Monitoring dynamics of OpenStreetMap

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Agenda

- OSM history analysis - with the ohsome framework
- Towards ohsome 2.0
  - OhsomeNow - near real time OSM stats
  - What is new in 2025 & forthcoming 2026
    - from OSHDB to ohsome planet
- Case study Landuse change
  - Laverdi initial results:
    Detecting landuse change via OSM & remote sensing
    (project with German national mapping agency BKG)
- Summary & Outlook
  - Complementary use of Street View Imagery (for road attributes etc.)

OSM Data Quality Analytics Framework

- heterogeneous OSM quality
- need for a framework supporting global OSM analysis
- reproducible & sustainable

=> Towards a

OSM data quality analytics framework

ohsome

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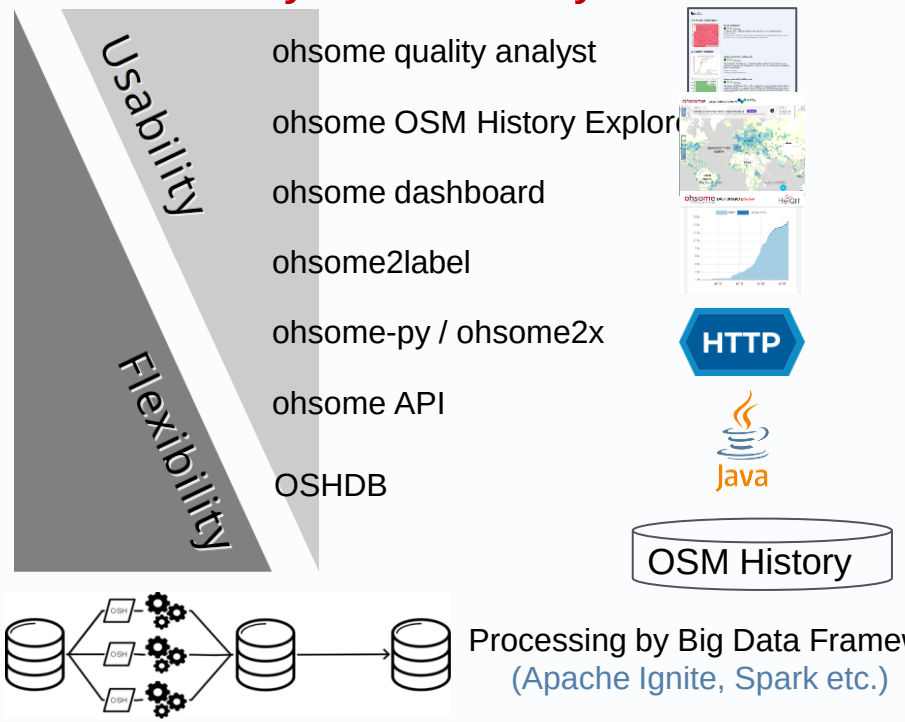
OSM History Data Analytics Platform



Raifer, M, Troilo, R, Kowatsch, F, Auer, M, Loos, L, Marx, S, Przybill, K, Fendrich, S, Mocnik, FB & Zipf, A (2019): OSHDB: a framework for spatio-temporal analysis of OpenStreetMap history data. Open Geospatial Data, Software & Standards, Springer.

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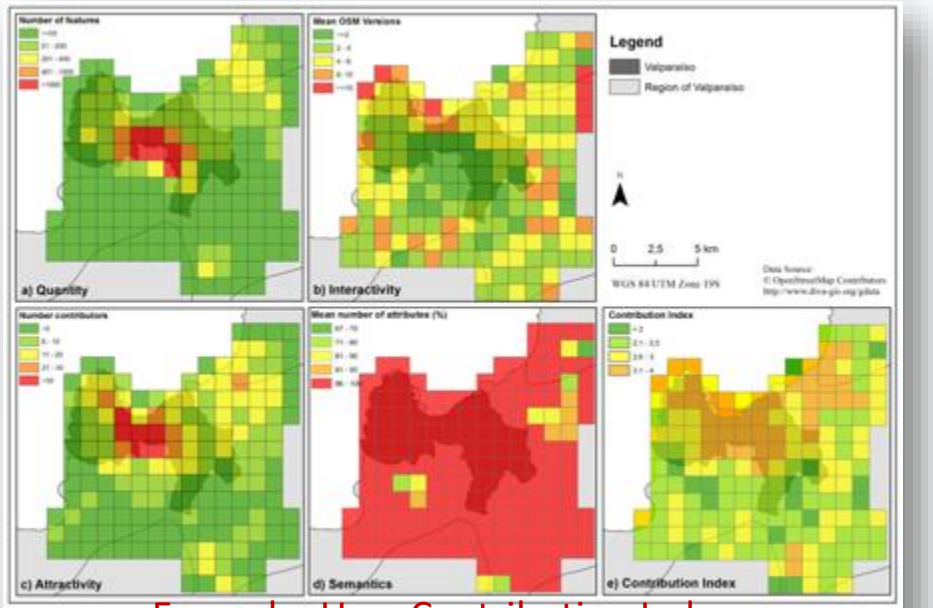
iOSManalyser: Intrinsic Quality Indicators

Barron, C., Neis, P. & Zipf, A. (2013): **A Comprehensive Framework for Intrinsic OpenStreetMap Quality Analysis.** Transactions in GIS . DOI:10.1111/tgis.12073.



Example: User Contribution Index

Jokar A., J., Mooney, P., Helbich, M., Zipf, A., (2015): **An exploration of future patterns of the contributions to OpenStreetMap and development of a Contribution Index**, Transactions in GIS. DOI:10.1111/tgis.12139.

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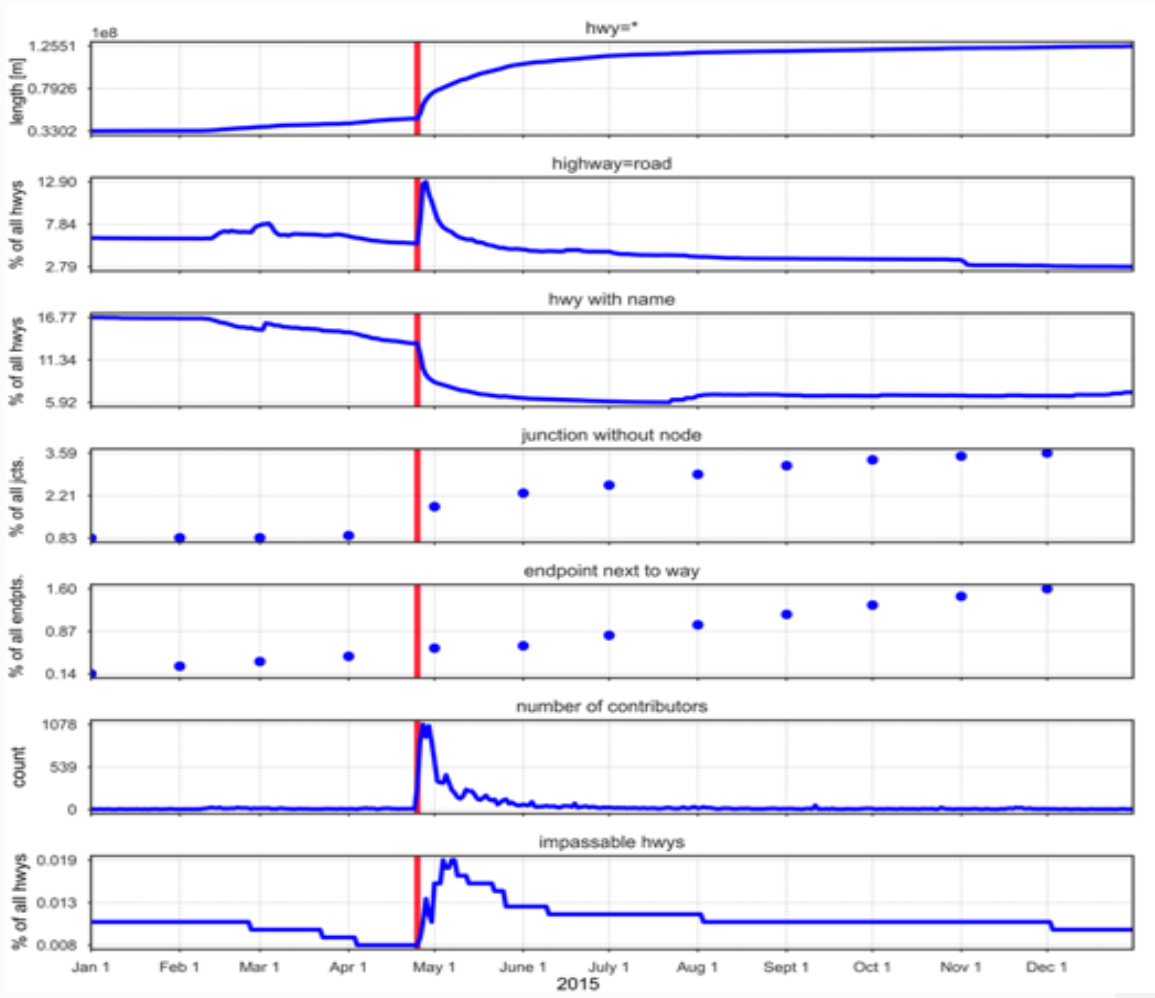
Analysing mapping respose to Nepal earthquake ´15

Intrinsic indicators are used to
investigate OSM mapping activities



Auer, M.; Eckle, M.; Fendrich, S.; Griesbaum, L.; Kowatsch, F.; Marx, S.; Raifer, M.; Schott, M.; Troilo, R.; Zipf, A. (2018): Towards Using the Potential of OpenStreetMap History for Disaster Activation Monitoring. ISCRAM 2018. USA.

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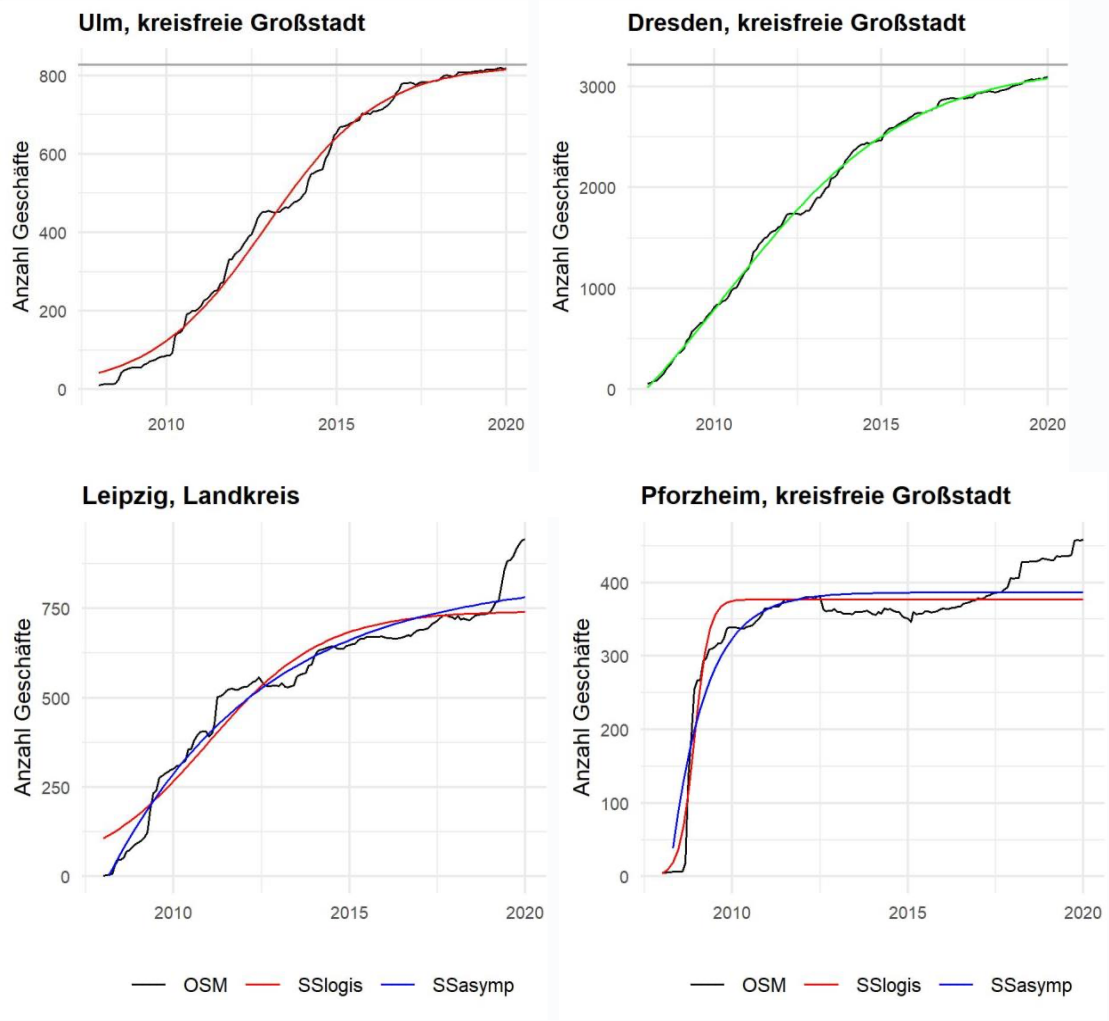
Fitting different type of saturation curves



Modell	Verlaufsform	Funktion
SSlogis	beschränktes, logistisches Wachstum	$f(input) = \frac{Asym}{(1 + e^{\frac{x_{mid} - input}{scal}})}$
SSfpl	beschränktes, logistisches Wachstum	$f(input) = \frac{A + (B - A)}{(1 + e^{\frac{x_{mid} - input}{scal}})}$
SSmicmen	beschränktes Wachstum (Michaelis Menten)	$f(input) = \frac{v_m \times input}{(K + input)}$
SSasymp	beschränktes Wachstum	$f(input) = Asym + (R_o - Asym) \times e^{(-\exp(lrc) \times input)}$

	SSlogis	SSasymp
Residualstandard-fehler, relativ	0,06	0,04
Steigung (Abweichung) [Geschäfte/Jahr]	3	8
Asymptote	585	718
Vollständigkeit [%]	93	76

Brückner, J., Schott, M., Zipf, A., Lautenbach, S. (2021): Assessing shop completeness in OpenStreetMap for two federal states in Germany, AGILE GIScience Series. 2(20): 1-7. DOI 10.5194/agile-giss-2-20-2021.

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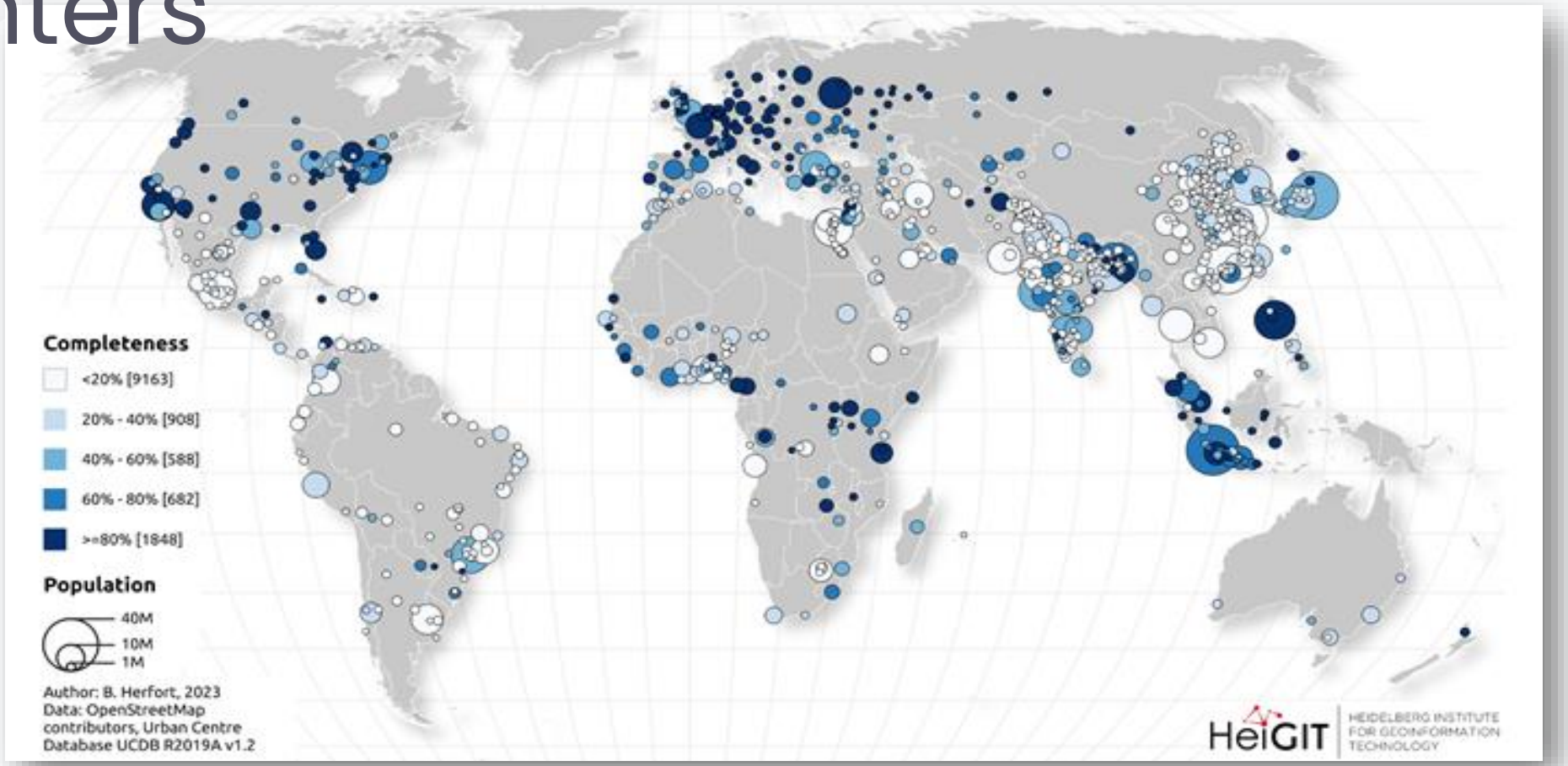
OSM building completeness in urban centers



