

SoilNet App: AI-assisted expert-level annotations of soil horizons

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KIDA KON 2026 · BfR Berlin · 29–30 Sept 2026

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Motivation

Why do soil horizons matter?

- Soils sustain
 - agriculture
 - water filtration
 - biodiversity
- Soil **horizons** are core units for soil classification and monitoring (WRB, KA5)
- Correct horizon labels need trained experts and great effort

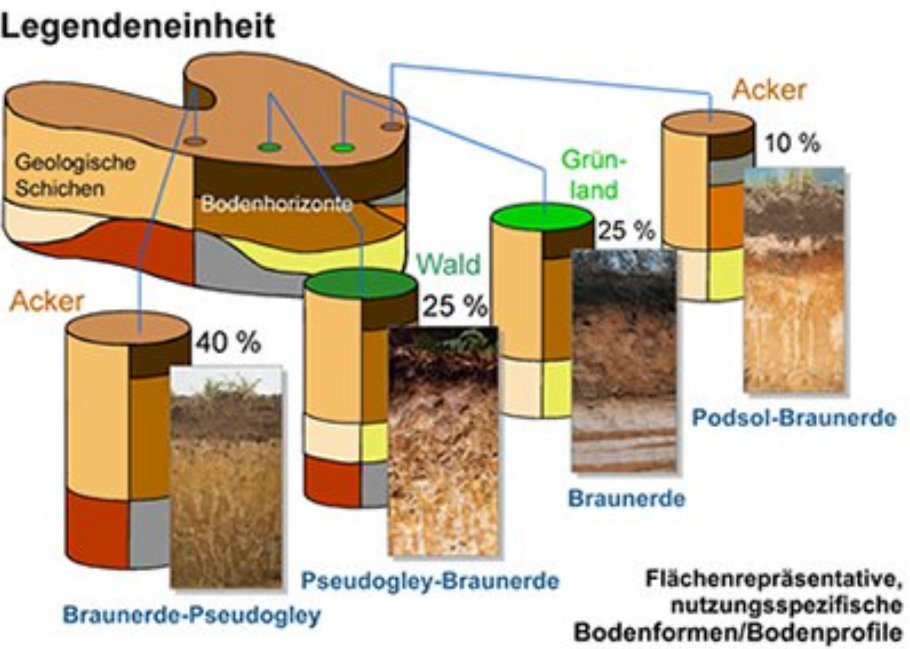


Horizon symbols
Horizon depth markers

Stones	Soil type	Rooting	...
2	us	W4	...
0	us	W3	...
0	ss	W1	...
0	lu	W0	...

Horizon-specific tabular information

Project: Soil Horizon Classification



Source: BGR

What makes annotation so difficult?

