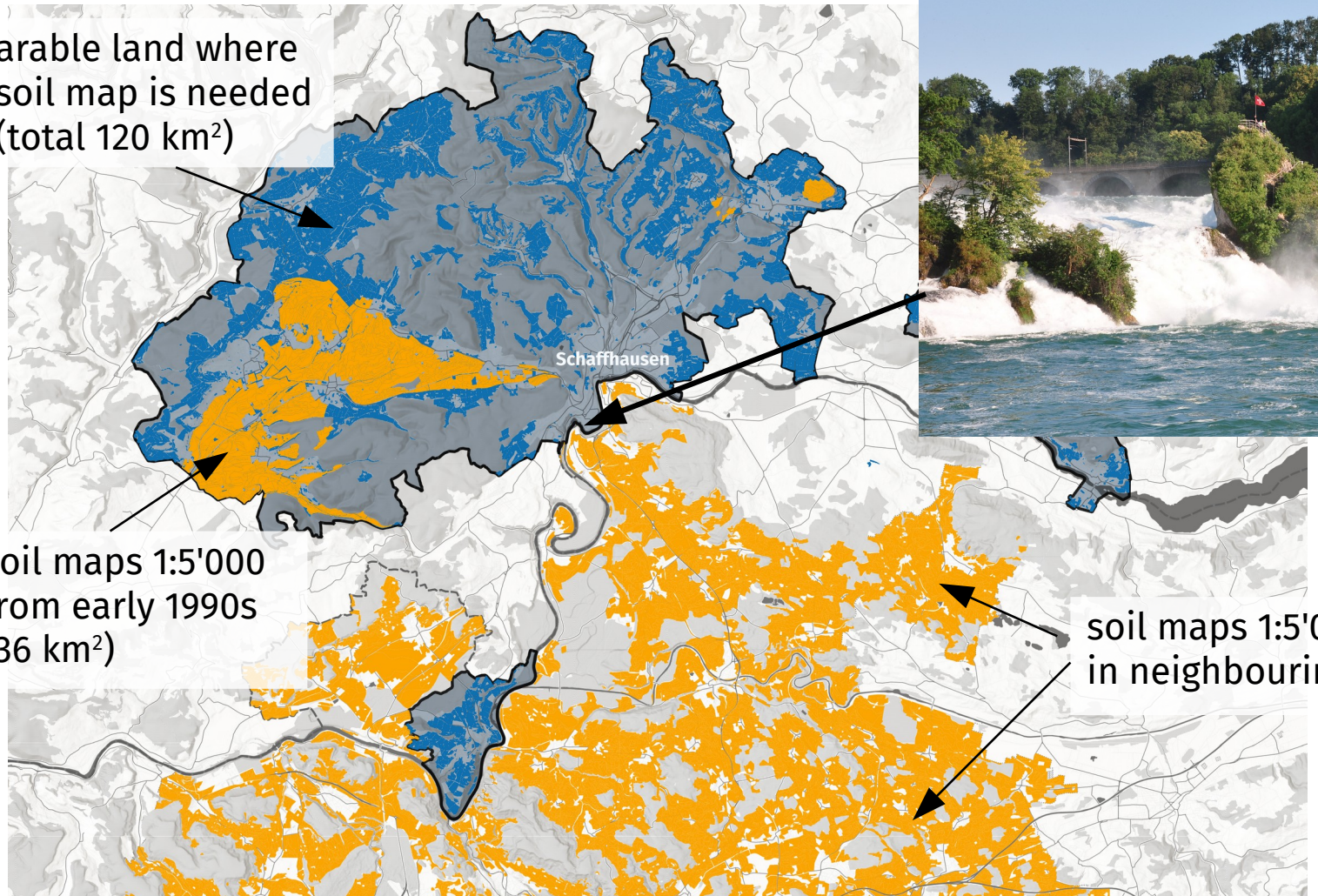
Soil maps Schaffhausen

needed for agricultural area needed.

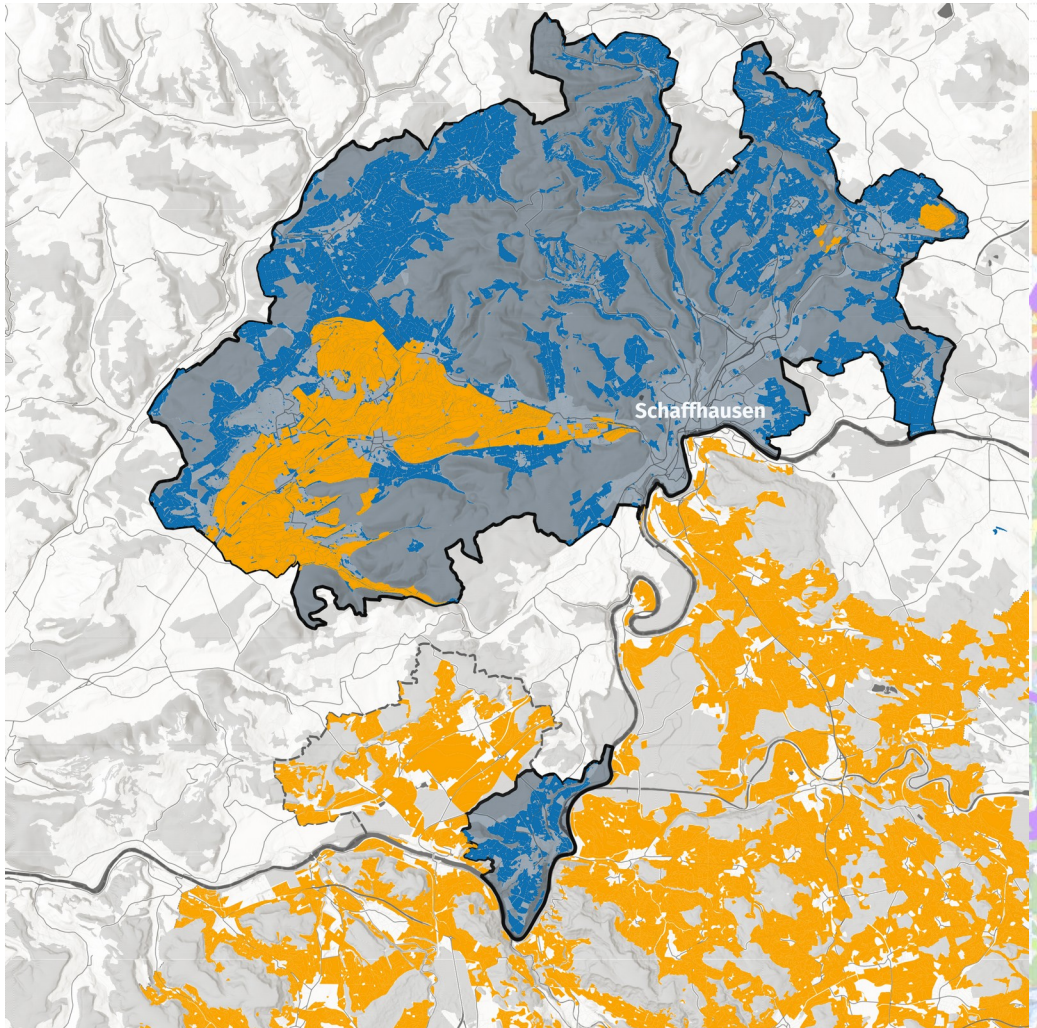
Main focus:

