Automatic built-up area mapping from SAR and optical data with cross-fusion neural networks

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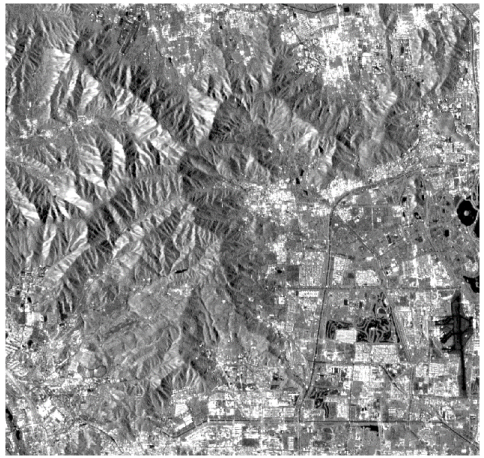
BACKGROUND

- As urban extent is growing fast, up-to-date information on built-up areas is critical for urbanization management and assessment of economic losses caused by natural disasters.
- Earth Observation (EO) data such as Synthetic Aperture Radar (SAR) and optical data enable consistent built-up area mapping across various temporal and spatial scales.
- Difficult to extract information of interest from EO data.
- Challenge for automatic algorithms to be scaled-up globally.

Sentinel-1 SAR data



Sentinel-2 optical data

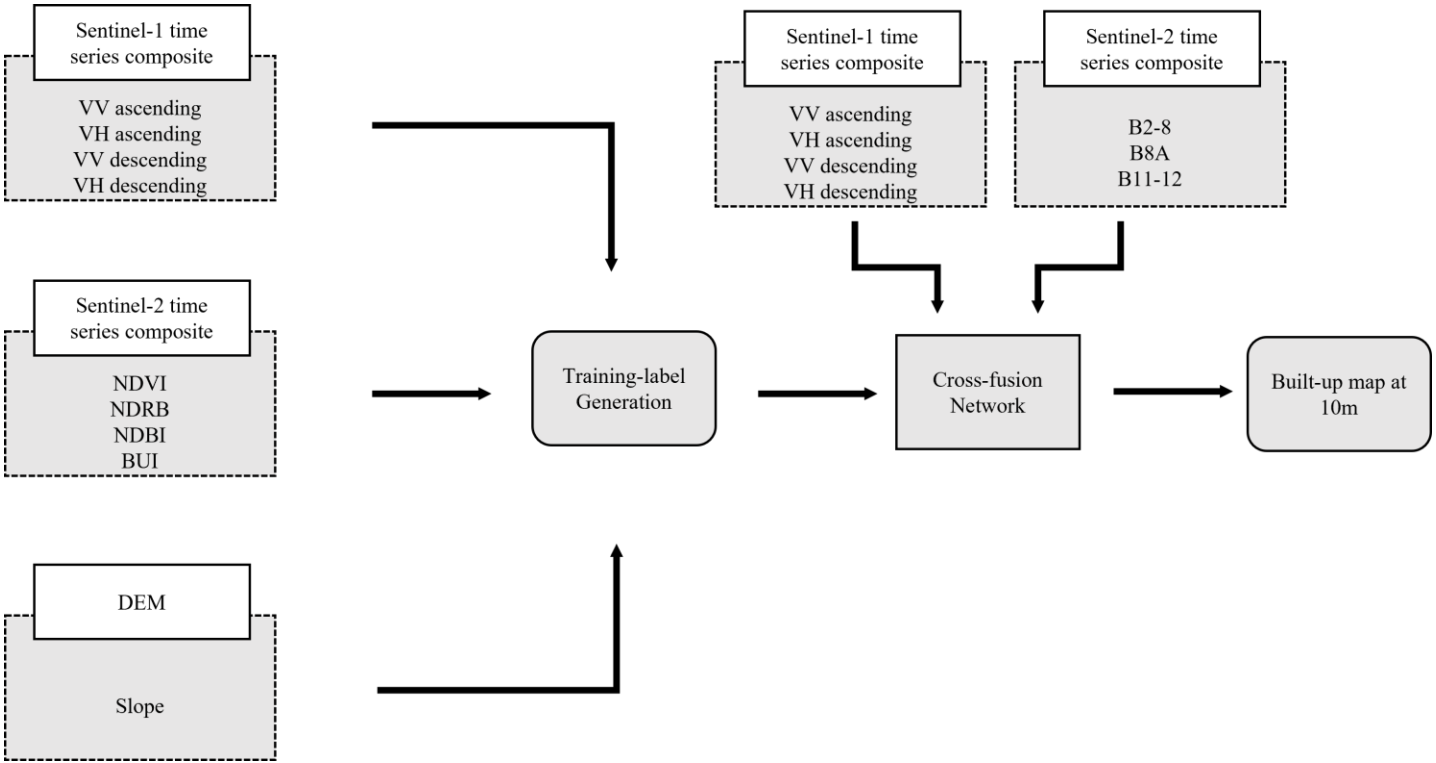
BACKGROUND

- Deep Learning (DL) methods are powerful for learning representations from complex and high-dimensional data.
    - Supervised DL models do not generalize well on test datasets that have a different distribution with respect to training data.
- Training data is expensive to collect and update.
    - Only sparse labelled training data are available at a large scale.

*Here, we develop an **automatic built-up area mapping** framework using **Sentinel-1** and **Sentinel-2** data that:*

- 1) Automatically generates labels for training data in a given area of interest.
- 2) Trains a cross-fusion neural network using synergies between Sentinel-1 SAR and Sententi-2 multi-spectral data.