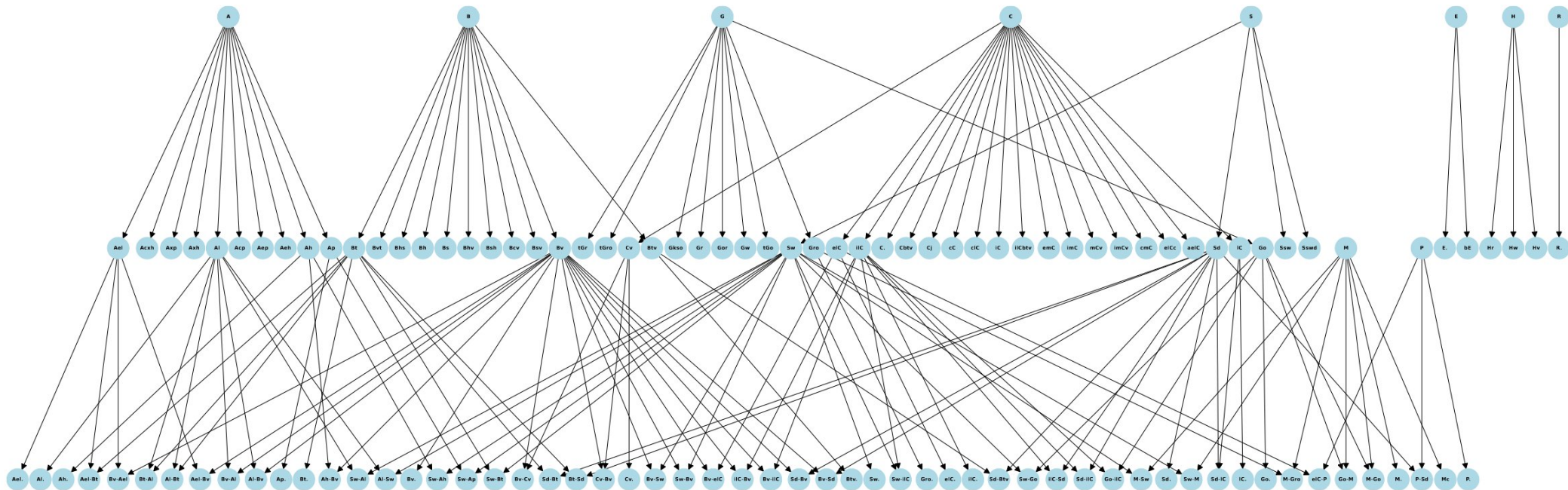
1,218

horizon symbols in the full taxonomy

99

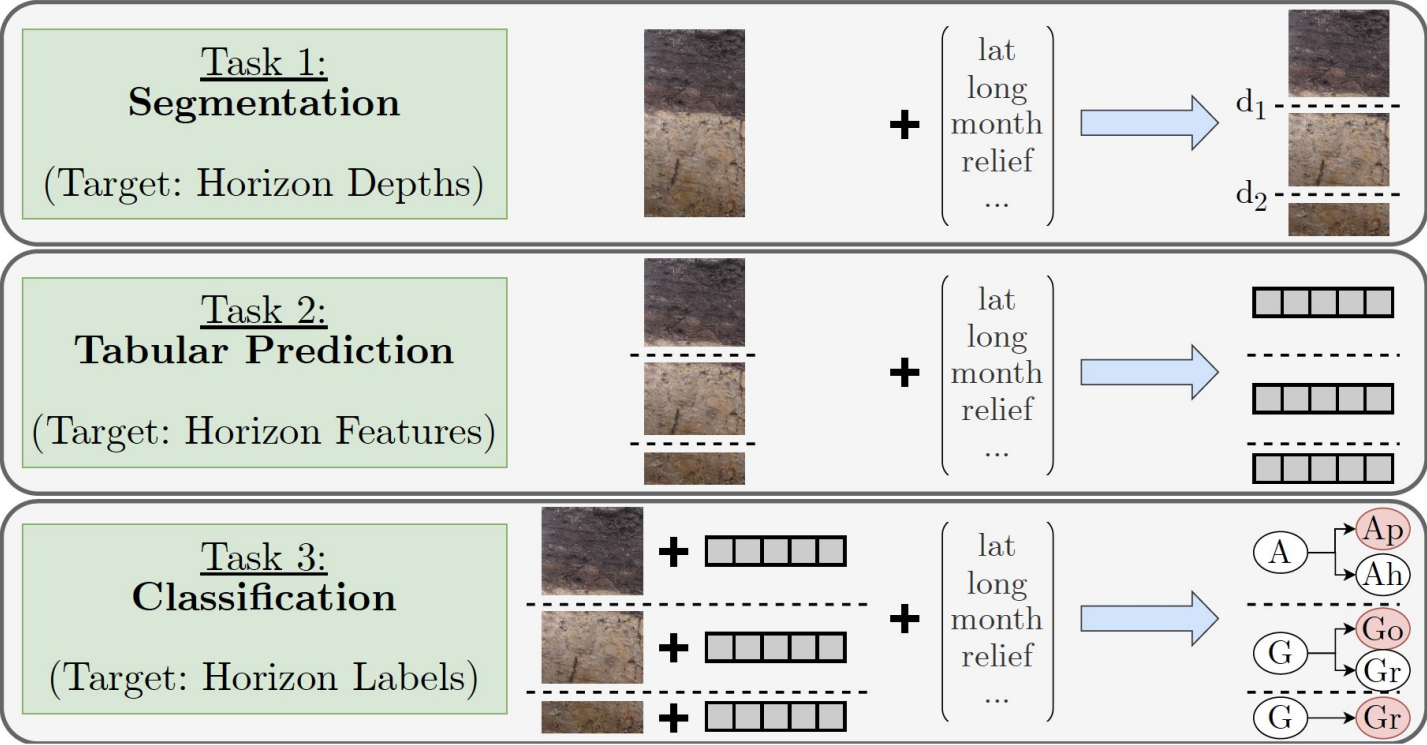
classes in our simplified hierarchical graph

- Overlapping characteristics
- Multiple parent–child relationships
- Symbols combine suffixes and mixtures



SoilNet in a nutshell

SoilNet mirrors the expert workflow in three tasks



Segment profile image into horizons

Predict features such as stones, soil type, rooting

Assign the hierarchical horizon symbol

Data: 3,349 profile images · 13,621 horizon stripes · tabular annotations for every stripe (BZE-LW - Thünen Institute & BGR)

