Sentinel-1 and Sentinel-2 for urban planning: an application for automatic near real-time redevelopment sites monitoring

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Context

- Urban planning is a challenge as it involves limiting the amount of new land being taken up

  → Authorities need to control the urban expansion, enhance the resilience of cities and preserve green spaces

- In former industrial regions, such as Wallonia (Belgium), there is a large number of brownfields, called "Redevelopment Sites" (RDS):
  - Sites now abandoned
  - Current condition represents a deconstruction of the urban canvas

  → Opportunity for sustainable urban planning

  → Need for global RDS monitoring

Context : RDS inventory

- *Challenge*:

Keeping the inventory, managed by the Walloon authorities, up-to-date

To guide the actors involved in urbanization

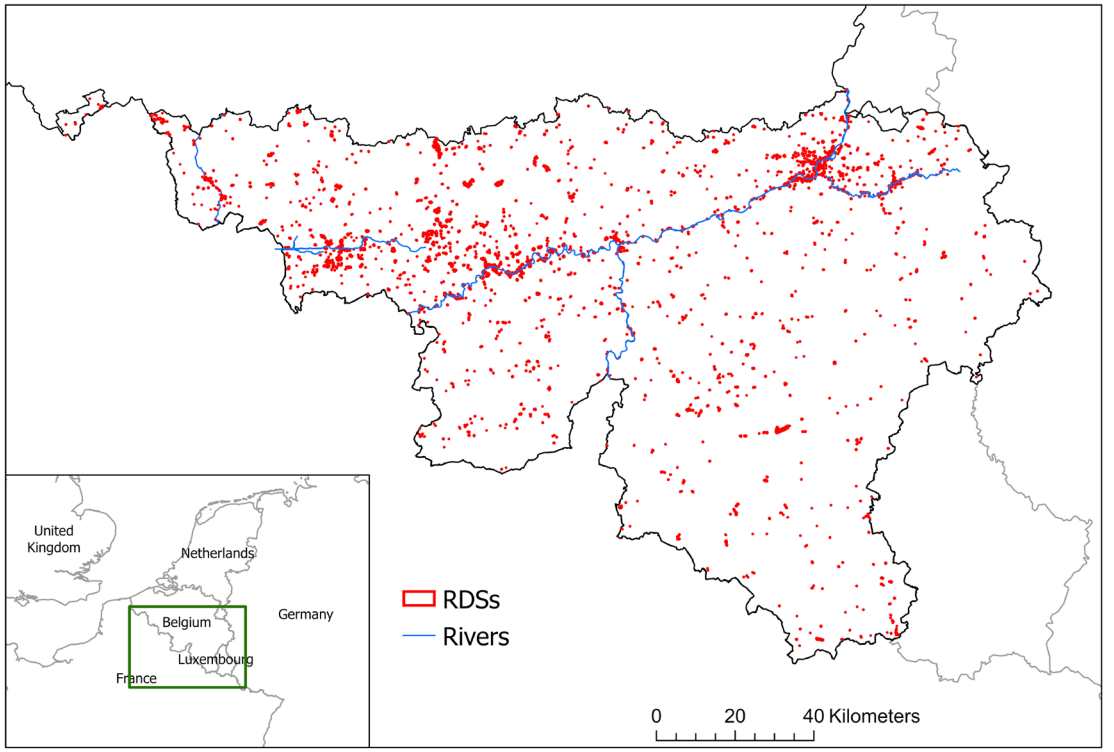
Knowing that 10% of RDSs are likely to "change" each year

- *Where*:

More than 2,200 sites spread all over Wallonia (Belgium), mainly in urban areas

- *Current methodologies:*
  - Systematic review (survey and field visit)
  - Ortho-photos (photo-interpretation by an operator)

