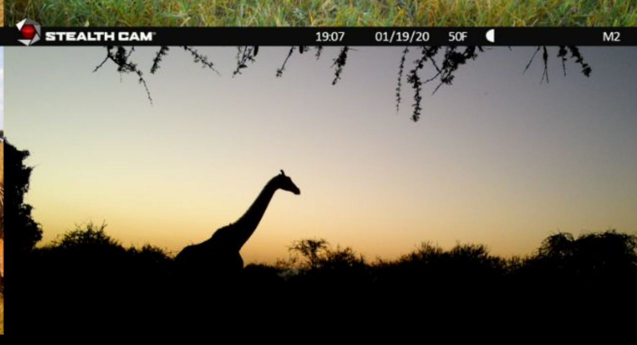
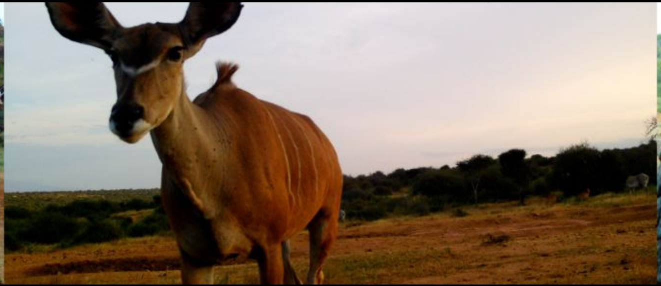
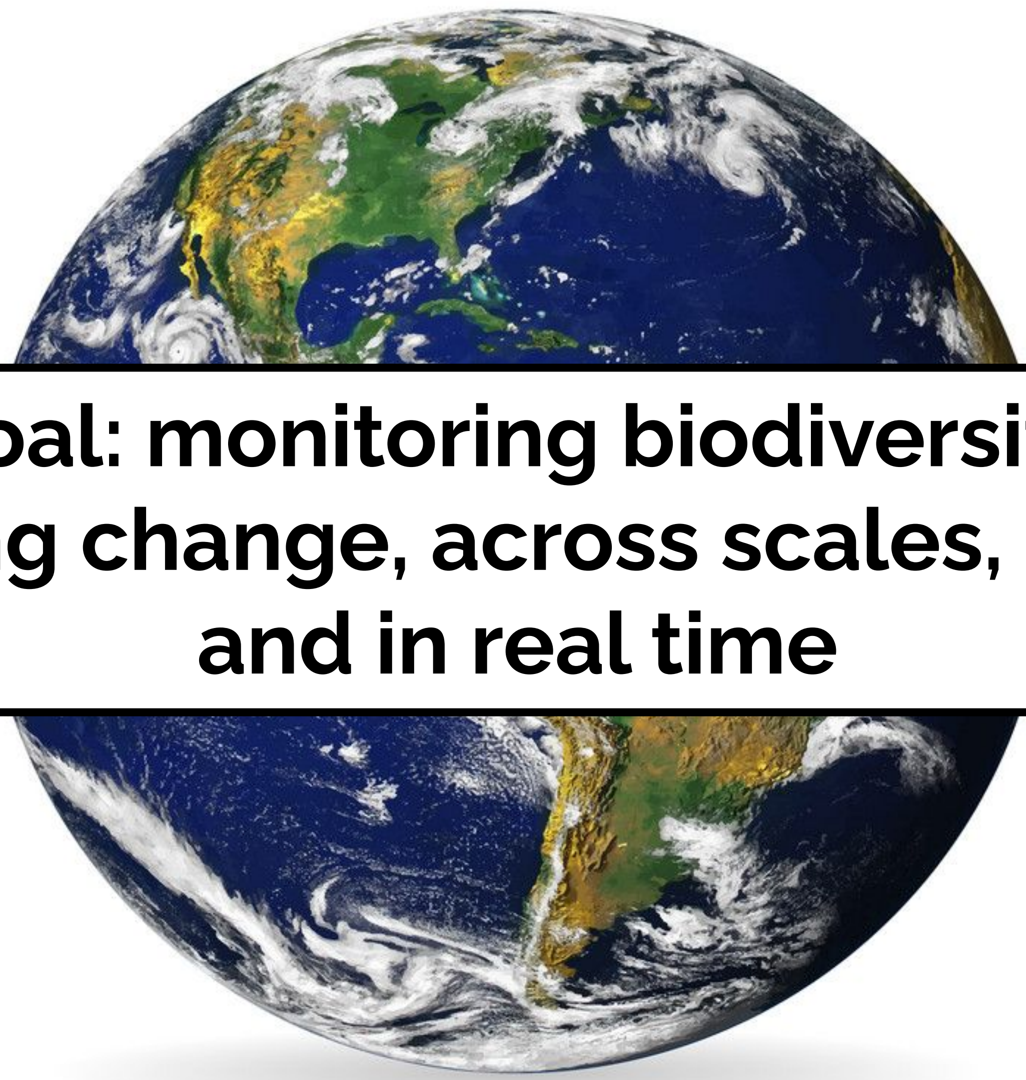


Computer Vision for Global-Scale Biodiversity Monitoring


Sara Beery | Harvard AI for Science | 2-1-24



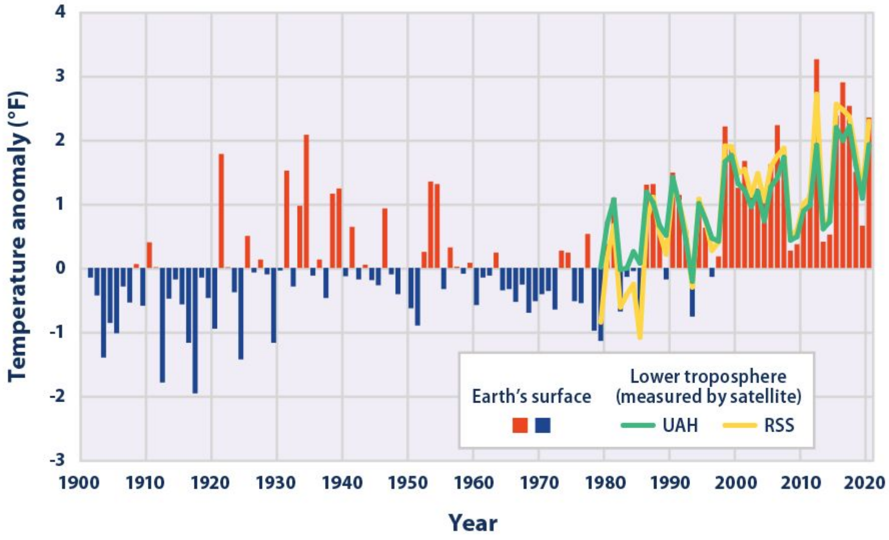


Big Goal: monitoring biodiversity and detecting change, across scales, globally, and in real time