The SoilNet App

Three questions behind the app

1

**How hard is image-only
horizon annotation?**

2

**How much do experts
agree with each other?**

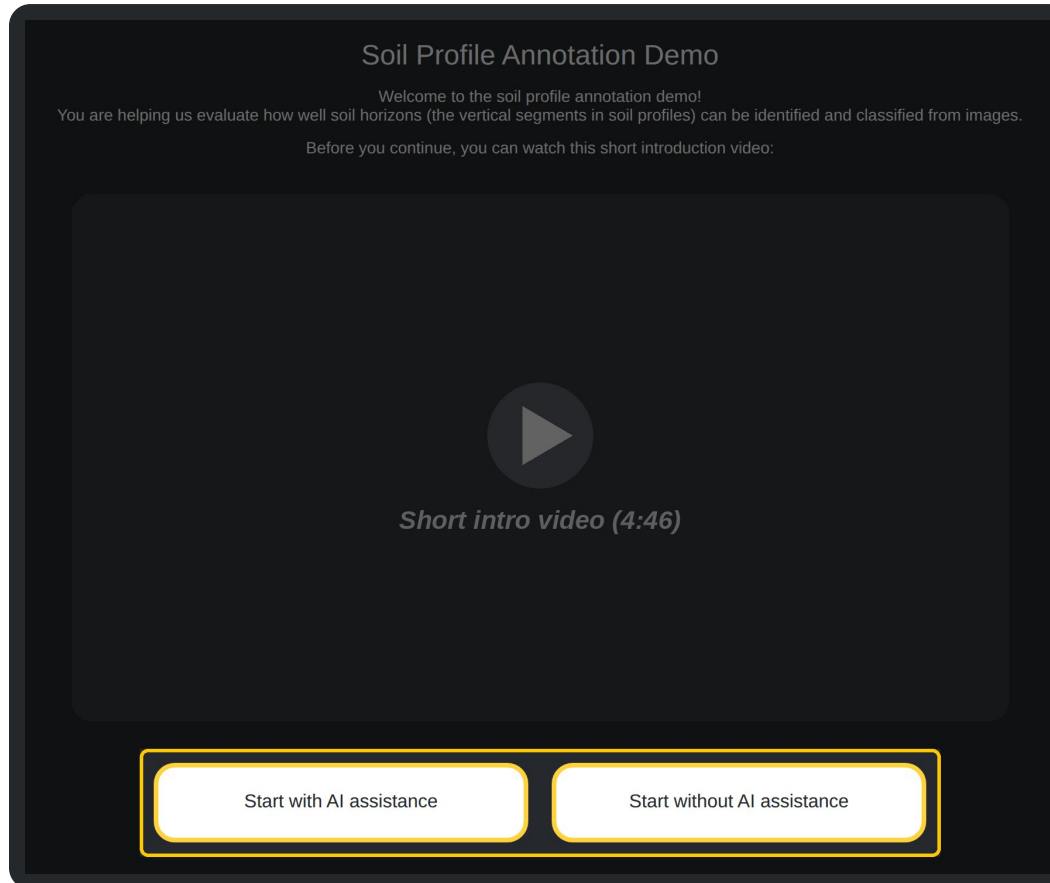
3

**Does AI assistance help
experts?**

An app guides experts through the same tasks as SoilNet

➤ Humans and model can be compared on equal terms

App walkthrough · Choose a mode

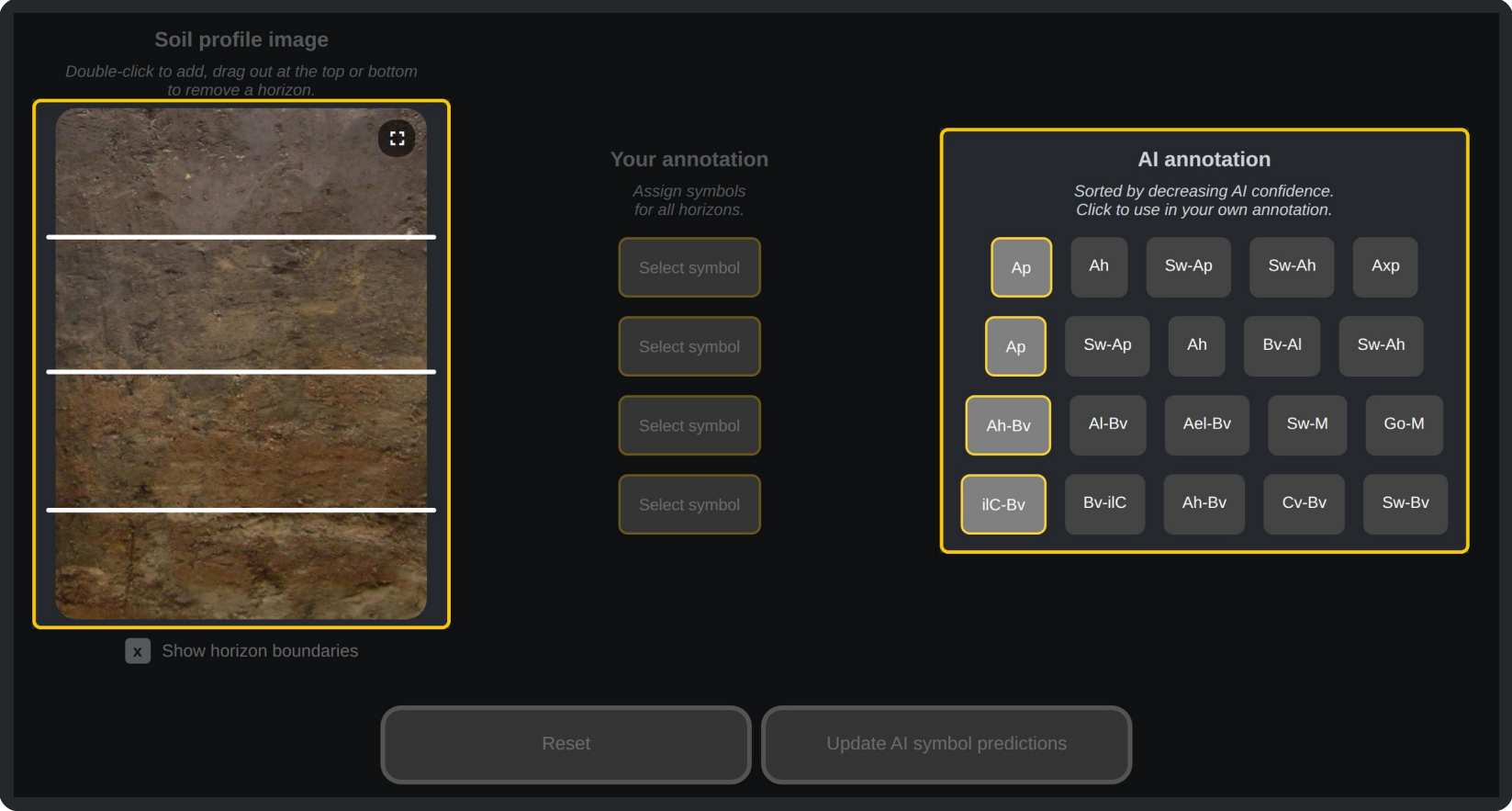