METHOD



Workflow of the automatic built-up area extraction framework

NDVI: Normalized Difference Vegetation Index

NDRB: Normalized Difference Red Blue

NDBI: Normalized Difference Built-up Index

BUI: Built-up Index

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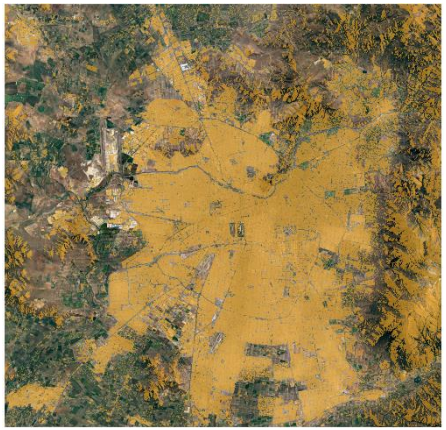
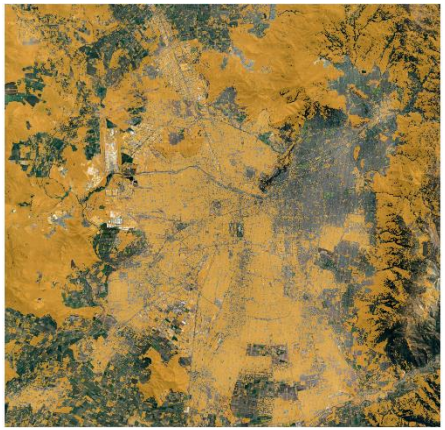
Automatic label generation

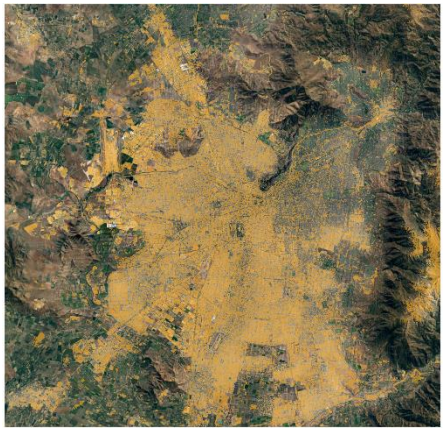
Santiago



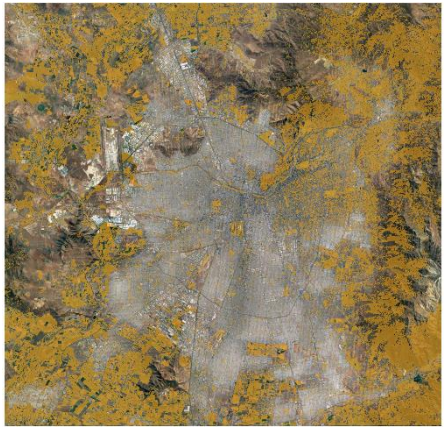
Sentinel-1 backscattering based built-up mask