B. Herfort et al.: Investigating the digital divide in OpenStreetMap: spatio-temporal analysis of inequalities in global urban building completeness. Nature Communications 14, 3985 (2023). https://www.nature.com/articles/s41467-023-39698-6

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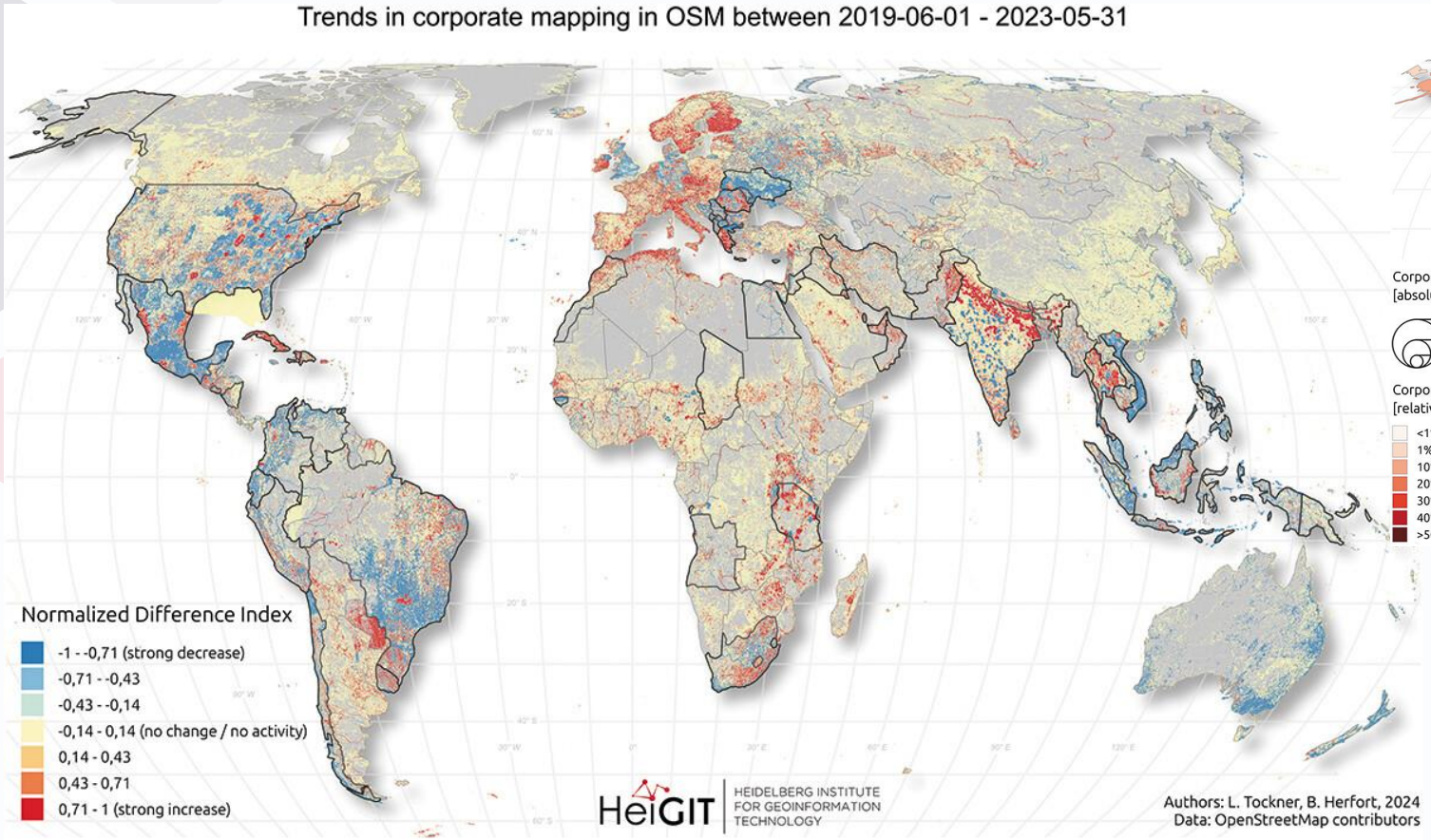
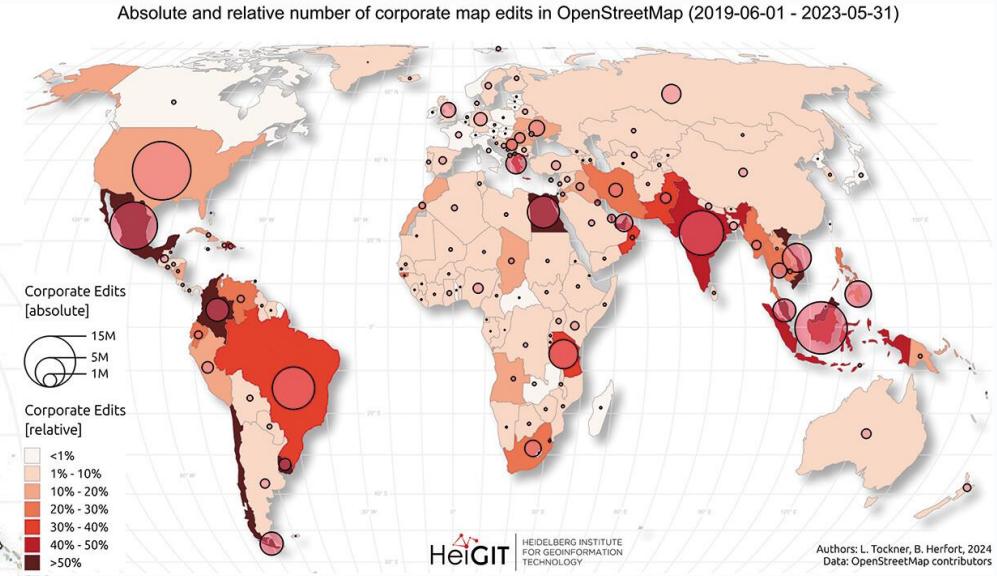
Trends in Corporate Mapping in OSM





Tockner, L., Herfort, B., Lautenbach, S., & Zipf, A. (2025). Corporate mapping in OpenStreetMap – shifting trends in global evolution and small-scale effects. Geo-Spatial Information Science, 1–20. https://doi.org/10.1080/10095020.2025.2493076

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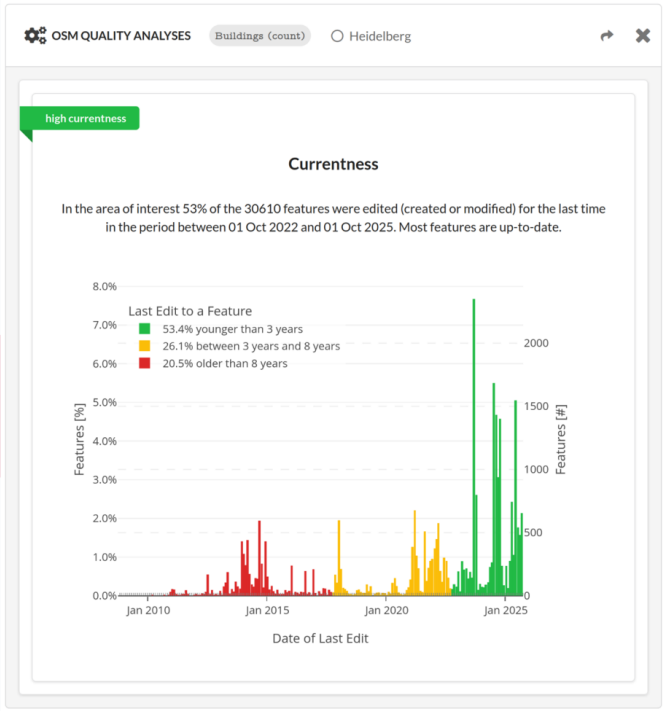
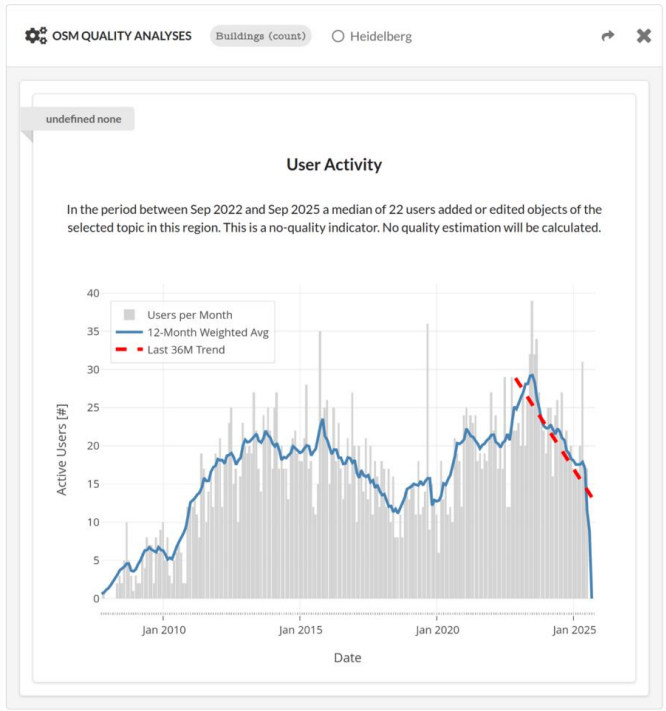
Ohsome: use cases & applications



data quality analysis



history insights

data extraction

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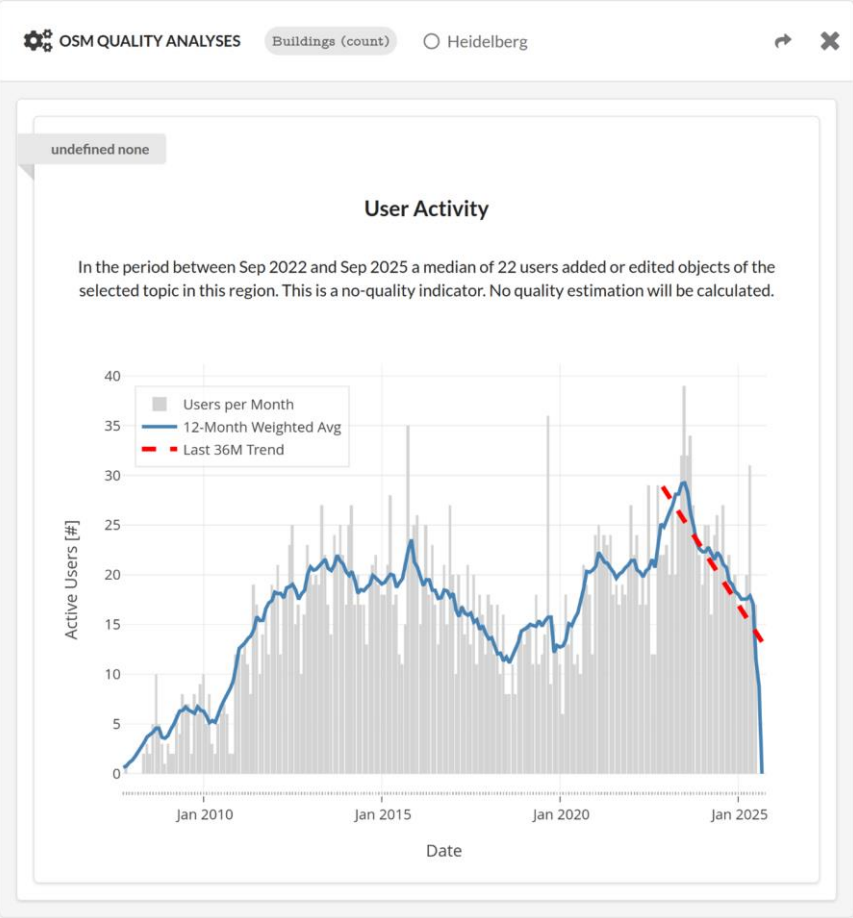
OSM history insights



How active is the OSM community?

Shows the count of unique mappers per month for the selected topic.

ohsome now STATS

up-to-date and global scale overview
statistics on
mapping activity in OpenStreetMap

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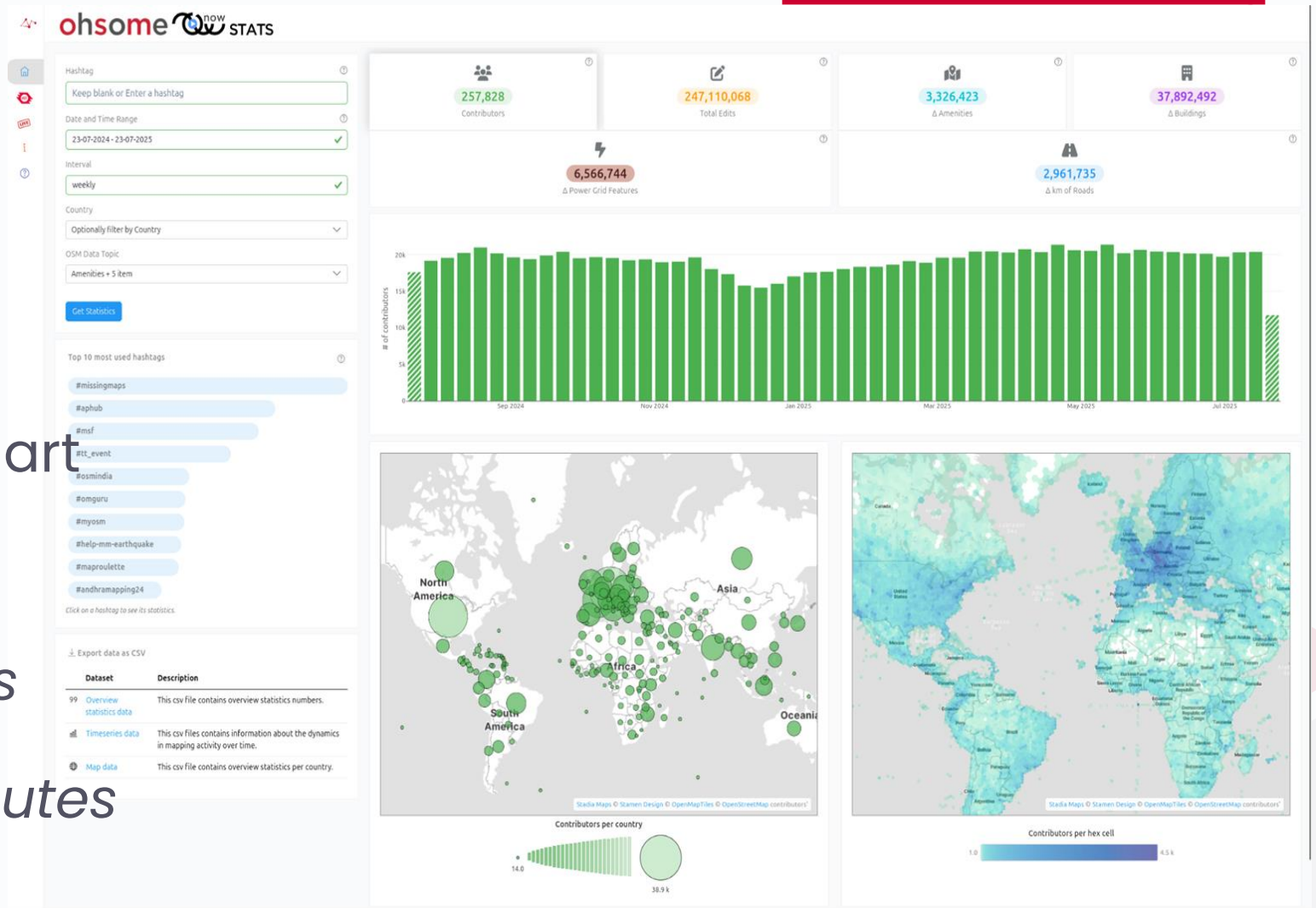
ohsomeNow stats

stats.now.ohsome.org

Current Features:

- Overview Statistics
- Country Map + H3 Hex Map
- Timeline Plot
- Trending Hashtags Chart
- Data Download
- Live Mode

“Every edit made to OSM is instantly reflected on the dashboard, just a few minutes after it happens.”



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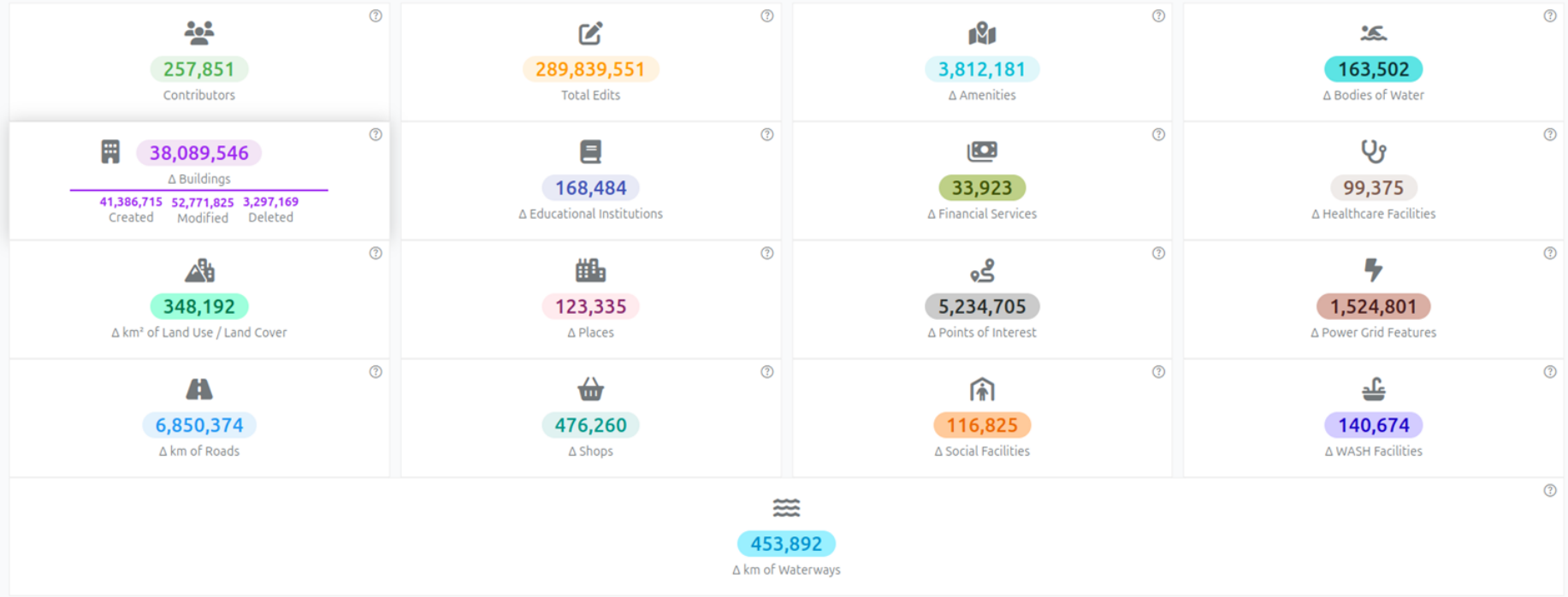
Overview statistics on topics

Currently, you can calculate overview statistics for up to **17 topics** at the same time.
For each topic you can check the number of (created, modified, deleted) OSM features.