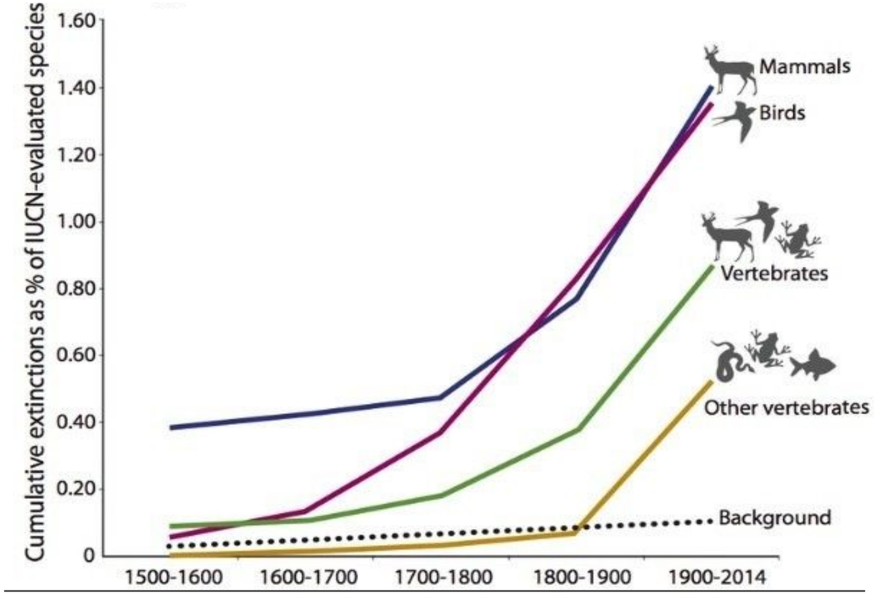
Why monitor biodiversity?

Why monitor biodiversity?

Increase in global temperatures



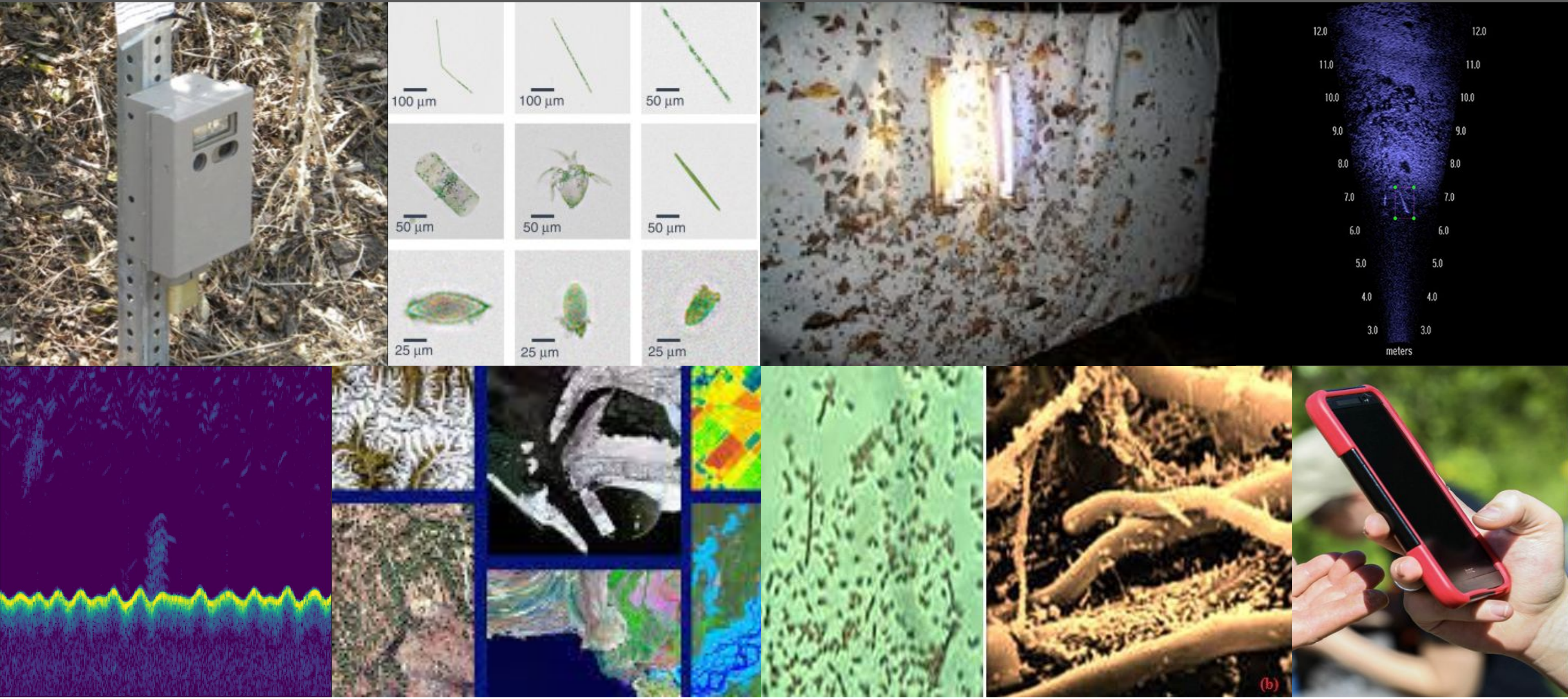
Mass extinction of species



Biodiversity data is diverse and large-scale

Seeing biodiversity: perspectives in machine learning for wildlife conservation, Tuia*, Kellenberger*, Beery*, Costelloe*, et al., Nature Comms (to appear)

No direct sensor for biodiversity across taxa & scale



National trends in closing spatiotemporal biodiversity knowledge gaps via complementary data types, Oliver et al., 2020

Manual data processing can’t keep up

Camera Traps

One project can collect >10M images/season

Community Scientists

>64M Species observations in iNaturalist

Aerial Surveys

One survey can generate >200TB of video

Scaling Biodiversity Monitoring for the Data Age - ACM XRDS 2021

Manual data processing can't keep up

Camera Traps

One project can collect >10M images/season

Community Scientists

>170M!