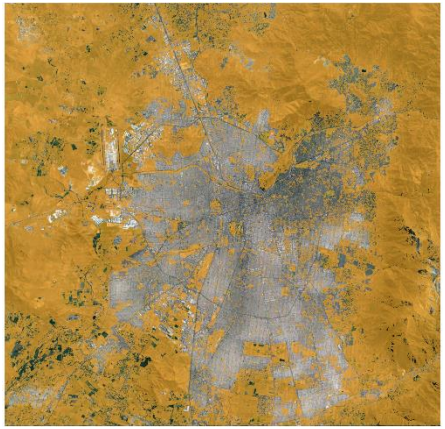
Sentinel-2 NDBI based built-up mask



Sentinel-2 BUI based built-up mask



Sentinel-2 NDVI based vegetation mask



Sentinel-2 NDRB based bareness mask

Labels of training data

Built-up

Non-built-up

LIST

Cross-fusion Network

Sentinel-1 data

Sentinel-2 data

CNN

CNN

Cross-attention module

Q

K

V

softmax

K

V

Q

softmax

Classifier head

Output

⊗ : Matrix Multiplication ⊕ : Add ⊙ : Concatenate

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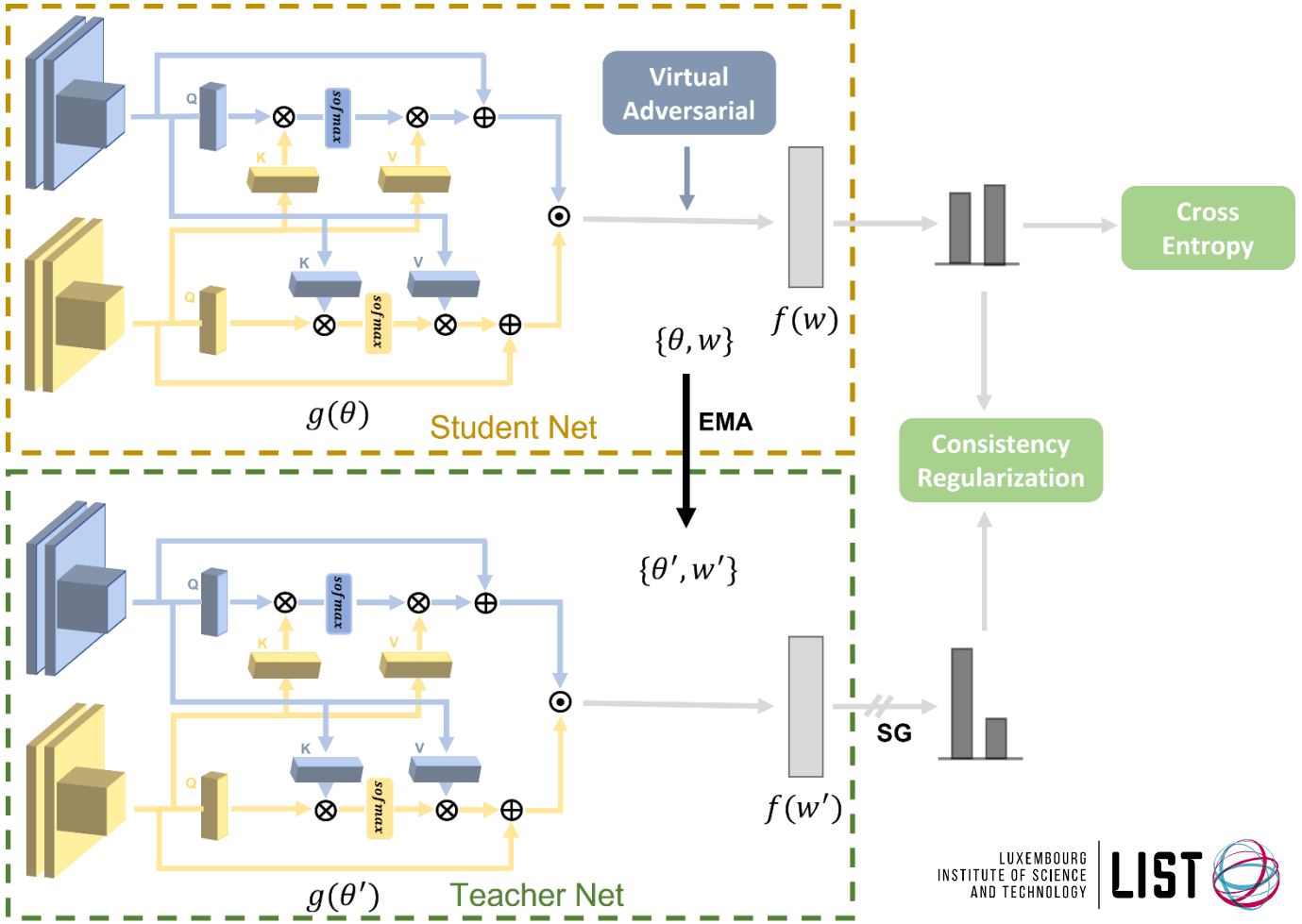
Cross-fusion Network with Virtual Adversarial Regularization

Sentinel-1 data

Sentinel-2 data



EMA: Exponential Moving Average

SG: Stop Gradient

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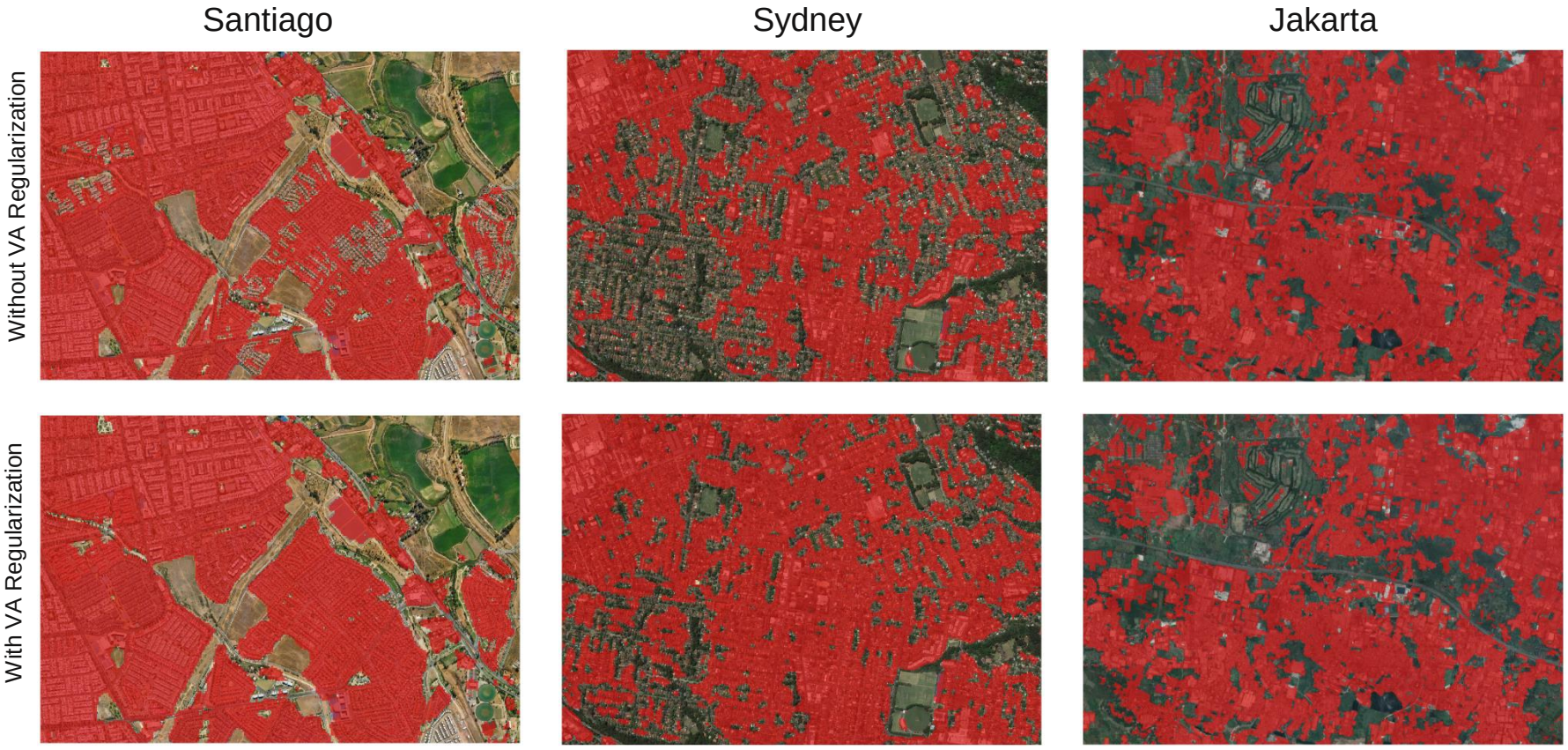
RESULTS