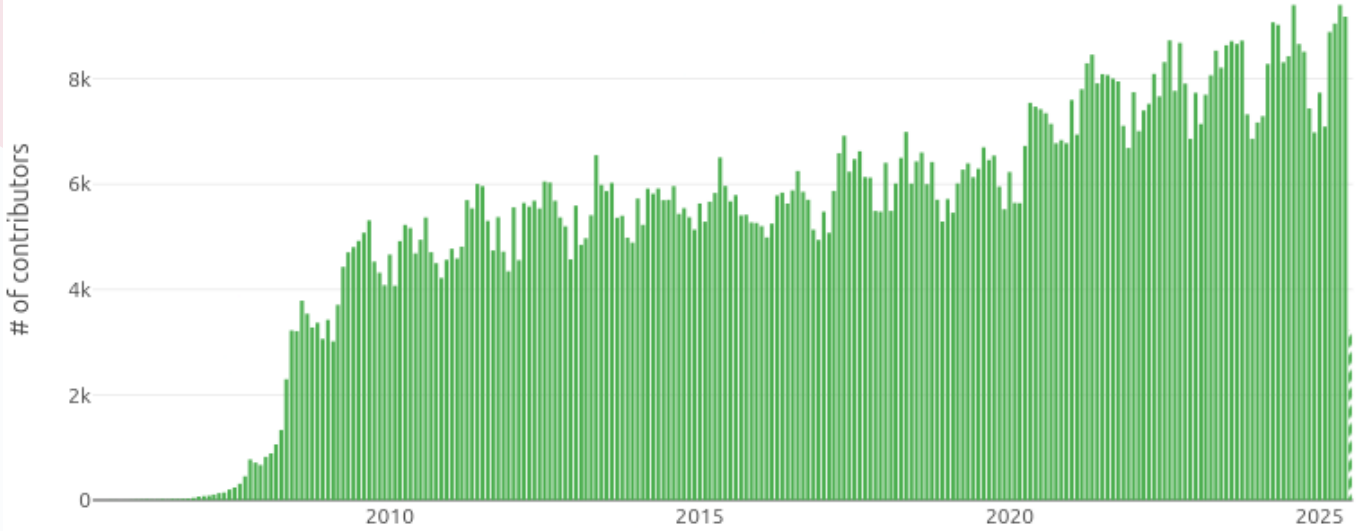
Overview statistics for [buildings in Germany 04-2005 - 07-2025]



ohsomeNow stats - Timeline Plot

shows how mapping in OSM has changed over time.

You can optionally filter for a OSM changeset hashtag or using a list of countries.



“I want to know how many mappers edit OSM every months since 2004 in Germany.”

about 9,000 monthly active mappers in Germany in 2025

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ohsomeNow stats - Timeline Plot

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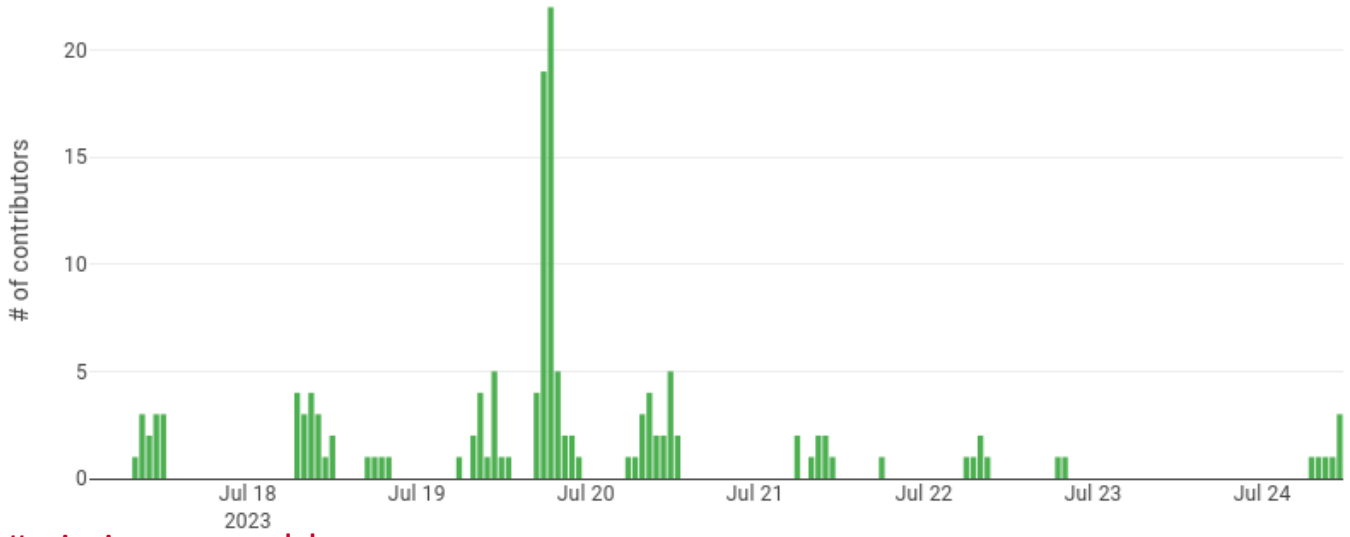


#missingmaps_drk

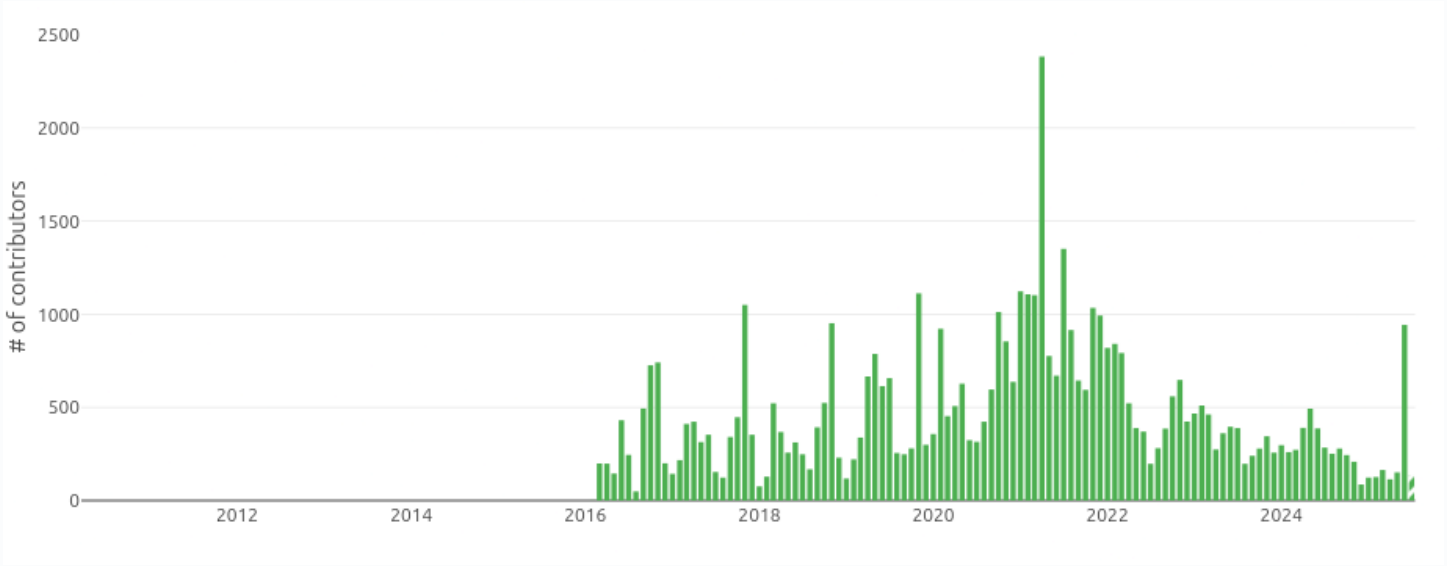
"Using hourly intervals can show the effectiveness of single mapathons."

ohsomeNow stats - Timeline Plot

shows how mapping in OSM has changed over time.

You can optionally filter for a OSM changeset hashtag or using a list of countries.

“Larger intervals of several days or even months can give information about the success of long-term mapping campaigns.”



#youthmappers

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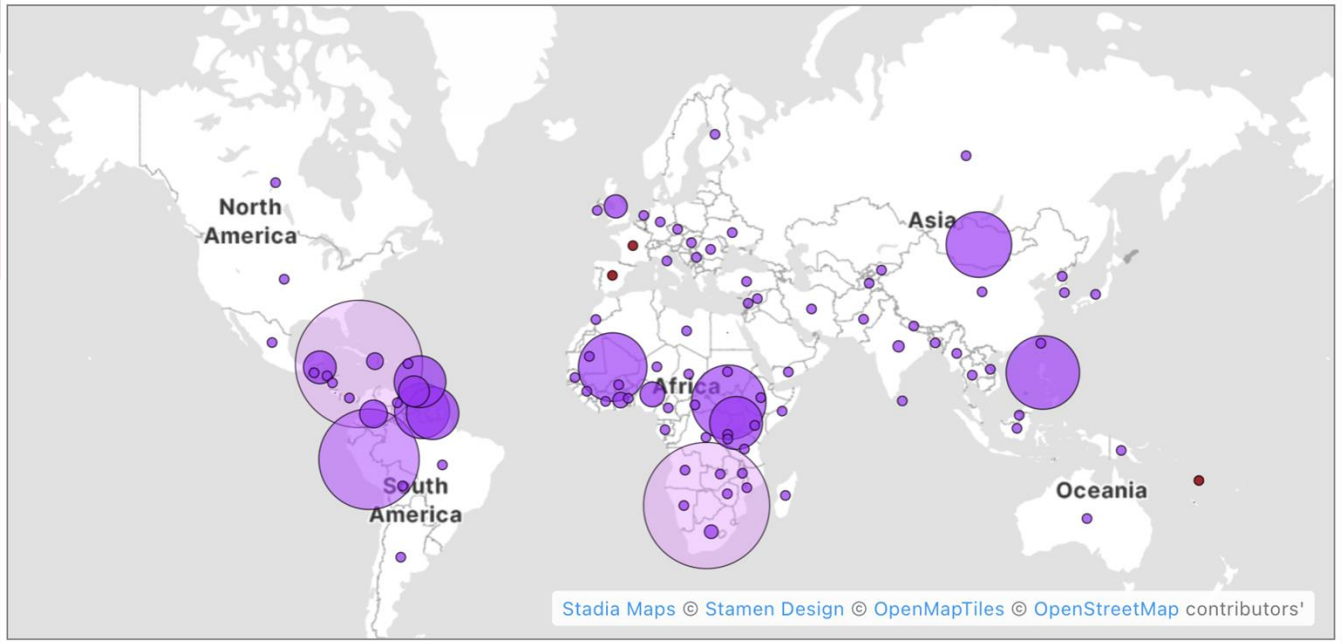
ohsomeNow stats - Country Map

Get an interactive world map on mapping activity per country



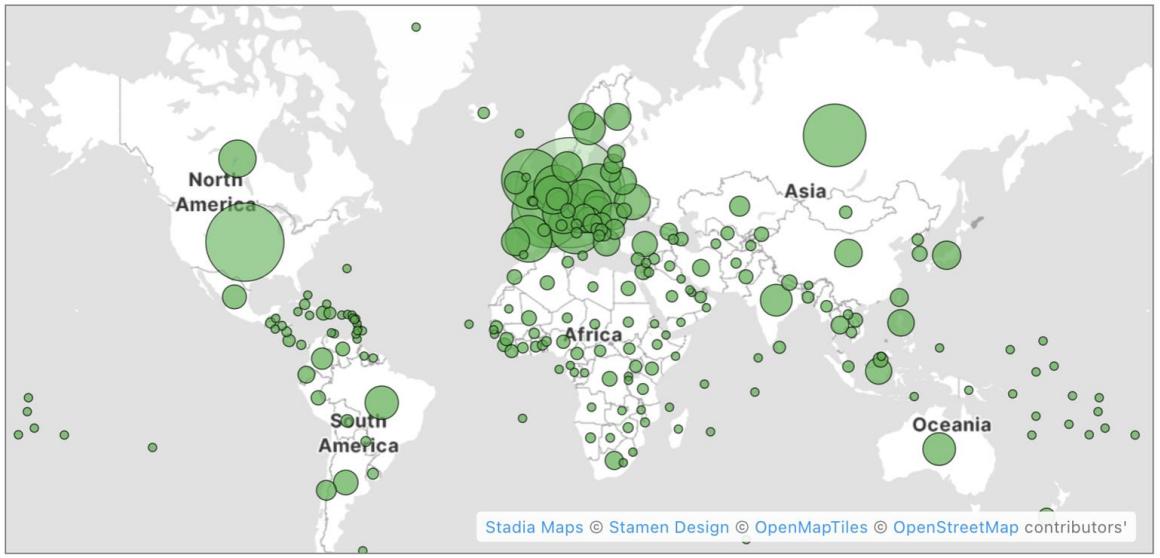
"How many buildings were added per country during the Covid-19 response mapping?"

#covid19

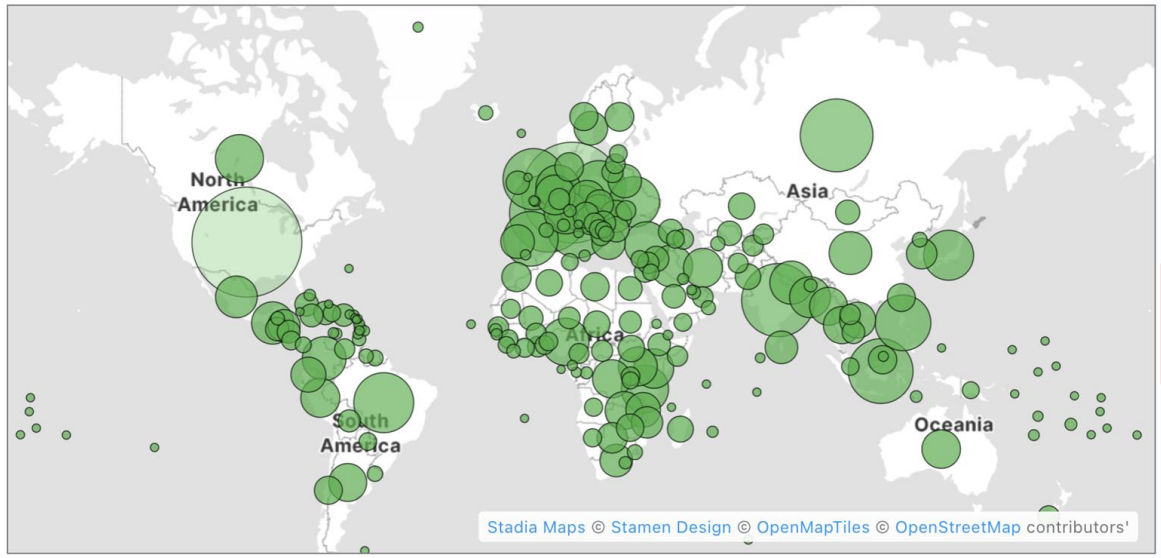
ohsomeNow stats - Country Map

"Compare mapping activity between two time intervals:
As of 2025, OSM has grown into a truly global community and is less biased than during its inception."

2005 - 2015

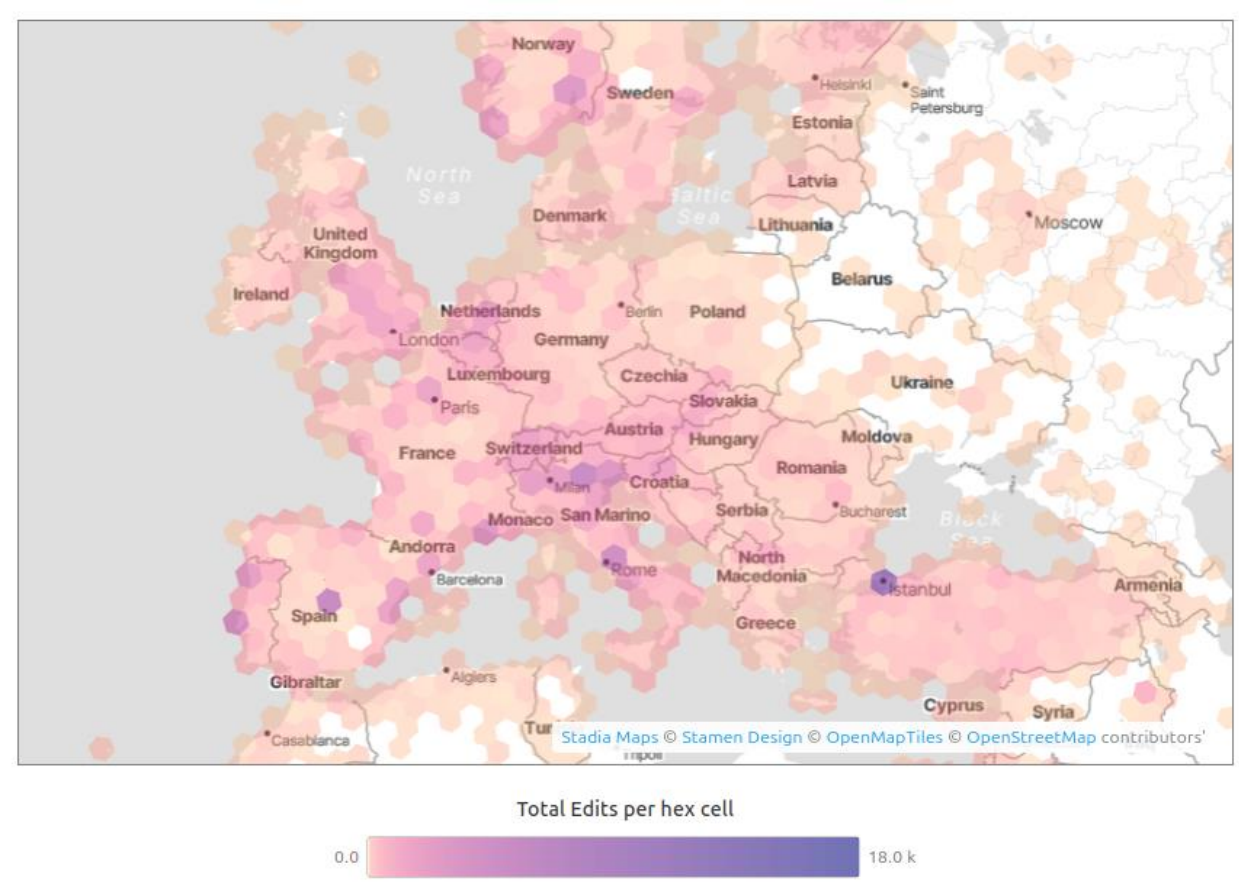


2015 - 2025



ohsomeNow stats - H3 Hex Map

#tomtom (23-07-2024 - 23-07-2025)



Inspect where mapping in OSM happened at a high spatial resolution using the H3 hexagonal grid.

