



# Predicting the liveability of Dutch cities with aerial images and semantic intermediate concepts

Alex Levering, Diego Marcos, Jasper van Vliet, Devis Tuia



Levering A, Marcos D, van Vliet J, Tuia D. **Predicting the liveability of Dutch cities with aerial images and semantic intermediate concepts.** Remote Sensing of Environment. (2023)



# Urban liveability

*“the degree to which its provisions and requirements fit with the needs and capacities of its members”*

Veenhoven R., Ehrhardt J., Ho M.S.D., de Vries A. **Happiness in nations: Subjective appreciation of life in 56 nations 1946–1992**, ISBN 978-90-72597-46-5, Erasmus University Rotterdam, Rotterdam, Netherlands (1993), p. 365



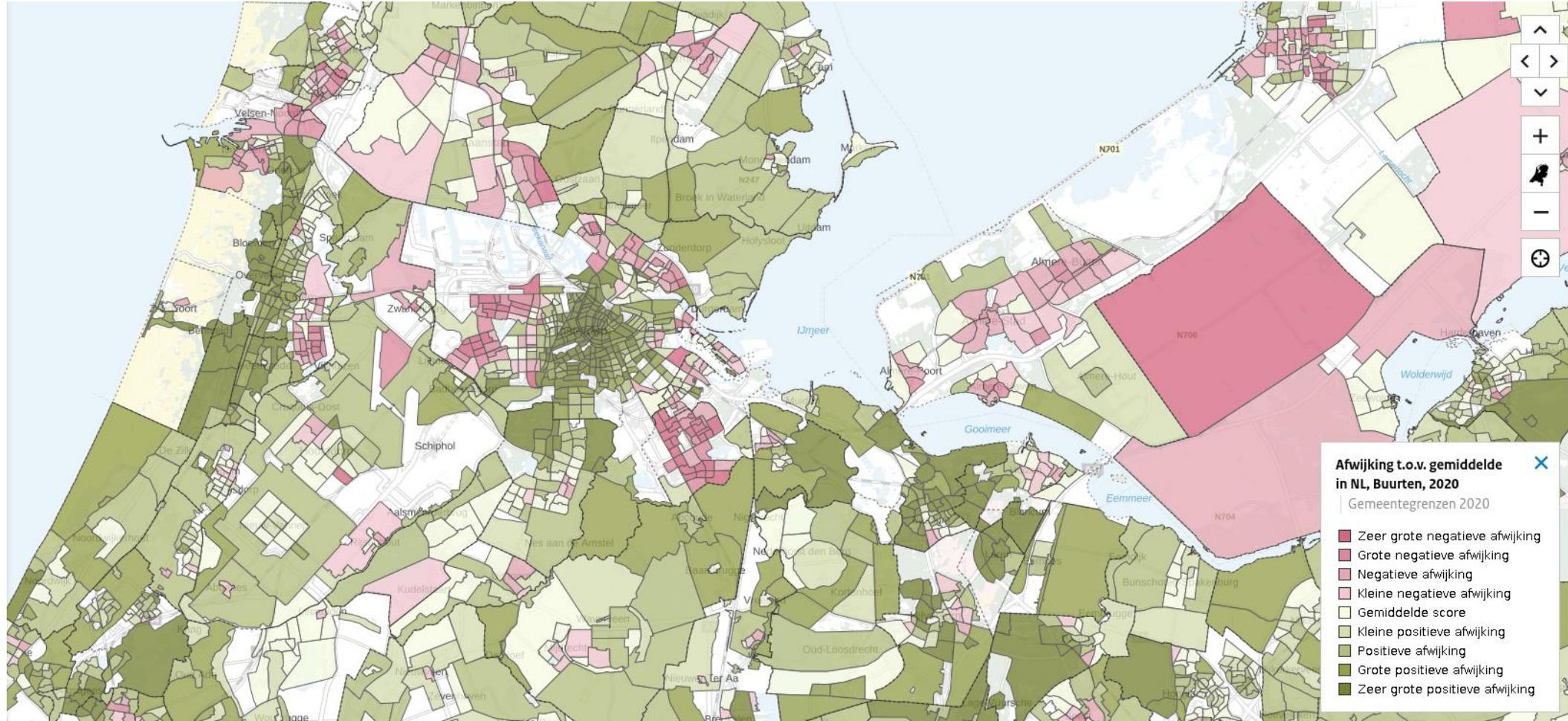
# The Dutch Leefbarometer

- Based on country-wide surveys
- Performed in: 2002, 2008, 2012, 2014, 2016, 2018, 2020
- Over 100 explanatory variables grouped in 5 domains

Leidelmeijer K., Marlet G., Ponds R., Schulenberg R., van Woerkens C. **Leefbaarometer 2.0: Instrumentenontwikkeling: Technical Report 2.** RIGO Research en Advies/Atlas voor Gemeenten, Amsterdam (2014), p. 151



# The Dutch Leefbarometer



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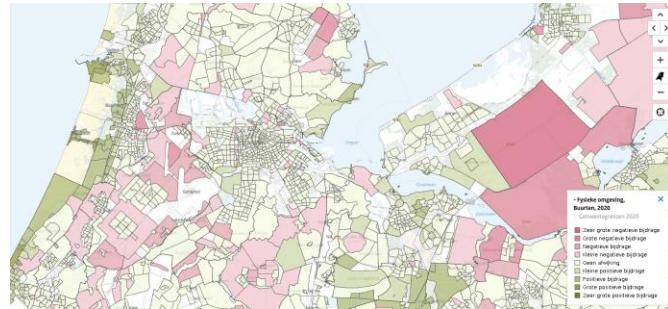