→ Need for an automatic tool



Context: proposed solution

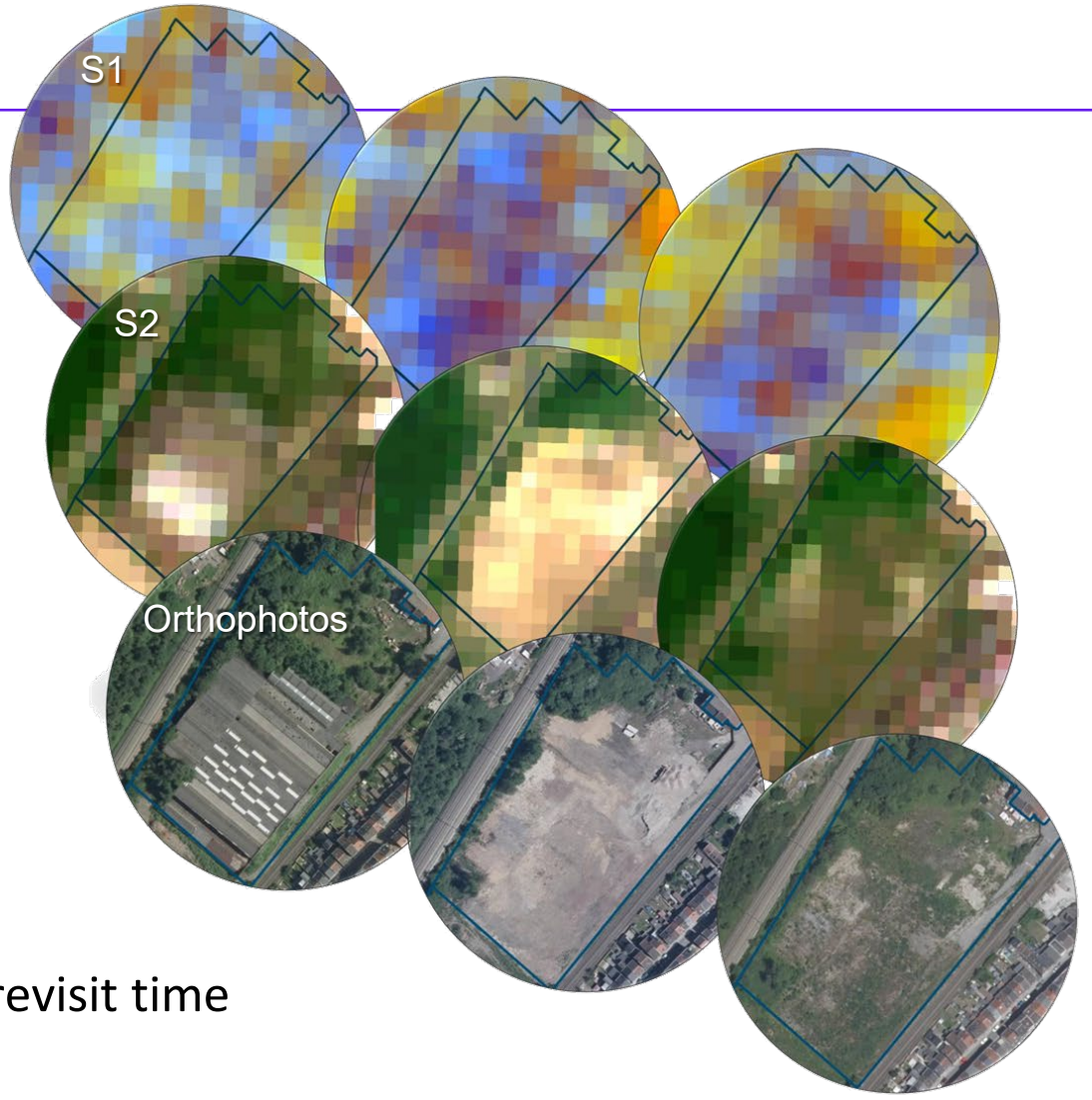
A method that provides a report of the changes (detection and classification) with the following characteristics :

- Automatic
- For each RDS
- Focus on vegetation, building & soil
- EO based: combination of satellite images at high temporal resolution
- Using time-series
- Near-real time
- Over the long term