"Where are the hotspots of TomTom's mapping activity in Europe?"

ohsomeNow stats - Permalinks

You can copy the URL & share your current dashboard configuration with others.

The permalink captures relevant user-defined settings, such as time range, hashtag, or country filter.

https://stats.now.ohsome.org/dashboard#**hashtag=heigit**&**start=2005-04-09T20:54:39Z**&**end=2025-07-08T16:46:59Z**&**interval=P1M**&**active_topic=edit**&**countries=NGA**&**topics=building,contributor,road,edit**

ohsome quality api

API & web client for easy access to OSM data quality estimations & full history statistics

Also used in OSM quality project with BKG

Bundesamt für Kartographie und Geodäsie

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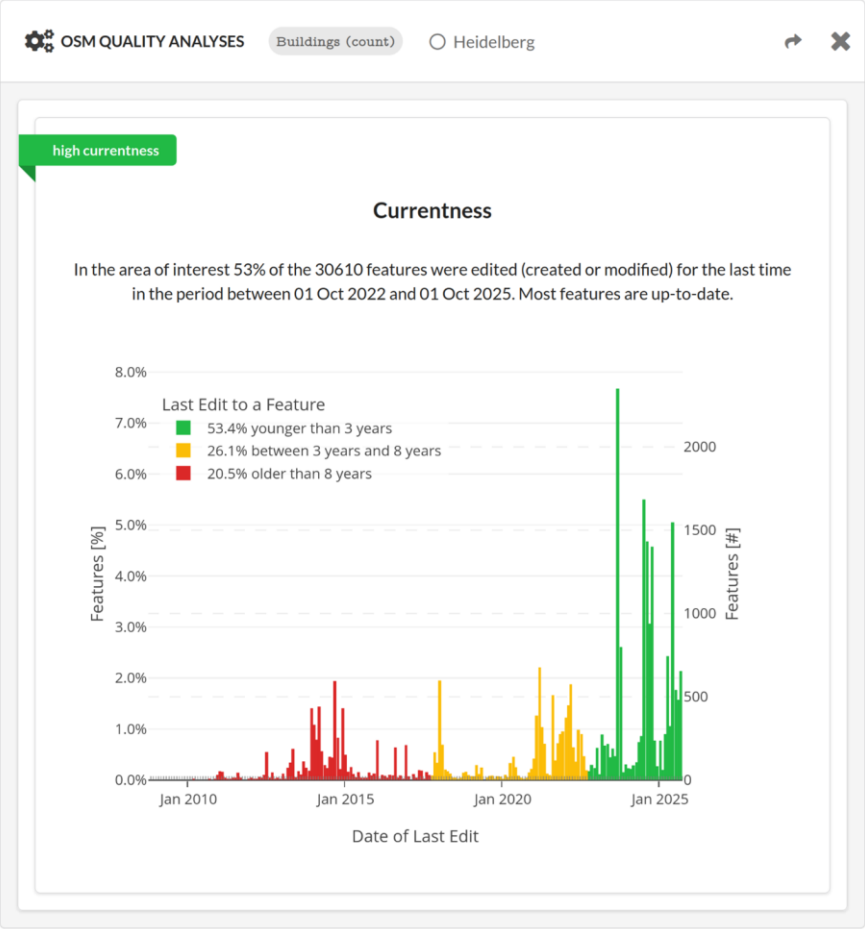
OSM data quality analysis



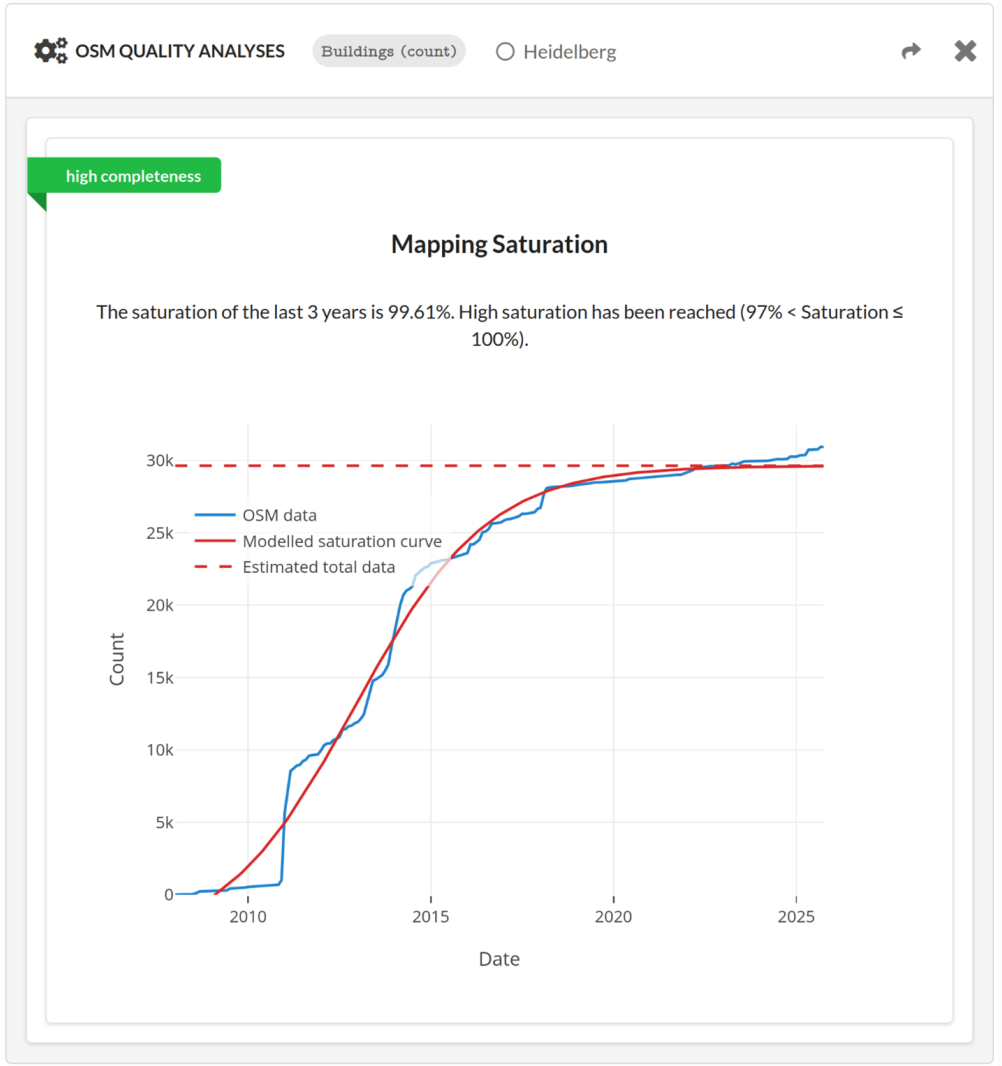
e.g. Is OSM up-to-date?

Estimate the currentness of OSM features by classifying contributions based on topic specific temporal thresholds into 3 groups:

up-to-date, in-between and out-of-date.

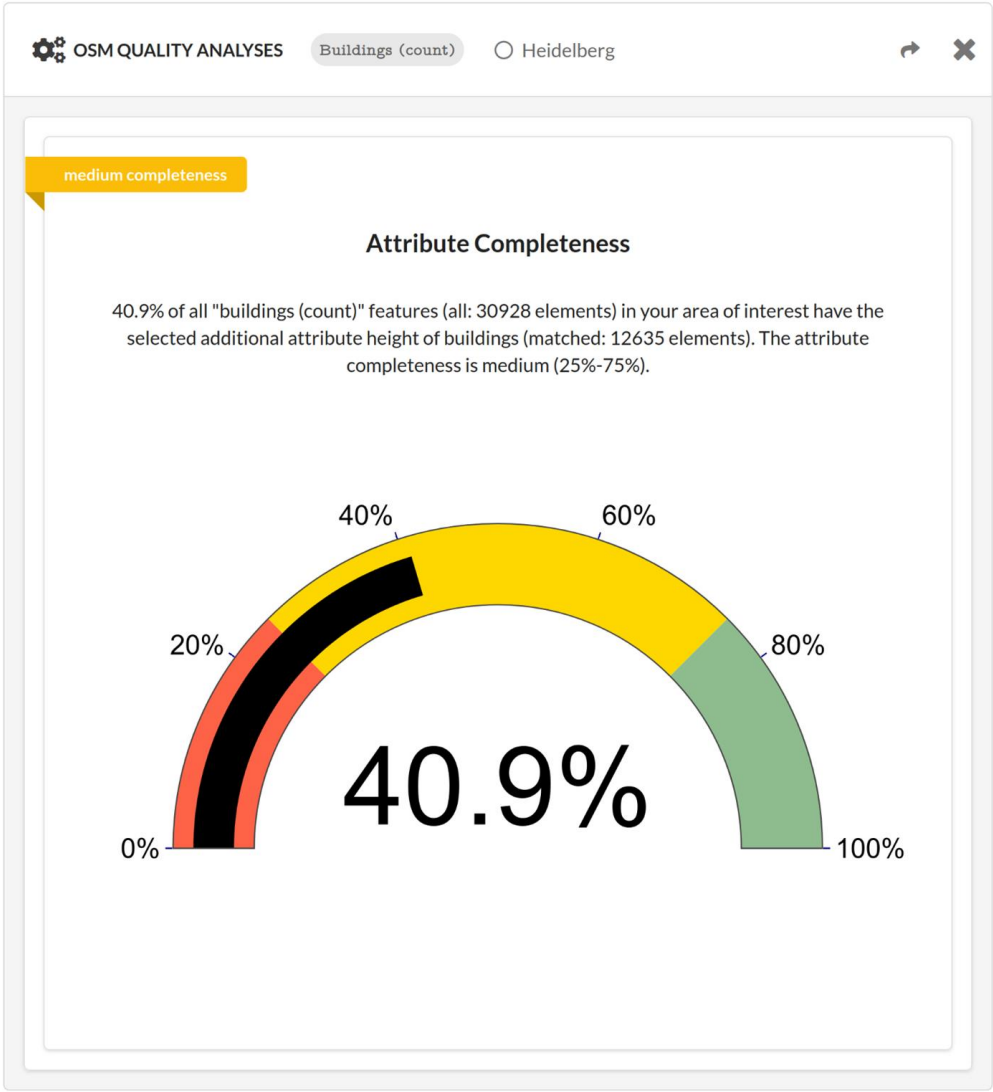
Mapping Saturation

Calculate if mapping has saturated. High saturation has been reached if the growth of the fitted curve is minimal.



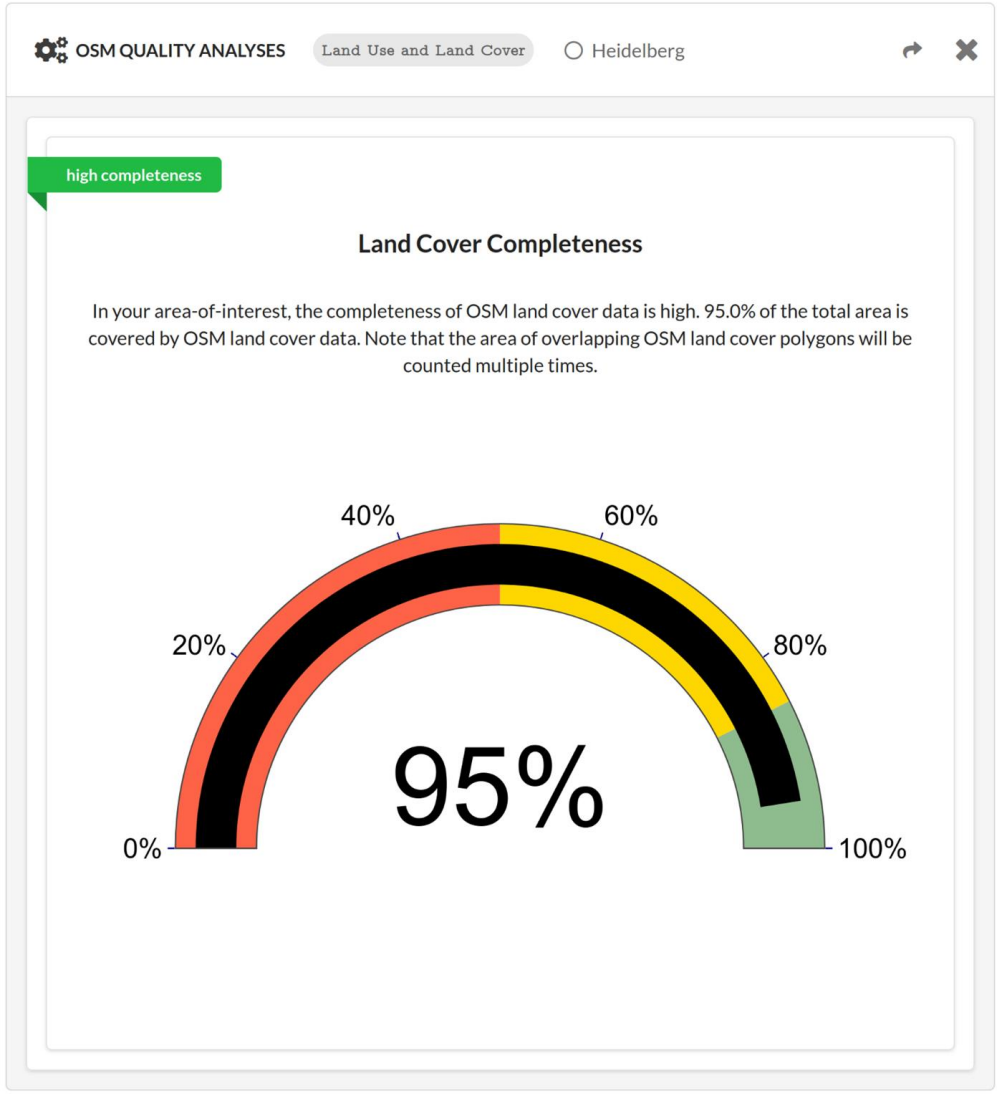
Attribute Completeness

Derive the ratio of OSM features compared to features that match additional expected tags (e.g. amenity=hospital vs amenity=hospital and wheelchair=yes).



Land Cover Completeness

Percentage of the area of interest that is covered by OSM land cover data.