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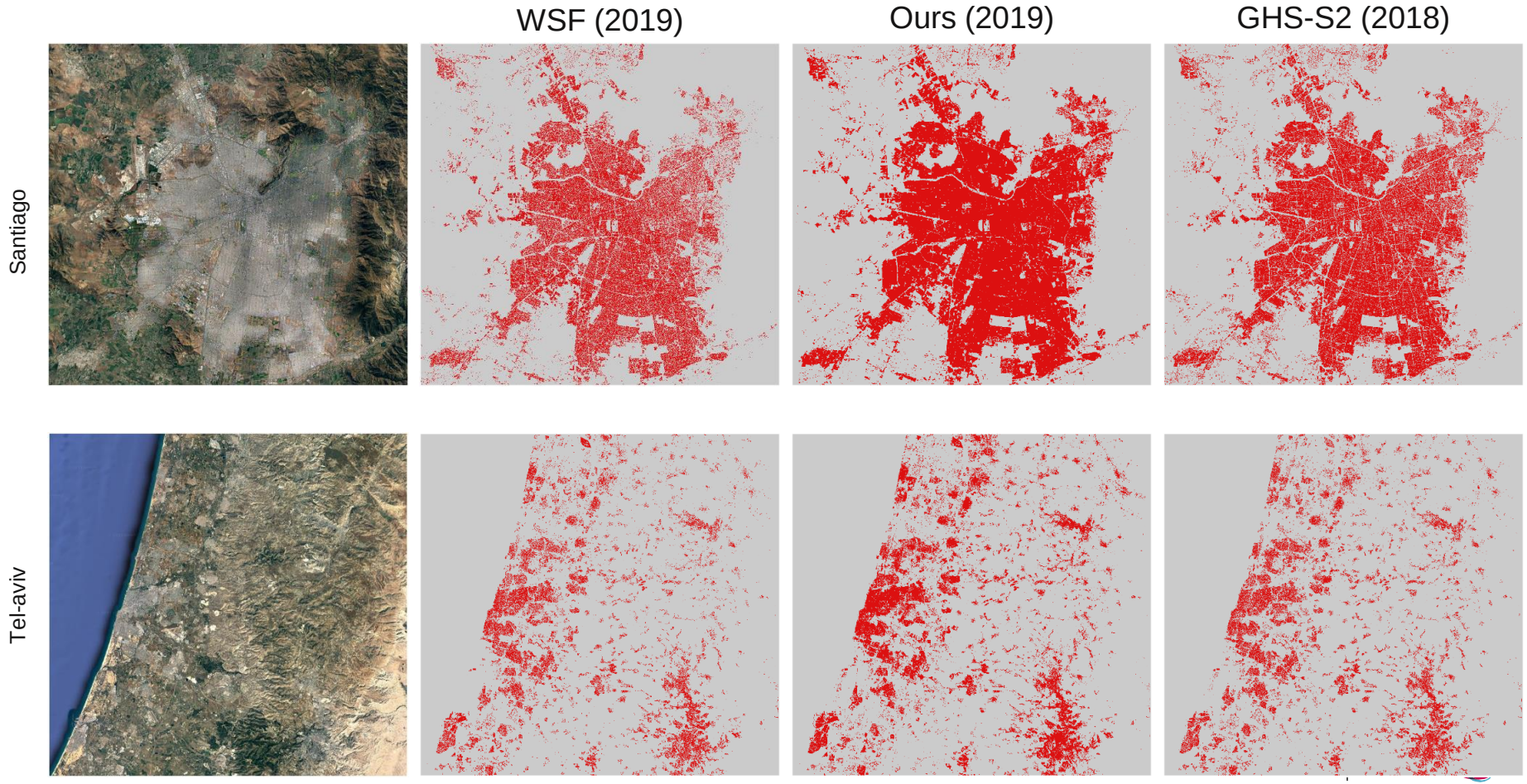
Comparison with SOTA global built-up products



