

## Living Planet Symposium 2022



**How well does deep learning  
performs in mapping sub-pixel urban  
landscapes in mountainous  
environments?**

Tzu-Hsin Karen Chen  
[karen.t.chen@yale.edu](mailto:karen.t.chen@yale.edu)

Donnelley postdoctoral associate  
Yale School of the Environment

**SETO LAB**



Yale Institute for Biospheric Studies

Deadly landslides in  
2013 Uttarakhand (183 persons/km<sup>2</sup>) in India  
2009 Kaohsiung (445 persons/km<sup>2</sup>) in Taiwan



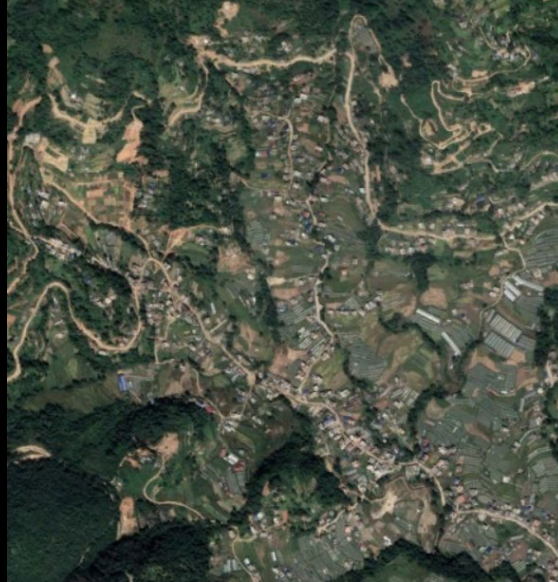