- tax values of land
- protection of good quality arable land

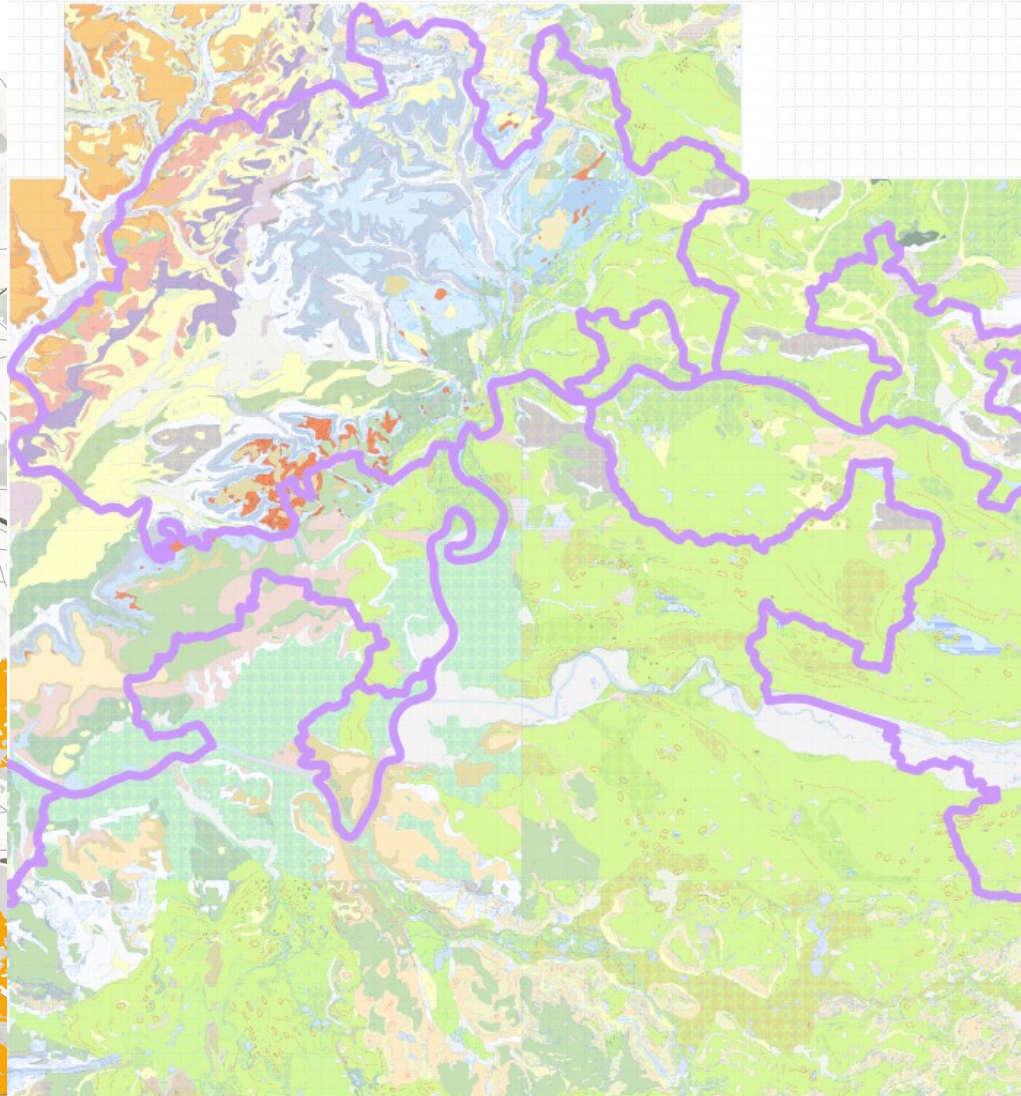
Situation in Schaffhausen



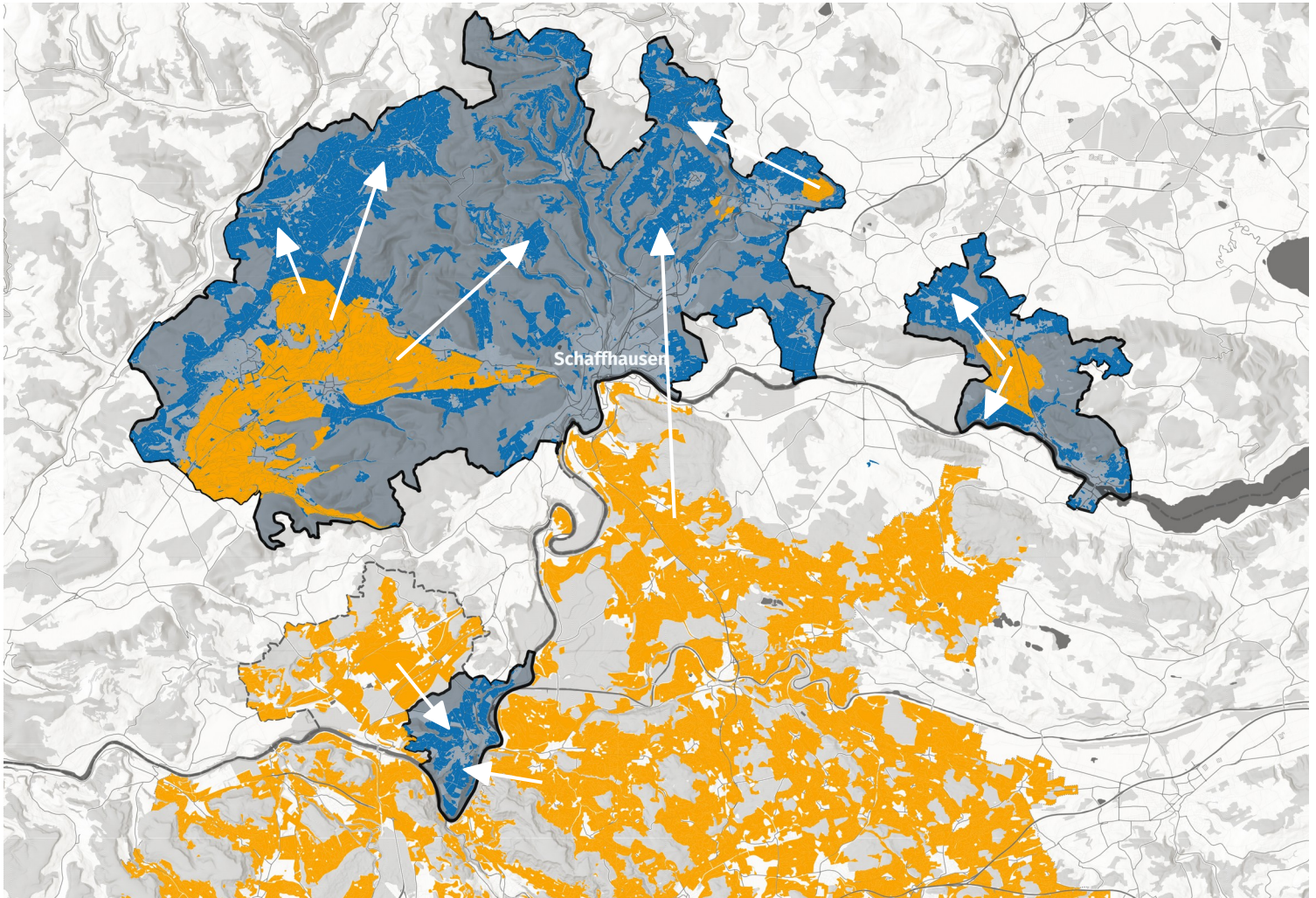
Situation in Schaffhausen

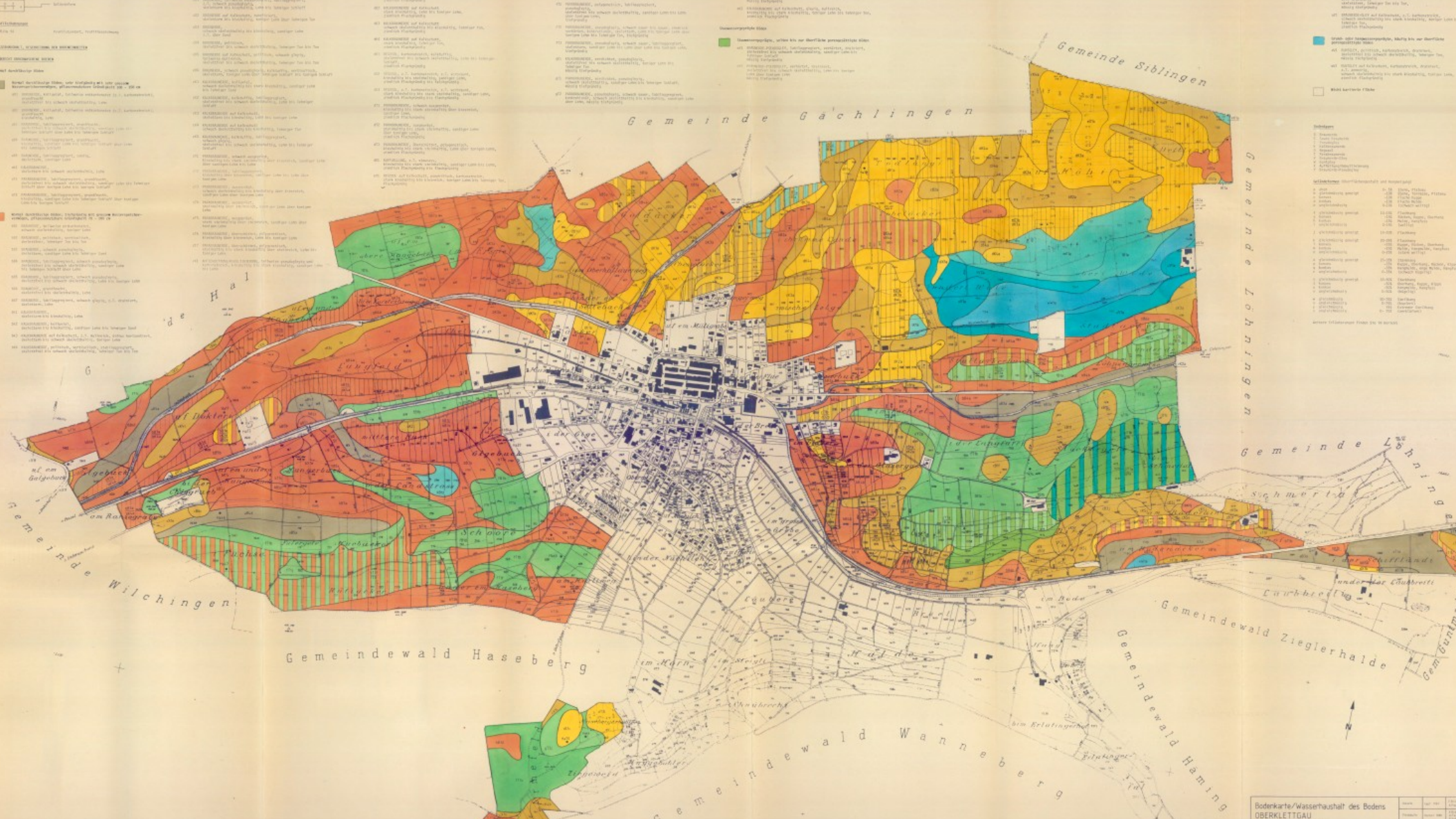


Geological Maps 1:25'000



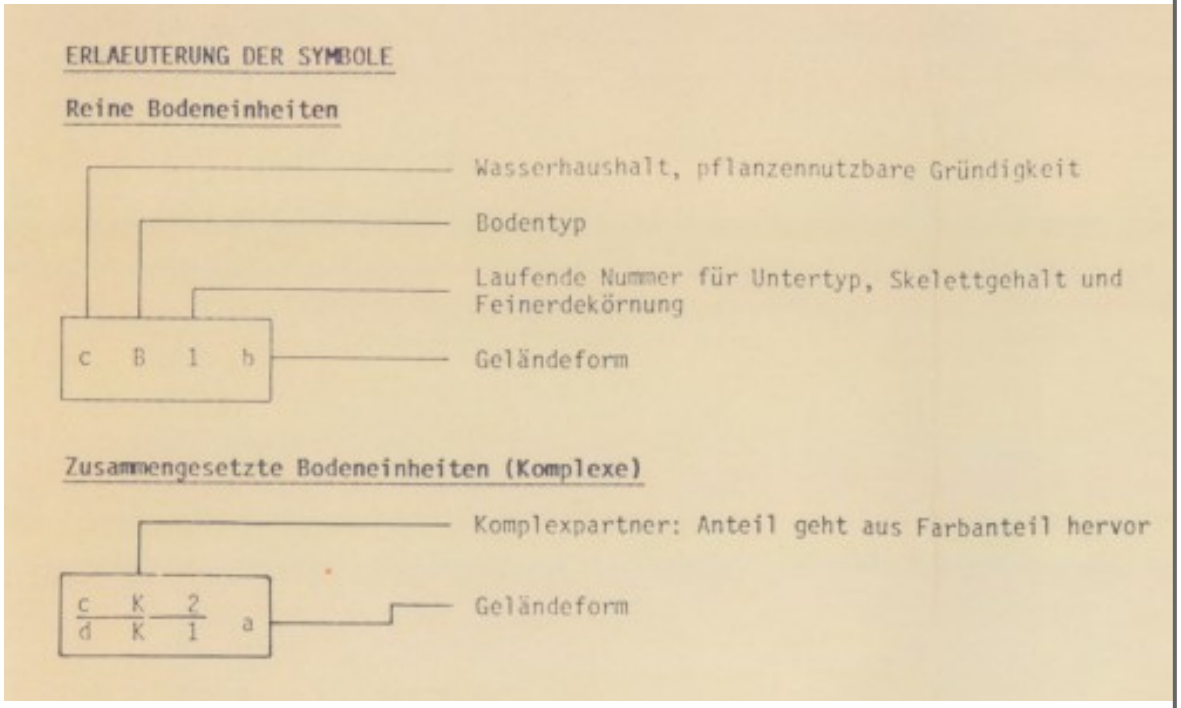
Extrapolating into non-mapped areas





Bodenkarte/Wasserhaushalt des Bodens
OBERKLETTGAU

Content of old soil map



For each of these legend codes:
further information in bocklet (prose)

aB3 BRAUNERDE, labilaggregiert, grundfeucht, skelettfrei bis schwach skeletthaltig, sandiger Lehm bis lehmiger Schluff über Lehm bis lehmigem Schluff

aB4 BRAUNERDE, labilaggregiert, grundfeucht, kieshaltig, sandiger Lehm bis lehmiger Schluff über Lehm bis lehmigem Schluff

aB5 BRAUNERDE, labilaggregiert, sandig, skelettarm, sandiger Lehm

aK1 KALKBRAUNERDE, skelettarm bis schwach skeletthaltig, Lehm

aT1 PARABRAUNERDE, labilaggregiert, grundfeucht, skelettfrei bis schwach skeletthaltig, sandiger Lehm bis lehmiger Schluff über tonigem Lehm bis tonigem Schluff

aT2 PARABRAUNERDE, labilaggregiert, grundfeucht, kieshaltig, sandiger Lehm bis lehmiger Schluff über tonigem Lehm bis tonigem Schluff

Normal durchlässige Böden; tiefgründig mit grossem Wasserspeicher-vermögen, pflanzennutzbare Gründigkeit 70 - 100 cm

bB1 BRAUNERDE, teilweise entkarbonatet, schwach skeletthaltig, toniger Lehm

bB2 BRAUNERDE, pelitisch, vertisolisch, skelettfrei, lehmiger Ton bis Ton

bB3 BRAUNERDE, schwach pseudogleyig, skelettarm, sandiger Lehm bis lehmiger Sand