~~>64M~~ Species observations in iNaturalist

Aerial Surveys

One survey can generate >200TB of video

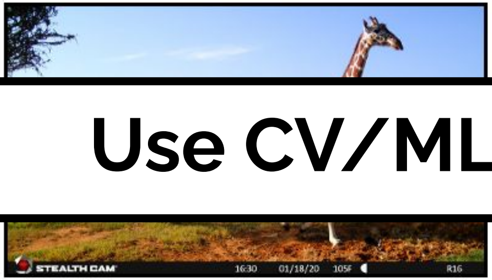
Scaling Biodiversity Monitoring for the Data Age - ACM XRDS 2021

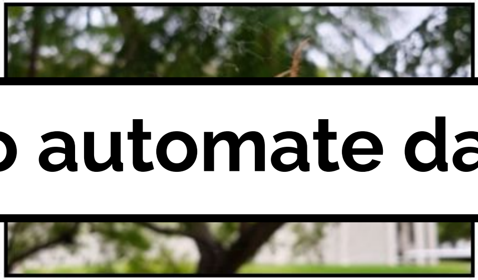
Manual data processing can't keep up

Camera Traps

Community Scientists

Aerial Surveys





Use CV/ML to automate data processing

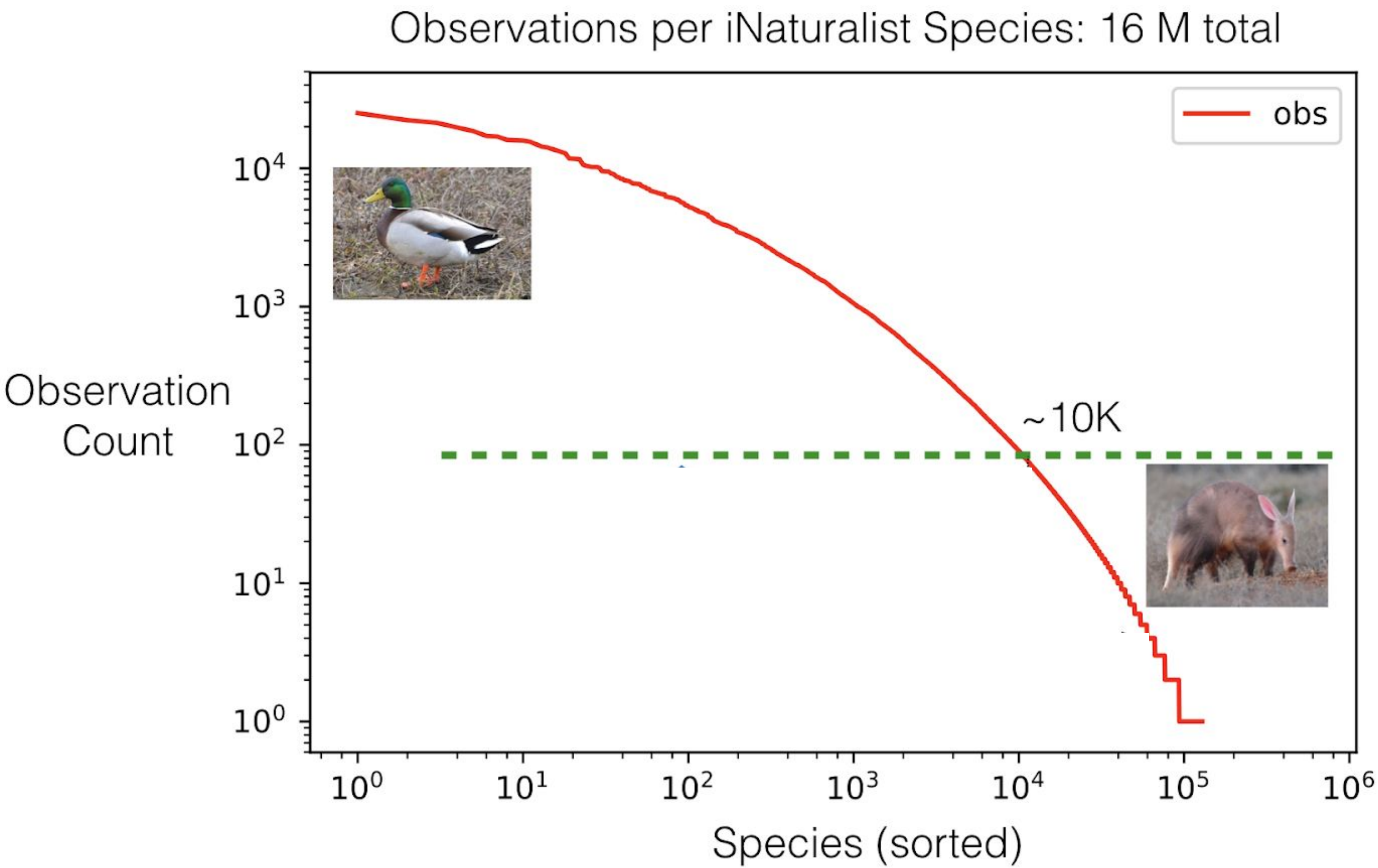
One project can collect >10M images/season