Orthophoto 2016 ⟶ Orthophoto 2018

Easily identify RDSs that require further (manual) investigation → Final report with a priority list for RDS monitoring, directly usable by public authorities

Sentinel Data



Multi-sensor and multi-temporal approach: combination of Sentinel-1 (S1) and Sentinel-2 (S2) from the European Union's Earth observation programme Copernicus:

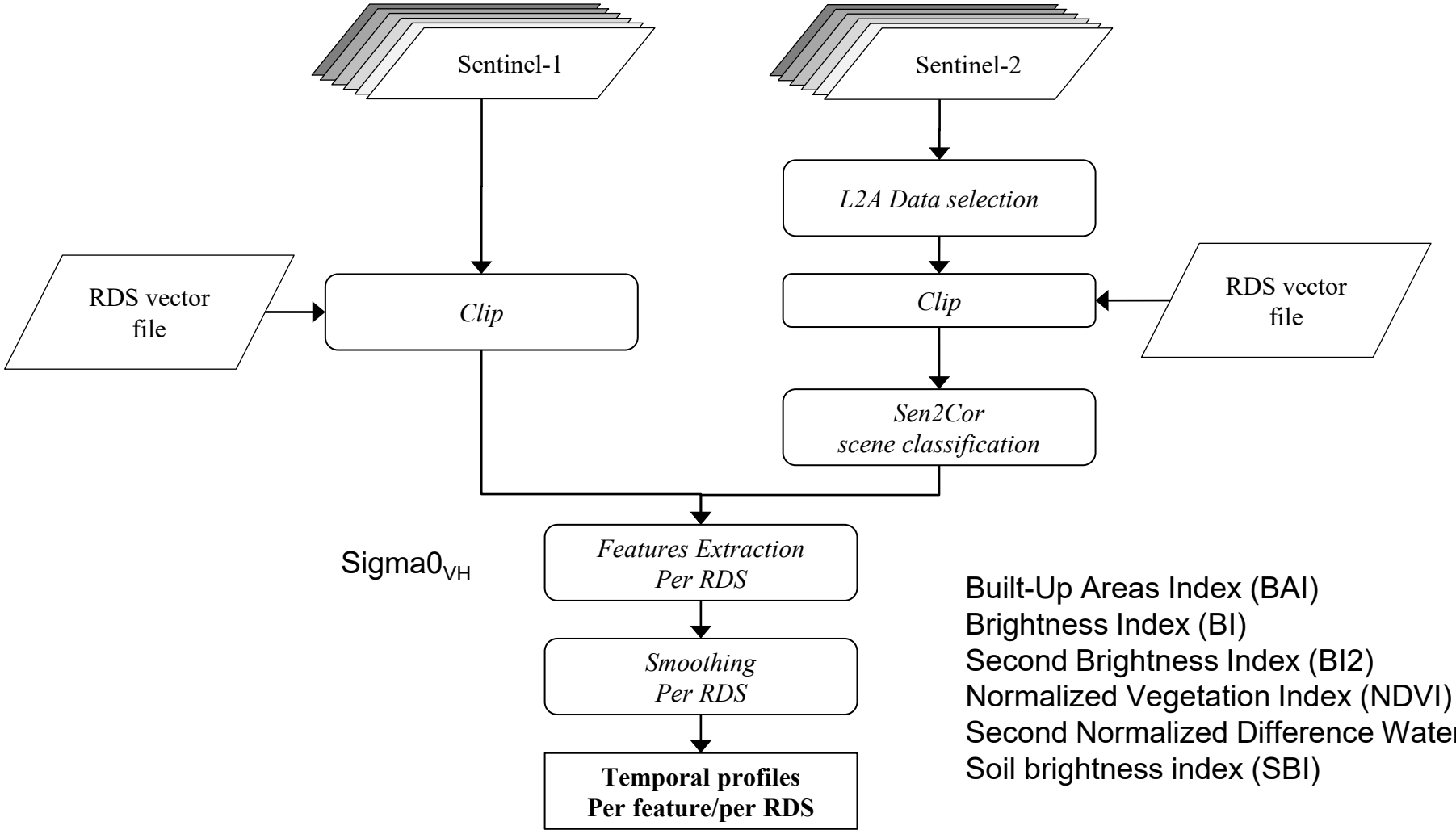
- Open data
- S1 C-band radar, 20 m spatial resolution, 6-day revisit time
- S2 multi-spectral imaging, 10-60 m spatial resolution, 5-day revisit time