STEP 1 OF 8

After a tutorial video, users start **with or without AI assistance**

Study: Phase I manual, Phase II AI-assisted

App walkthrough · SoilNet pre-annotates the profile

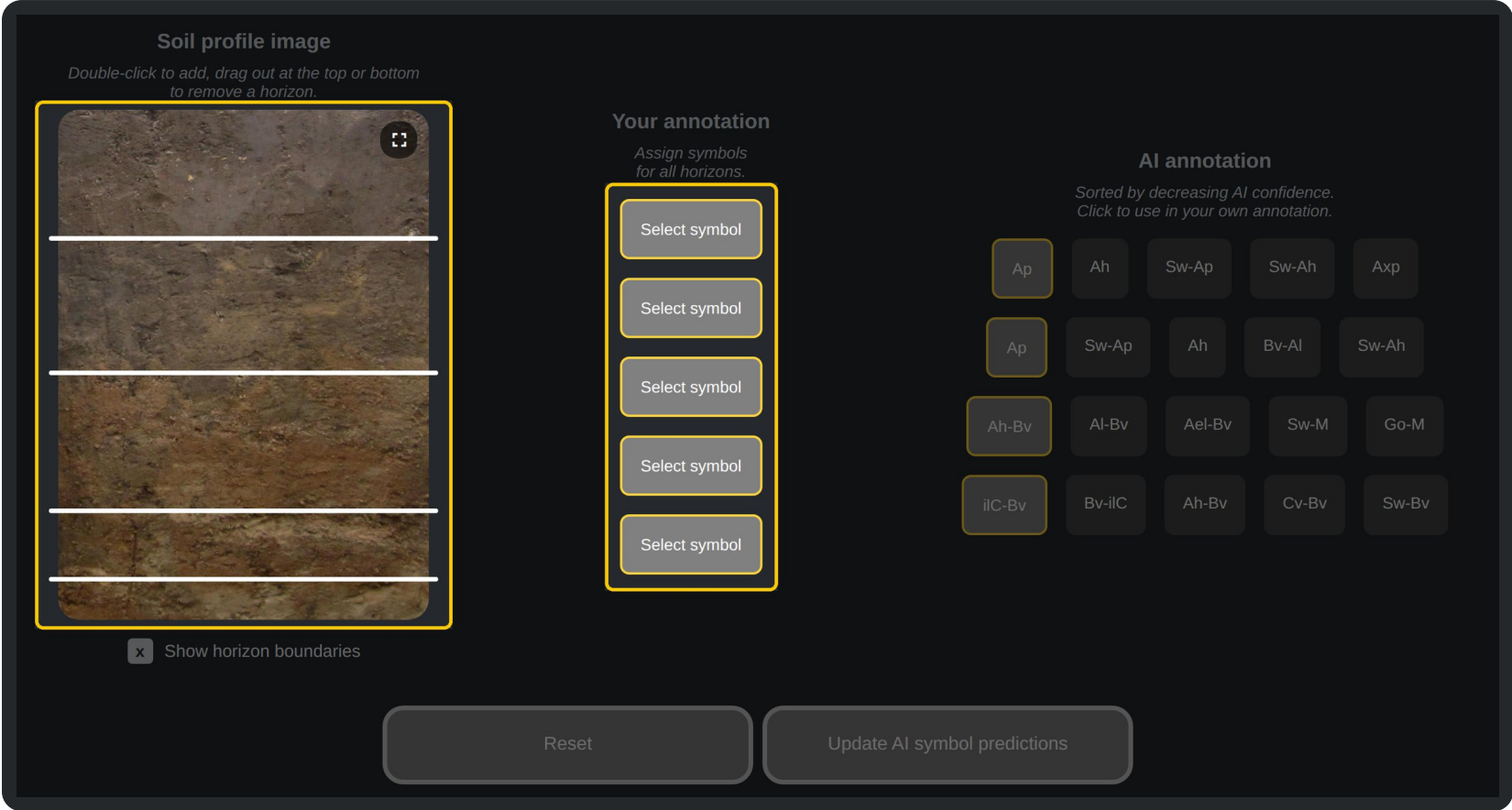


STEP 2 OF 8

Predicted **horizon boundaries** on the image

Top-5 symbols per horizon, most confident on the left

App walkthrough · Segmentation: adjust the boundaries