>170M!
~~>64M~~ Species observations in iNaturalist

One survey can generate >200TB of video

Scaling Biodiversity Monitoring for the Data Age - ACM XRDS 2021

Biodiversity data has a long tail

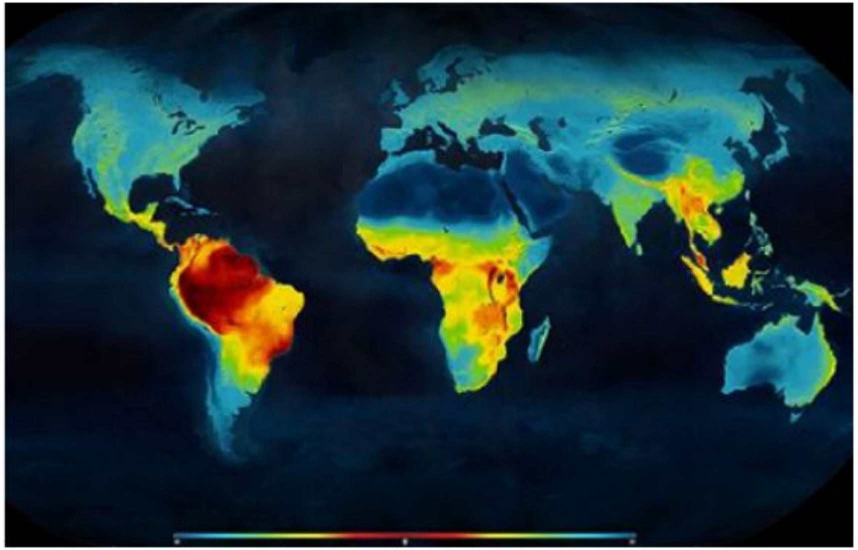


Biodiversity data is fine-grained

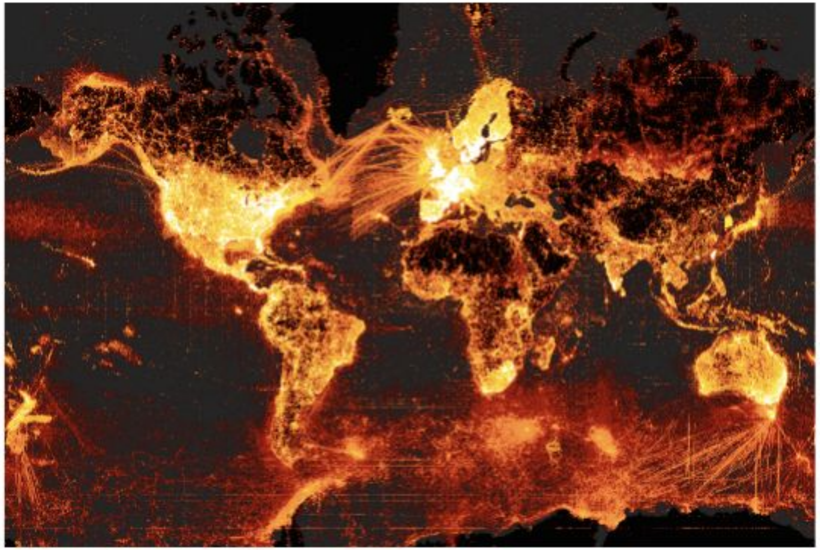
American Crow

Common Raven

Biodiversity data is not IID - spatially, temporally, or taxonomically



Map of global biodiversity



Species occurrence data in GBIF

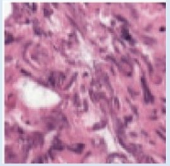
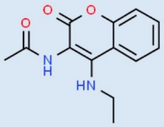
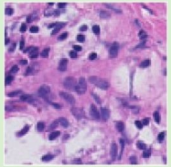
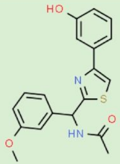
Scaling Biodiversity Monitoring for the Data Age - ACM XRDS 2021

Distribution shifts are ubiquitous in real-world scenarios

WILDS

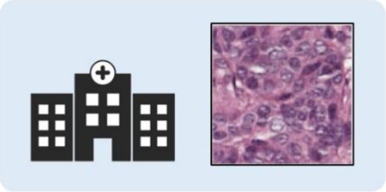
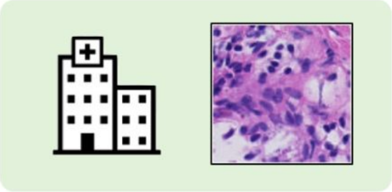
https://wilds.stanford.edu/

Pang Wei Koh*, Shiori Sagawa*, Henrik Marklund, Sang Michael Xie, Marvin Zhang,
Akshay Balsubramani, Weihua Hu, Michihiro Yasunaga, Richard Lanas Phillips, Sara Beery,
Jure Leskovec, Anshul Kundaje, Emma Pierson, Sergey Levine, Chelsea Finn, and Percy Liang

	Camelyon17	iWildCam	PovertyMap	FMoW	Amazon	CivilComments	OGB-MolPCBA
Shift	Hospitals	Locations	Countries	Time	Users	Demographics	Scaffold
Train					Overall a solid package that has a good quality of construction for the price.	What do Black and LGBT people have to do with bicycle licensing?	
Test					I *loved* my French press, it's so perfect and came with all this fun stuff!	As a Christian, I will not be patronizing any of those businesses.	
Adapted from	Bandi et al. 2018	Beery et al. 2020	Yeh et al. 2020	Christie et al. 2018	Ni et al. 2019	Borkan et al. 2019	Hu et al. 2020

Performance degradation is also ubiquitous

shifts across hospitals in histopathology

ID accuracy 93.2% **-22.9%** → **OOD accuracy** 70.3%

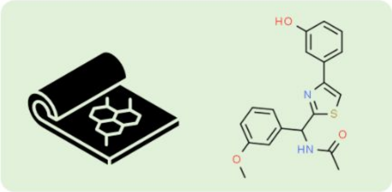
shifts across time in satellite imagery


ID accuracy 48.6% **-16.3%** → **OOD accuracy** 32.3%

shifts across regions in wheat head detection


ID accuracy 63.3% **-13.7%** → **OOD accuracy** 49.6%

shifts across scaffold in bioassay prediction

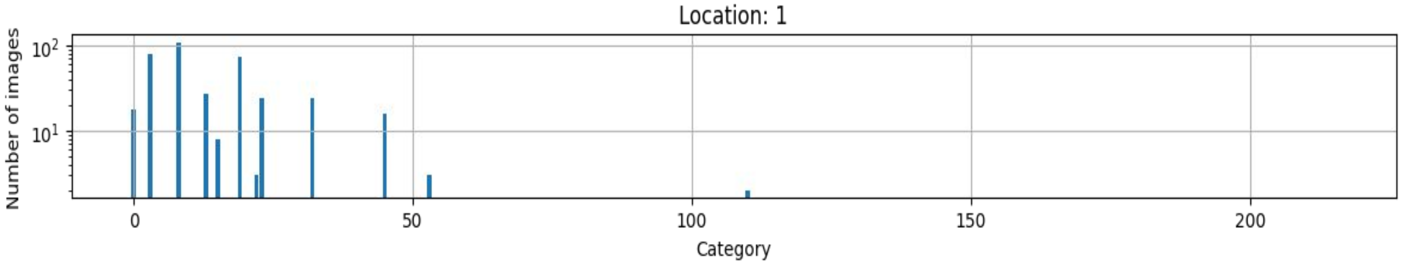



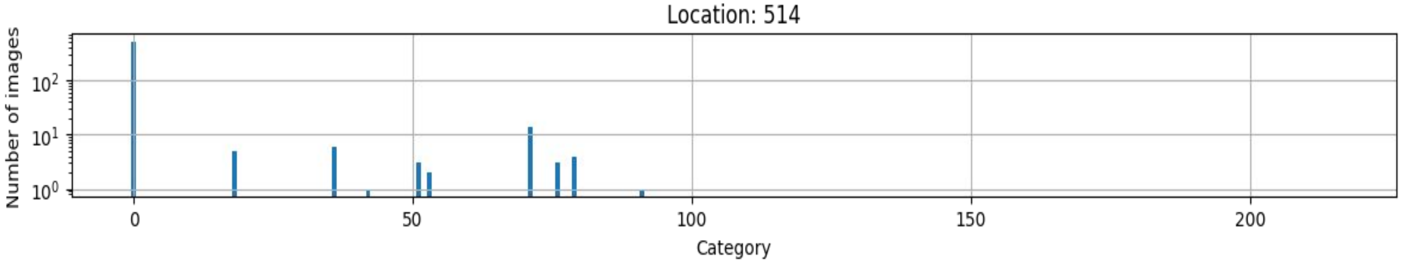
ID AP 34.4% **-7.2%** → **OOD AP** 27.2%