Charikot, Nepal  
Photo: Raut Suresh



Charikot, Nepal  
Photo: Raut Suresh

# Heterogeneous built environments in the Himalayas

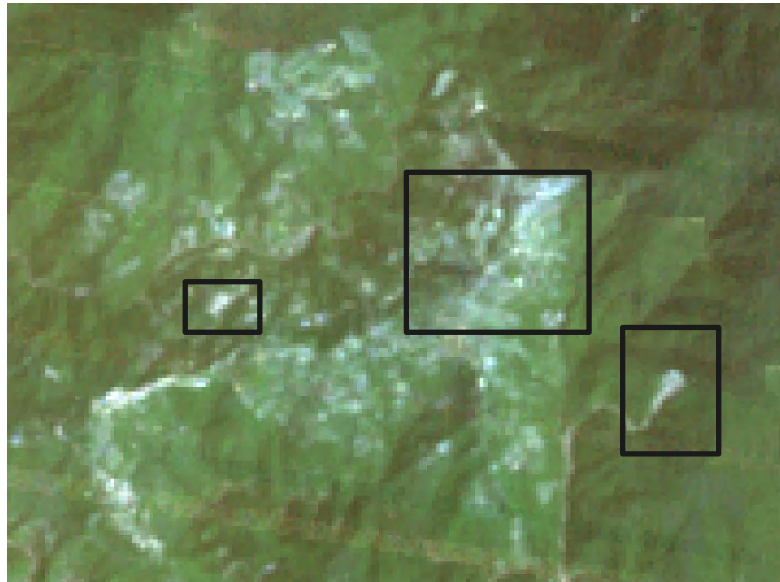




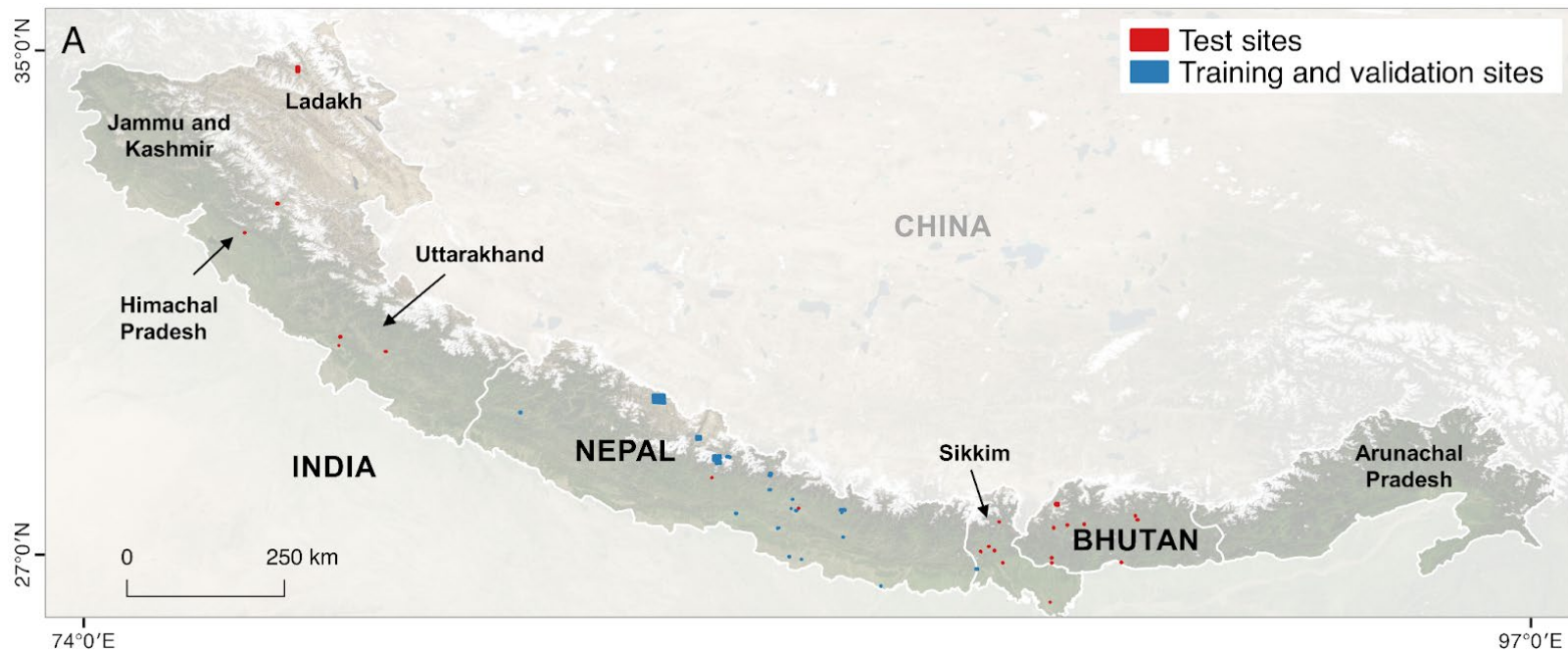
Global Urban Change (Liu et al. 2020, *Nature Sustainability*):  
< 1% of human settlement change is explained



# Interspersed landscapes



Landslide  
Terraced fields  
Human settlements



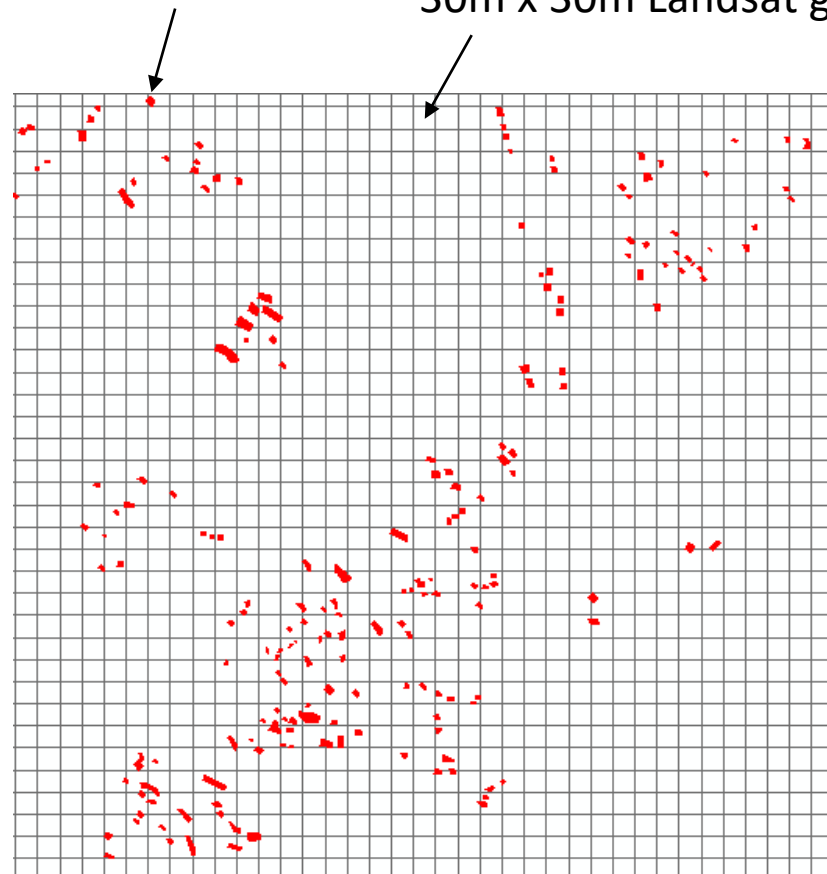
40 sites across India, Nepal, and Bhutan