Computing Environment

- TERRASCOPE plateform:
  - The Belgian Copernicus Collaborative Ground Segment (https://terrascope.be)
  - Pre-processed S1 and S2 images
  - Easily accessible and long-term maintenance
  - Virtual Machines
  - Computational capacity
  - Ability to set up high level scripts, in Python:
    - Manipulate data
    - Re-generate times series when adding new sites/information

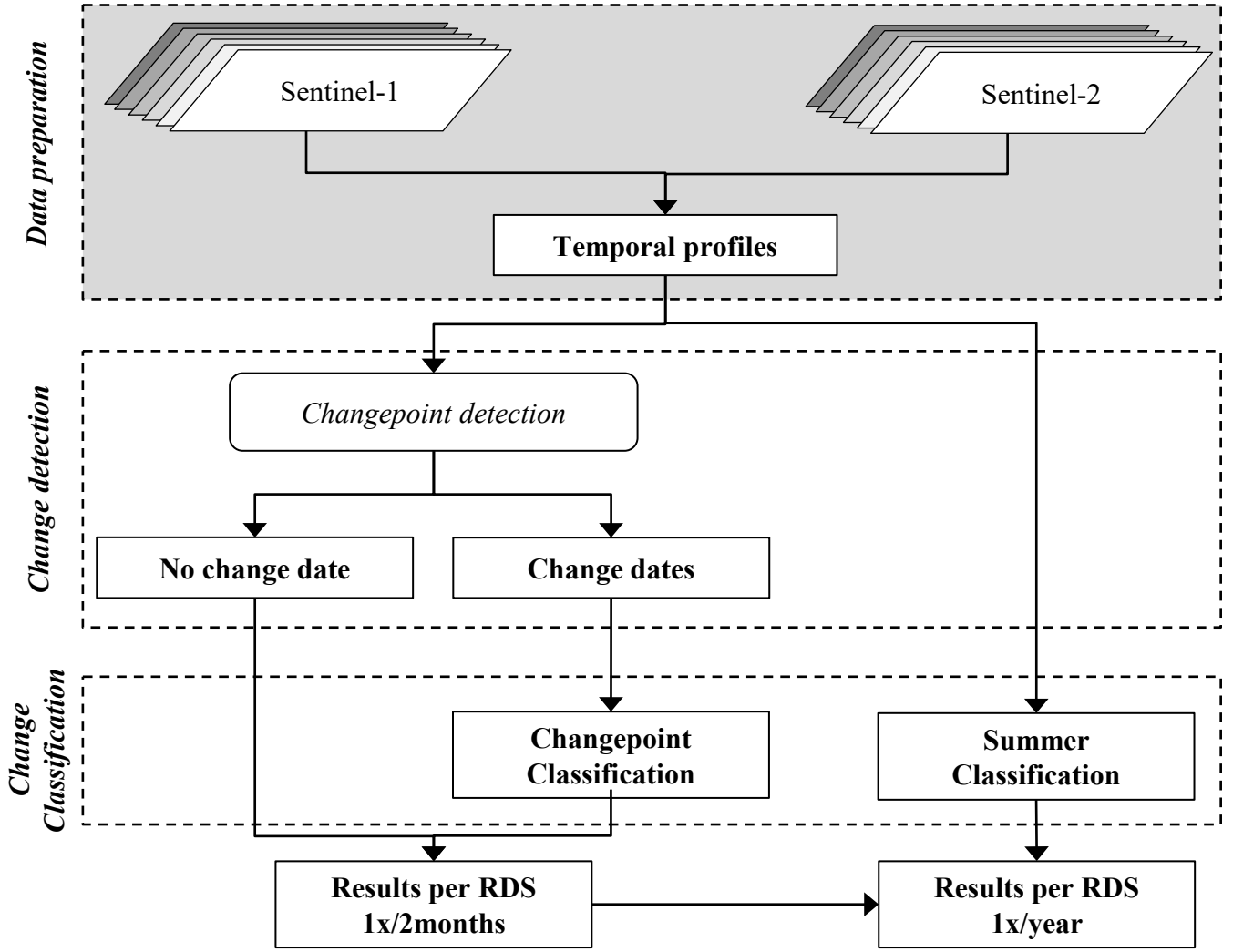
→ This enabled the automation of the process while processing and analyzing large volumes of data and images