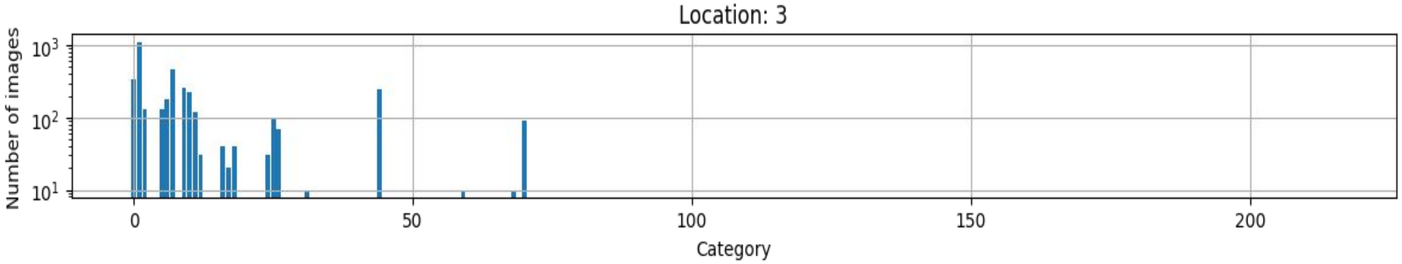
[Koh et al., 2021]

Slide from Shiori Sagawa

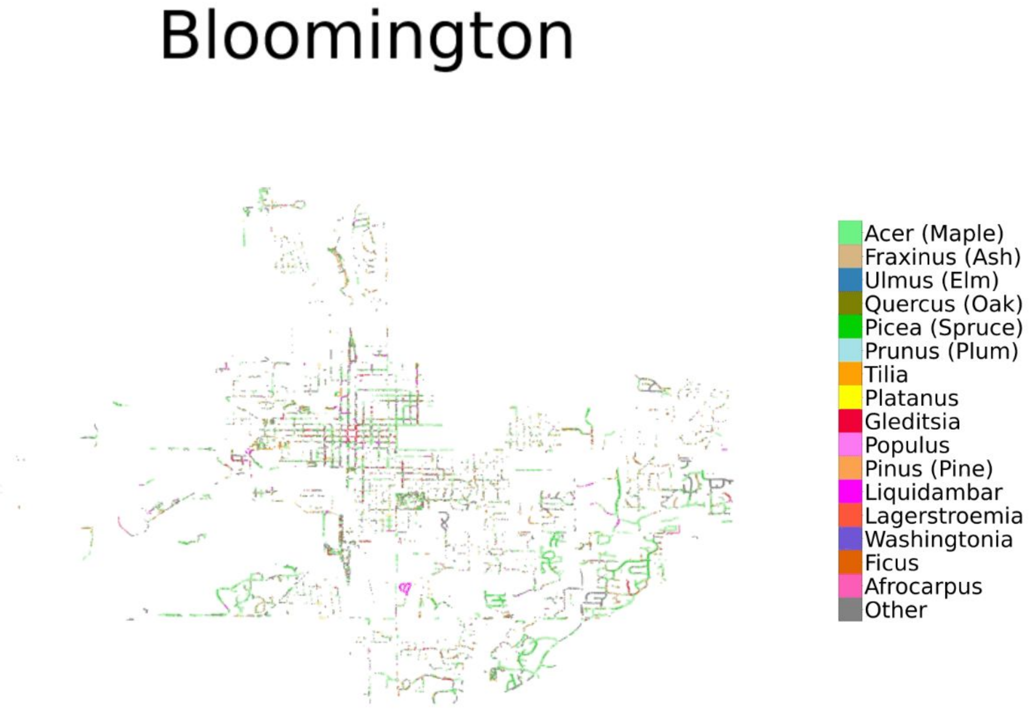
Each geospatial location has a distinctive habitat and class distribution