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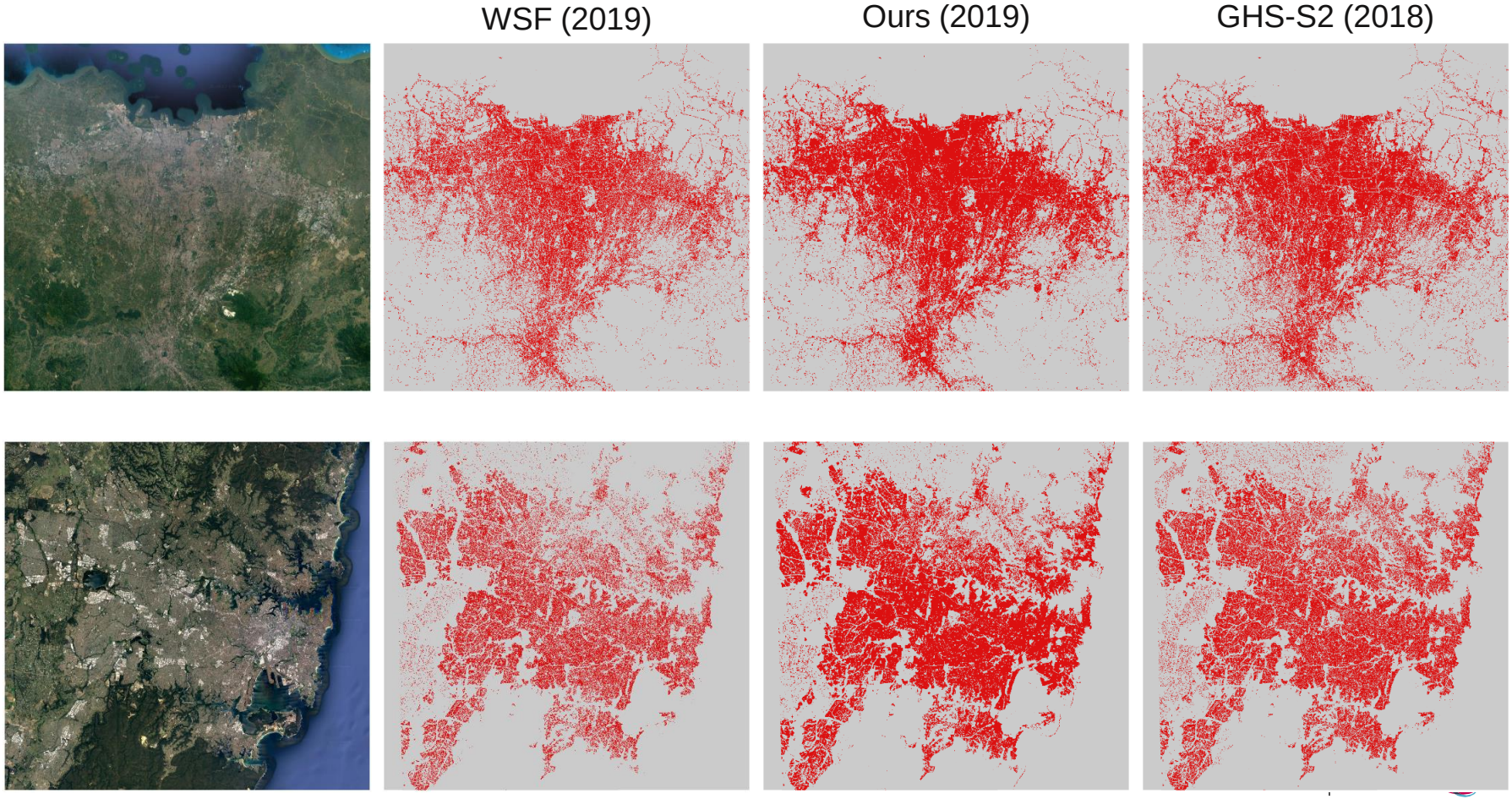
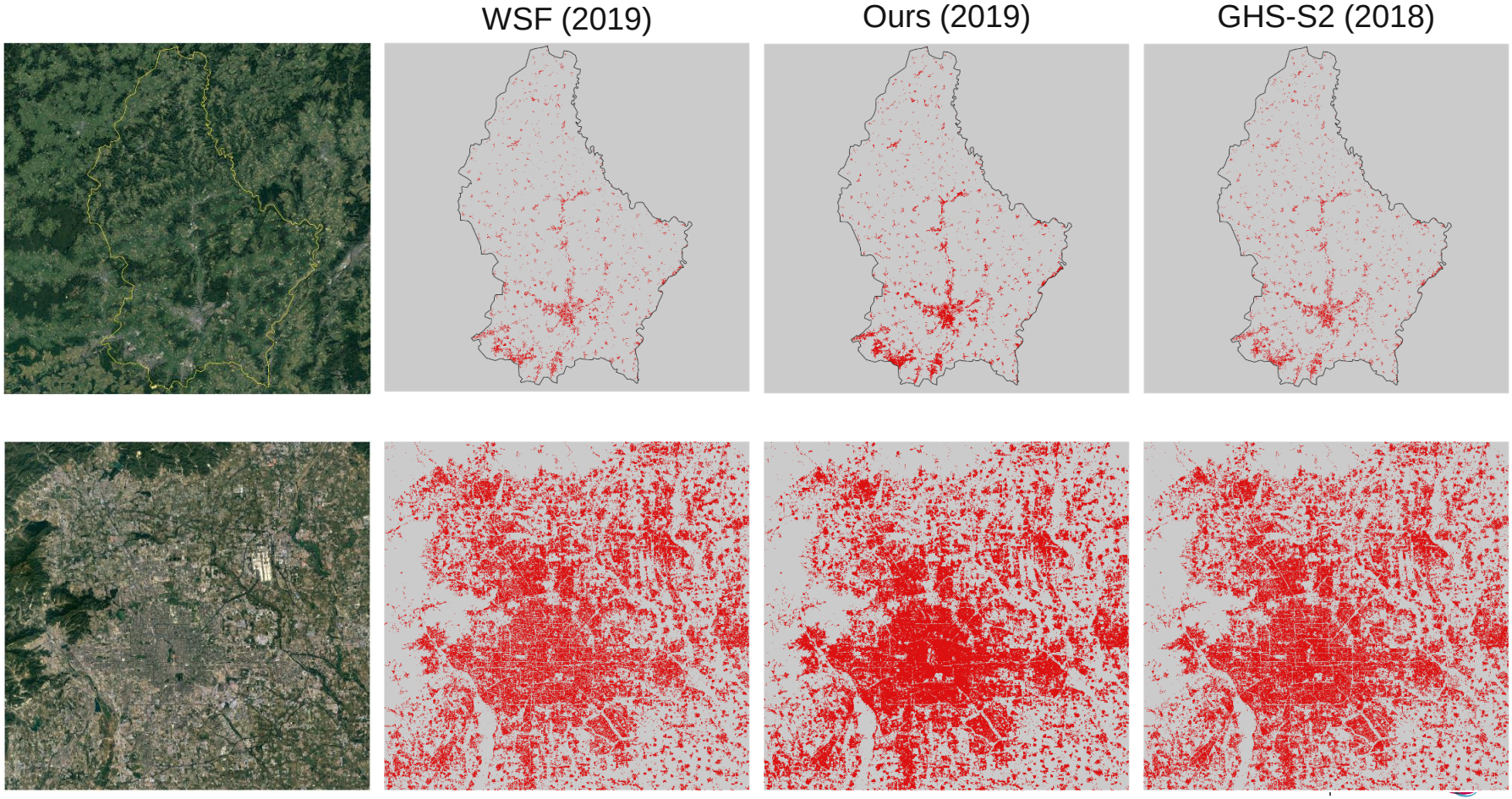