bB4 BRAUNERDE, labilaggregiert, schwach pseudogleyig, skelettfrei bis schwach skeletthaltig, sandiger Lehm bis lehmiger Schluff über Lehm

bB5 BRAUNERDE, labilaggregiert, schwach pseudogleyig, skelettfrei bis schwach skeletthaltig, Lehm bis toniger Lehm

bB6 BRAUNERDE, grundfeucht, skelettfrei bis skeletthaltig, Lehm

bB7 BRAUNERDE, labilaggregiert, schwach gleyig, z.T. drainiert, skelettarm, Lehm

bK1 KALKBRAUNERDE, skelettarm bis kieshaltig, Lehm

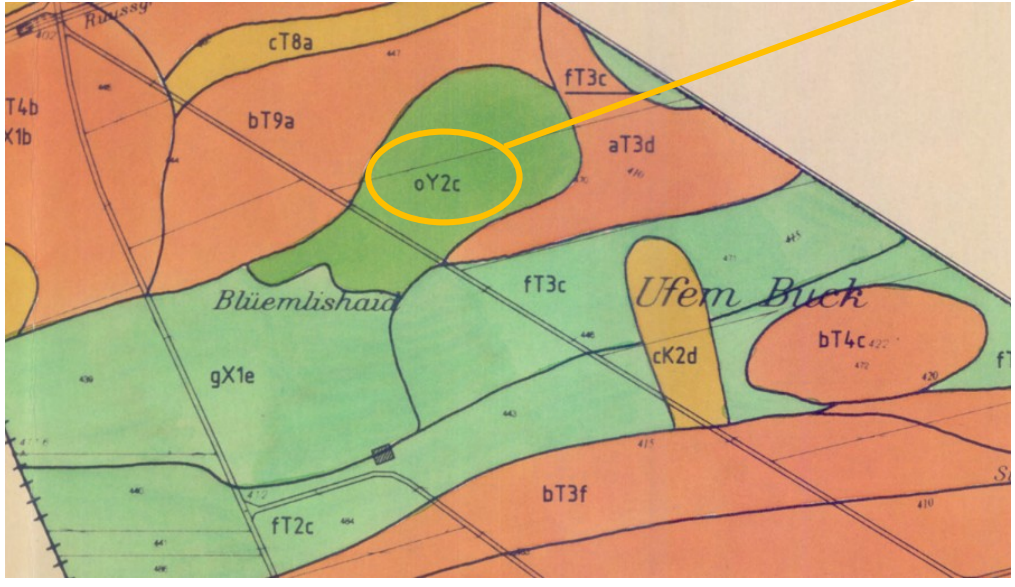
bK2 KALKBRAUNERDE, kolluvial, skelettarm bis kieshaltig, sandiger Lehm bis lehmiger Sand

bK3 KALKBRAUNERDE auf Kalkschutt, z.T. mullreich, diffus horizontiert, skelettarm bis schwach skeletthaltig, toniger Lehm

bK4 KALKBRAUNERDE, pelitisch, vertisolisch, stabilaggregiert, skelettfrei bis schwach skeletthaltig, lehmiger Ton bis Ton

Legacy soil maps

scale 1:5'000
200 soil profiles in Swiss soil database
→ many augerings, only recorded as polygons



Legend booklet

STAUWASSERGEPRAEGTE BOEDEN

selten bis zur Oberfläche porengesättigte Böden

oY1 BRAUNERDE-PSEUDOGLEY, labilaggregiert, verhärt
skelettfrei bis schwach skeletthaltig, sandige
lehmiger Schluff, mässig tiefgründig

oY2 BRAUNERDE-PSEUDOGLEY, verhärtet, drainiert,
skelettfrei bis schwach skeletthaltig, Lehm bi
Lehm über tonigem Lehm, mässig tiefgründig

Stauwassergeprägte, häufig bis zur Oberfläche poren

qI1 PSEUDOGLEY, labilaggregiert, verhärtet, draini
schwach skeletthaltig, Lehm bis lehmiger Schlu

Tables with value ranges

Skelettklasse	Skelettgehalt Vol. %
skelettfrei	< 5
schwach skeletthaltig	5 - 10
kieshaltig*	10 - 20
steinhaltig	10 - 20
stark kieshaltig*	20 - 30
stark steinhaltig	20 - 30
kiesreich*	30 - 50