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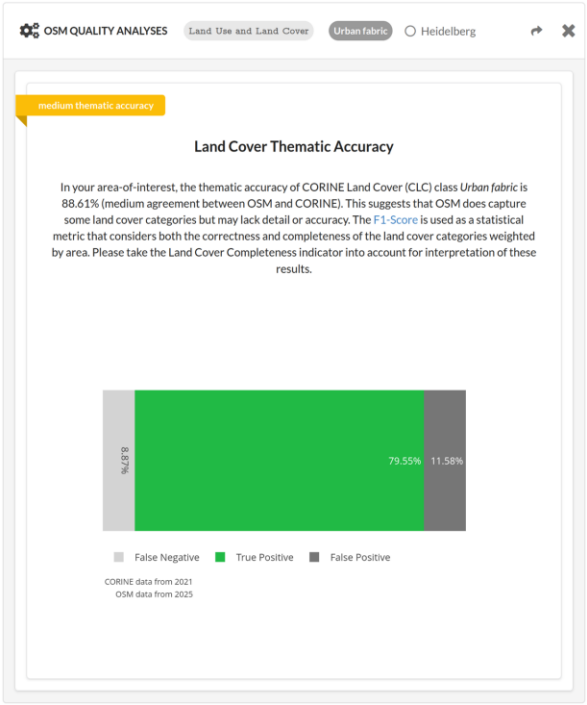
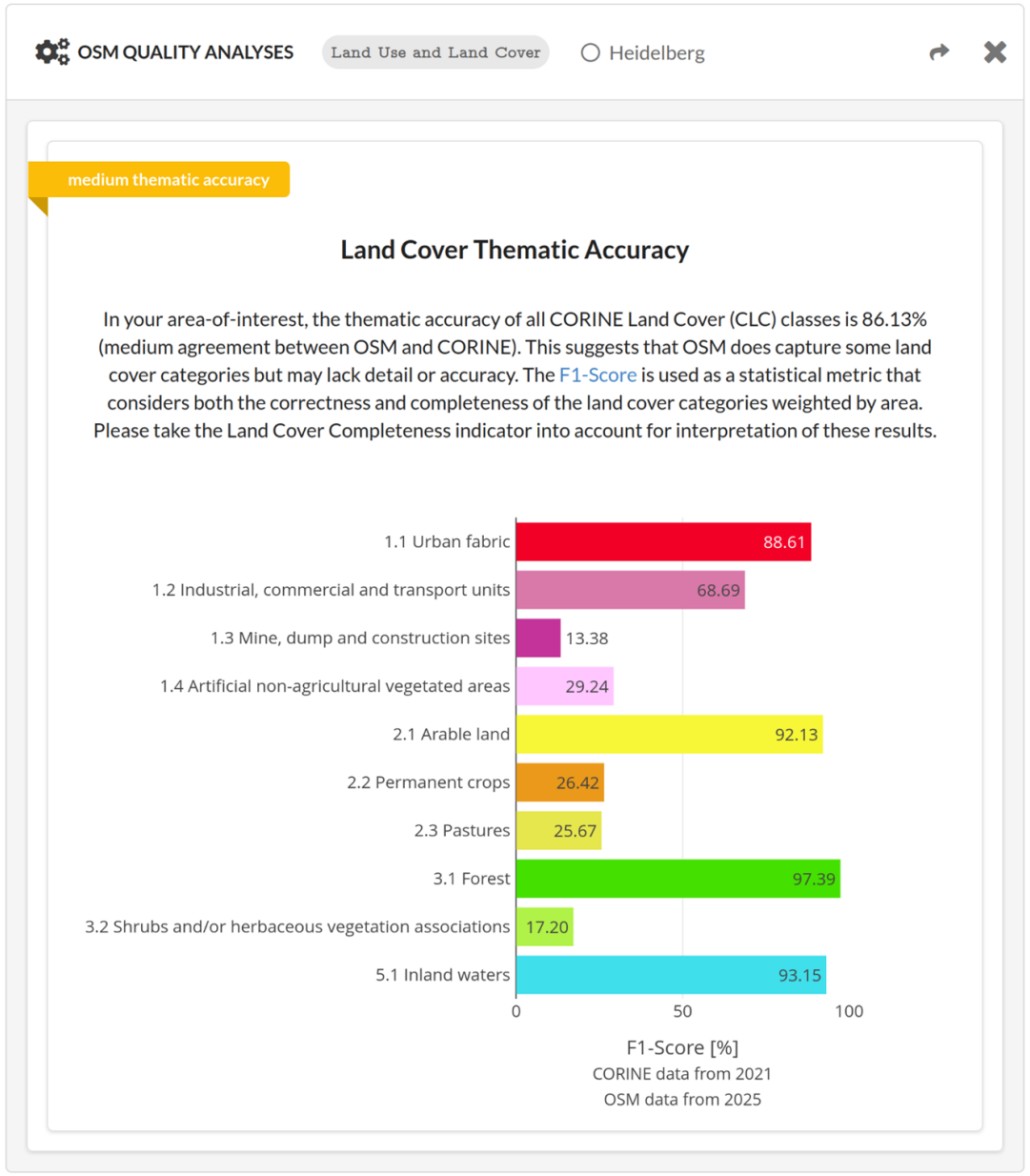
Land Cover Thematic Accuracy

Thematic accuracy of OSM land cover data in comparison to the CORINE Land Cover (CLC) dataset.





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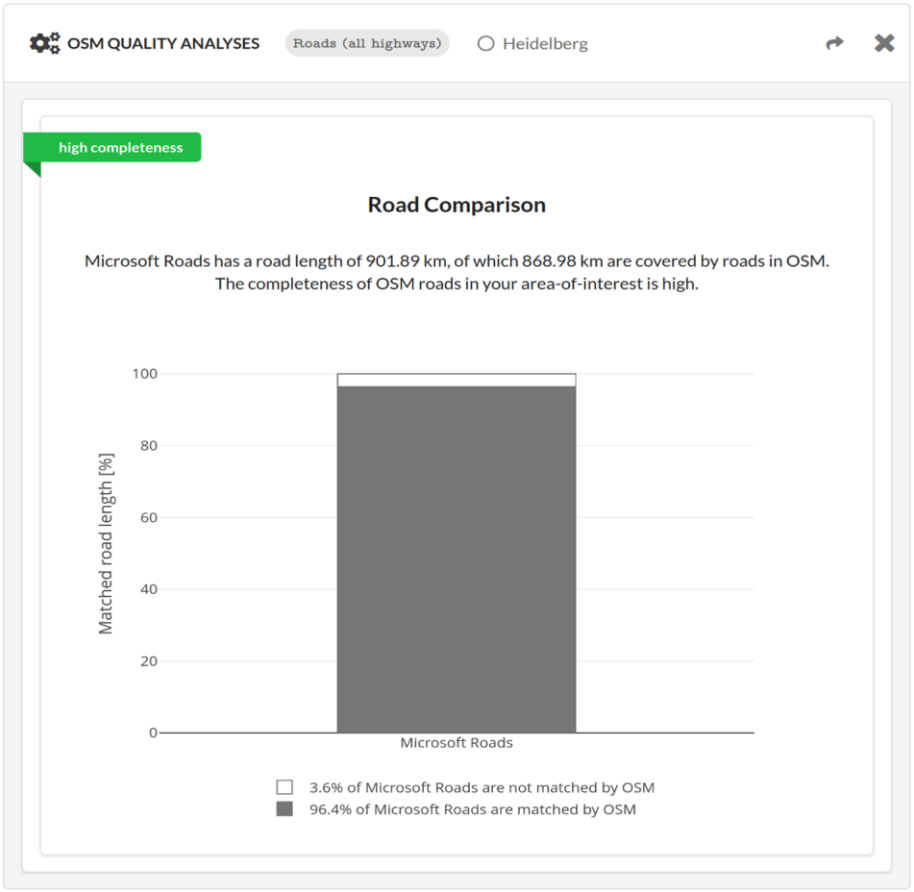
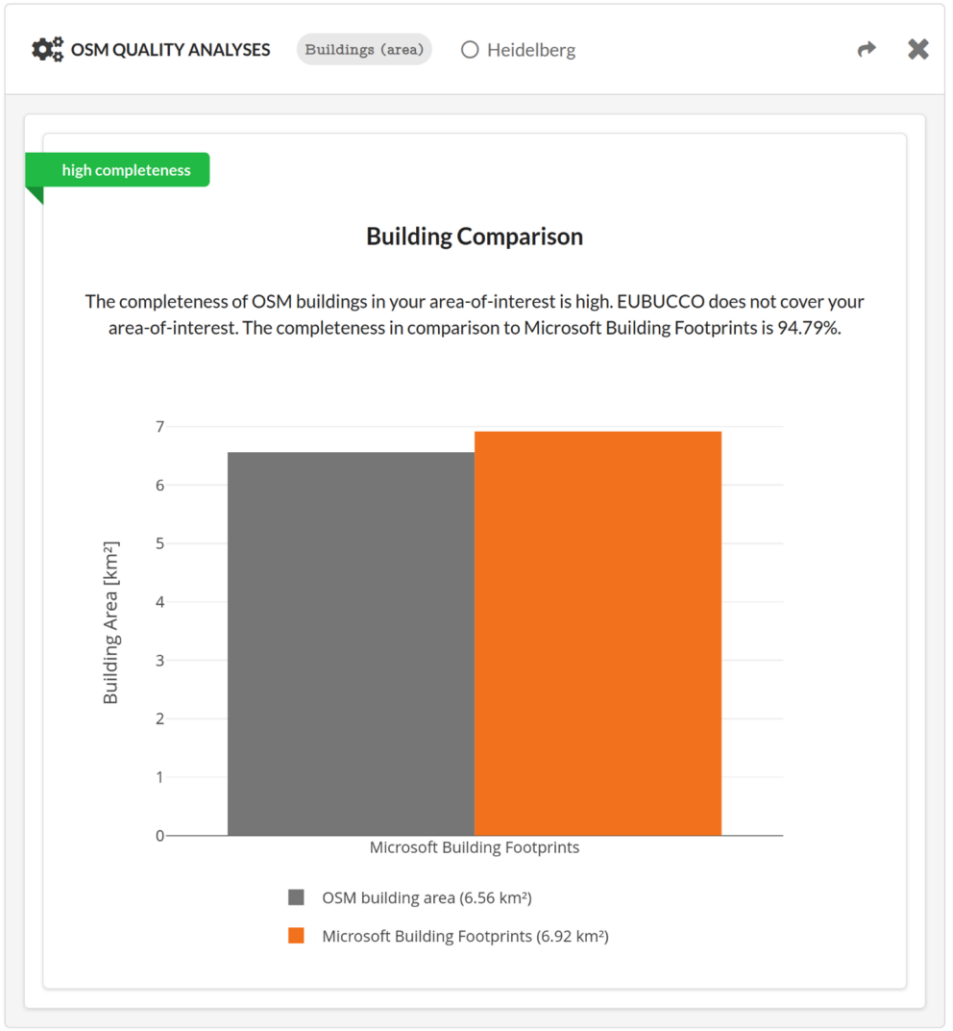
Building or Road Comparison

Comparing OSM buildings or roads with reference datasets.





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OSM data extraction

Extract road surface information
e.g. for a bikability indicator

in the HeiGIT Climate Action Navigator.

Paths made of certain materials (e.g., asphalt) are generally good for cycling, while others (e.g., cobblestones) are rather uncomfortable or even unsafe.

This map classifies paths by the most common surface types tagged in OSM.

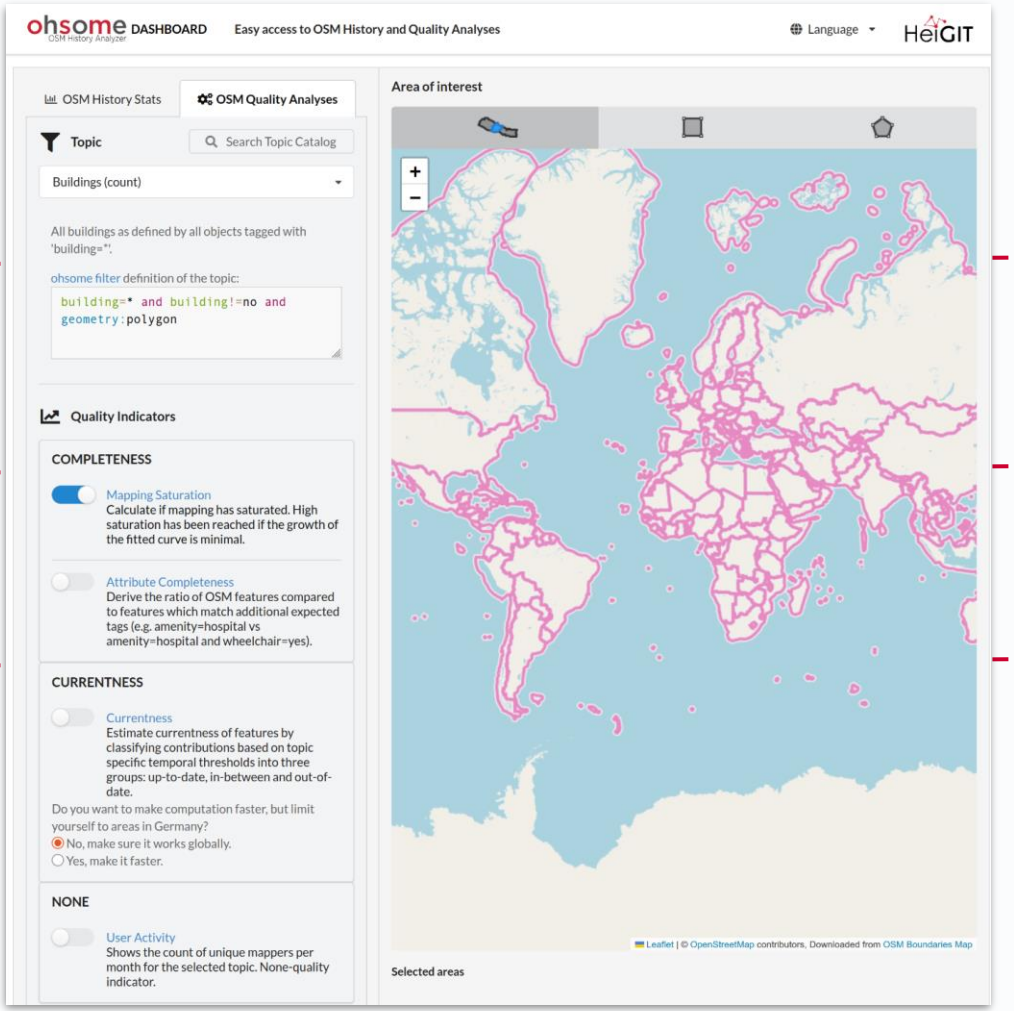
Towards ohsome 2.0

'o:səm

Usage & future improvements

Web Client for easy access

to OSM Data Quality Analyses & History Insights



https://dashboard.ohsome.org/

ohsome dashboard

ohsome API
ohsome quality API

ohsomeDB
ohsome-filter-to-sql

ohsome planet

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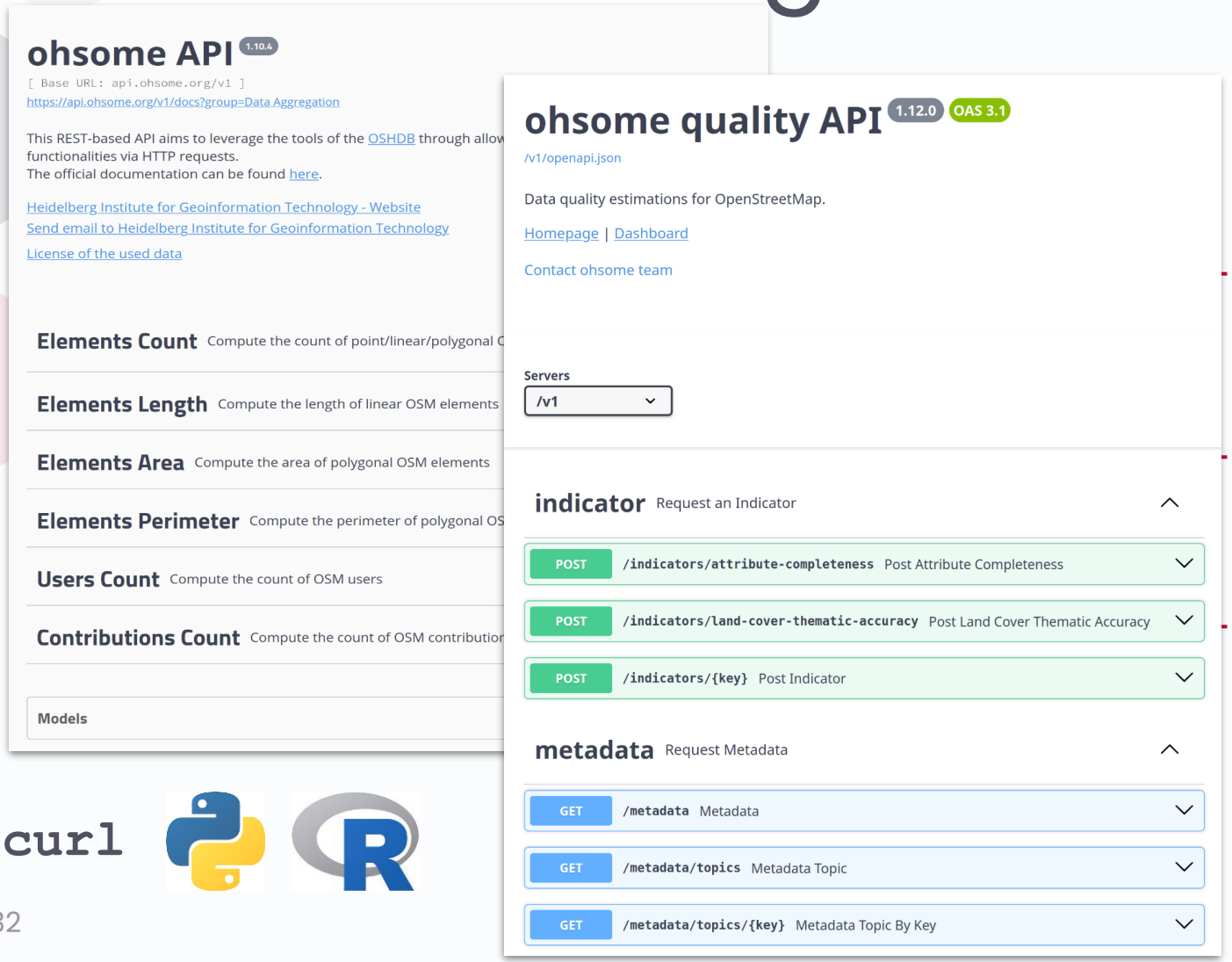
Upcoming Improvements

- faster
- UI for data extraction
- new data quality indicators (e.g., road thematic accuracy)
- new history insights indicators (e.g. user activity, changeset filter)
- pre-defined ohsome filters (“topics”) can be used everywhere

APIs for analysing OSM data quality & historic changes



curl

ohsome dashboard

ohsome API
ohsome quality API

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Upcoming Improvements

- **major refactoring!**
- simplified / consistent ohsome API endpoint structure
- response as **GeoParquet** for data extraction
- response compatible with Pandas, Polars for aggregation stats
- user management & API keys