Urban fraction	2017	2010	2005
0	133643	137282	66968
0-0.1	5519	8056	4994
0.1-0.2	3059	4796	3548
0.2-0.3	2595	3792	3138
0.3-0.4	2739	3559	2890
0.4-0.5	2849	3394	2640
0.5-0.6	2128	2511	1990
0.6-0.7	1333	1556	1241
0.7-0.8	790	883	681
0.8-0.9	494	544	393
0.9-1	698	740	347
	<b>Nepal</b>	<b>Total</b>	<b>423,056</b>

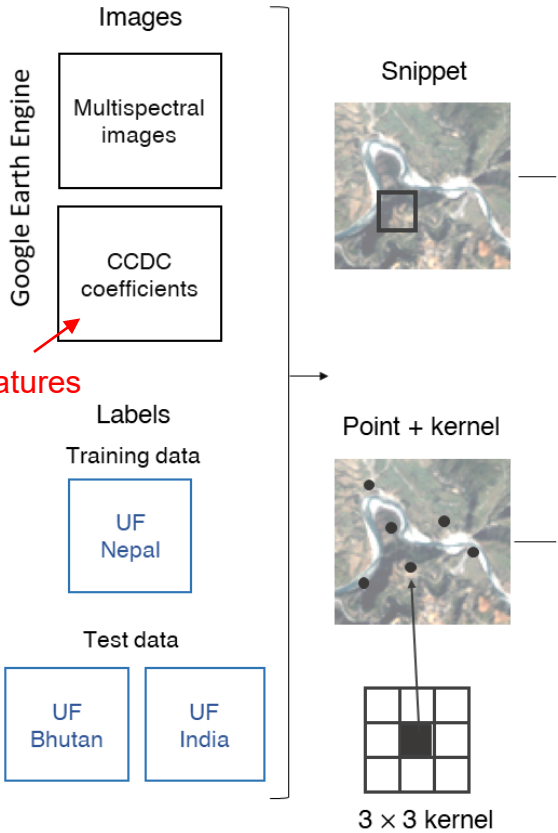