Methodology: Data preparation



Built-Up Areas Index (BAI)
Brightness Index (BI)
Second Brightness Index (BI2)
Normalized Vegetation Index (NDVI)
Second Normalized Difference Water Index (NDWI2)
Soil brightness index (SBI)

Methodology : Global workflow

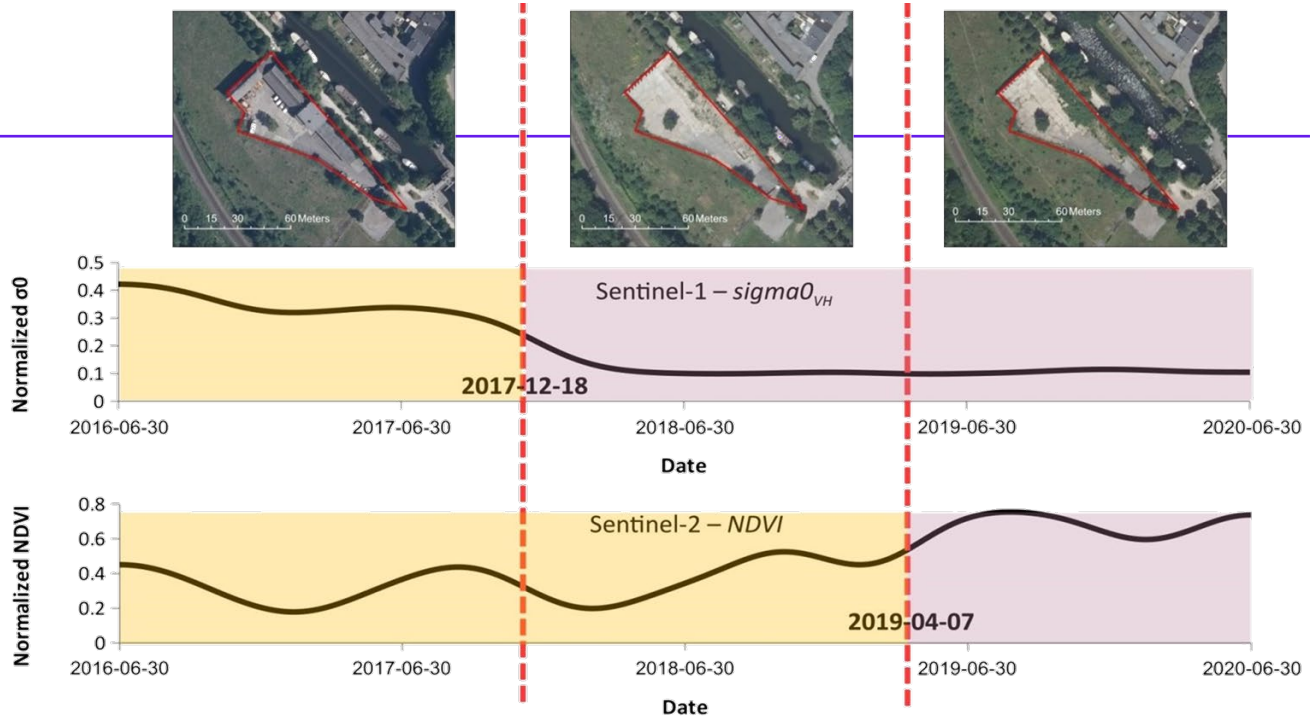


Change detection and classification

- Change detection:
  - Change YES/NO
  - If YES → Change date estimation
  - Sigma0$_{VH}$ (S1) & NDWI2 (S2) time series
  - Pruned Exact Linear Time (PELT) methodology*