Legacy soil maps

harvested soil properties

pH		carbonates		gravel %		topsoil clay %		subsoil clay %		topsoil silt %		subsoil silt %		soil depth	
from	to	topsoil	subsoil	from	to	from	to	from	to	from	to	from	to	from	to
.1	7	part.	yes	0	10	20	30	20	30	0	50	0	50	100	150
.1	7	part.	yes	10	20	20	30	20	30	0	50	0	50	100	150
.1	7	no	yes	0	10	10	20	10	30	0	100	0	100	100	150
.1	7	no	yes	10	20	10	20	10	30	0	100	0	100	100	150
.1	7	no	yes	0	5	5	20	10	20	0	50	0	50	100	150
.1	7	no	yes	0	5	40	50	40	60	0	50	0	50	100	150
.1	7	no	yes	10	20	40	60	40	60	0	50	0	50	100	150
7	8	yes	yes	0	10	20	30	20	30	0	50	0	50	100	150
7	8	yes	yes	5	20	50	60	50	60	40	50	0	50	100	150
.3	7	no	no	0	10	10	20	30	40	0	100	0	100	100	150
.3	7	no	no	10	20	10	20	30	40	0	100	0	100	100	150
.3	7	no	no	0	5	10	20	20	30	0	50	0	50	100	150
.1	7	no	yes	5	10	30	40	30	40	0	50	0	50	70	100
.1	7	no	yes	0	0	50	60	40	50	40	50	0	50	70	100
.1	7	no	yes	0	5	5	20	2	20	0	50	0	50	70	100
.1	7	no	no	0	10	10	20	20	30	0	100	0	50	70	100
.1	7	no	yes	0	10	20	40	20	40	0	50	0	50	70	100
.1	7	no	yes	0	20	20	30	20	30	0	50	0	50	70	100
.1	7	no	yes	5	10	20	30	20	30	0	50	0	50	70	100
.1	7	no	yes	0	5	10	20	10	25	0	50	0	50	70	100

Legend booklet

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selten bis zur Oberfläche porengesättigte Böden

oY1 BRAUNERDE-PSEUDOGLEY, labilaggregiert, verhärt
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lehmiger Schluff, mässig tiefgründig

oY2 BRAUNERDE-PSEUDOGLEY, verhärtet, drainiert,
skelettfrei bis schwach skeletthaltig, Lehm bi
Lehm über tonigem Lehm, mässig tiefgründig

Stauwassergeprägte, häufig bis zur Oberfläche poren

qI1 PSEUDOGLEY, labilaggregiert, verhärtet, draini
schwach skeletthaltig, Lehm bis lehmiger Schlu

Tables with value ranges

Skelettklasse	Skelettgehalt Vol. %
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kieshaltig*	10 - 20
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stark kieshaltig*	20 - 30
stark steinhaltig	20 - 30
kiesreich*	30 - 50

Complex soil map polygons

- small scale variability
- 2-3 units in one map polygon
- Ratio according to colouring
  → could not be bothered to measure..
- Used default ratios from other soil map:
  2 units: 60 - 40 %
  3 units: 50 - 30 - 20 %

Create “virtual samples” as real samples have not been recorded

Create response vector by

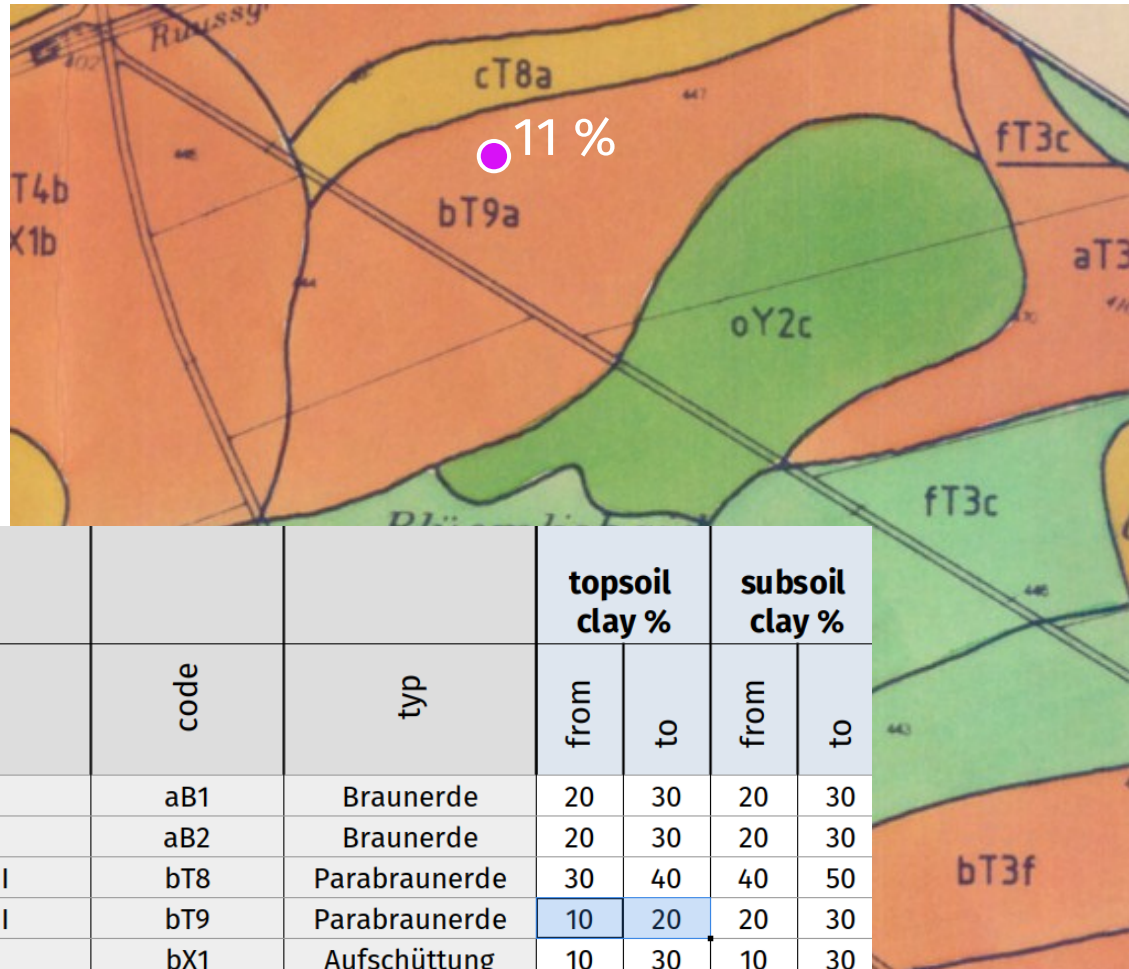
1. Select a point sample with 4 sampling strategies

2. For complex polygons (>1 map units): sample unit code by weights

3. Assign value out of range in legend (uniform distribution)

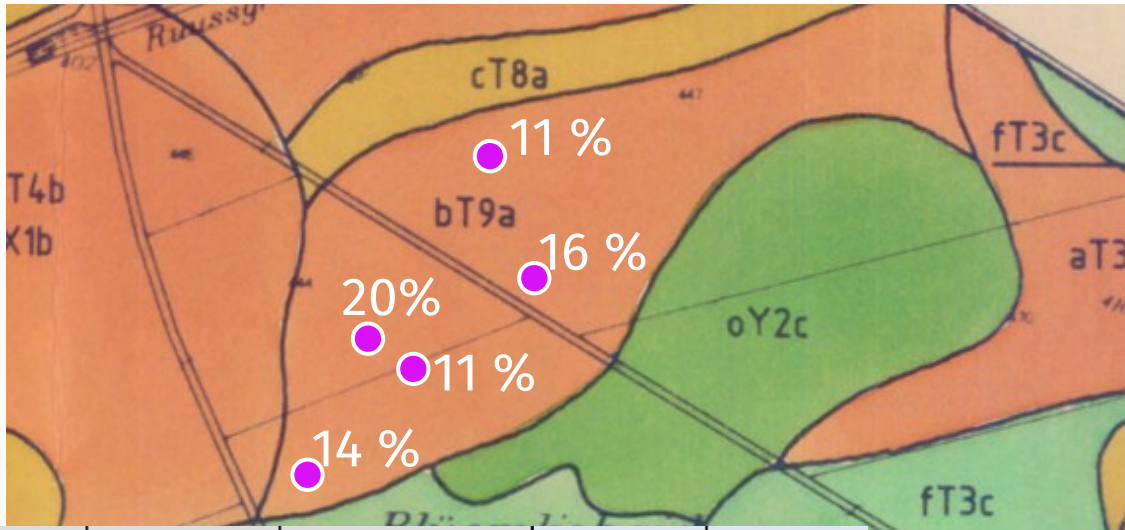
→ Repeated 30 times for each sampling strategy.