Human settlement  
boundaries

30m x 30m Landsat grid

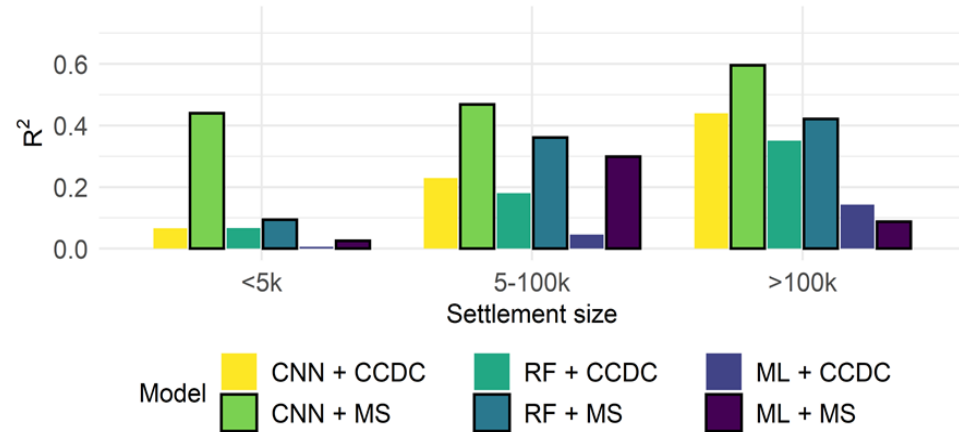


## Datasets

## Models



# CNN's accuracy increase is larger for smaller settlements



CCDC: temporal features

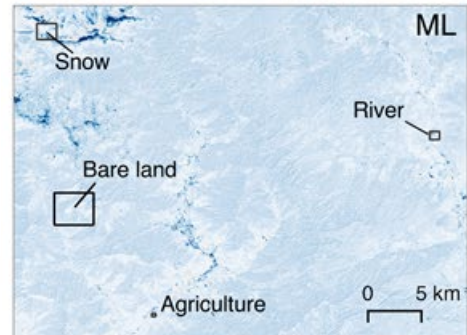
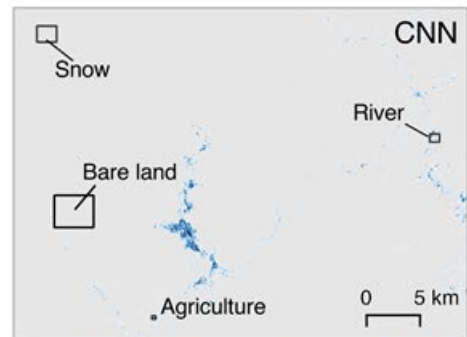
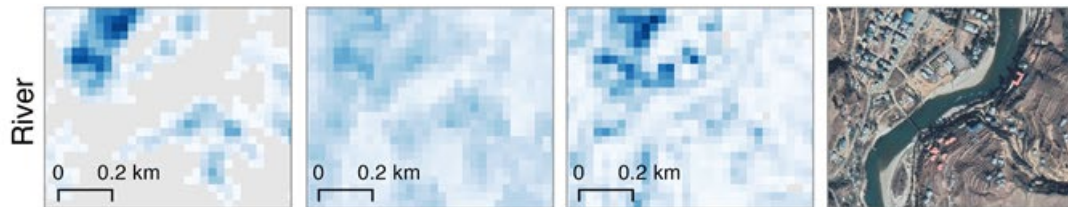
MS: multispectral imagery