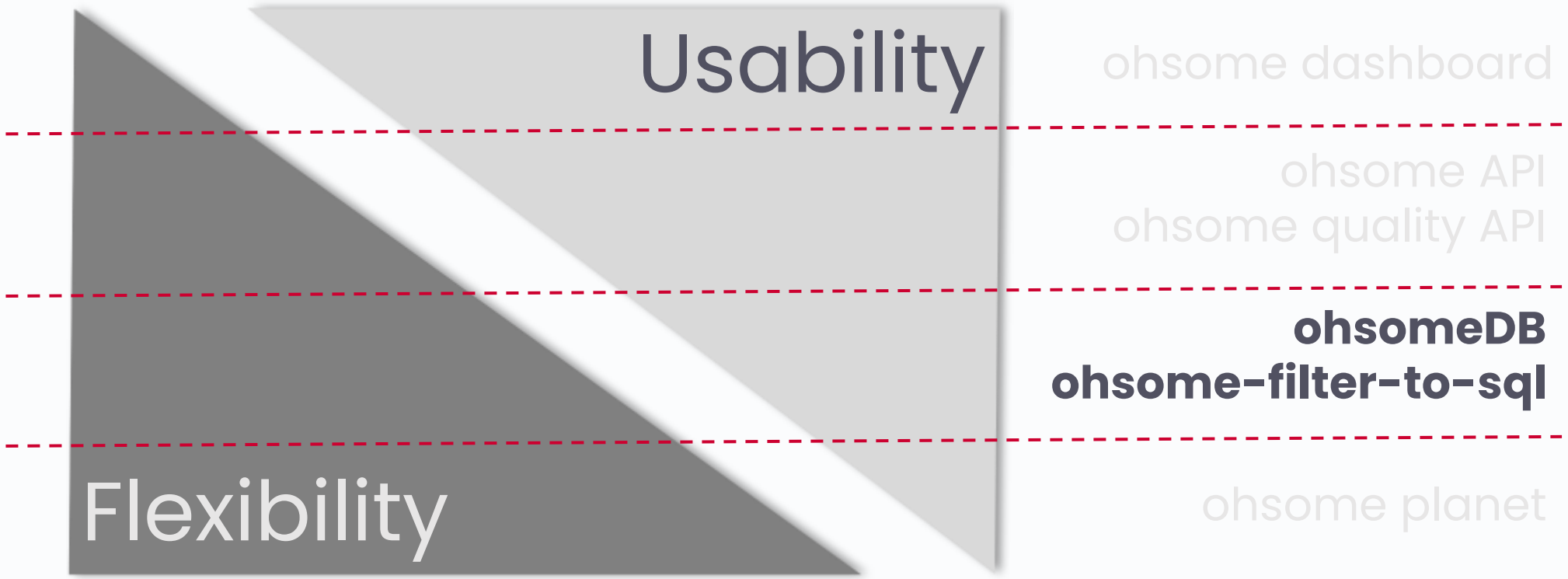
ohsome dashboard

ohsome API
ohsome quality API

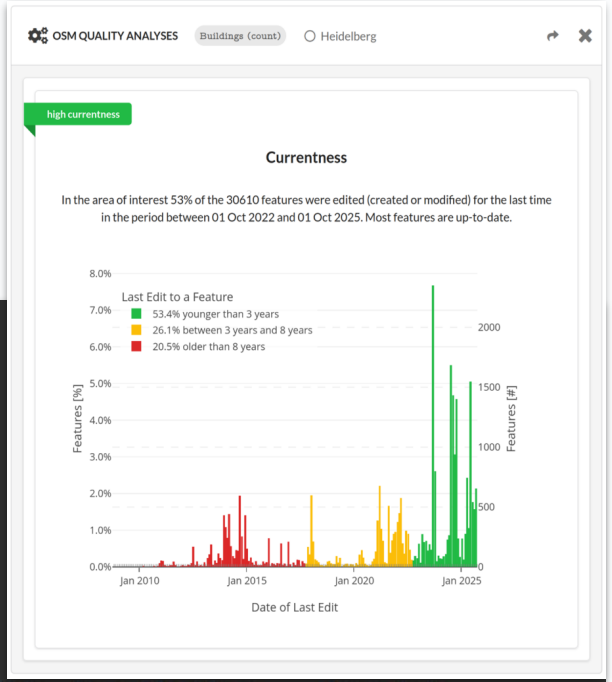
ohsomeDB
ohsome-filter-to-sql

ohsome planet

The technology layer - going SQL



ohsomeDB – e.g., currentness




```sql
SELECT
    date_trunc('month', valid_from) as month,
    count(*)
FROM contributions
WHERE 1=1
    AND ST_Intersects(
        geom,
        ST_MakeEnvelope(13.3721739,52.4943749,13.4370268,52.5345756, 4326)
    )
    AND (status_geom_type = ('latest','Polygon')::status_geom_type_type
        or status_geom_type = ('latest','MultiPolygon')::status_geom_type_type)
    AND tags ? 'building'
GROUP BY month
ORDER BY month;
```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Transform OSM (history) PBF files into GeoParquet

Enrich with OSM changeset metadata & country information

DuckDB

```
-- list all columns
DESCRIBE FROM read_parquet('out-karlsruhe/*.parquet');

-- result

| column_name |
|   varchar   |

| status      | VARCHAR
| valid_from  | TIMESTAMP WITH TIME ZONE
| valid_to    | TIMESTAMP WITH TIME ZONE
| osm_type    | VARCHAR
| osm_id      | BIGINT
| osm_version | INTEGER
...
| bbox        | STRUCT(xmin DOUBLE, ymin DOUBLE, xmax DOUBLE, ymax DOUBLE)
| centroid    | STRUCT(x DOUBLE, y DOUBLE)
| xzcode      | STRUCT("level" INTEGER, code BIGINT)
...
| countries   | VARCHAR[]
| build_time  | BIGINT

| 27 rows
```

Full access to all OSM data without complex setup!

Java

```
java -jar ohsome-planet-cli/target/ohsome-planet.jar contributions \
    --pbf data/karlsruhe.osh.pbf \
    --country-file data/world.csv \
    --changeset-db "jdbc:postgresql://HOST[:PORT]/changesets?user=USER&password=PASSWORD" \
    --output out-karlsruhe \
    --overwrite
```

ohsome dashboard

ohsome API
ohsome quality API

ohsomeDB
ohsome-filter-to-sql

ohsome planet

Upcoming Improvements

- provide *minutely GeoParquet* files *with all OSM changes*
- updates for OSM changeset DB
- enrichment with OSM user experience attributes
- faster geometry building for complex multipolygon relations

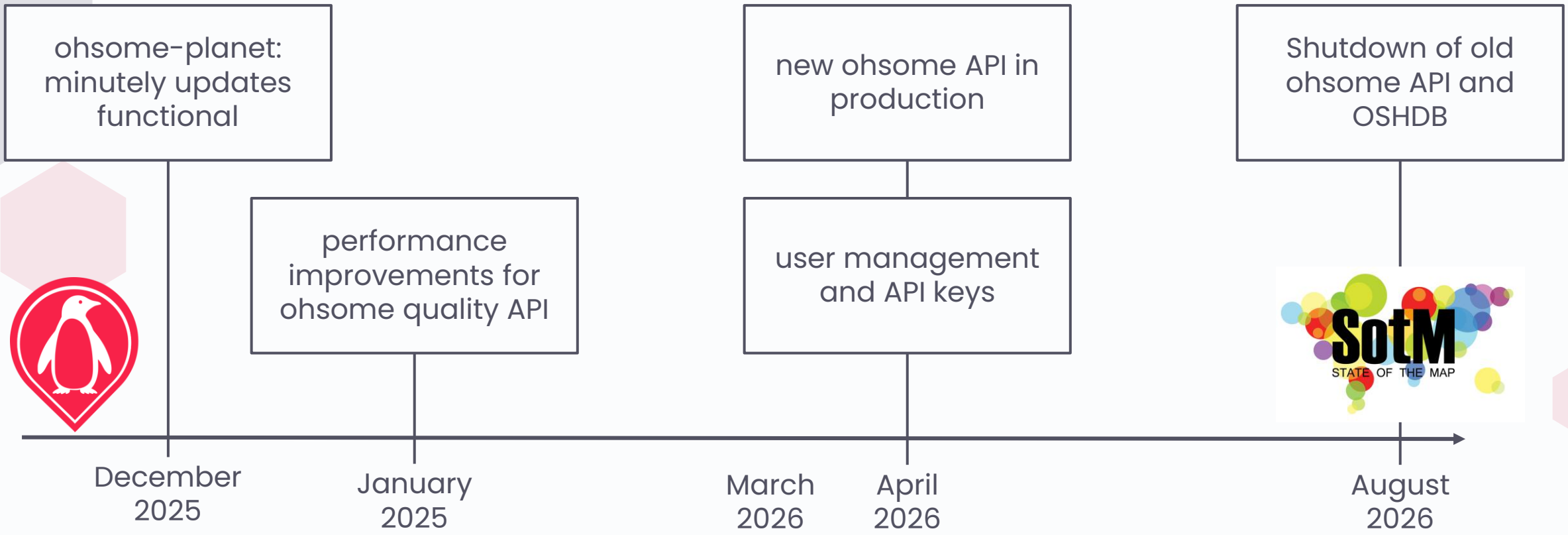
ohsome dashboard

ohsome API
ohsome quality API

ohsomeDB
ohsome-filter-to-sql

ohsome planet

From Dundee to Paris - Timeline



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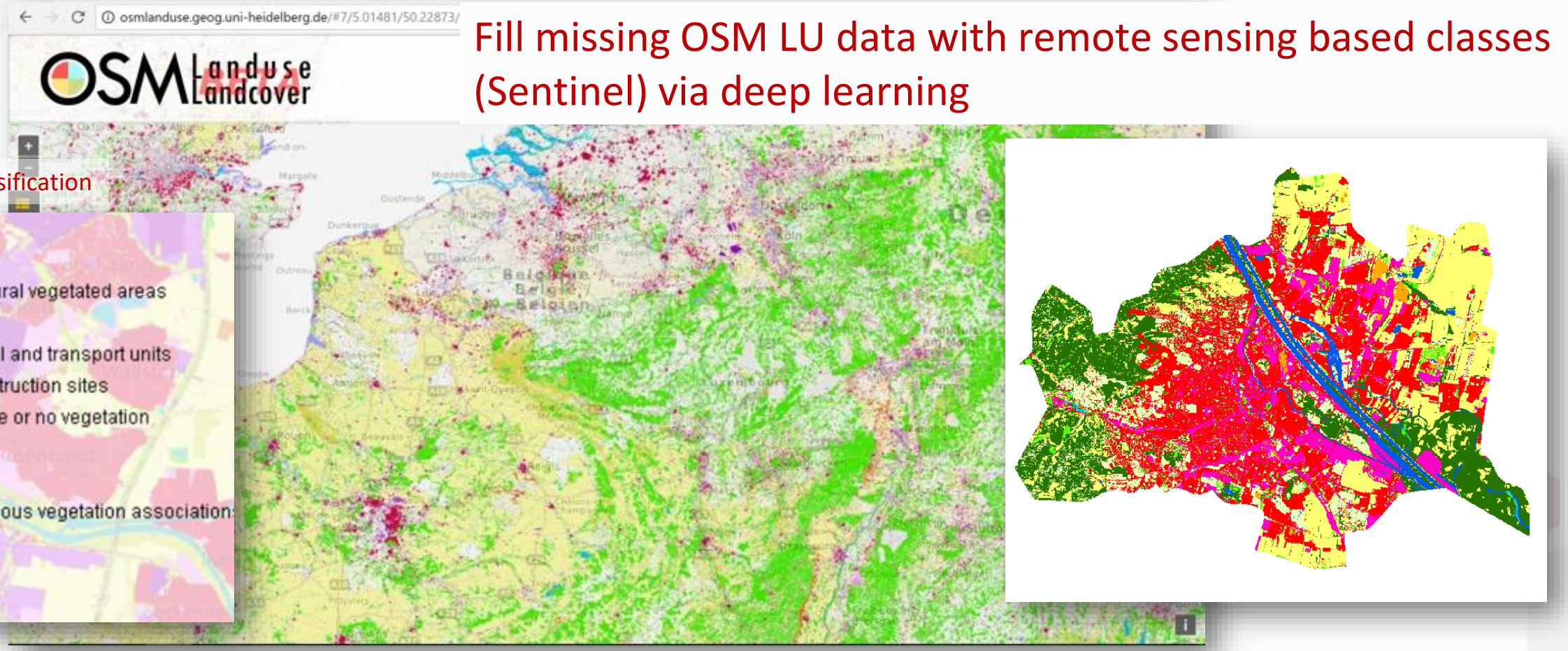
OSMlanduse.org 2.0

Fill missing OSM LU data with remote sensing based classes (Sentinel) via deep learning



Schultz, M., Li, H., Wu, Z., Wiell, D., Auer, M., Zipf, A. (2025): OSMlanduse , a dataset of European Union land use at 10 m resolution derived from OpenStreetMap and Sentinel-2. ***Nature Scientific Data*** 12, 750 (2025). doi.org/10.1038/s41597-025-04703-8

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LaVerDi: Automated National Land-Cover Change Service

Existing Service by BKG based on remote sensing

New project with HeiGIT extending LaVerDi **towards continuous monitoring** through integrating crowdsourced semantics & earth observation data

Bundesamt für Kartographie und Geodäsie

Knoefel, P., Herrmann, D., Sindram, M., and Hovenbitzer, M.: GERMANYS FIRST CLOUD-BASED WEB SERVICE FOR LAND MONITORING USING COPERNICUS SENTINEL-2 DATA, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., V-3-2021, 133–140, https://doi.org/10.5194/isprs-annals-V-3-2021-133-2021, 2021.

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Marrying Crowdsourced Semantics with Satellite Objectivity

OpenStreetMap

Human-generated collective sensor providing semantic labels, land-use classifications, & real-time updates reflecting social & infrastructural dynamics

Challenge:
Subjective, prone to omissions and misclassifications

Satellite Imagery

Objective, observation recording surface state with consistent temporal & spatial coverage & resolution

Challenge:
Lacks semantic meaning & land-use labels

Synergistic Integration

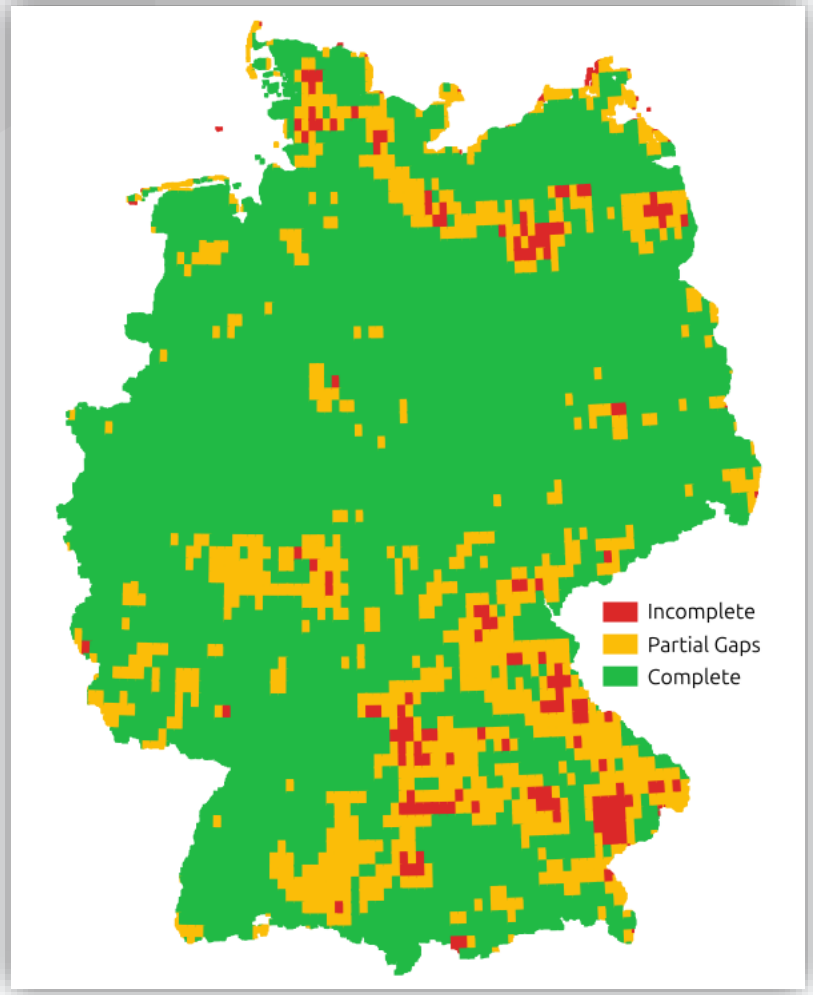
Combined approach achieves richer, verified change detection capabilities

OSM tells us **what** changed

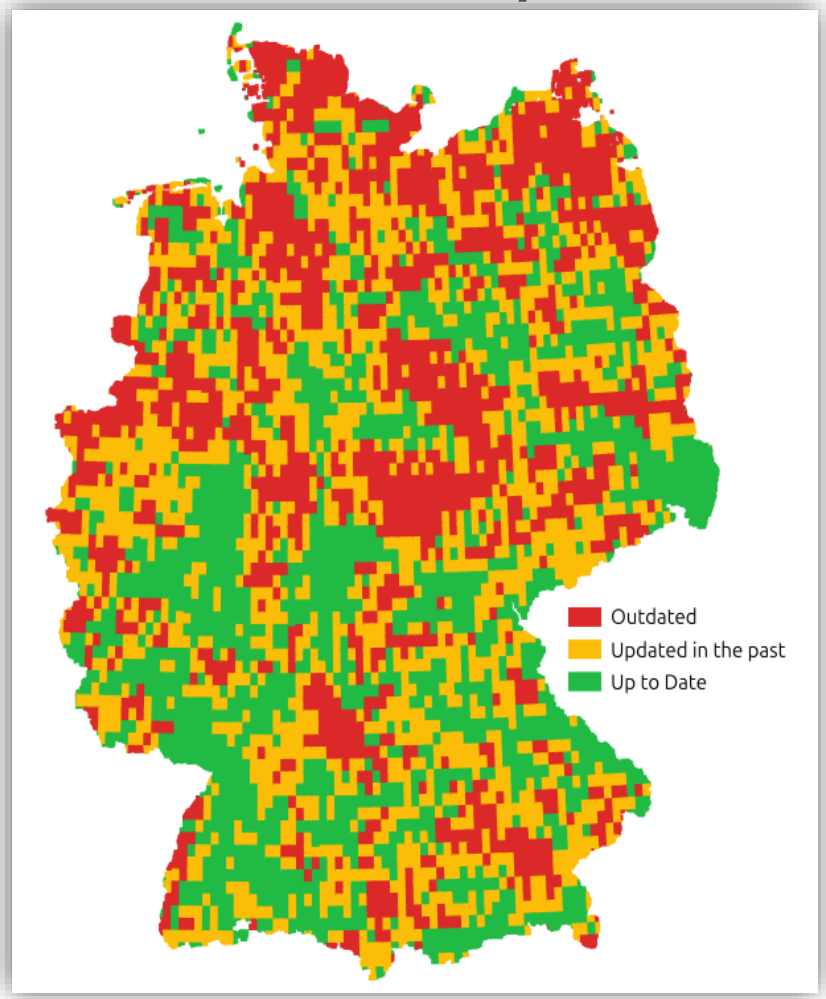
Satellite tells us **whether** it really did

This synergy enables detection of true landscape change by leveraging the complementary strengths of human interpretation & objective observation.