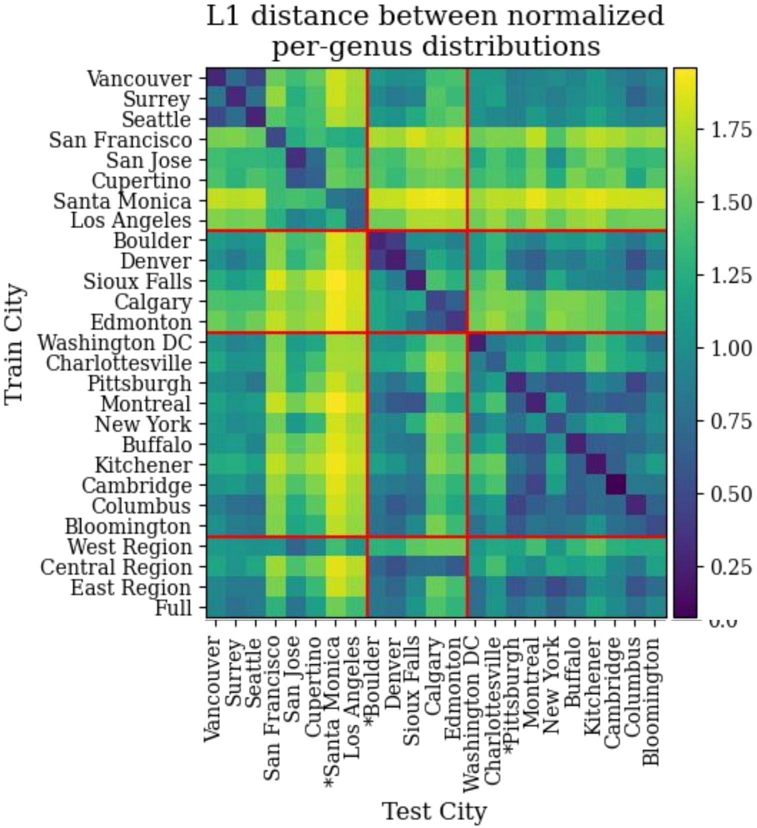


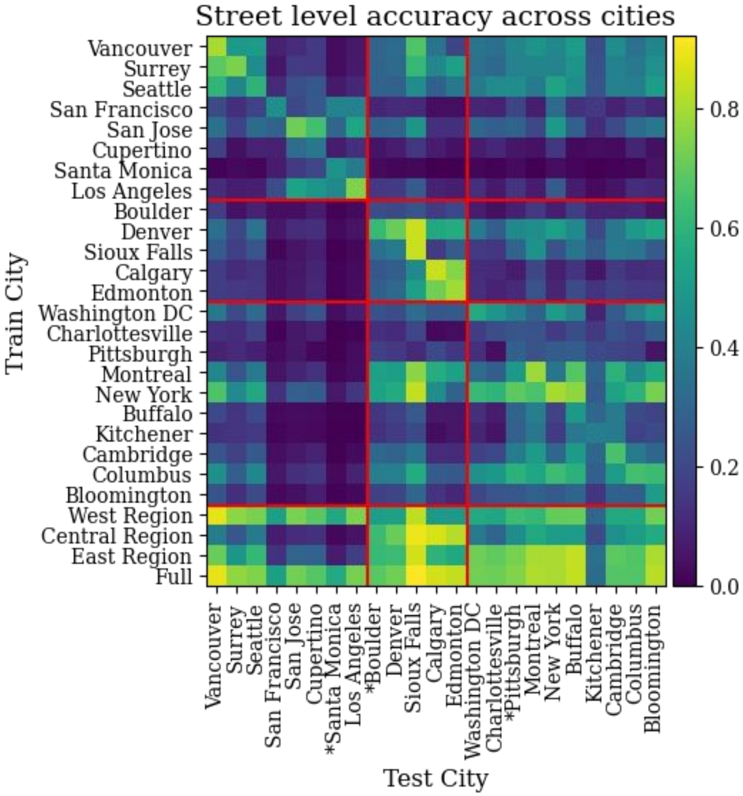


The distribution of urban tree species changes dramatically across North America



Performance has strong correlation with distribution similarity in urban forests





Class-agnostic localization generalizes: less impact from context, distribution shift, and the long tail

https://github.com/microsoft/CameraTraps/blob/main/megadetector.md

Efficient Pipeline for Camera Trap Image Review, Beery, et al., DMAIC @ KDD 2019

Sarah Bassing @S_Bassing · May 19

Thank goodness for the #MegaDetector helping me find the ONE animal image mixed in with 170,787 pictures of blowing grass and clouds from this #CameraTrap! Image recognition software is a game changer. #painless #tech4wildlife #WAPredatorPreyProject

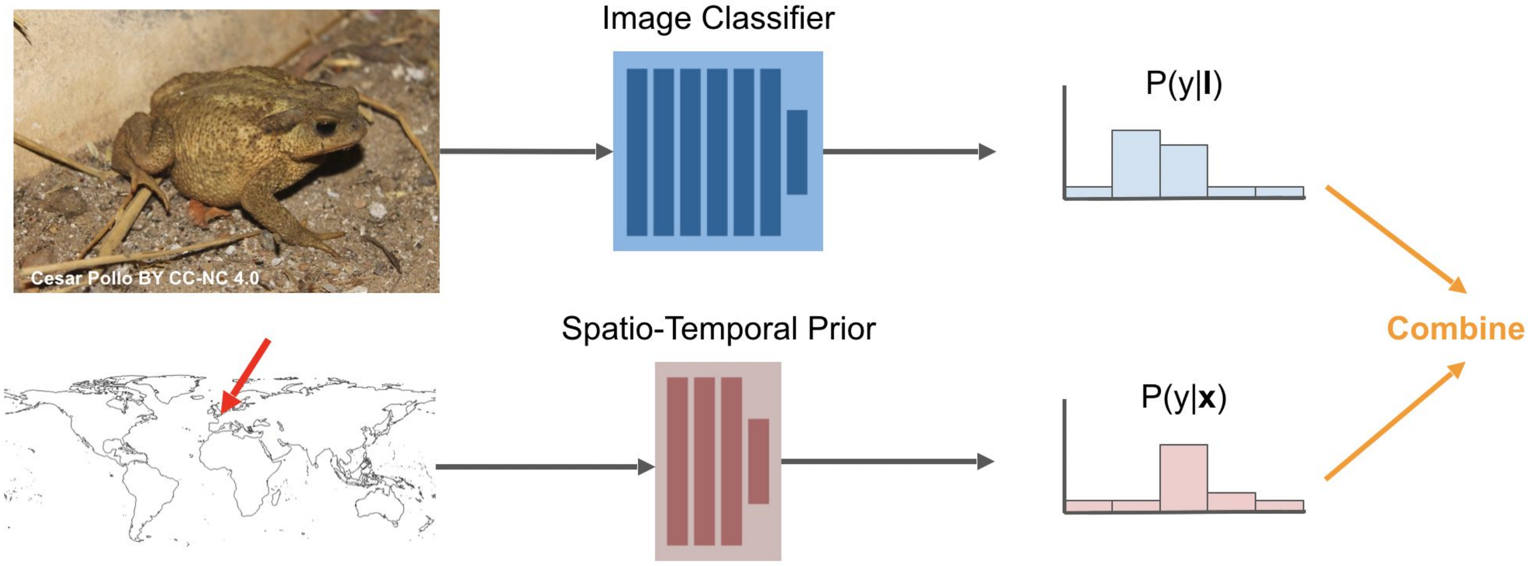
Active learning to adapt models to new regions efficiently

- Use the MegaDetector to crop
- Cluster animals based on visual similarity in new cameras
- Humans ID examples from each cluster (active learning criteria)
- Gets same accuracy with **99.5% fewer labels**

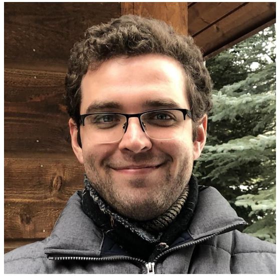
A deep active learning system for species identification and counting in camera trap images, Norouzzadeh, Morris, Beery, Joshi, Jojic, Clune, Methods in Ecology & Evolution, 2021

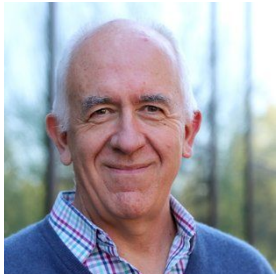
Learn a spatiotemporal prior to provide context

$$P(y|I,\mathbf{x}) \propto P(y|I)P(y|\mathbf{x})$$



$\mathbf{x}$ = (longitude, latitude, day)





Presence-Only Geographical Priors for Fine-Grained Image Classification, Mac Aodha, Cole, Perona, ICCV 2019

Exploring global model performance across data modalities: Multiview Urban Forest Monitoring

Benefits of the Urban Forest

Biodiversity

Cities support regional biodiversity

Large trees and a diverse, connected urban forest supporting a rich array of wildlife, particularly birds