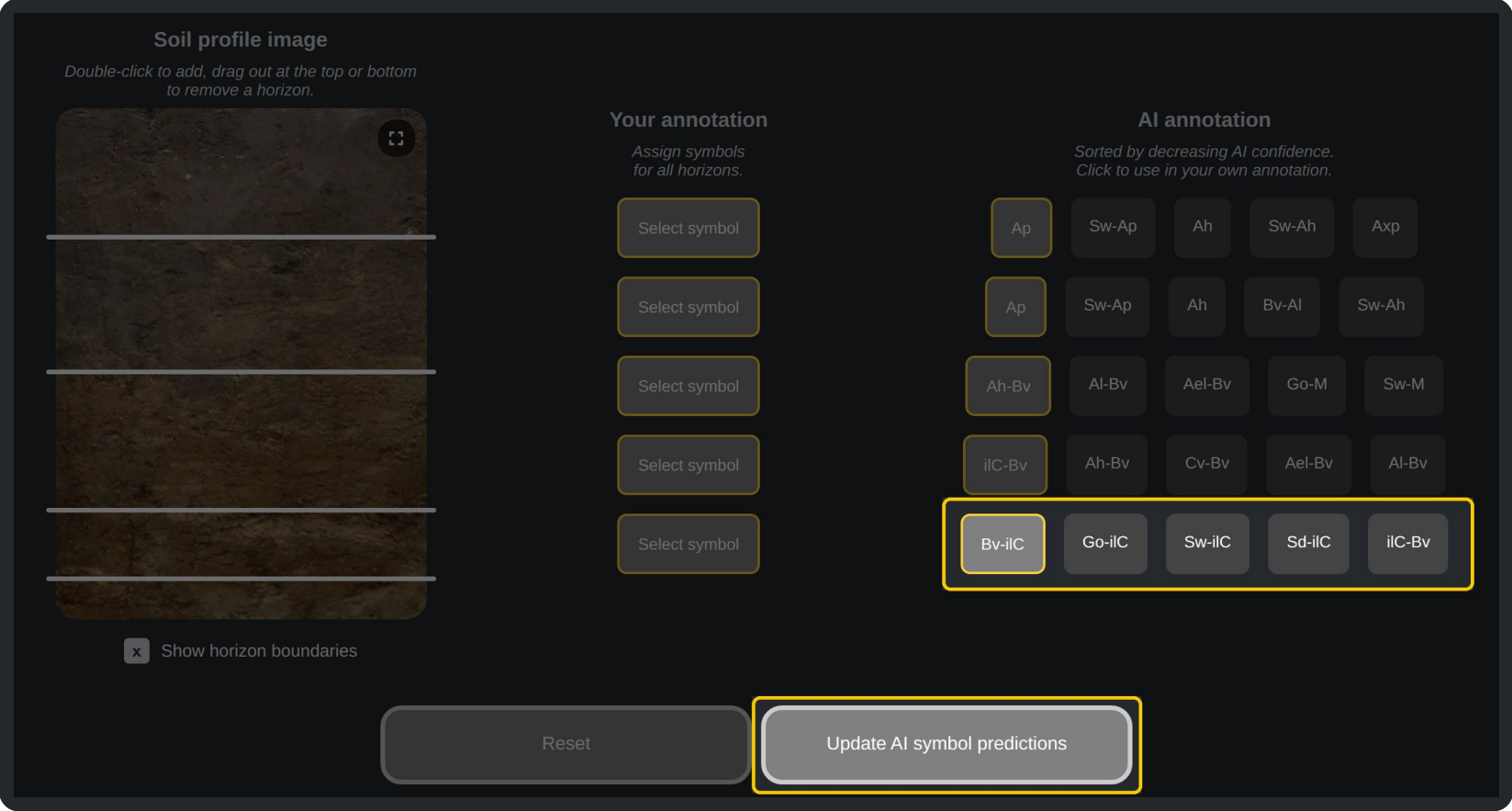


STEP 3 OF 8

Add boundaries, move or remove them

Here: a fifth horizon was added

App walkthrough · Re-predict for your boundaries

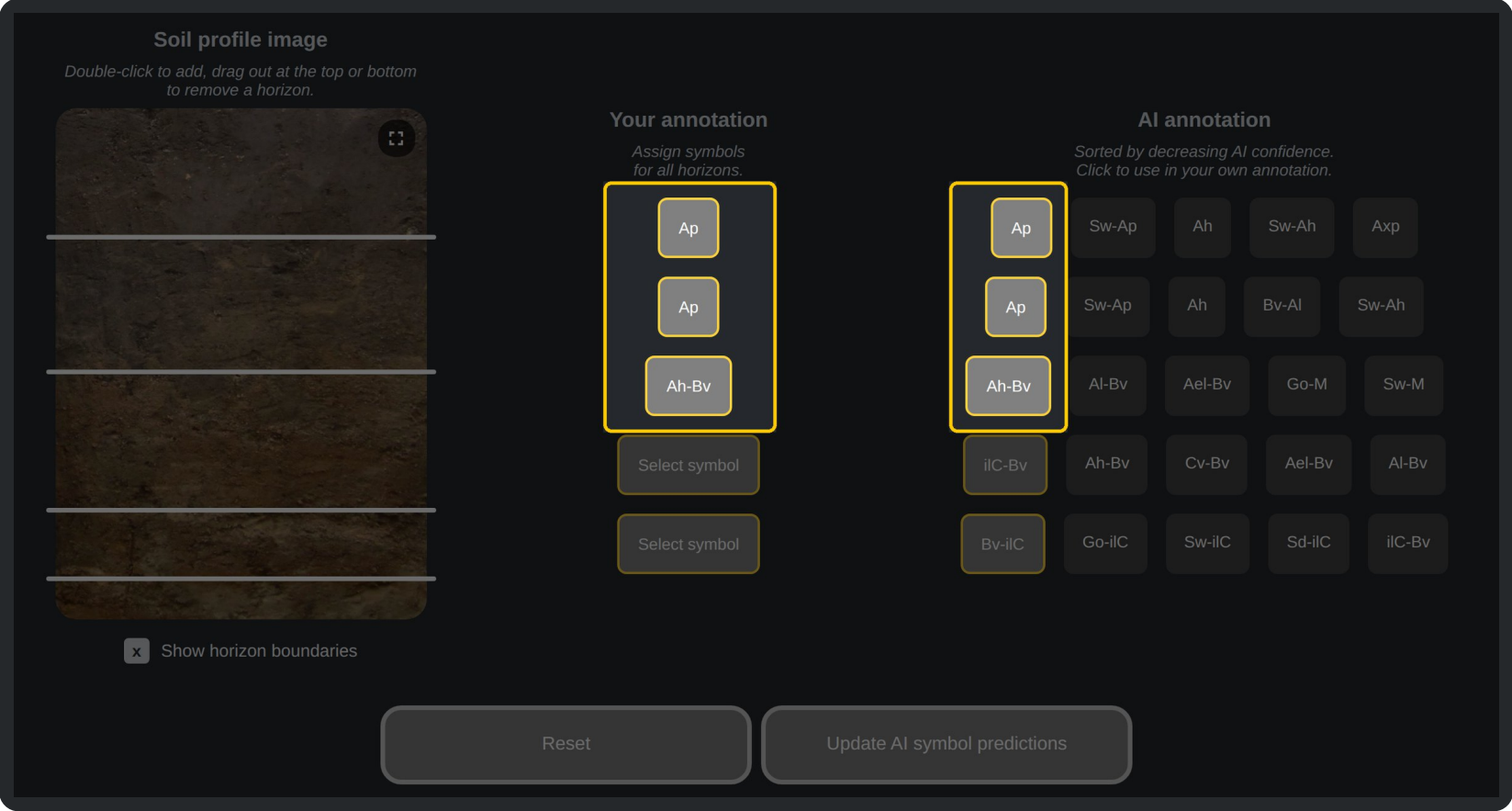


STEP 4 OF 8

Update AI symbol predictions sends the edited boundaries to SoilNet

New horizons get new Top-5 predictions

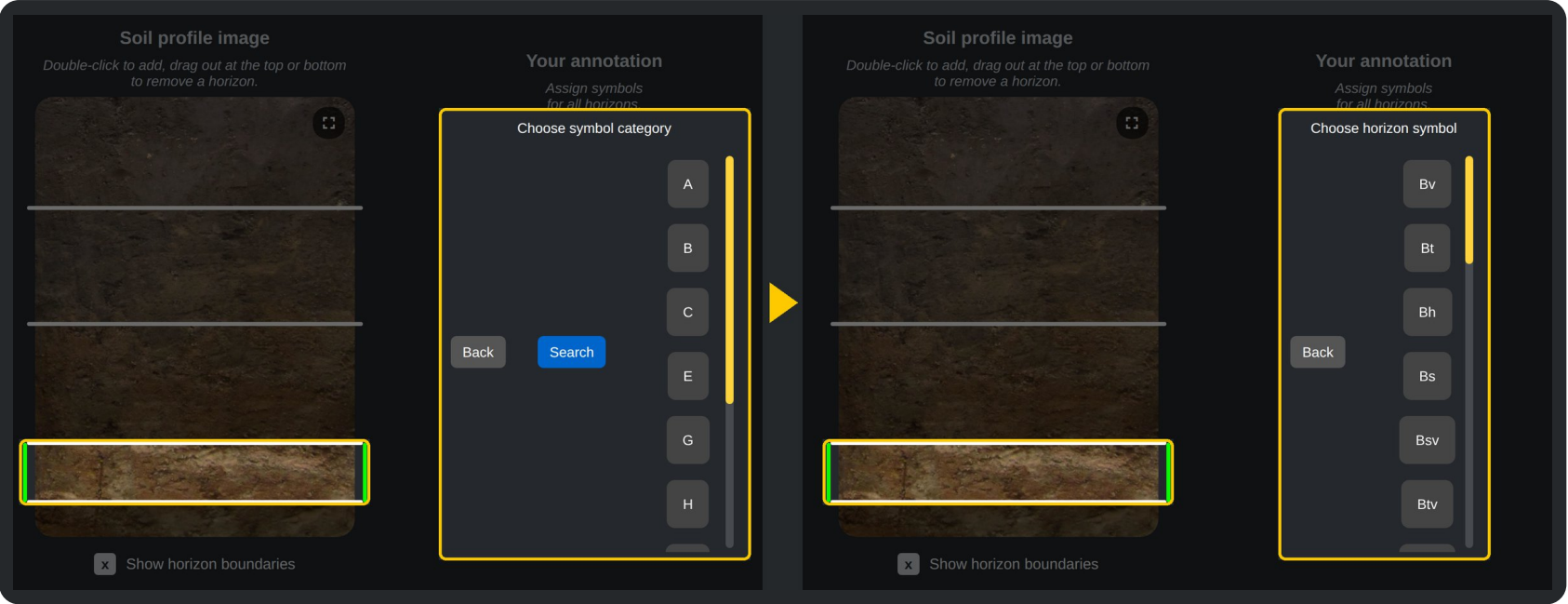
App walkthrough · Adopt a suggestion with one click