# The Dutch Leefbarometer

Buildings



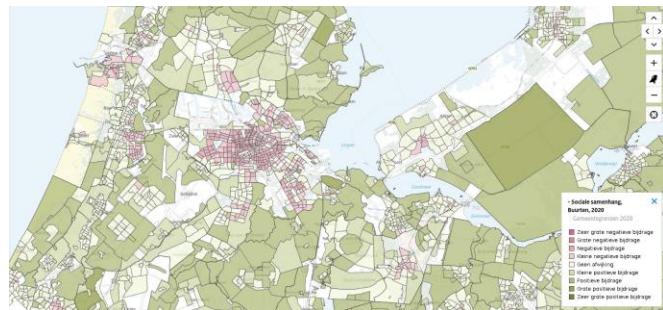
Physical environment



Amenities



Population



Safety

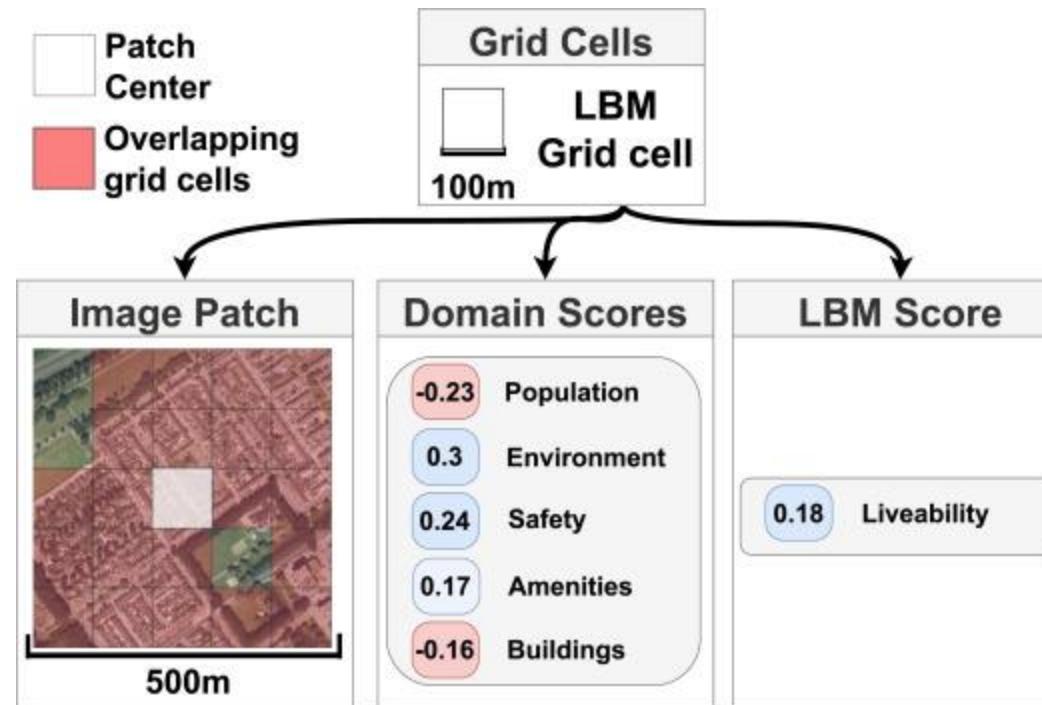


Leidelmeijer K., Marlet G., Ponds R., Schulenberg R., van Woerkens C. **Leefbaarometer 2.0: Instrumentenontwikkeling: Technical Report 2.** RIGO Research en Advies/Atlas voor Gemeenten, Amsterdam (2014), p. 151