Comparison with SOTA global built-up products



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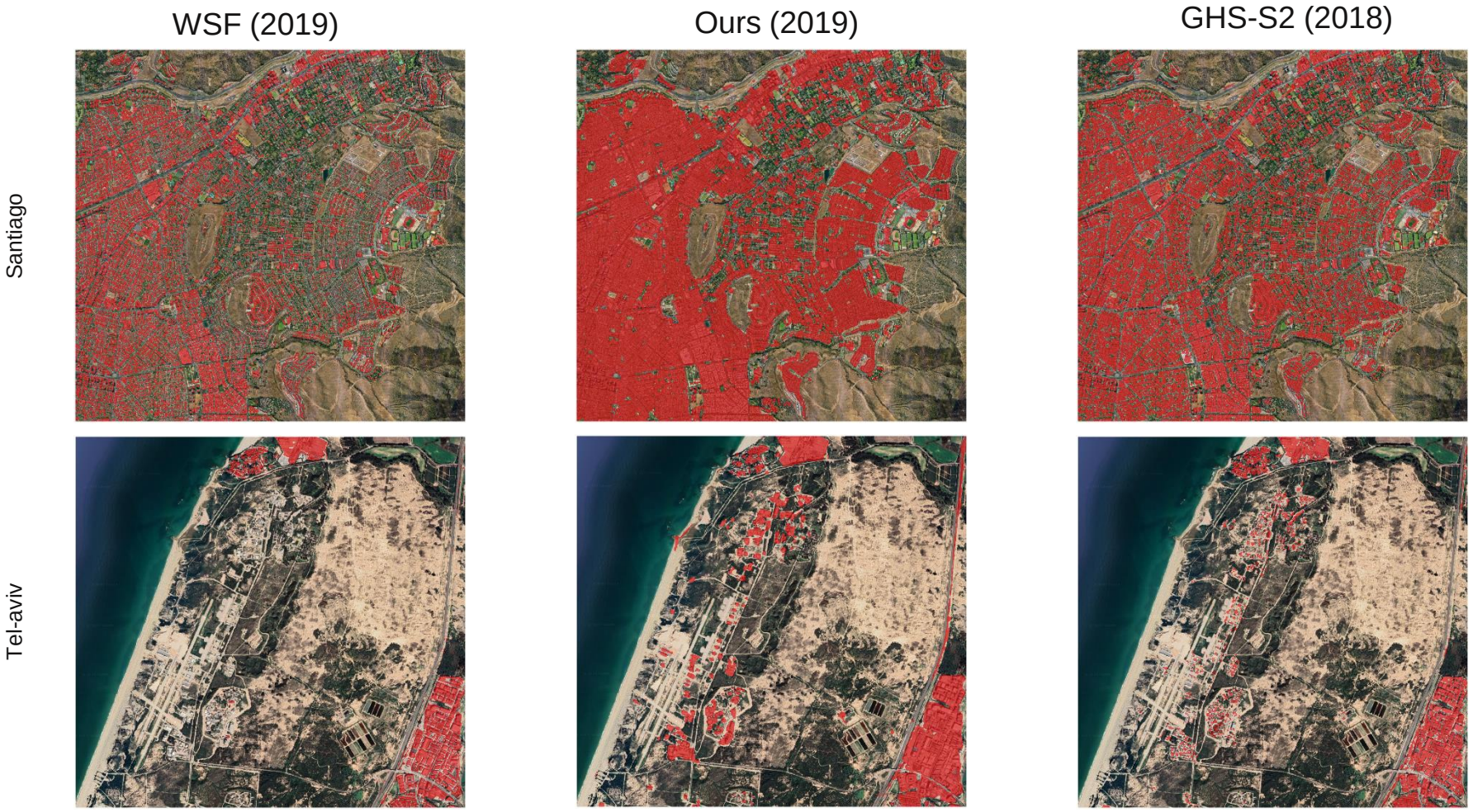
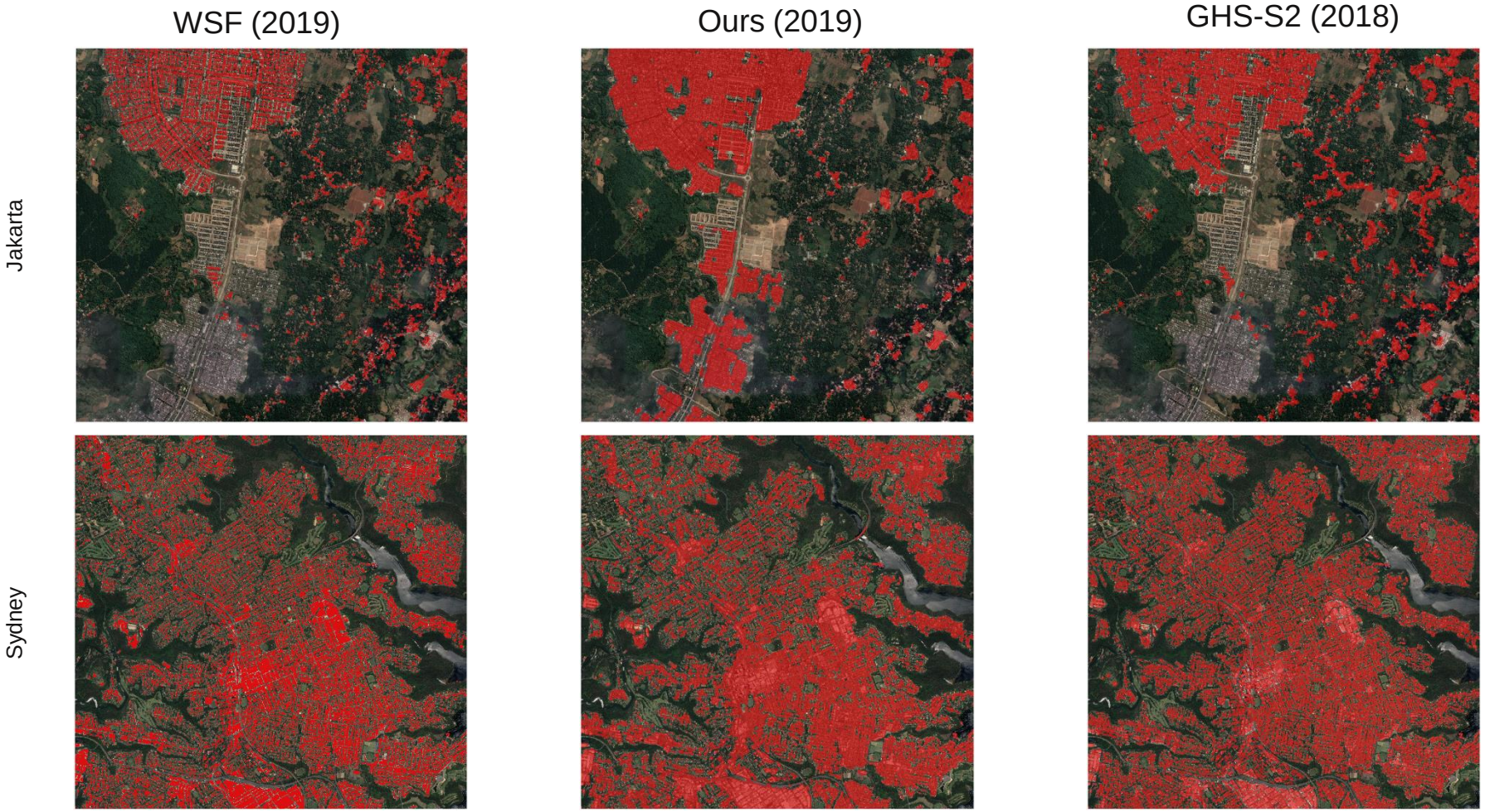