Ensuring OSM Quality using ohsome Quality API (OQAPI)



Completeness Indicator. Ratio of total area covered to area covered by OSM LULC data. The thresholds for yellow is 0.5, for green it is 0.85.



Currentness Indicator. Ratio of all OSM LULC data to the OSM LULC data last edit in the past 3 years. The thresholds for yellow is 0.5, for green it is 0.75.

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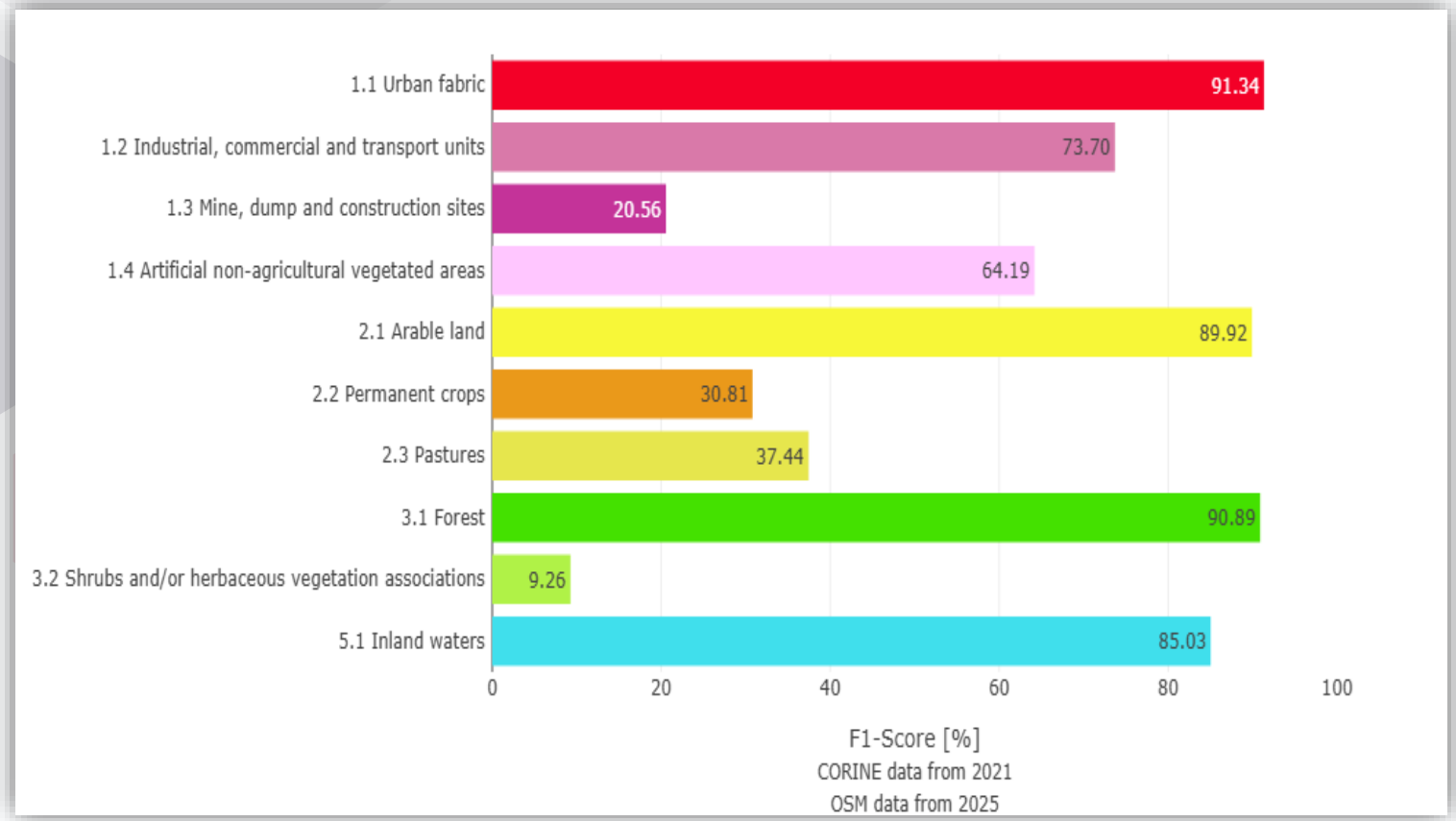
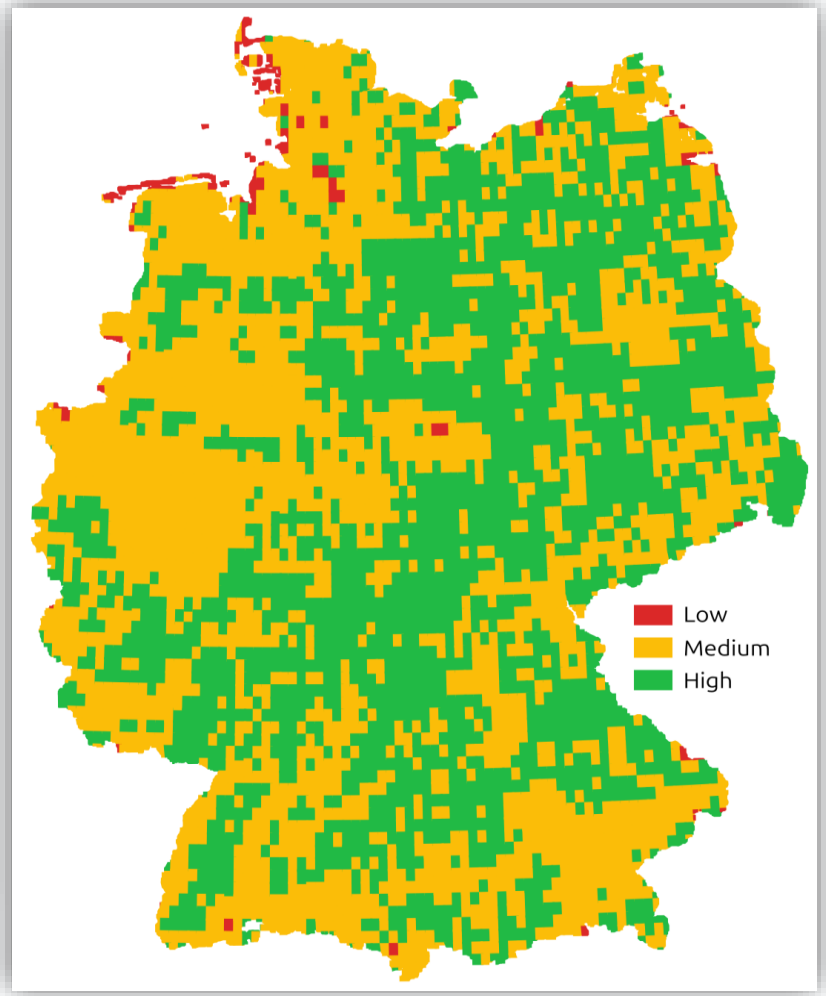
Ensure OSM Quality Before ML Integration





Thematic Accuracy Indicator for LULC OSM data. Each bar shows the F1-Score for the match between CORINE & OSM for this class.

Land Cover Thematic Accuracy Indicator. F1-score when matching CORINE data with corresponding OSM LULC data. The thresholds for yellow is 0.6, for green it is 0.85.

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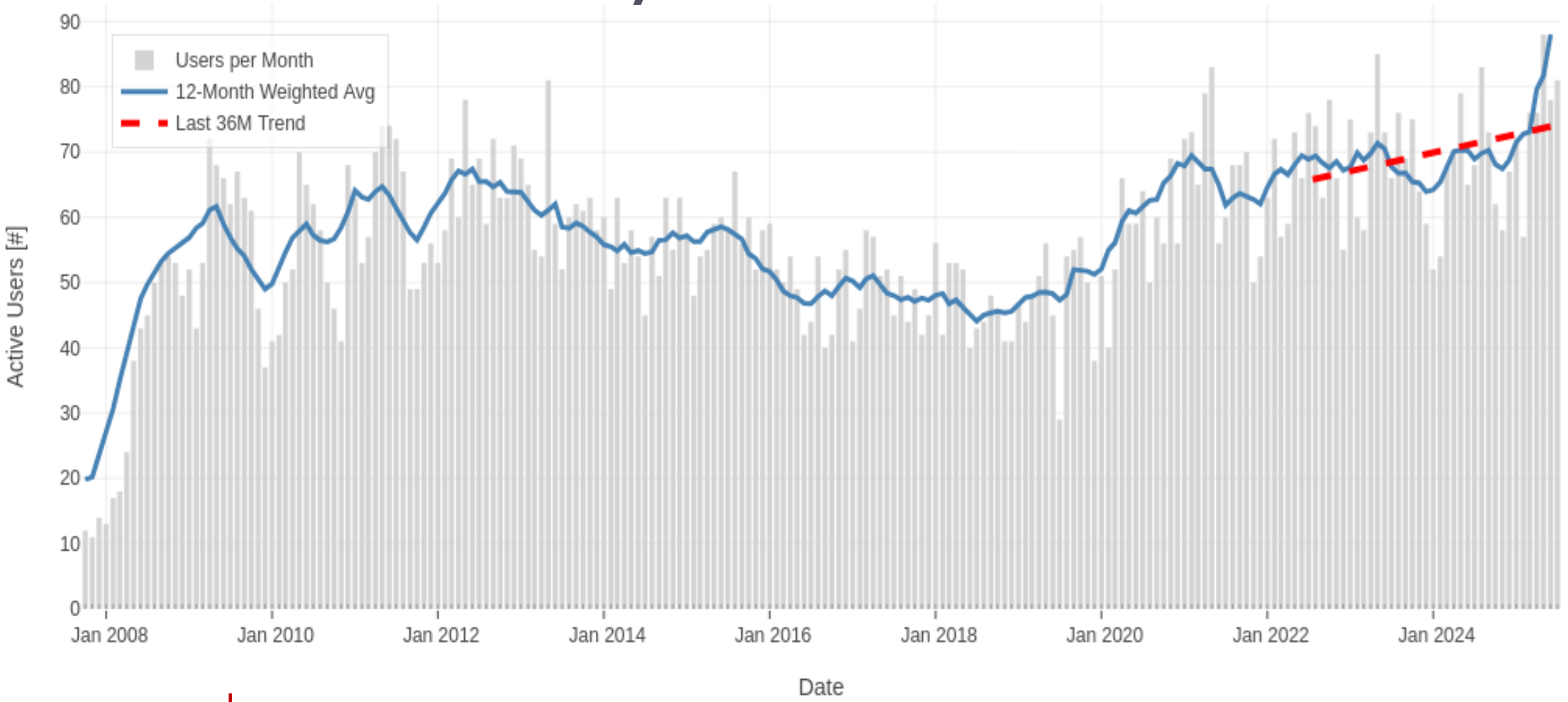
Users Activity



Nr of unique OSM users that added or edited OSM LULC data in that month.

https://ohsome.org/apps/dashboard-test/en/#backend=oqtApi&topic=land-cover&adminids=-285864&indicators=user-activity

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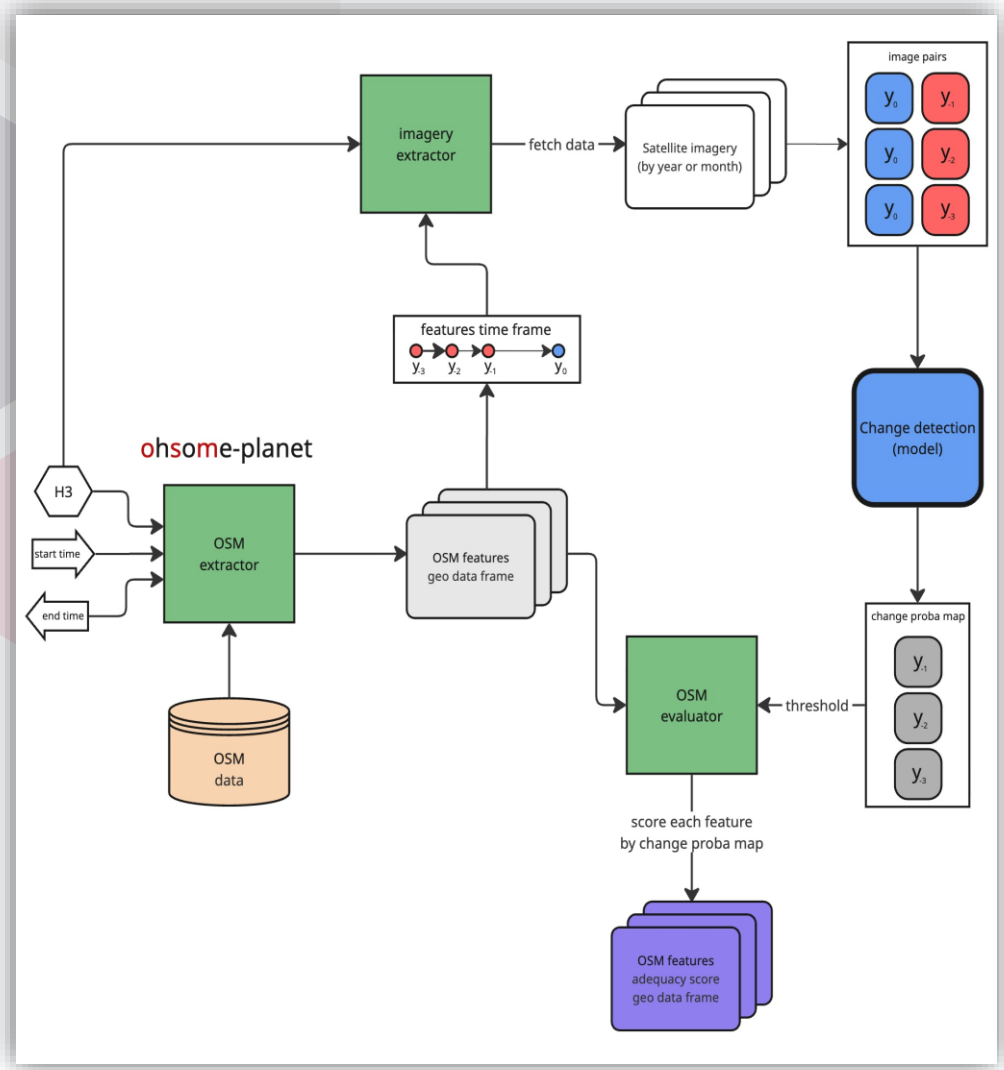
OSM–Satellite Change Detection Pipeline



Pipeline Workflow

Data Extraction Layer
Imagery extractor retrieves multi-temporal satellite data by year (Planet & Sentinel).
OSM extractor collects features within specified timeframes, ensuring temporal alignment between sources.

Change Detection Core
ChangeStar model performs deep learning-based change detection, comparing multi-temporal image pairs to generate pixel-wise change probability maps.

Evaluation Engine
OSM evaluator scores features by change probability, assessing likelihood that OSM changes reflect genuine land-cover transformations.

Output Generation
System produces **OSM features adequacy scores** in Geo format, providing quantitative plausibility assessments based on historical satellite patterns.

The workflow not only detects changes but also judges their plausibility, enabling automated credibility assessment of crowdsourced updates through satellite-validated confidence metrics.