CNN

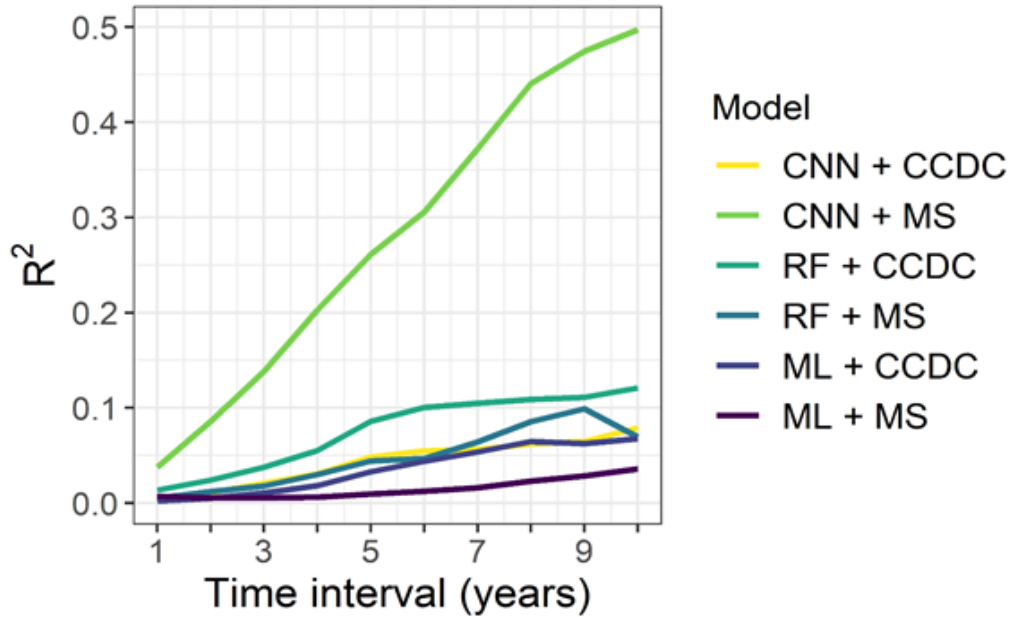
RF

ML

Google image



# Temporal accuracy



1985-Kathmandu valley



# 1995-Kathmandu valley



# 2005-Kathmandu valley





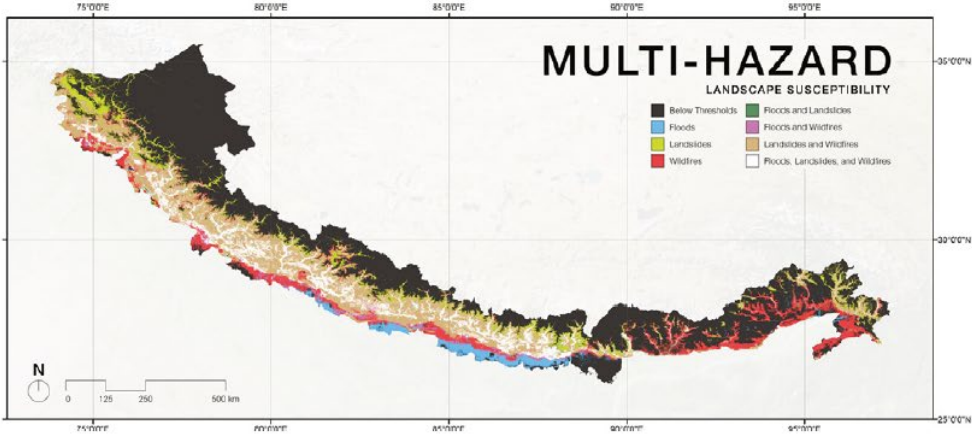
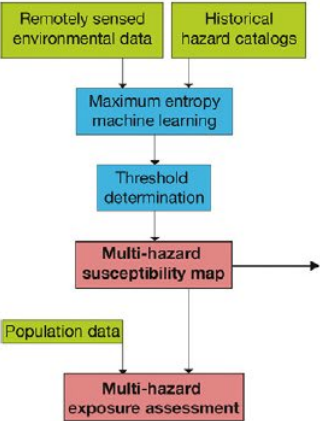
# 2015-Kathmandu valley