Following DSMART-Algorithm (Odgers et al. 2014).



			topsoil clay %		subsoil clay %	
bericht	code	typ	from	to	from	to
Klettgau I	aB1	Braunerde	20	30	20	30
Klettgau I	aB2	Braunerde	20	30	20	30
Klettgau II	bT8	Parabraunerde	30	40	40	50
Klettgau II	bT9	Parabraunerde	10	20	20	30
Klettgau I	bX1	Aufschüttung	10	30	10	30

Create “virtual samples” as real samples have not been recorded



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Klettgau I	bX1	Aufschüttung	10	30	10	30

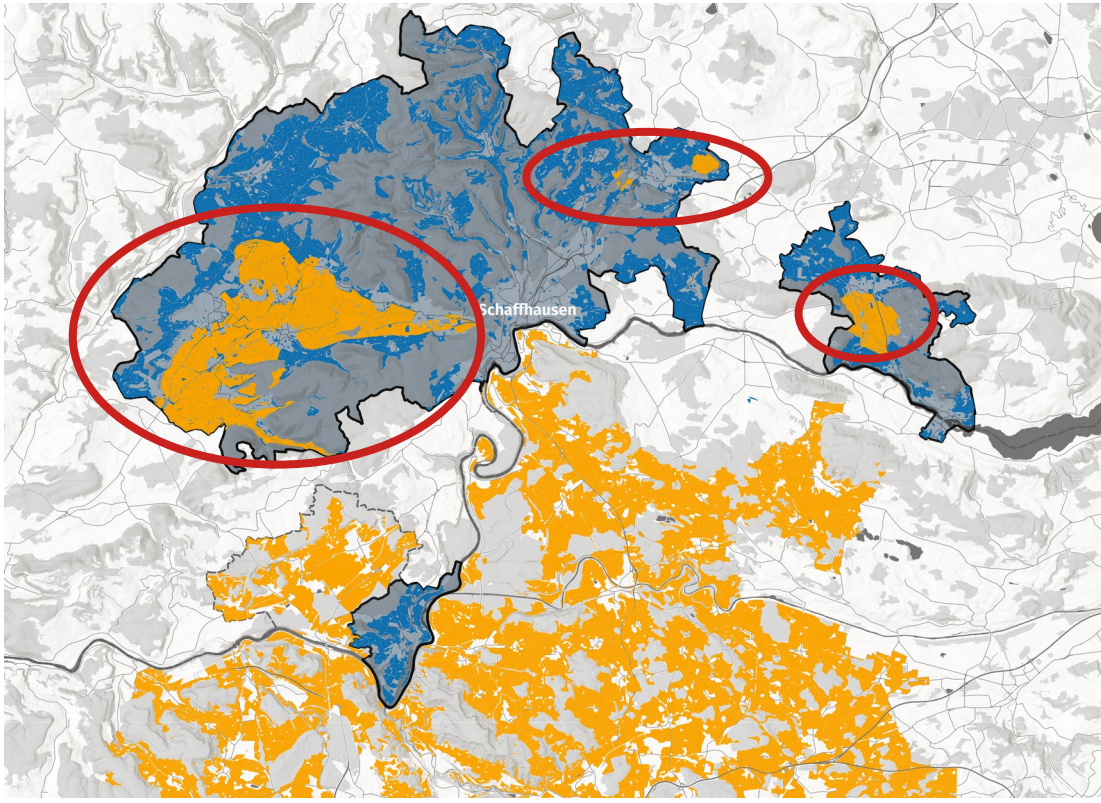
Different sampling designs

- Simple random sample
  - soil maps Zurich and Schaffhausen
  - only soil maps Schaffhausen

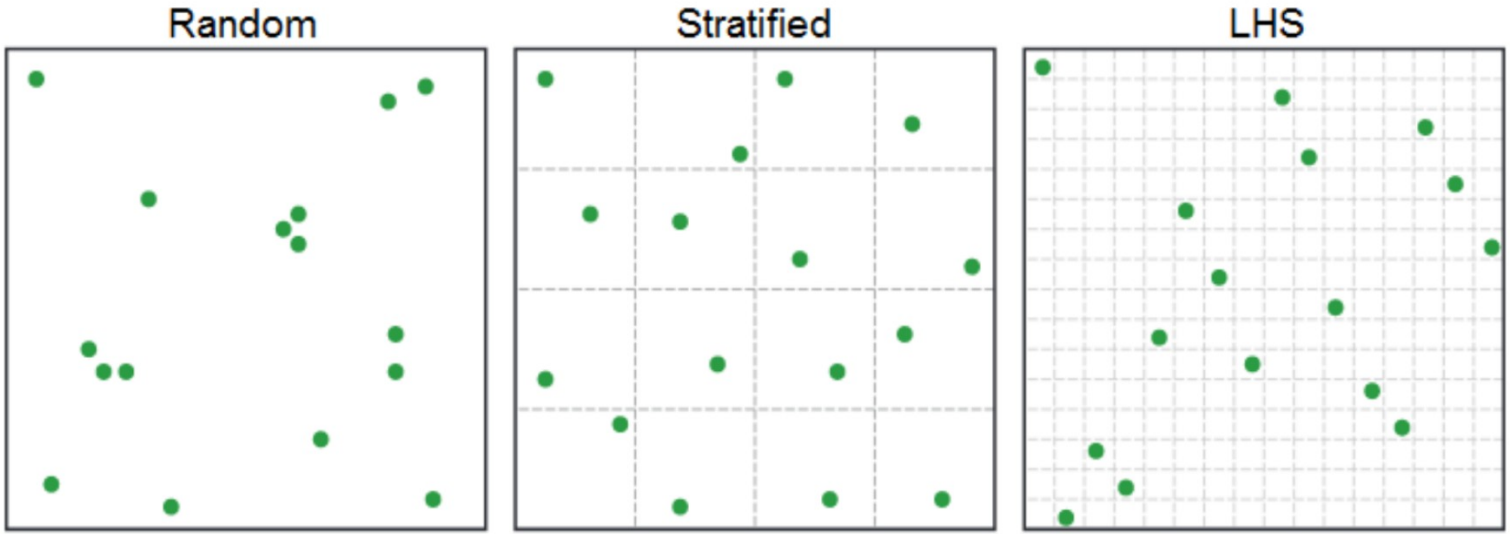
- Stratified random sample
  → Strata: geological units
  → Weights: area per unit in agricultural land to be mapped

- Conditional Latin Hypercube Sampling

- number of virtual samples:
  1 000 / 3 000 / 6 000 / 10 000 / 35 000



Different sampling designs



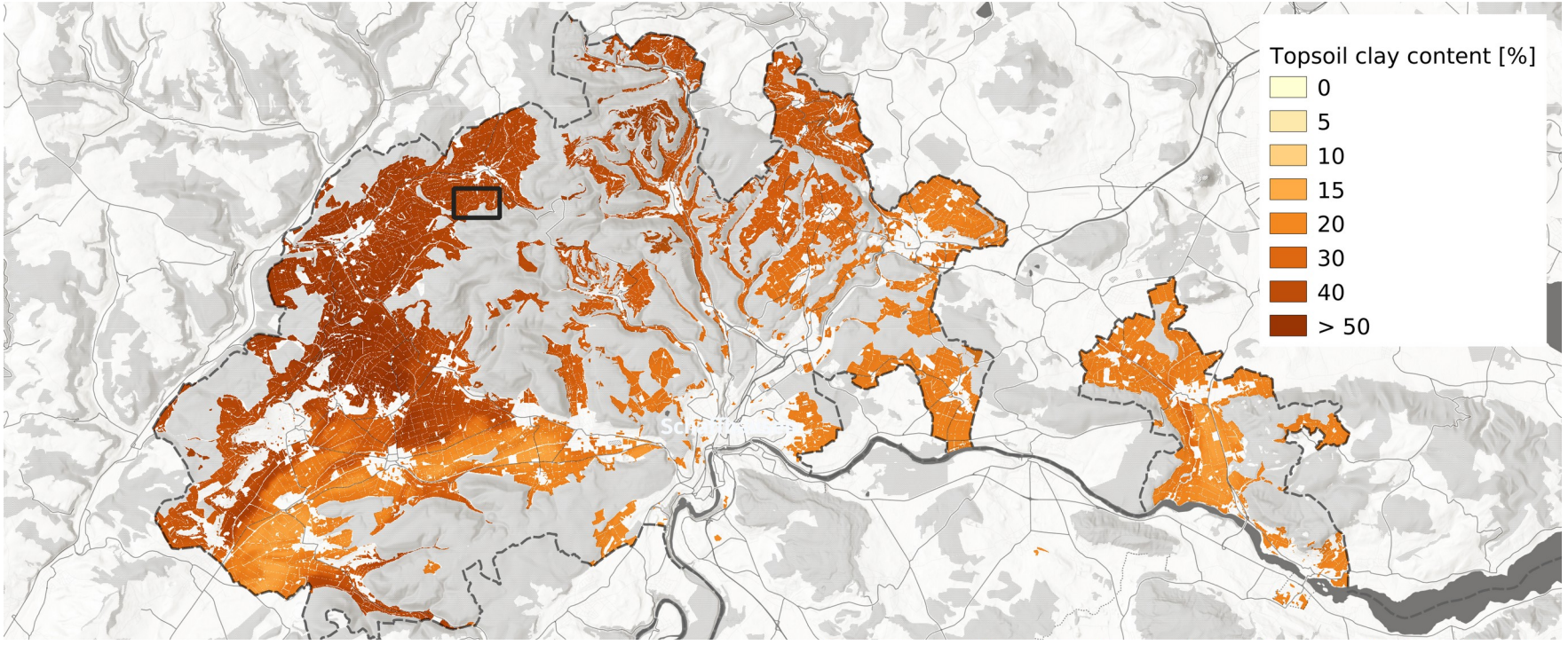
LHS: conditioned latin hypercube sampling