STEP 5 OF 8

Clicking an AI symbol copies it into **your annotation**

App walkthrough · ... or pick from the hierarchical menu

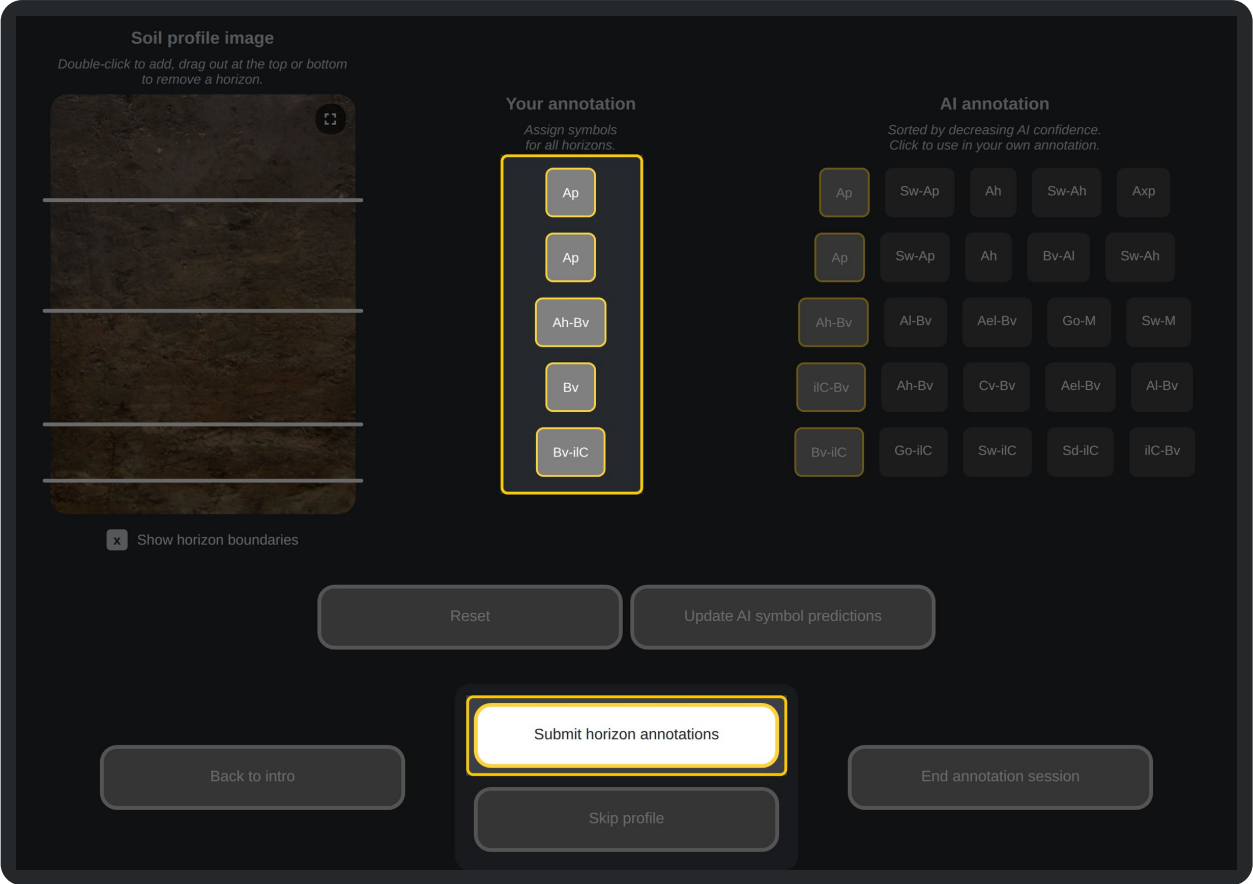


STEP 6 OF 8

Hierarchical label selection

Active horizon is highlighted in green

App walkthrough · Submit and continue



STEP 7 OF 8

All horizons labelled: **submit**
and next profile

Or skip a profile or end the
session

App walkthrough · Feedback and comparison with field data

Soil Profile Annotation Demo

Thanks for annotating soil profiles!
You can return later to classify more soil horizons by reloading this page.

If you want, please share your field-description experience. This helps us better interpret demo results:
How many years of field-description experience do you have?

How many field descriptions do you make per year?

Less than 10

10-50

50-100

100-200

More than 200

Would you like to leave any additional feedback?

Your feedback...

Submit responses

Cancel

Compare annotations

1.

Your annotations

Ap

Ap

Ah-Bv

Bv

Bv-iIC

Annotation comparison

Field annotations

Ap

Al

C.