# Can remote sensing help interpolate ?

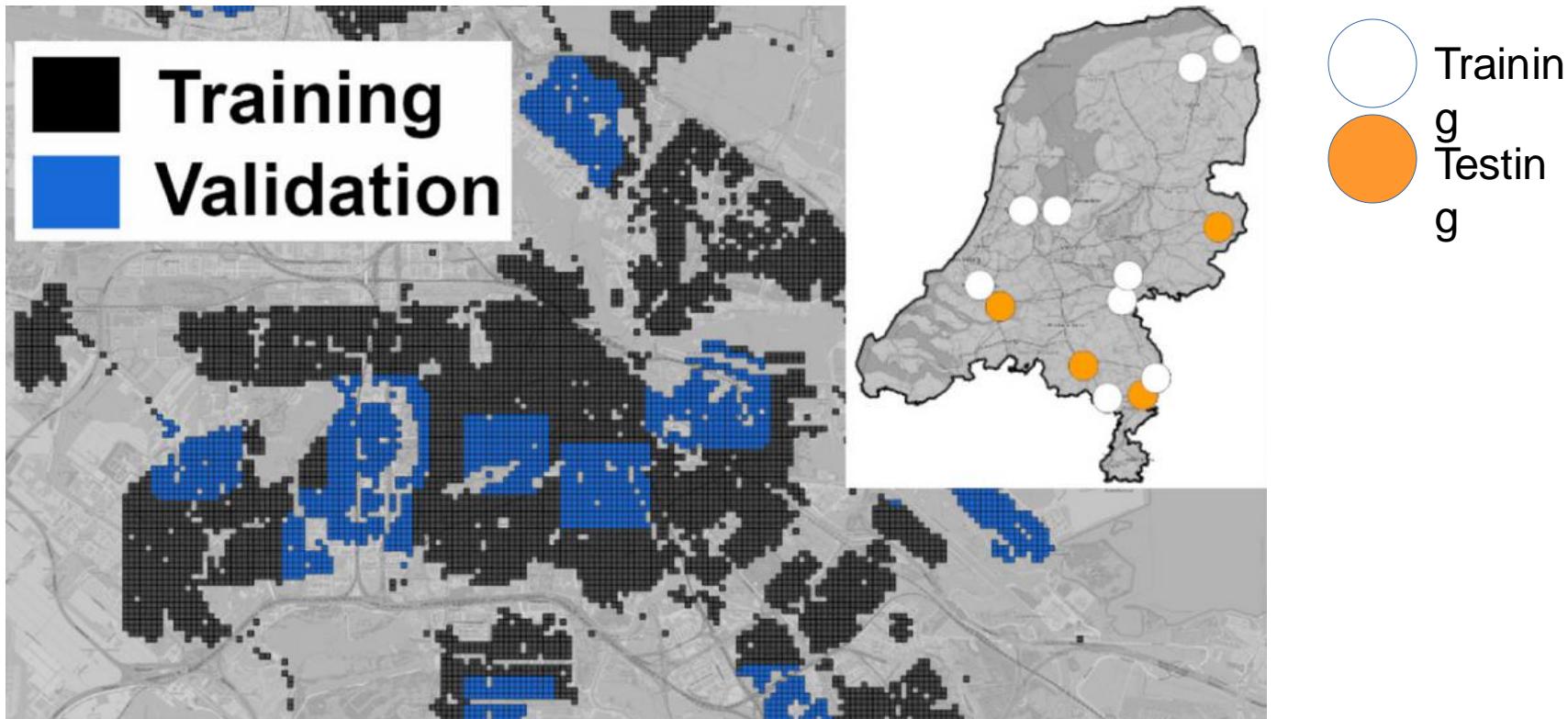
## Data setup





# Can remote sensing help interpolate ?

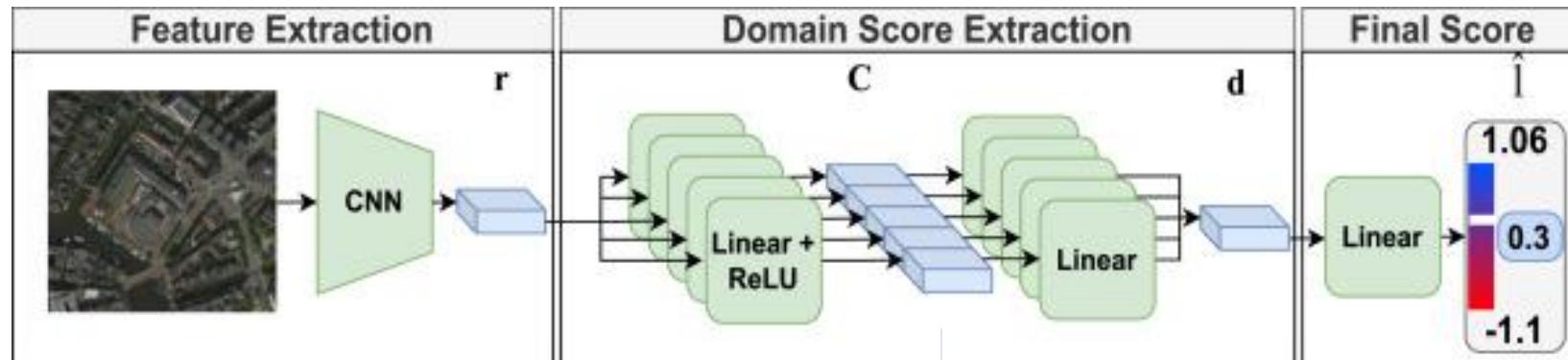
## Data setup





# Can remote sensing help interpolate ?

## Model setup



$$\mathcal{L}_{domain} = \sum_{i=1}^D (\mathbf{d}_i - \hat{\mathbf{d}}_i)^2 \quad \mathcal{L}_{final} = (l - \hat{l})^2$$



# Results on the test set

$R^2$  scores and Kendall's tau w and w/o bottleneck

Configuration	Val $R^2$	Test $R^2$	Val $\tau$	Test $\tau$
Bottleneck	0.861	0.670	0.670	0.521
Baseline	0.801	0.674	0.606	0.484



# Results on the test set per town

R<sup>2</sup> scores of the prediction per test city

Region	Pop.	P.env	Safety	Amen.	Buildings	Liveability
Dordrecht	0.65	0.47	0.65	0.71	0.76	0.70
Eindhoven	0.66	0.62	0.66	0.57	0.76	0.75
Beesel	0.24	0.31	0.54	0.03	0.60	0.45
Hengelo	0.42	0.56	0.62	0.47	0.65	0.63