- Number of strata = number of samples to be taken
- Hypercube: stratification on many covariates possible
- Conditioned: only combinations that actually exist are sampled
- Every combination only once → like a Sudoku

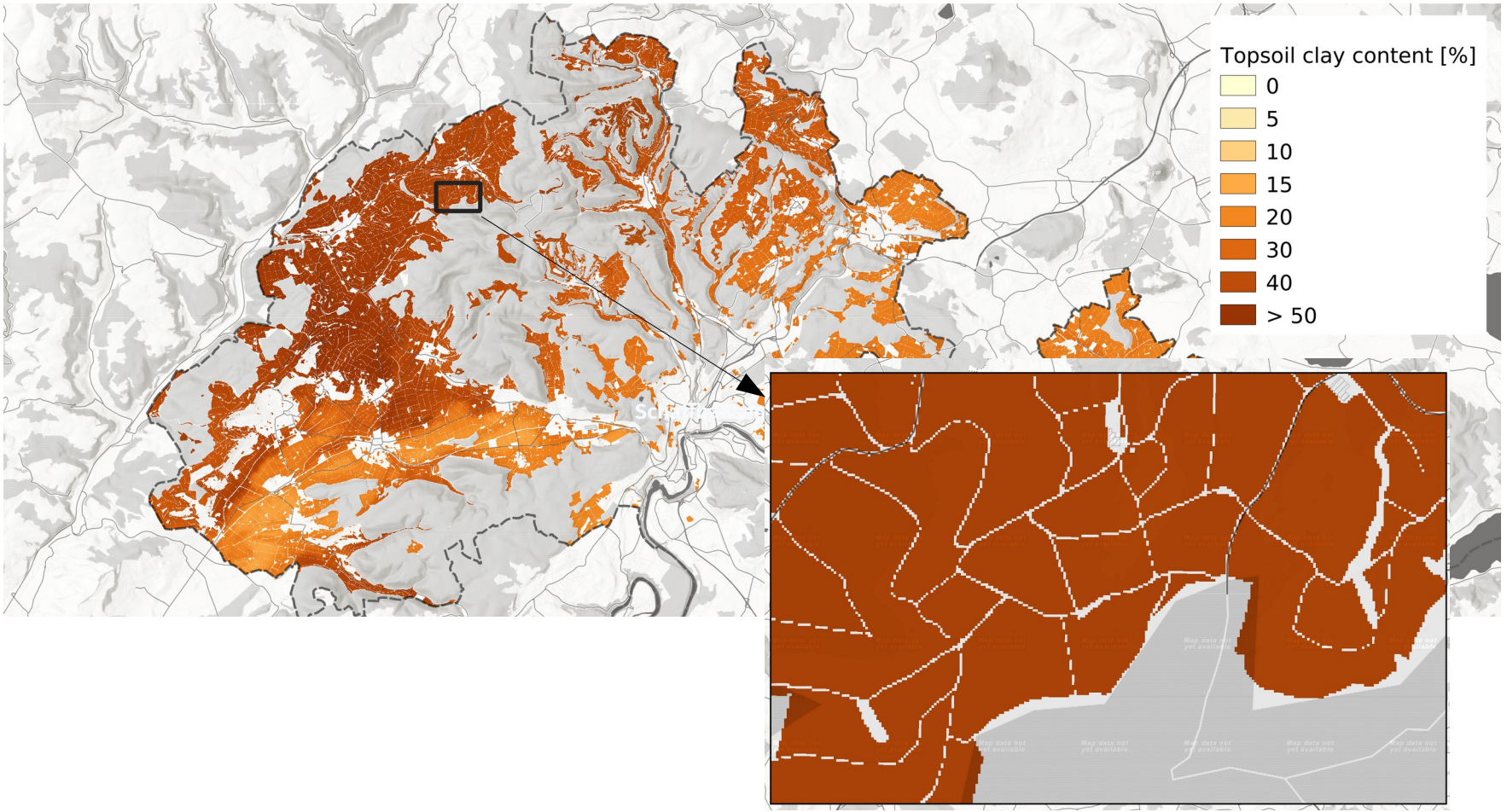
Modelling

- 30 repetitions of sampling procedure for each sampling strategy
- Separate models for each soil property and each repetition
- Model:
  Random Forest (package ranger)
  simple fit without tuning (first go).
- Covariates:
  Geological units, simple and complex terrain attributes, vertical and horizontal distances to rivers