Reduces Air Pollution

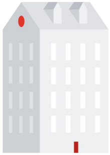
Removes some 784k tons of air pollution annually

Implied global value: $15-20B/yr
Potential impact: $1.5B-$5B/yr

Carbon Sequestration

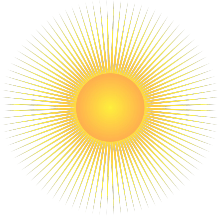
Total opportunity for additional carbon sequestration ranges from 1GT to 2.4GT

At $50/ton, that's a value of $50B-$120B, cumulatively (i.e., not annually)



Reduced Energy Use

Trees reduce building energy use and avoided pollutant emissions ($8B+ value in U.S. alone)



Extreme Heat Islands

Lowers surface and air temperatures by providing shade and through evapotranspiration

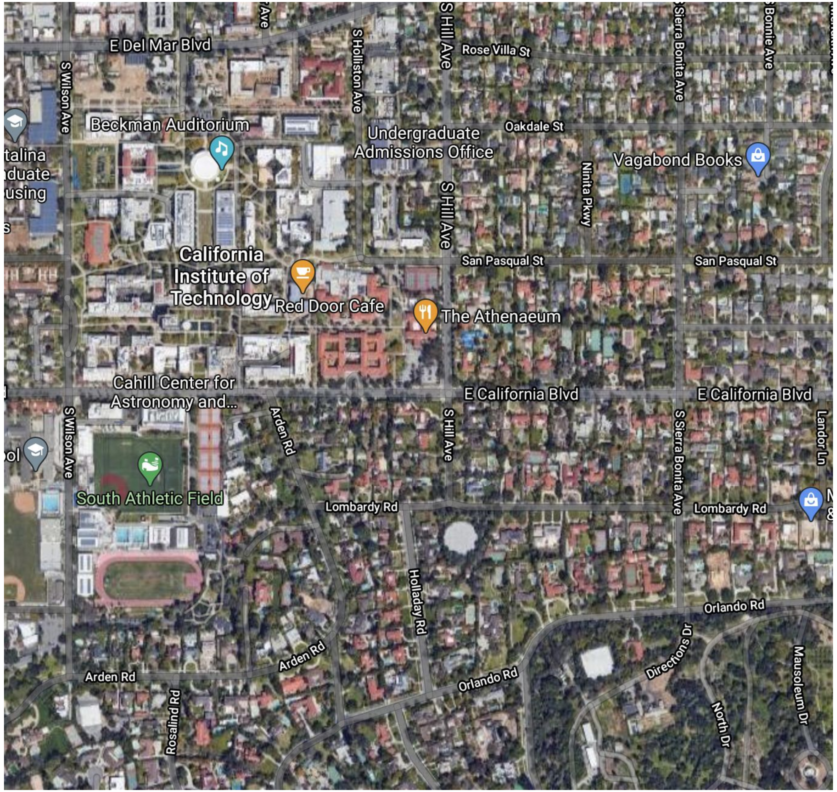
Physical + Mental Health

Trees in a community correlate with lower asthma rates, reduced hospital visits during heat waves and improved mental health

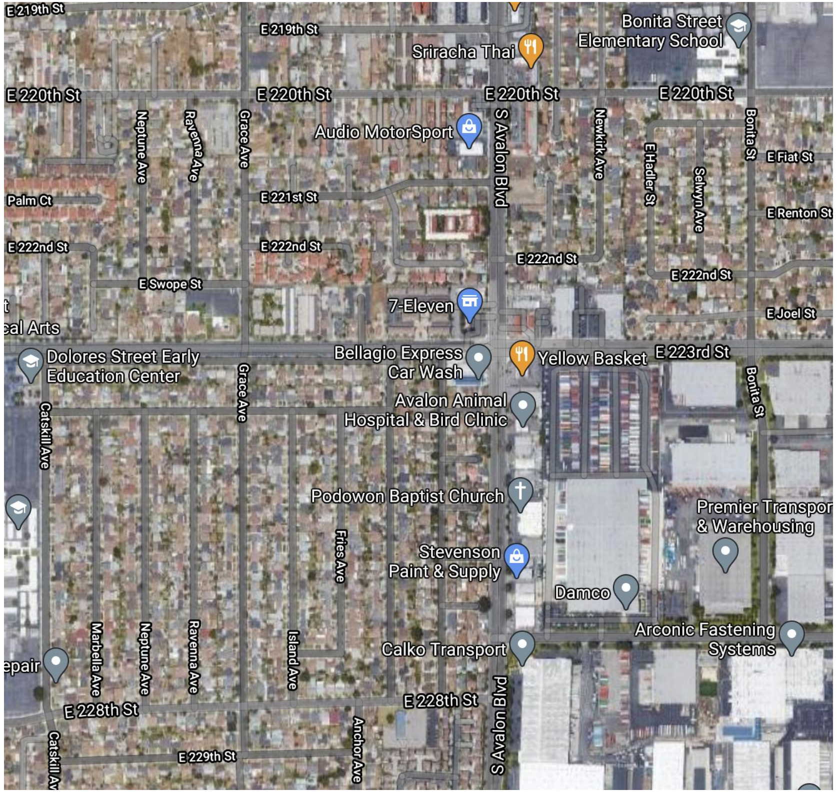
Slide thanks to Google AI for Nature and Society