- Change classification:
  - Vegetation, building & soil
  - If YES → Change direction for vegetation & building
  - Sigma0$_{VH}$ (S1) & NDVI, BI, BI2, SBI & BAI indices (S2)
  - Methodology based on change thresholds (Rule-based classifier)
  - Yearly comparison

→ 2 types of reports : 1x/2months & 1X/year



* R. Killick, P. Fearnhead, and I. Eckley, "Optimal detection of changepoints with a linear computational cost", *Journal of the American Statistical Association*, 107(500), pp. 1590–1598, 2012.

Validation

Methodology tested on:

- 141 sites with orthophotos
  - 1 image per year: summer 2016 and 2018
  - 25 cm spatial resolution
  - Sites with major changes

- 161 sites with Pléiades
  - 1 image per month acquired between January 2019 and December 2020
  - 0.5 m spatial resolution
  - Sites with changes and no changes

Ground truth	Vegetation	Building	Soil	Total changes	Total RDSs
Orthophotos	97	60	125	282	141
Pléiades	13	8	15	36	161
Total changes	110	68	140	318	302

Results

Changepoint analysis

	TPR	FPR	F_1-score	OA
Full dataset	66%	10%	0.74	79%
Pléiades	55%	7%	0.59	87%

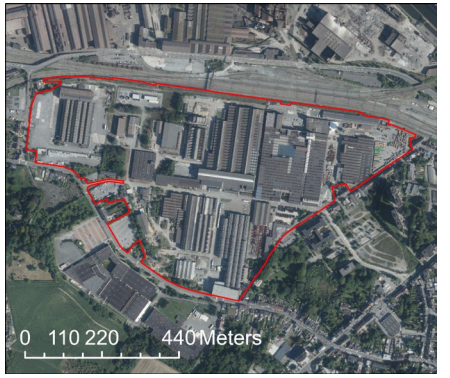
"Changepoint classification" (Pléiades dataset)

	TPR	FPR	F_1-score	OA
Vegetation	67%	6%	0.75	84%
Building	70%	6%	0.78	85%
Soil	73%	36%	0.73	69%

"Summer classification" (full dataset)

	TPR	FPR	F_1-score	OA
Vegetation	87%	9%	0.80	90%
Building	79%	26%	0.71	76%
Soil	74%	16%	0.77	79%

Results: exemples

Report	Vegetation decrease Soil change	Building decrease Soil change	Vegetation decrease Building decrease Soil change	No changes
t_{-1}				
t				

Illustrated with orthophotos

Conclusion

- Multi sensor approach, Sentinel-1 SAR and Sentinel-2 multi-spectral
- Regular & fast revisiting time allowing **near-real time** results, at **regular** interval, on **long term**
- **Automated** method to highlight the sites with the most changes
- **Results can be directly used** by the authorities to monitor the evolution of sites that present a high potential for redevelopment

  → Guides the work of the field operators for a more efficient and reactive work
- Further use: the processing chain could be used to monitor other types of sites in the field of urban planning, but also in agriculture, forestry or in disaster response

e.g. poster from C5.03 Open Source Science, toolboxes and Jupyter technologies in EO session

Thank you!

More information

- https://eo.belspo.be/en/news/sarsar-sentinel-data-urban-planning-and-land-management
- https://terrascope.be/en/cases/automatic-redevelopment-sites-monitoring-using-sentinel-data
- Petit, S.; Stasolla, M.; Wyard, C.; Swinnen, G.; Neyt, X.; Hallot, E. A New Earth Observation Service Based on Sentinel-1 and Sentinel-2 Time Series for the Monitoring of Redevelopment Sites in Wallonia, Belgium. Land 2022, 11, 360. https://doi.org/10.3390/land11030360