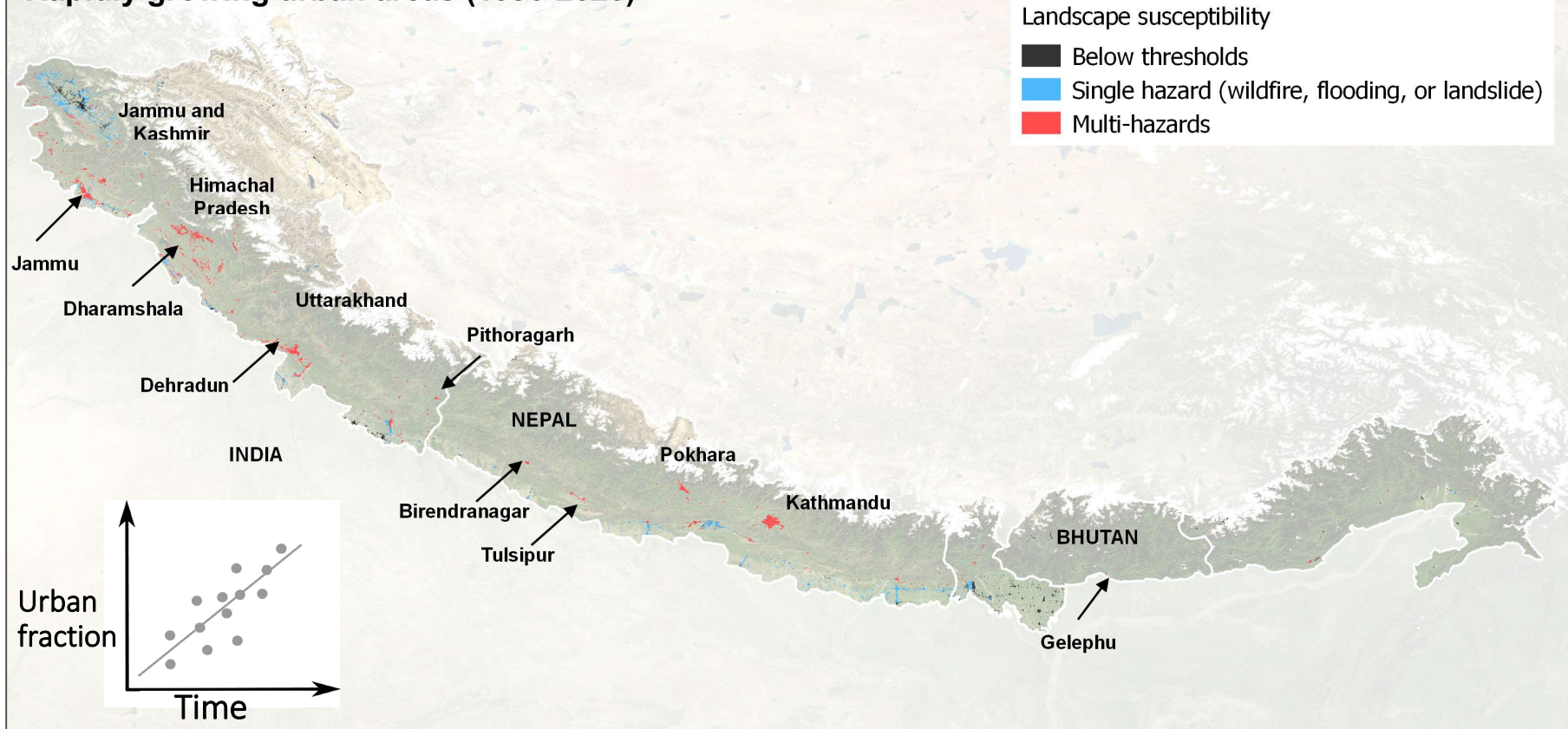
# How does urbanization interact with natural hazard risk?

## GRAPHICAL ABSTRACT

(Rusk and Chen et al. 2022)

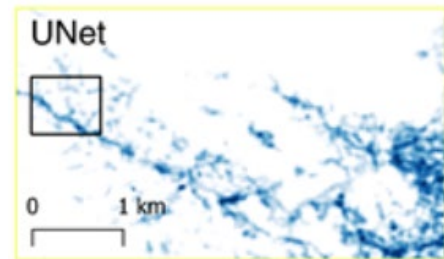


## Rapidly growing urban areas (1990-2020)

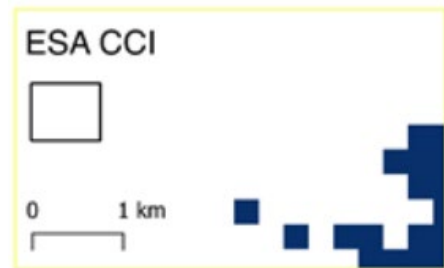


# Take-home message

- **Three times** existing estimates of the built-up areas in the Himalaya
  - Increasing multi-**hazard risk**
- The superiority of CNN over RF and ML increases for **small settlements**
- Next gap: temporal accuracy



Nepal





Thank you!