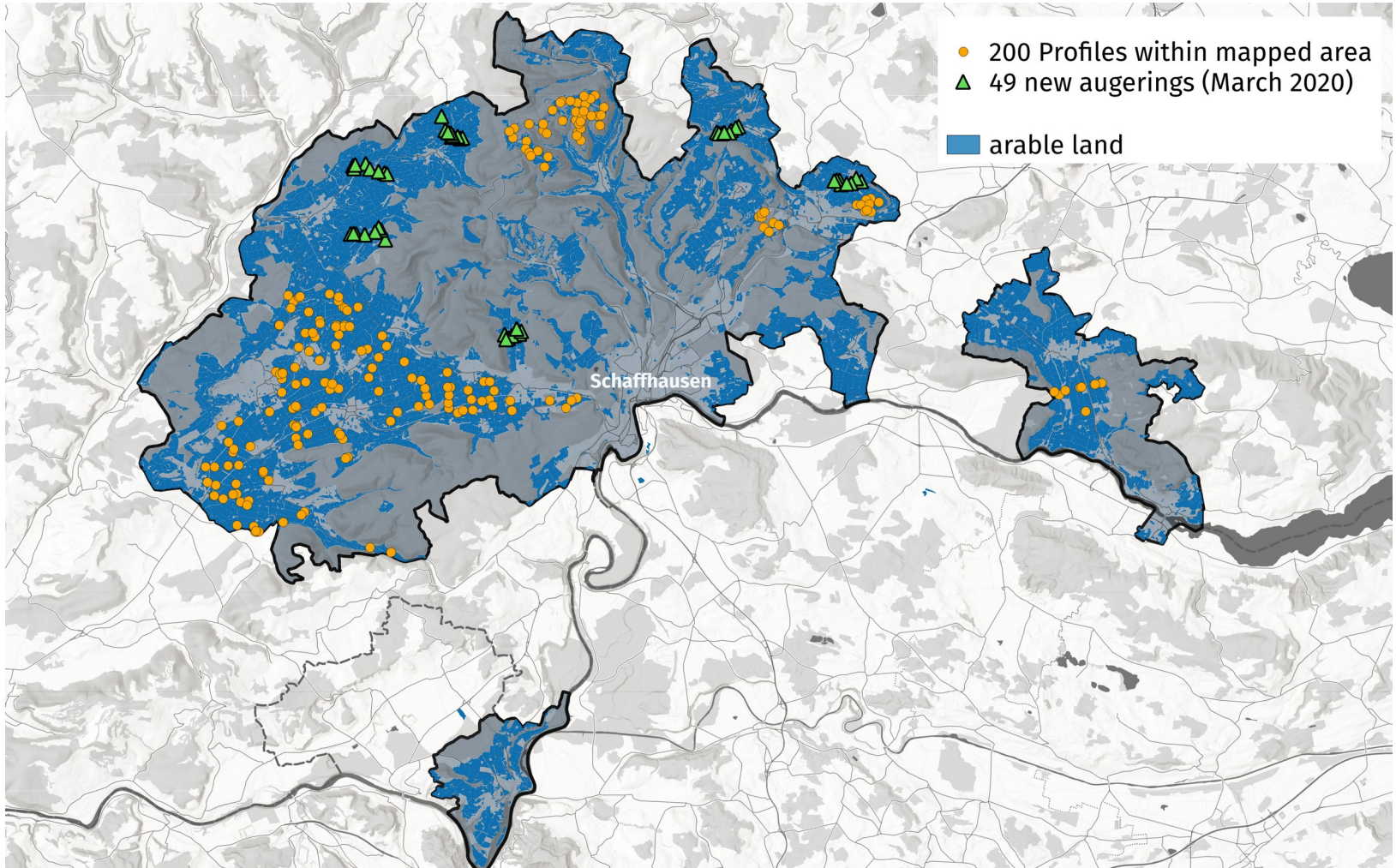
Resulting map



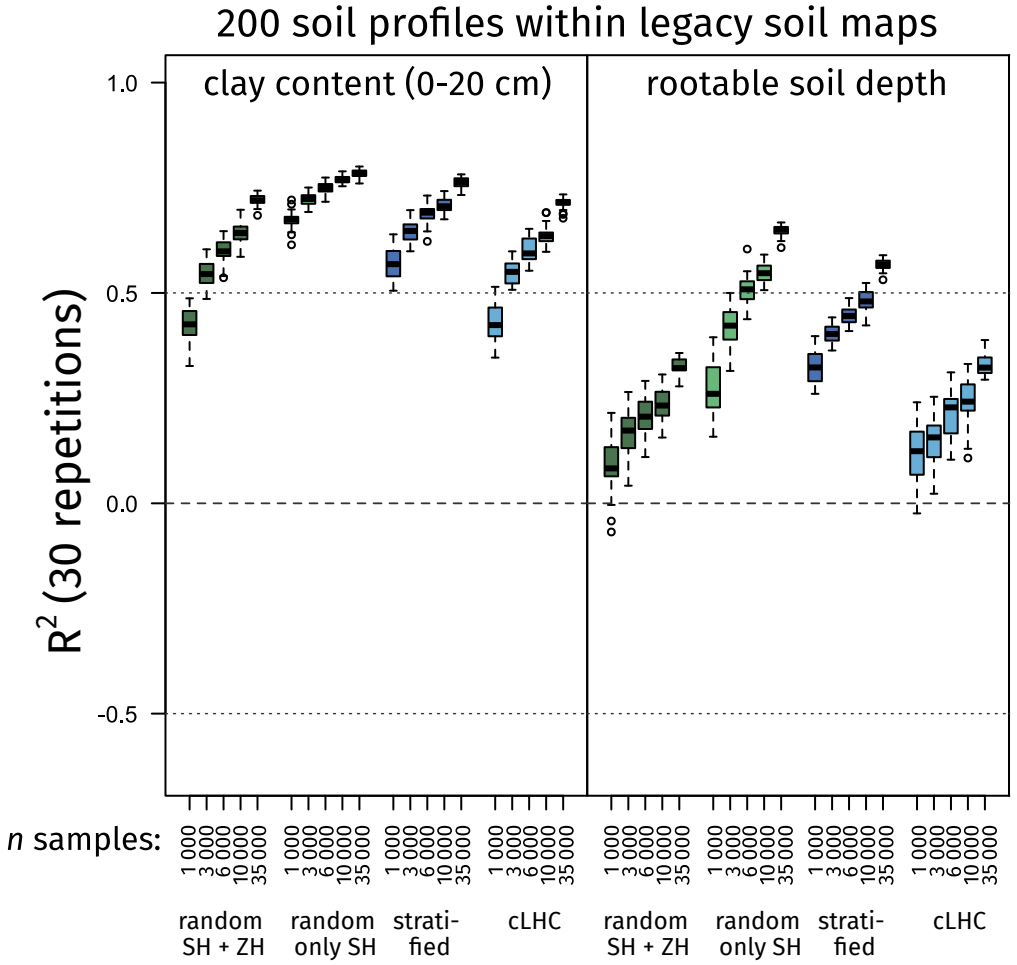
Resulting map



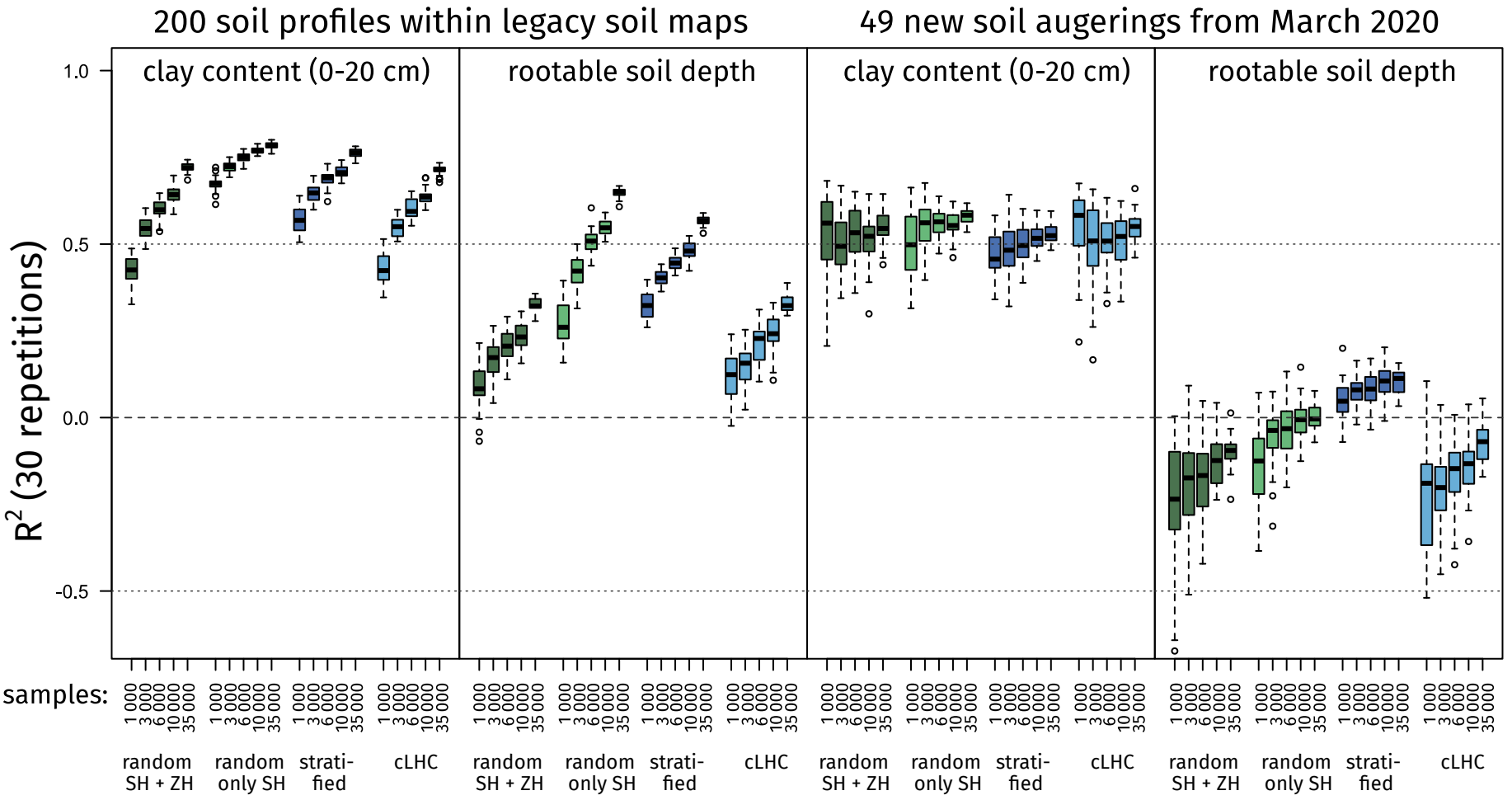
Results – Validation Samples



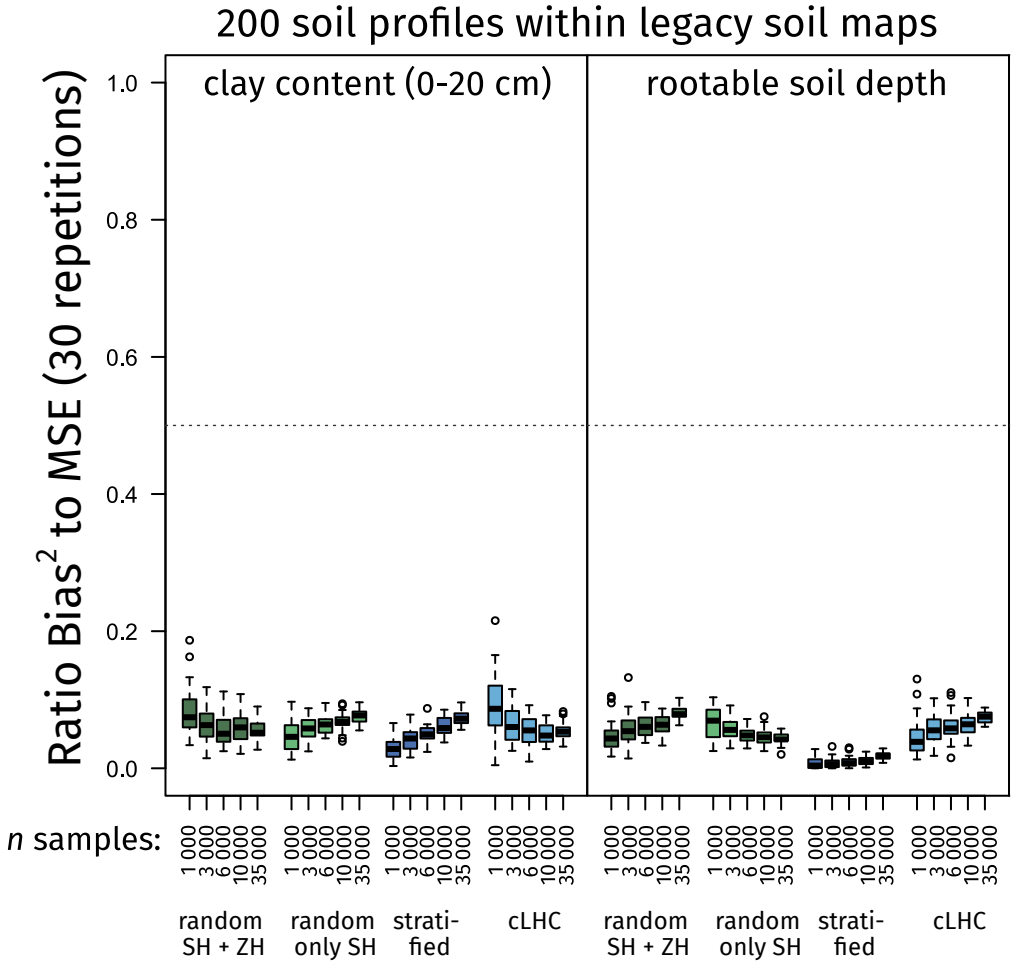
Validation – R^2



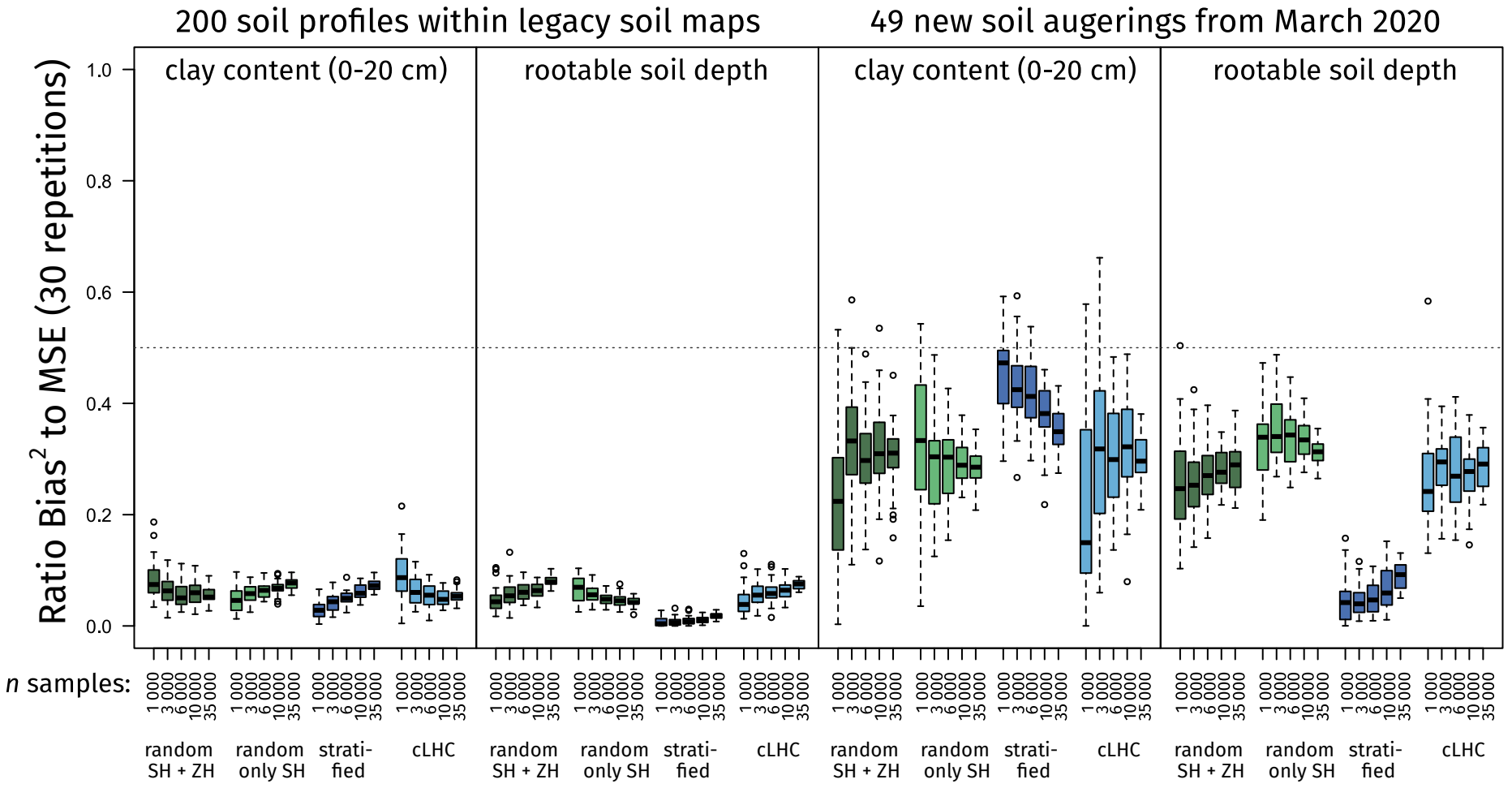
Validation – R^2



Validation – Bias



Validation – Bias



Conclusion and Outlook

Models based on legacy soil maps

Extrapolation into new areas

- possible, but with care!
- large dependence on target soil attribute