Comparison with SOTA global built-up products



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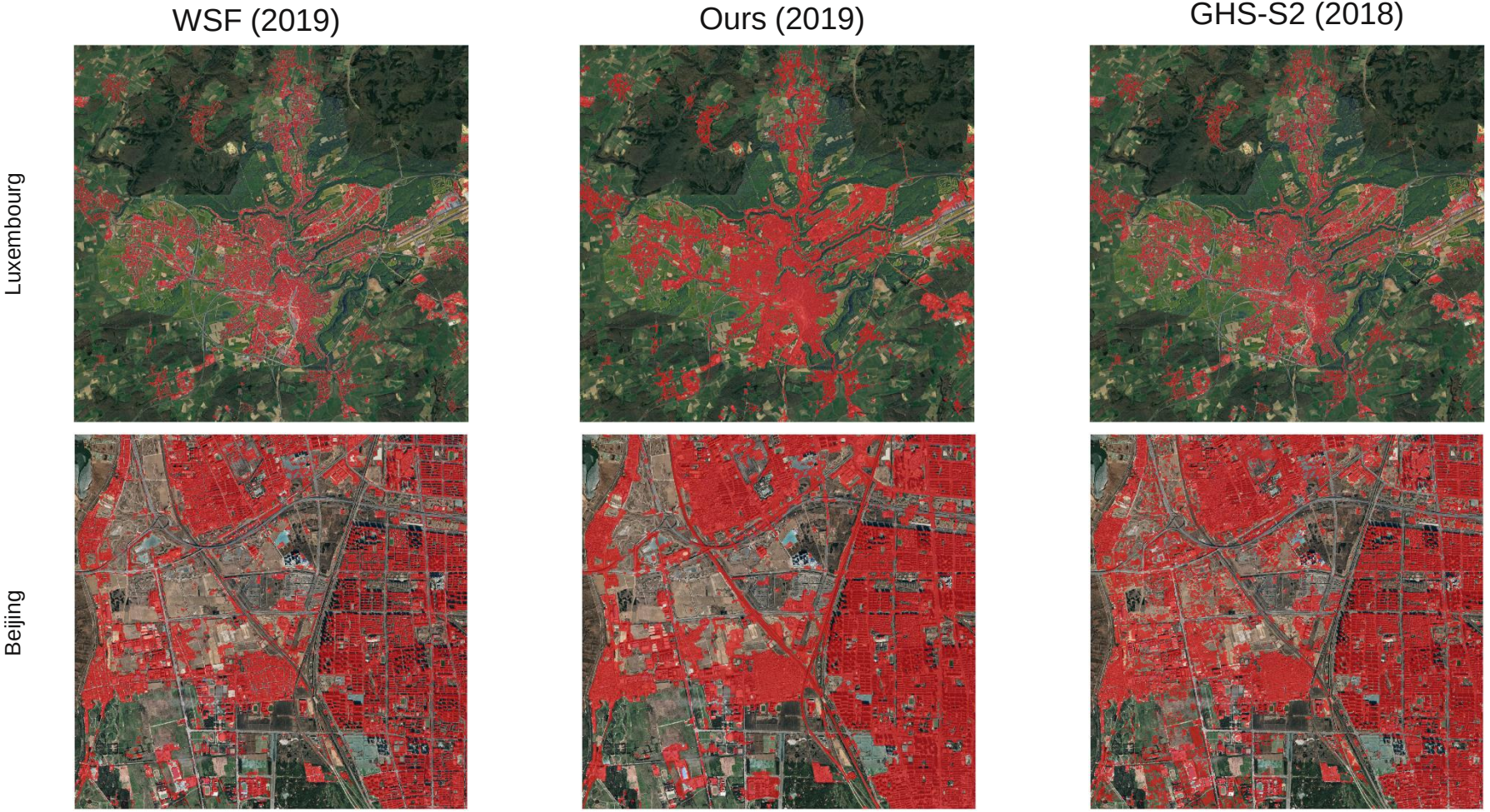


CONCLUSION

- It is possible to sample reliable training samples for built-up area mapping by exploring synergies of SAR and optical data.

- Mitigate domain shift effects by performing training and inference at a local scale.

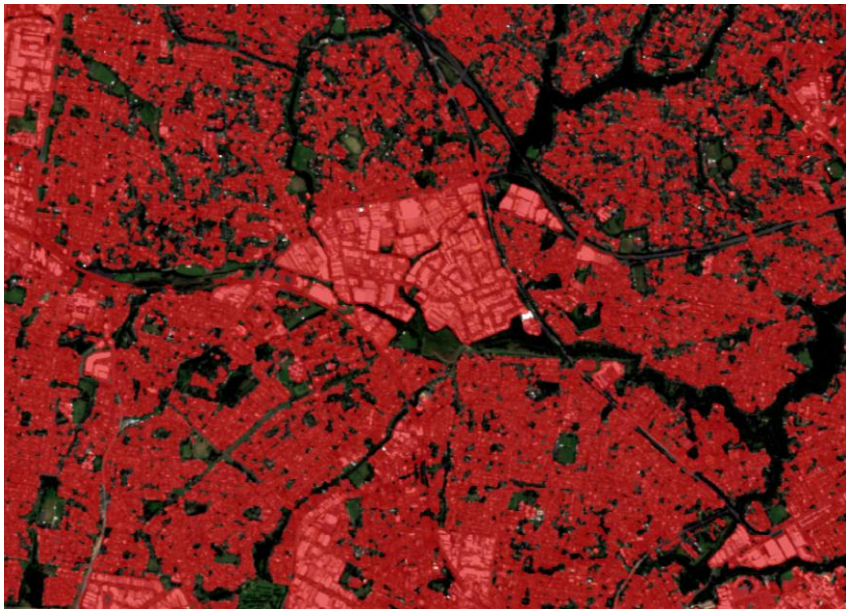
- The proposed automatic built-up area mapping framework achieves comparable results to the SOTA products achieved by supervised learning based on manually-labelled training data.

- The proposed framework is flexible to be applied across various temporal and spatial scales.

OUTLOOK

Label super-resolution

10m optical data



10m built-up mask

0.5m optical data

0.5m built-up mask?

Thank you!

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