STEP 8 OF 8

Feedback form

Compare with field description

User study

Study design: manual vs. AI-assisted

	Phase I manual	Phase II AI-assisted	Total
Participants	22	23	40*
Profile images	63	104	142*
Annotations	172	240	412
True horizon labels	682	988	1670
Annotator horizon labels	695	1053	1748

* unique counts; some participants and images overlap between phases

- Experienced soil surveyors
- Images drawn from SoilNet's held-out **test split** (670 images): the model never saw them
- Up to **3 independent annotations** per image
- No annotator sees the same image twice

How we measure performance and agreement

PERFORMANCE VS. FIELD DATA

IoU (1D)

Overlap of annotated and true horizon boundaries

Accuracy

Exact horizon symbol

Main symbol accuracy

Correct at the main level of the hierarchy

AGREEMENT

IUA · Inter-User Agreement

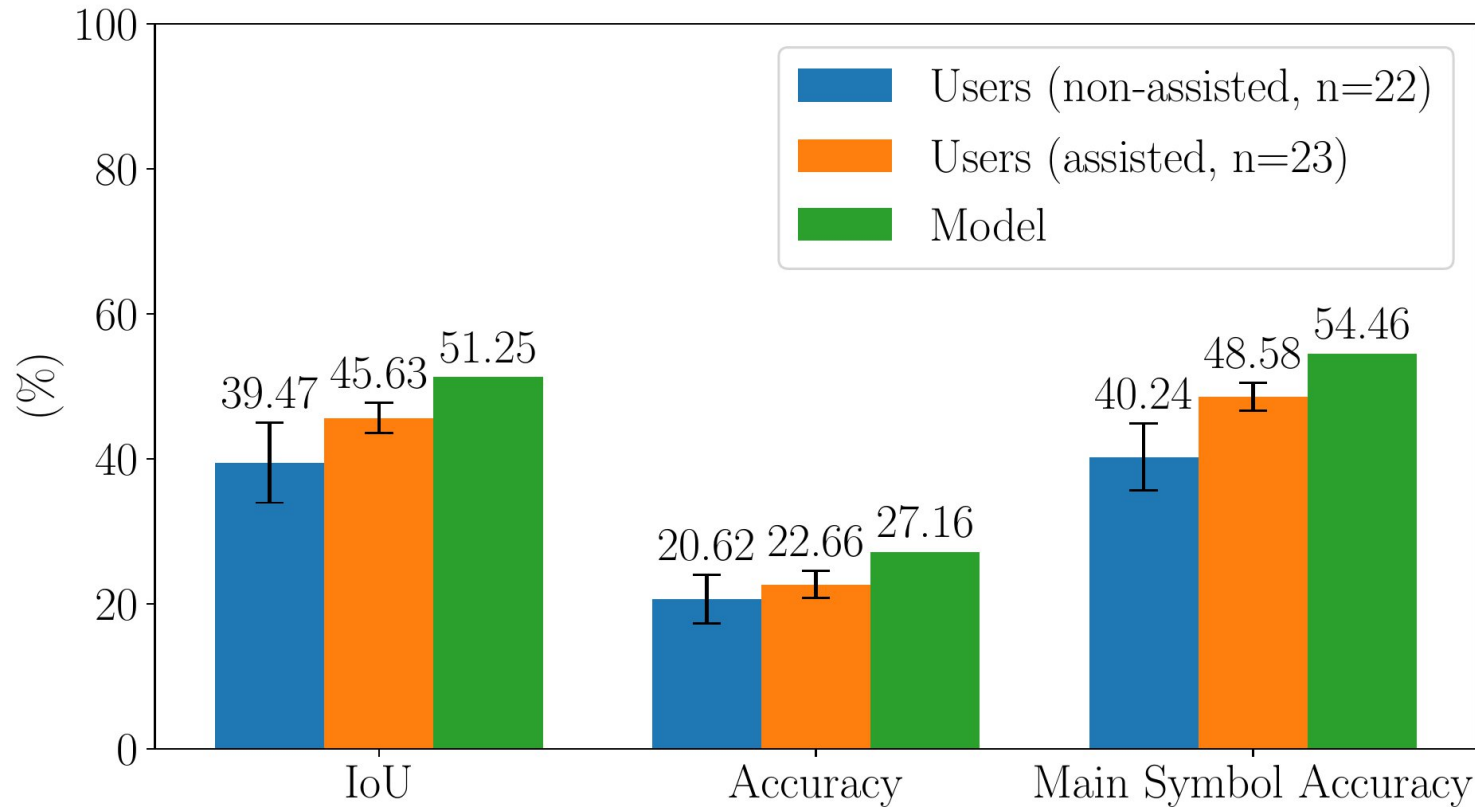
Percent agreement among experts on the same horizon

UMA · User-Model Agreement

Share of expert labels that match SoilNet's Top-1 or Top-5 prediction

Results

AI assistance improves expert performance



Weighted by the number of annotations per user; error bars show the standard error of the mean.

- Image-only annotation is hard: Accuracy low for everyone
- Assisted users score higher on every metric
- Model still scores highest

Inter-User Agreement: assisted experts agree more

Metric	Hierarchical Level	AI-Assisted?	
		No	Yes
IUA	Full	36.86	39.94
	Main	58.43	67.10
UMA	Full	–	15.45
	Main	–	52.12
Top-5 UMA	Full	–	44.25
	Main	–	60.99

➤ AI assistance makes experts **more consistent**

Table 2 of the paper. Percent agreement, averaged over horizons with at least 3 annotations.

User-Model Agreement: how closely experts follow SoilNet

Metric	Hierarchical Level	AI-Assisted?	
		No	Yes
IUA	Full	36.86	39.94
	Main	58.43	67.10
UMA	Full	—	15.45
	Main	—	52.12
Top-5 UMA	Full	—	44.25
	Main	—	60.99

- Higher alignment within the Top-5
- Experts agree more **with each other** than with SoilNet's top suggestion
- They weren't just copying the model's Top-1

Table 2 of the paper. Share of assisted users' labels that match SoilNet's Top-1 or Top-5 prediction.

Take-aways

1

Image-only horizon annotation is hard, even for experts

Without in-field context: Symbol accuracy between 21 and 27 %.