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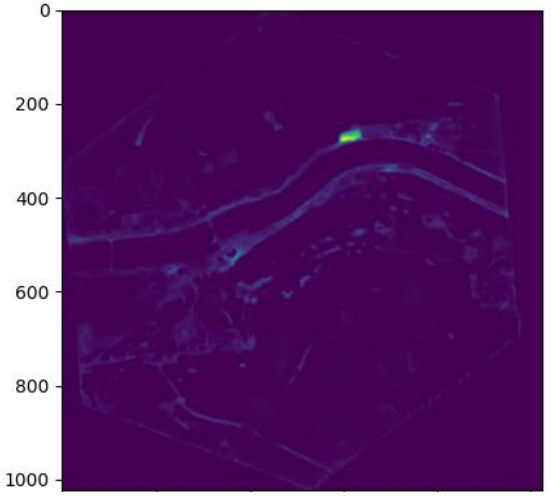
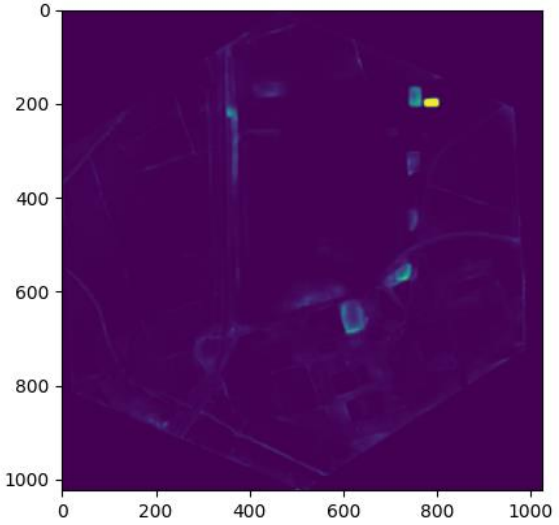
First results with ChangeStar DL model





t_0: 2022

t_1: 2024

Probability map

"s1_init_s1c1_changestar_vitl_1x256" model

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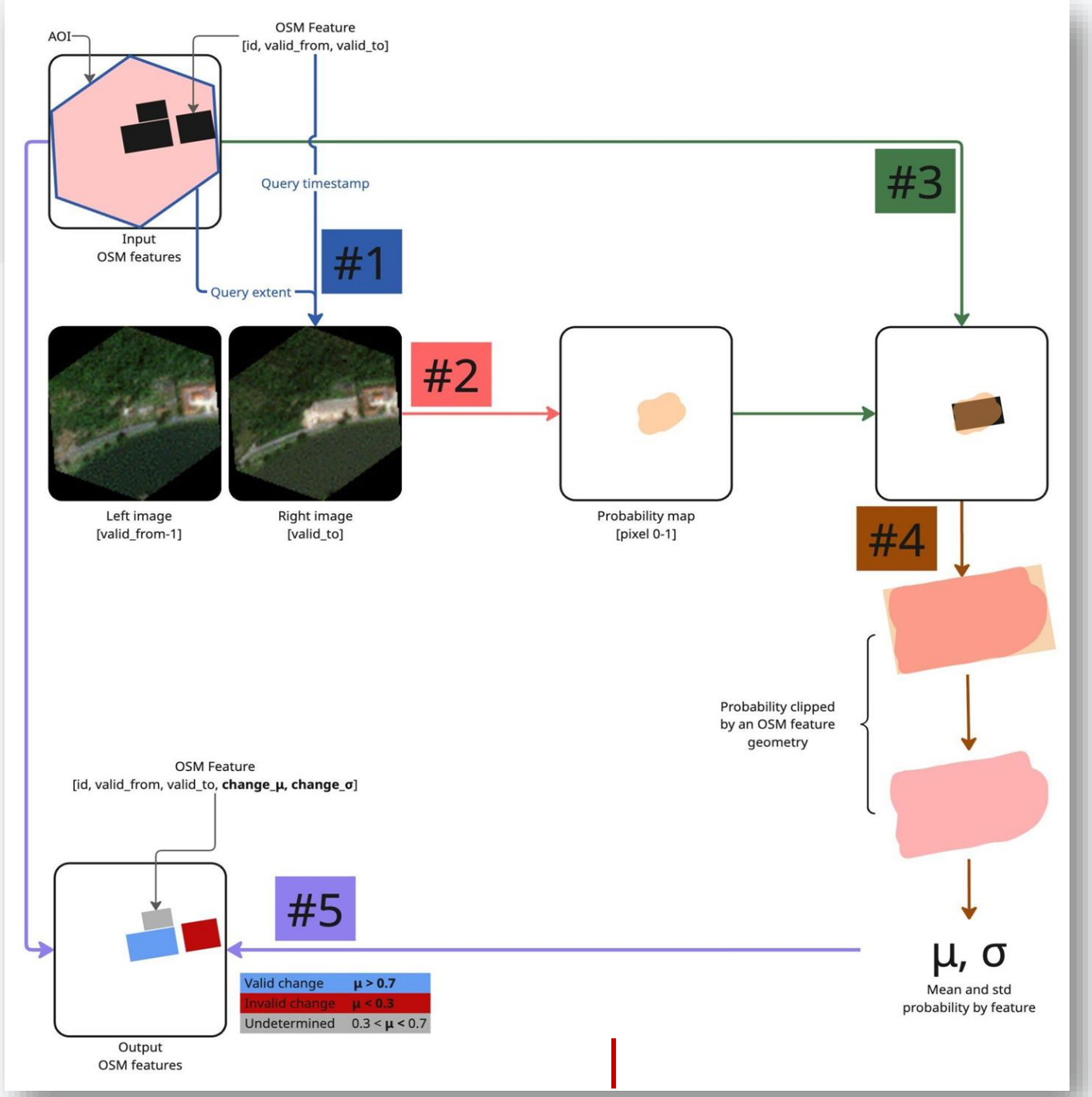
Example Workflow



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Laverdi Summary

New approach to automate landscape change detection & verification, leveraging the strengths of both OSM & satellite imagery.

Integrated Data Sources

Combining semantic depth from OSM with more objective satellite data offers a comprehensive view of landscape change.

AI-Powered Validation

Deep learning models like ChangeStar identify changes & validate crowdsourced updates for accuracy & trust.

Scalable & Open Future

Re-train ChangeStar to make it work with Sentinel-2.

Benchmark other open change detection models.

The integrated approach allows more **accurate, timely, & trustworthy** monitoring, bridging the gap between mapping & reality

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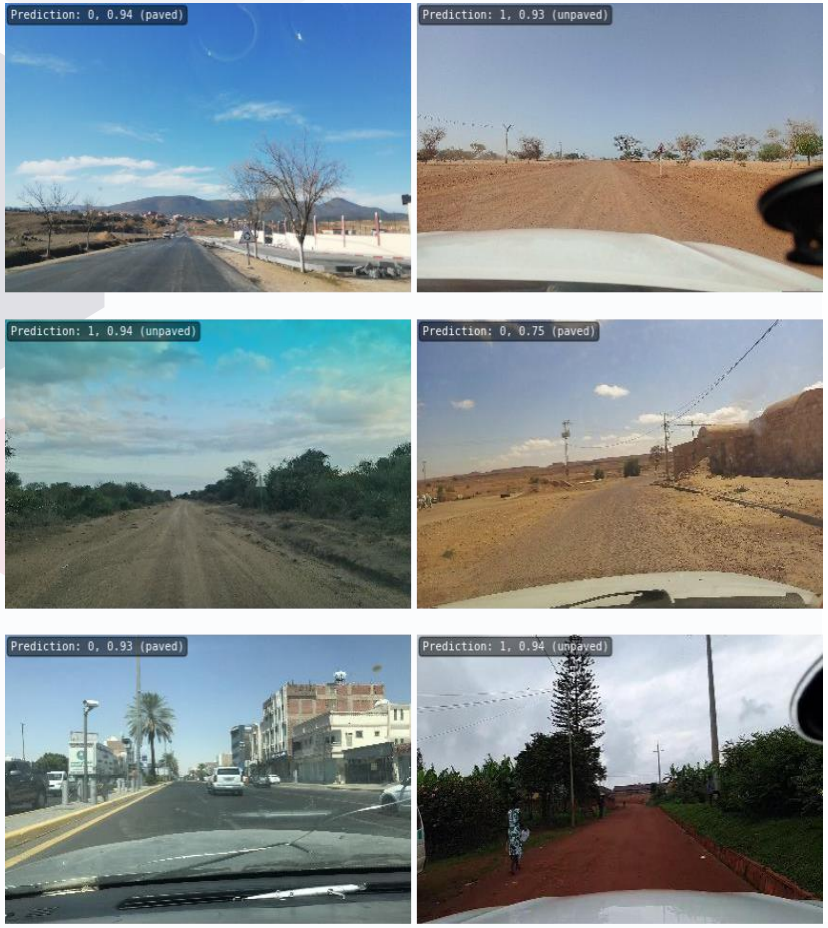
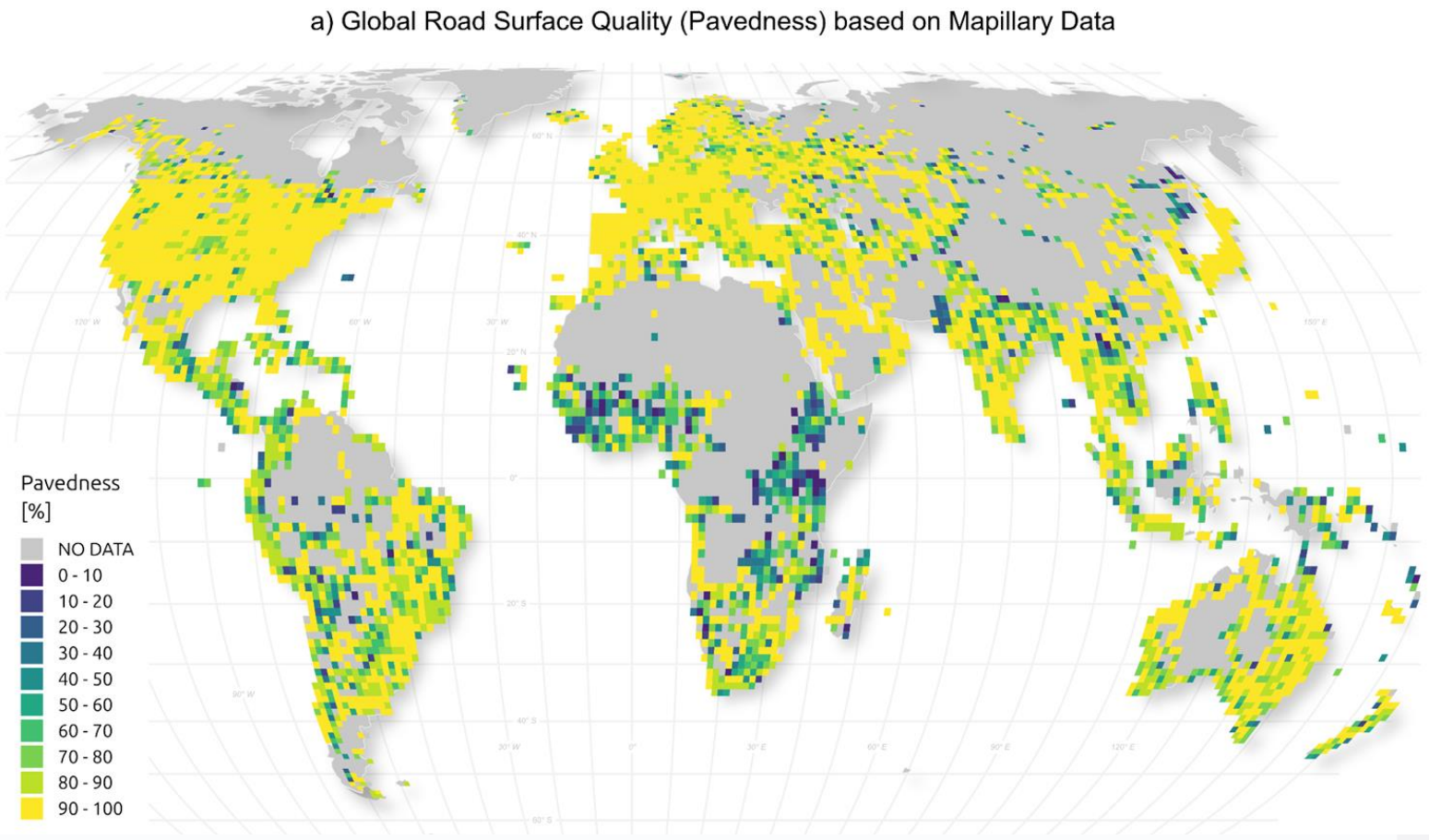
Global Road Pavement Prediction w. Street View Images





Randhawa, S., Aygün, E., Randhawa, G., Herfort, B., Lautenbach, S., Zipf, A. (2025): Paved or unpaved? A deep learning derived road surface global dataset from Mapillary street-view imagery, ISPRS Journal of Photogrammetry and Remote Sensing, 2025, 223, 362-374, doi.org/10.1016/j.isprsjprs.2025.02.020

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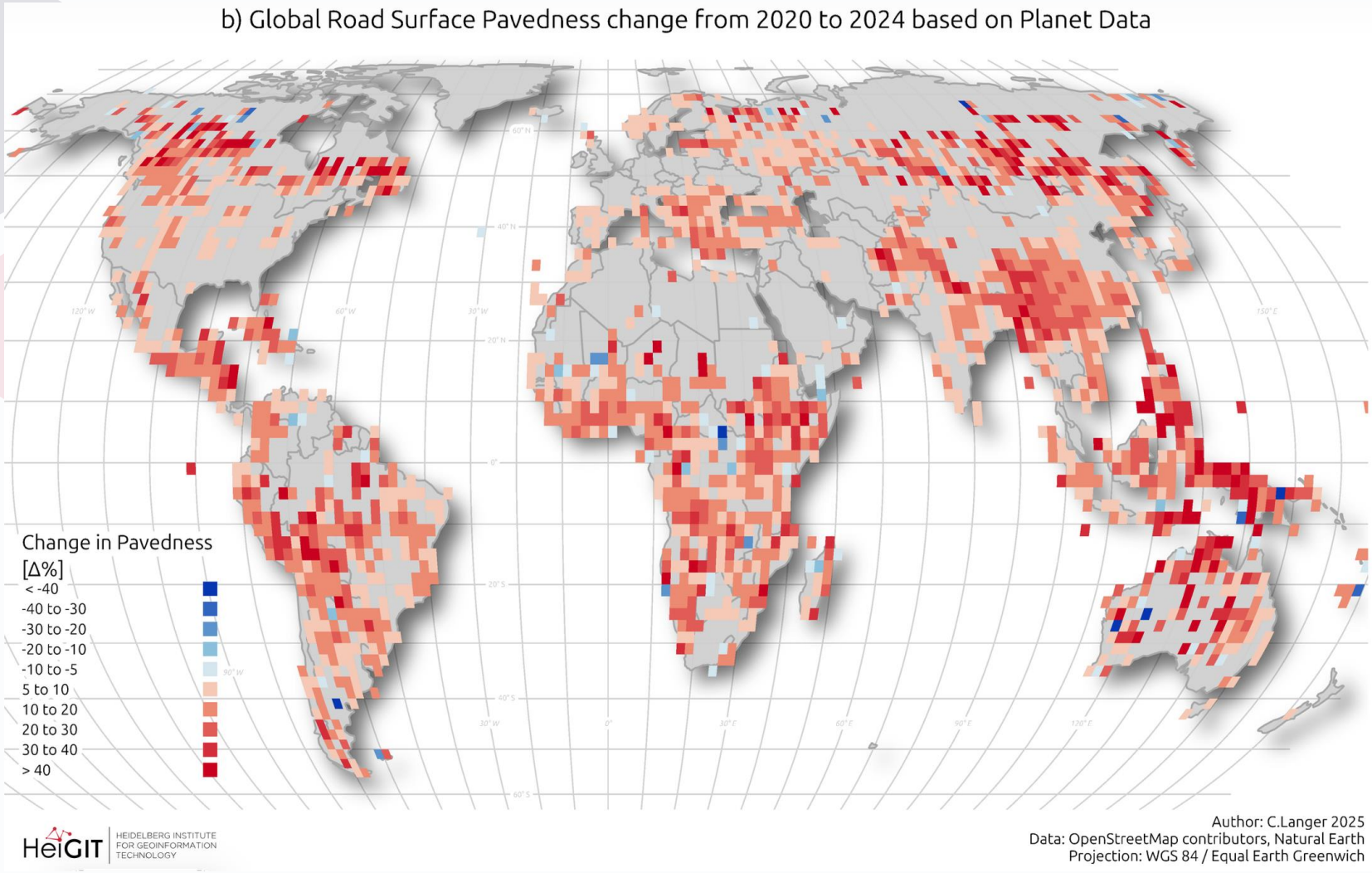
Global Road Surface Pavedness Change 2020-2024

(satellite images: Planet)



Further work in progress:

Pipelines for ML detection using also Panoramax.fr

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Thank you very much!

We love to collaborate!

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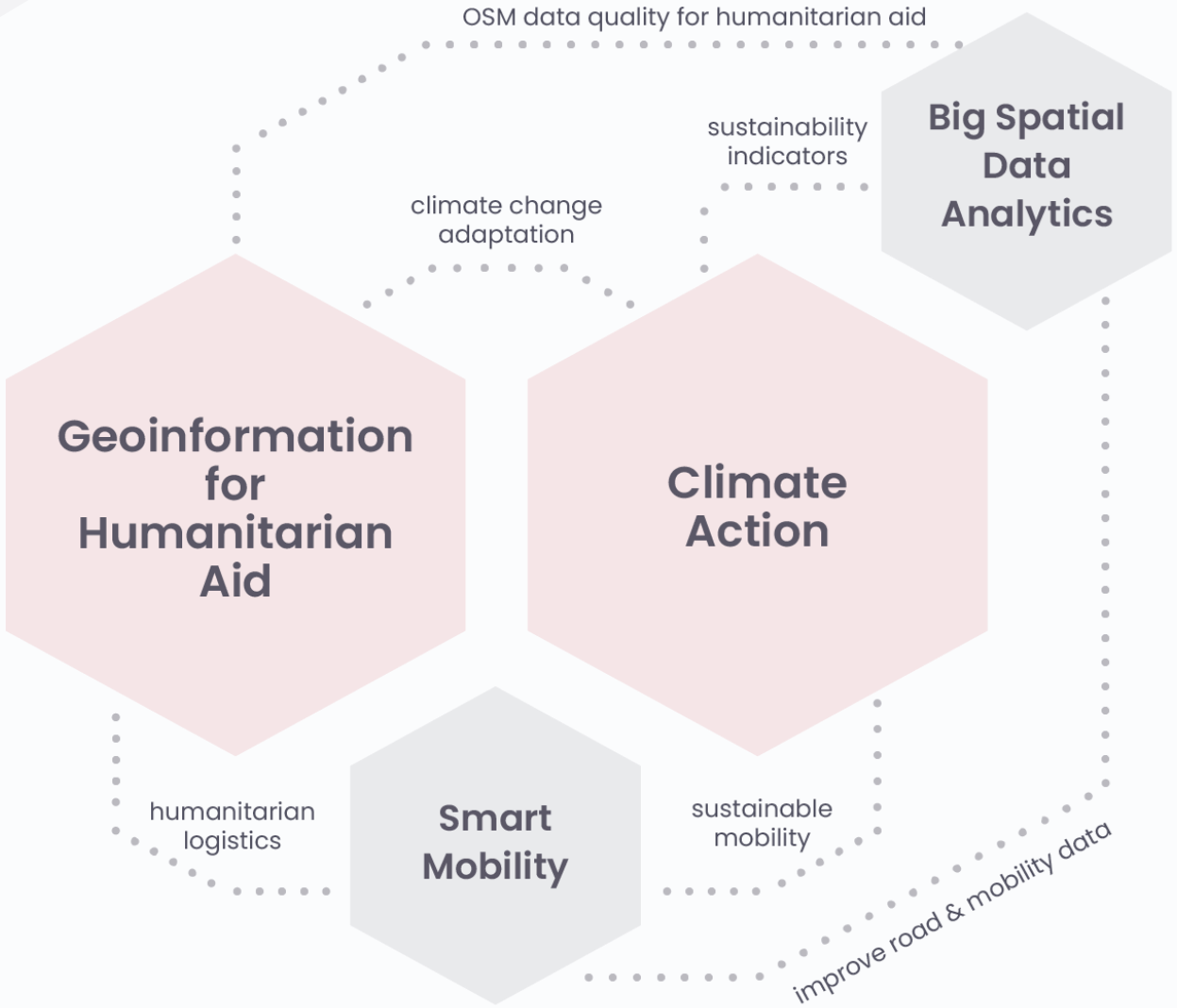

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