- no decision on optimal sampling design

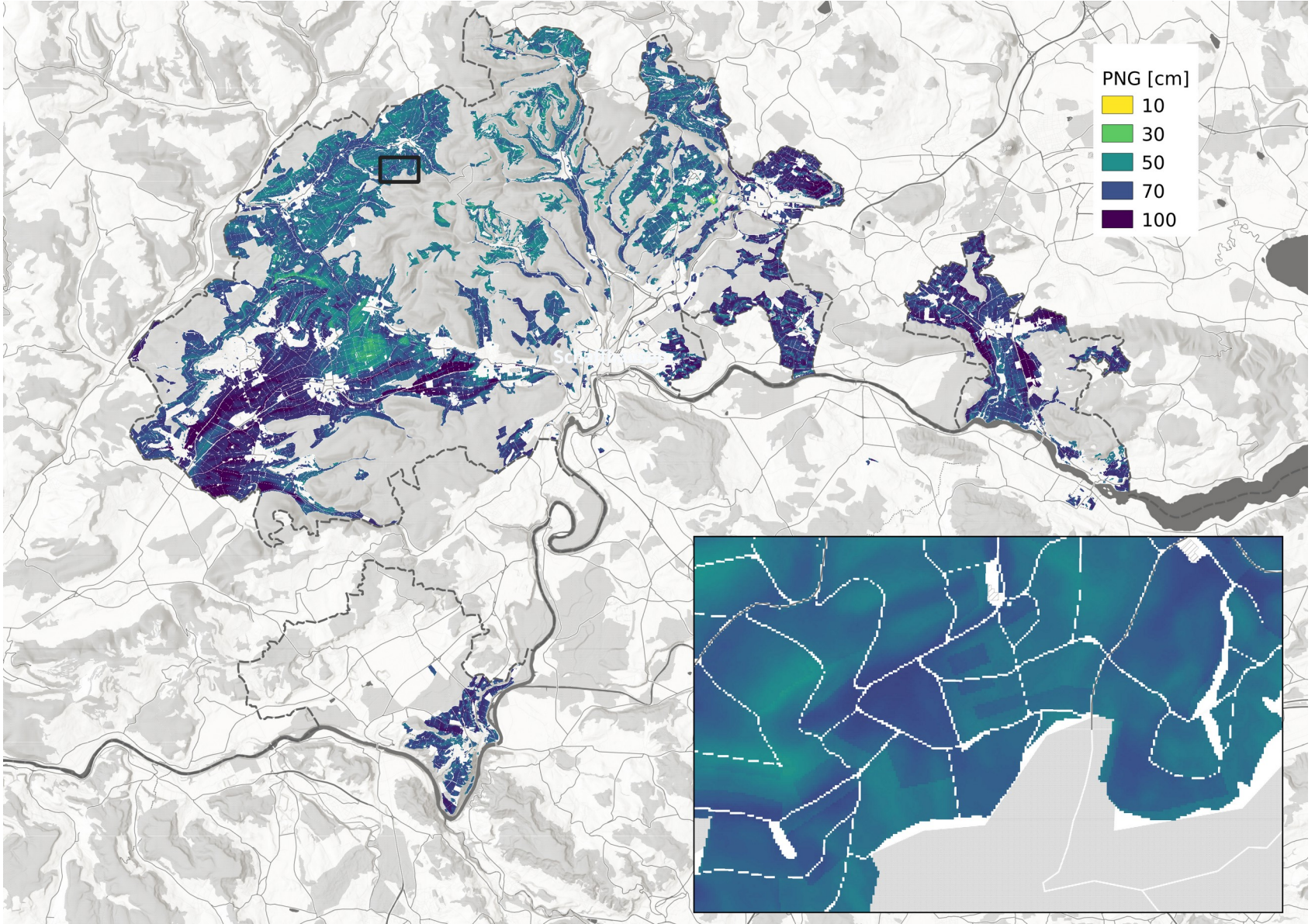
Further work:

- Validation 300 new soil augerings and 10 soil profile pits until end of 2020
- Integration of interpreted crop map and property tax values (1950s, based on soil sampling)

Many thanks to …

Stéphane Burgos – Stefan Oechslin – Liv Kellermann – Christian Sprecher – Adrian Hochreutener

Funding: Canton of Schaffhausen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