2

AI assistance raises expert performance

Assisted users improve on metrics and come closer to the model performance.

3

AI assistance makes experts more consistent

Inter-user agreement on main symbols rises

Limitations and future work

Limitations

- Two phases: different image subsets, time and participants
- Cookie-based IDs: individuals can't be tracked reliably
- 99-class taxonomy differs from the full pedological standard

Future work

- Add explanations to the app
- Refine the label taxonomy
- Analyze automation bias
Do experts over-trust the AI?

Join us: SoilNet Workshop 2026

*AI in Soil Science – Automated detection and classification of soil horizons:
Workshop on digital methods, research, and practice*

🕒 **Wednesday, 9 December 2026 • 9:00–12:00**

🏠 Einstein Center Digital Future, Wilhelmstraße 67, Berlin

👥 Live demo and a short hands-on study: annotate soil profiles with and without AI

Call for posters

Digital methods in **soil science and soil protection**: AI & computer vision • digital soil assessment • remote sensing • data quality • apps & visualisation • legal and regulatory frameworks

Submit a title + abstract at registration until 10th October 2026*

Early-stage work is explicitly welcome.

*preliminary deadline



Scan for details

calgo-lab.de/soil-workshop

Try it yourself

- Questions? Contact us on GitHub or me at vipin.singh@bht-berlin.de

SoilNet Workshop · 9 Dec 2026



Call for posters until 10 Oct
calgo-lab.de/soil-workshop

SoilNet App



soilnet.demo.calgo-lab.de

SoilNet paper



[ScienceDirect · Geoderma 466](https://www.sciencedirect.com/journal/geoderma)

App paper (IJCAI-26)



[DOI: 10.24963/ijcai.2026/993](https://doi.org/10.24963/ijcai.2026/993)

GitHub

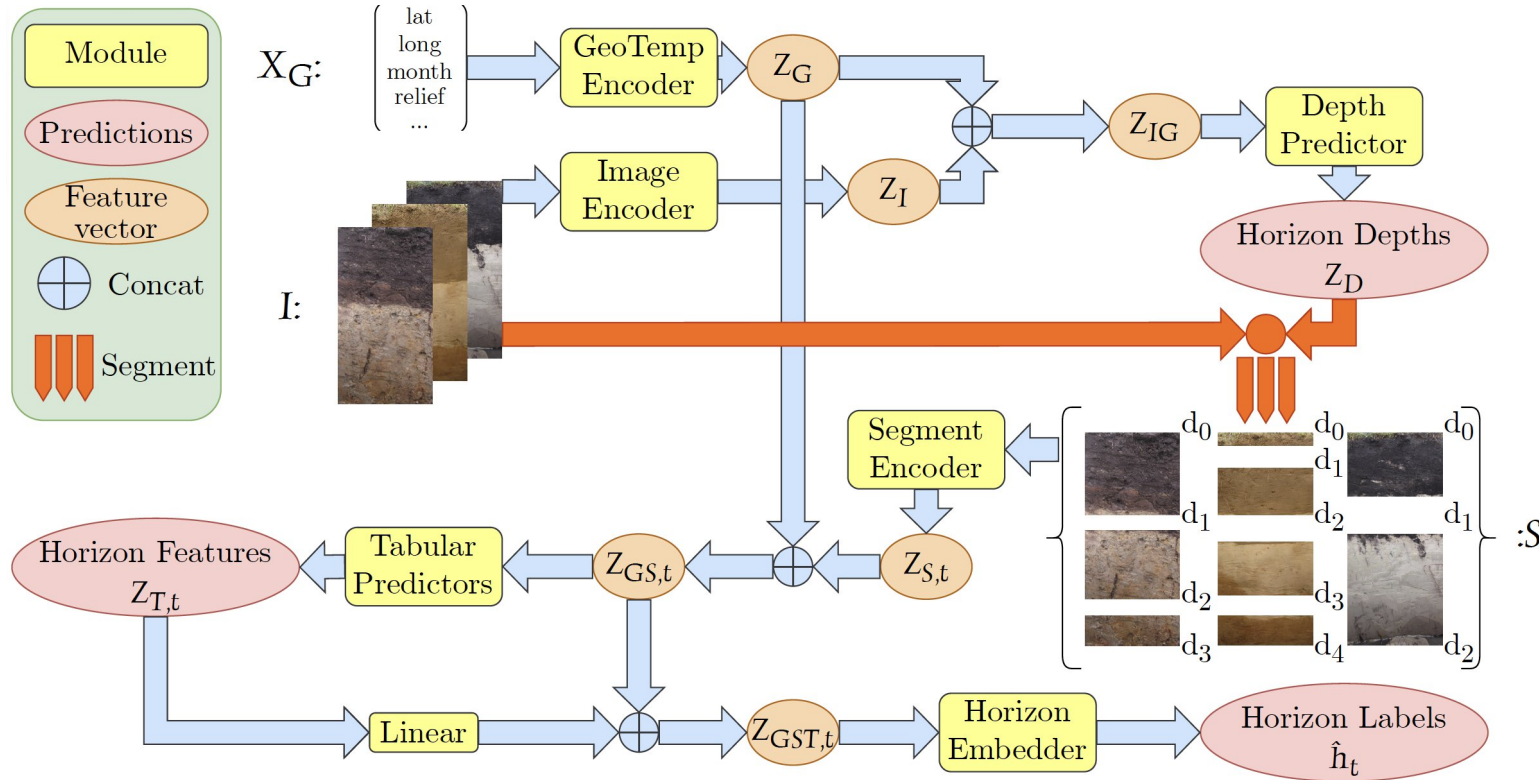


github.com/calgo-lab/BGR

Funded by the German Research Foundation (DFG), project 528483508 – FIP 12.

Backup

End-to-end horizon classification



- Inputs: profile image + location, month and relief
- Modules predict depths → features → symbols
- Each step can be inspected, like the expert's workflow
- Hierarchical graph loss respects the taxonomy

Singh et al. (2026). SoilNet: A multimodal multitask model for hierarchical classification of soil horizons. *Geoderma* 466:117684