**SETO LAB**

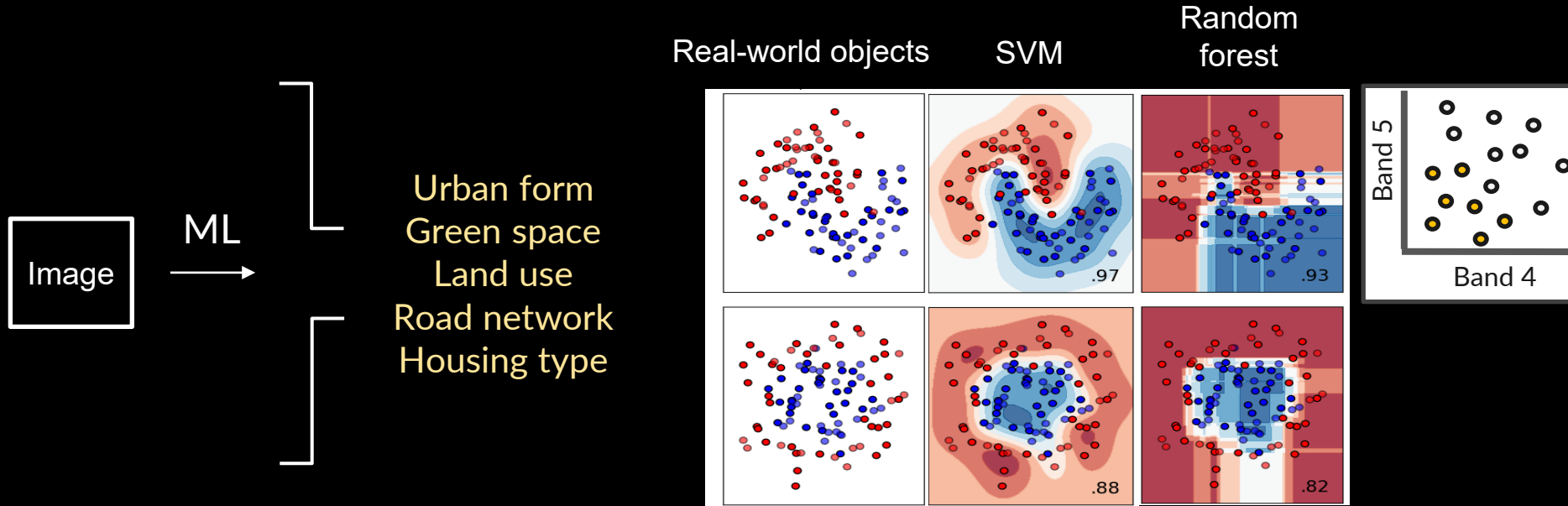
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- See more

[karen.t.chen@yale.edu](mailto:karen.t.chen@yale.edu)

# Advantage of RS+ML to environmental health studies

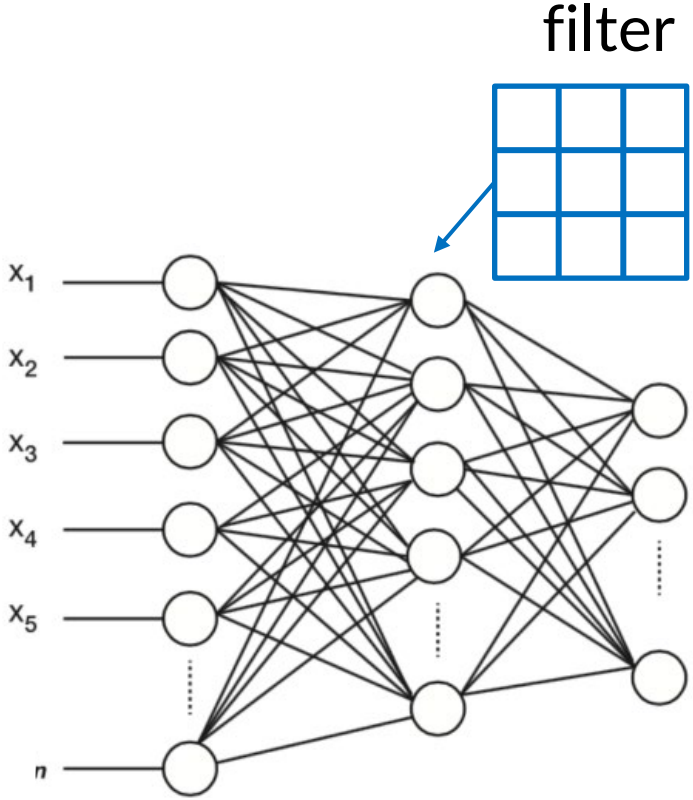


Good models:

Accurate predictions of the built, natural, or social factors of health

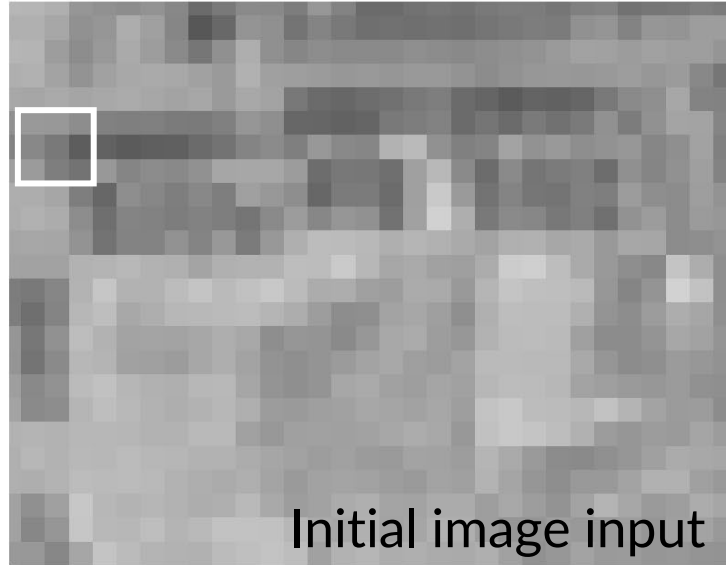
Generalizable to predict multi-site and multi-annual information

# Deep Learning: Convolutional Neural Network



(Chen, et al. 2020, *Remote Sensing of Environment*)

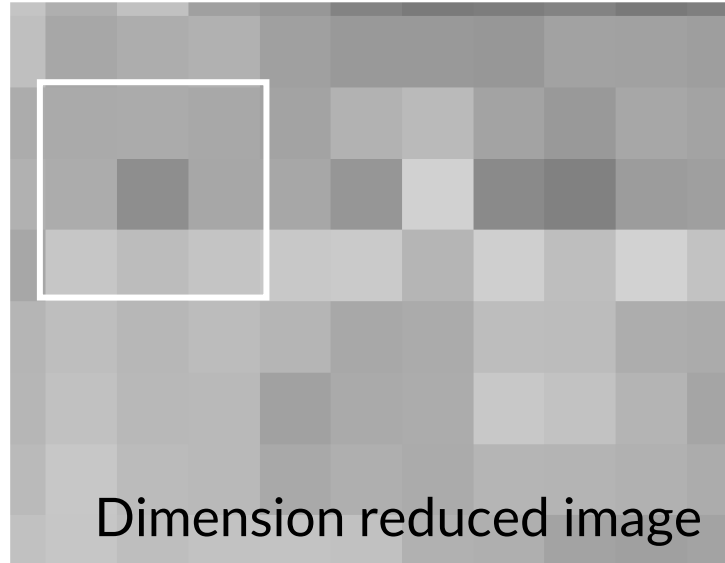
3\*3 filter



Pattern of sparse high-rise: shadow



3\*3 filter

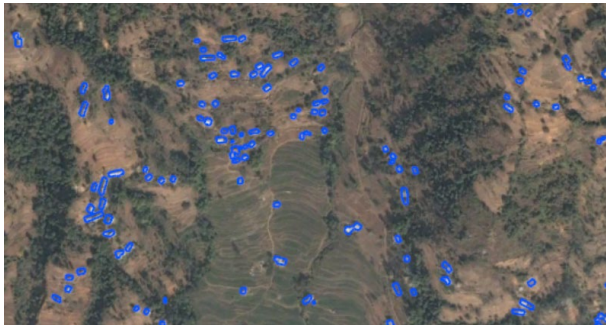


Dimension reduced image

Pattern of sparse high-rise: wide roads around dark shadow

Data collection

2003



2010



2017