# Results on the test set per town

R<sup>2</sup> scores of the prediction per test city

Region	Pop.	P.env	Safety	Amen.	Buildings	Liveability
Dordrecht	0.65	0.47	0.65	0.71	0.76	0.70
Eindhoven	0.66	0.62	0.66	0.57	0.76	0.75
Beesel	0.24	0.31	0.54	0.03	0.60	0.45
Hengelo	0.42	0.56	0.62	0.47	0.65	0.63

Smaller town than  
any in the training  
set



# Results on the test set per town

R<sup>2</sup> scores of the prediction per test city

Region	Pop.	P.env	Safety	Amen.	Buildings	Liveability	
Dordrecht	0.65	0.47	0.65	0.71	0.76	0.70	
Eindhoven	0.66	0.62	0.66	0.57	0.76	0.75	
Beesel	0.24	0.31	0.54	0.03	0.60	0.45	
Hengelo	0.42	0.56	0.62	0.47	0.65	0.63	Geographically most isolated town



# Results on the test set per score

$R^2$  scores and Kendall's tau in the validation set and test set

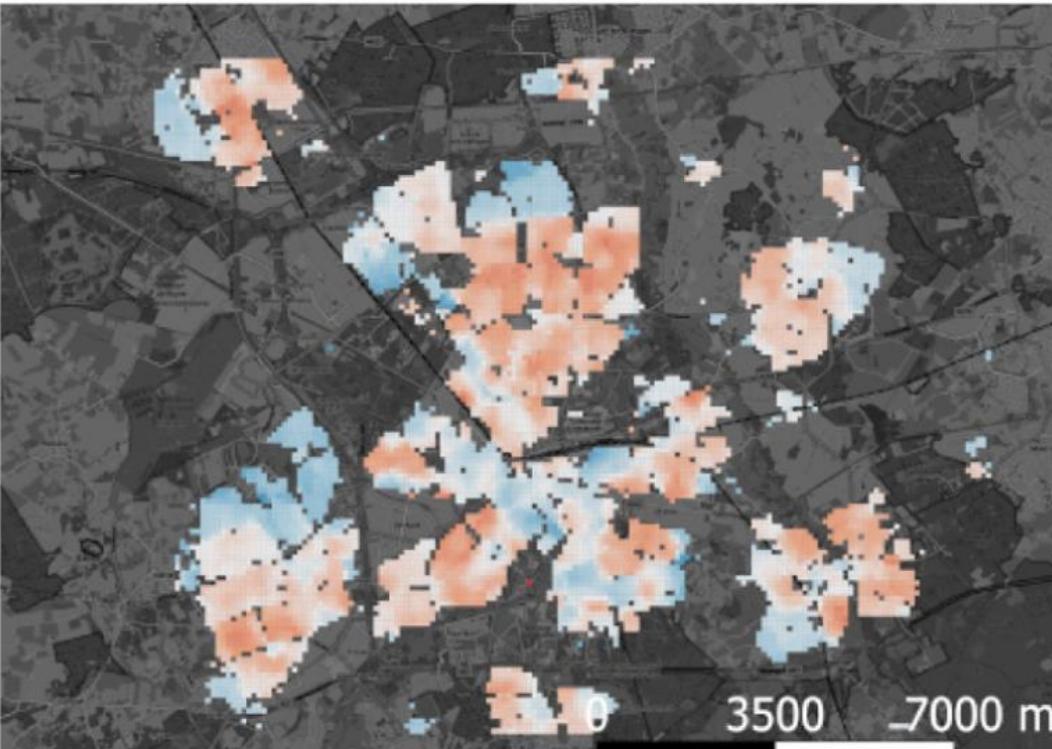
Score	$R^2$	% Change	Kendall's $\tau$	% Change
Population	0.84	-26.5%	0.66	-27.4%
Phys. env	0.87	-29.8%	0.64	-21.3%
Safety	0.84	-26.6%	0.65	-36.8%
Amenities	0.95	-41.9%	0.71	-48.9%
Buildings	0.85	-16.4%	0.68	-24.4%
Liveability	0.86	-18.3%	0.67	-22.2%



# Results on the test set per town

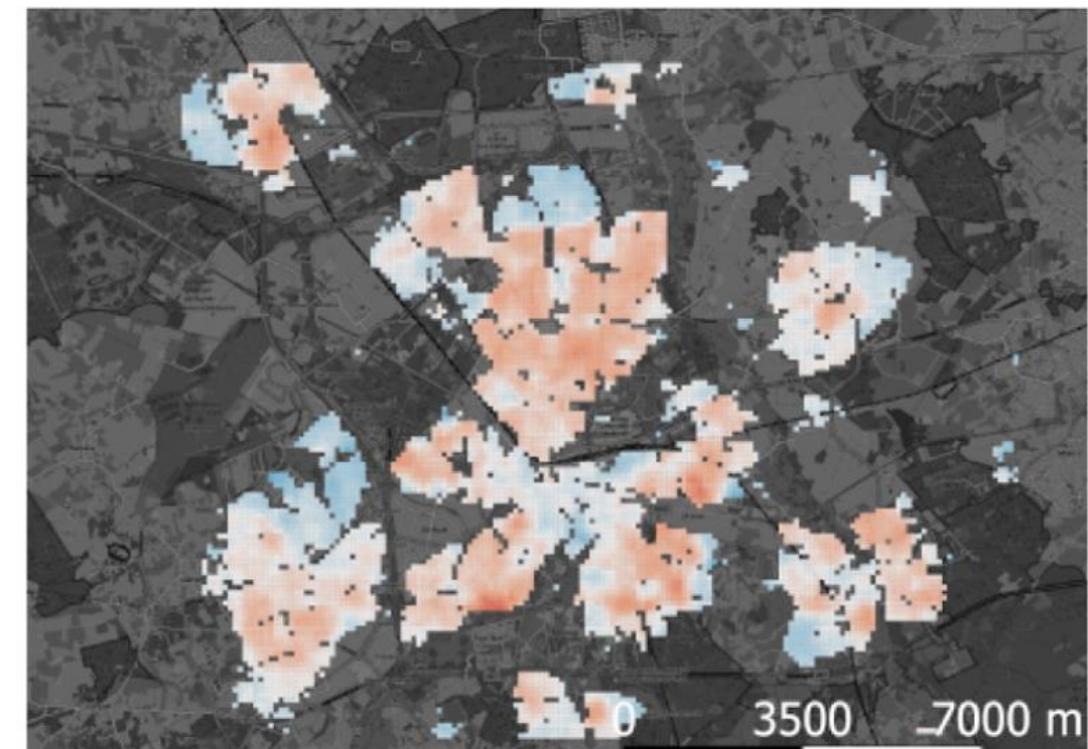
Eindhoven

Ground truth



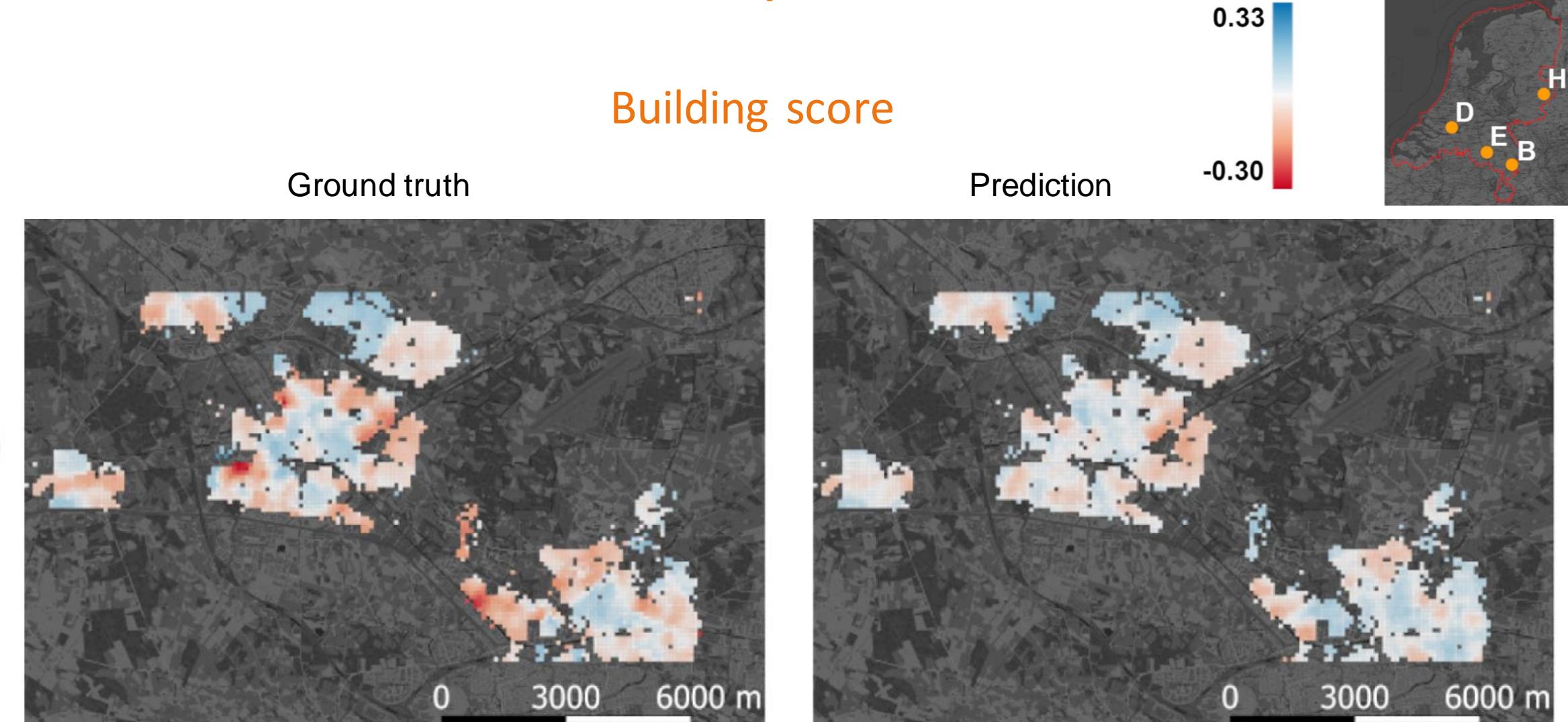
Building score

Prediction



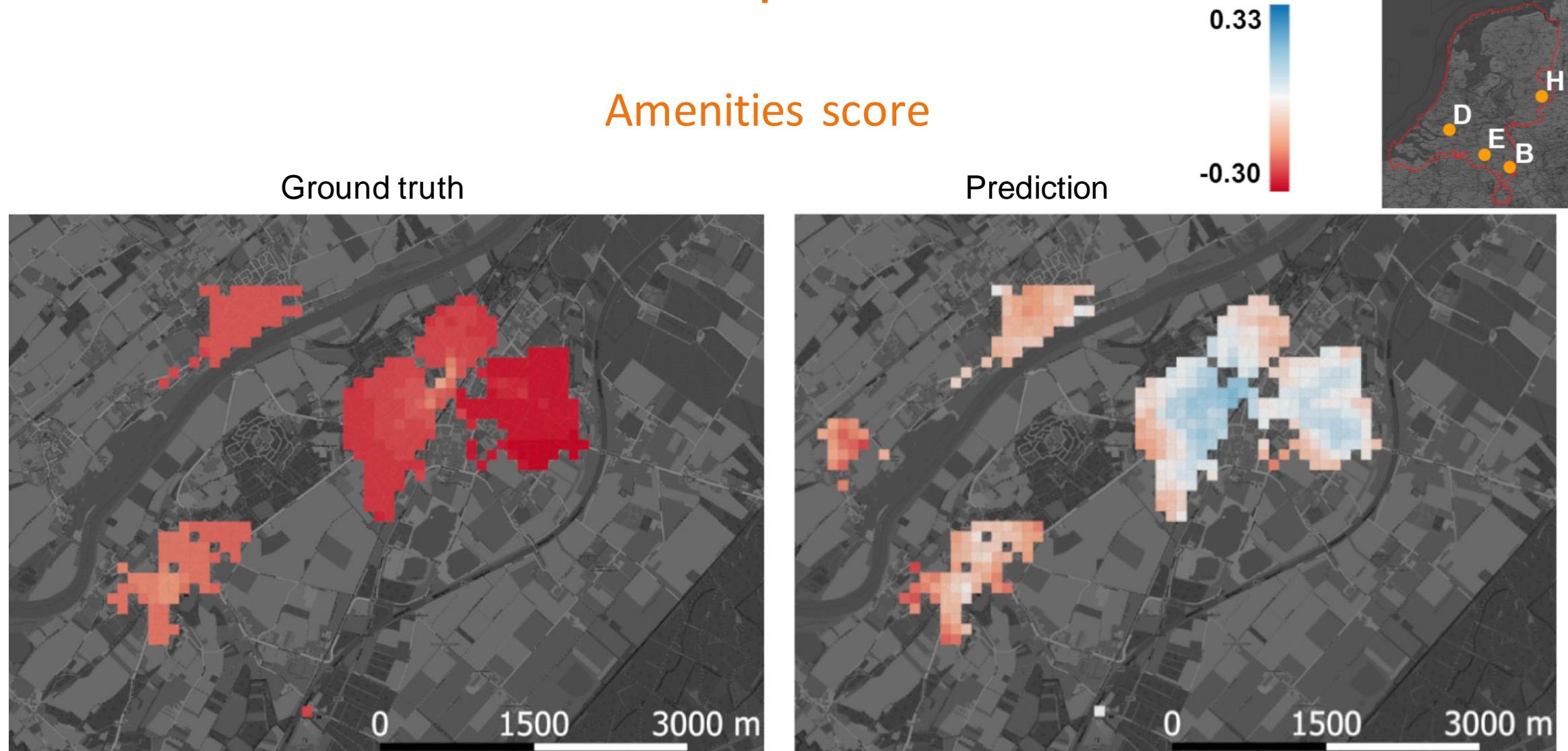


# Results on the test set per town





# Results on the test set per town





## Conclusions

- RS+DL can be used to estimate (some aspects of) urban liveability
- Only physical aspects can be extrapolated to new cities
- This extrapolation only works when cities have a similar structure to those in training

# Questions ?

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A horizontal collage of various aerial and satellite images showing urban landscapes, agricultural fields, and coastal areas.

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## Train-Test split

Samples per split and municipal population census numbers for each built-up area.  
Population data is derived from the Dutch statistics agency ([CBS, 2016](#)).

Built-up area	Training	Validation	Testing	Population (2016)
Almere	1,856	1,206	–	198,145
Amsterdam	7,116	2,609	–	833,624
Arnhem	3,713	722	–	153,818
Beesel	–	–	388	13,388
Dordrecht	–	–	3,548	118,801
Eemsdelta	607	238	–	47,080
Eindhoven	–	–	6,490	224,755
Groningen	2155	718	–	200,952
Hengelo	–	–	3,034	81,075
Nijmegen	3,071	1,068	–	172,064
Rotterdam	8,439	1,823	–	629,606
Venlo	1,074	664	–	100,371
Weert	1,008	234	–	49,100
Total	29,039	9,282	13,460	–