These benefits are not accessible to all

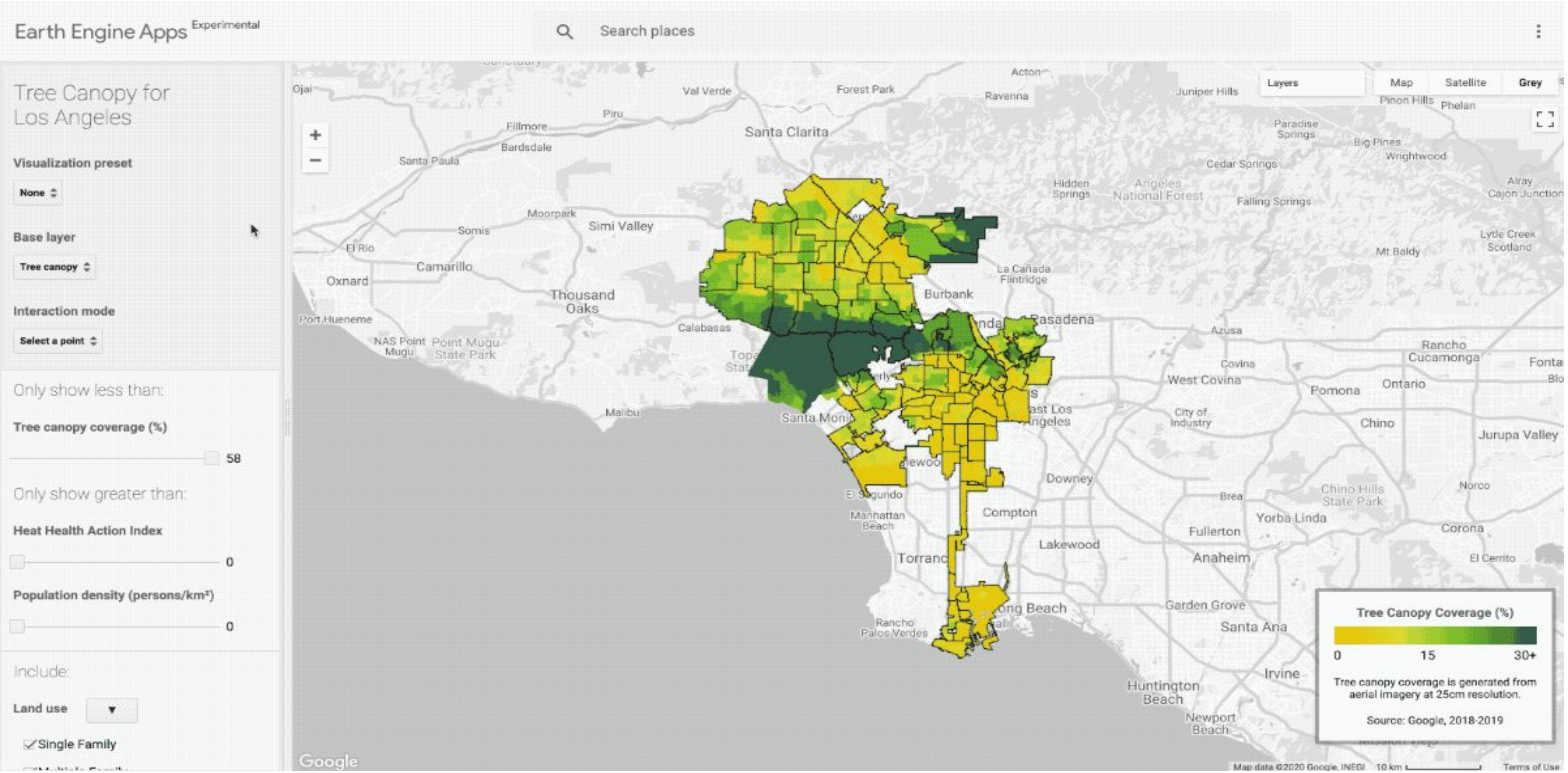
Pasadena



Carson

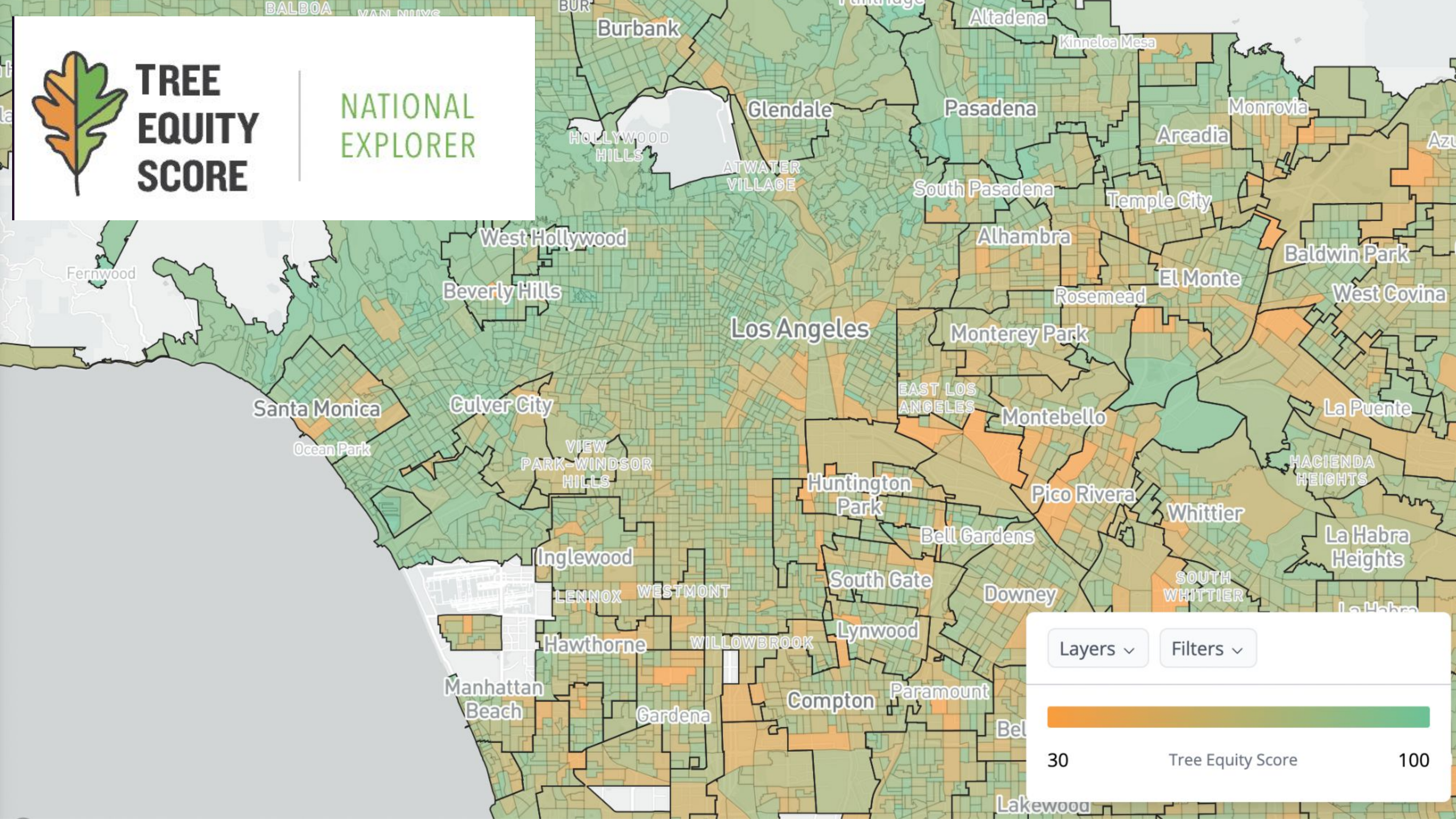


Tree canopy prediction via Google's Urban Ecology Team



https://insights.sustainability.google/labs/treecanopy

TREE EQUITY SCORE | NATIONAL EXPLORER



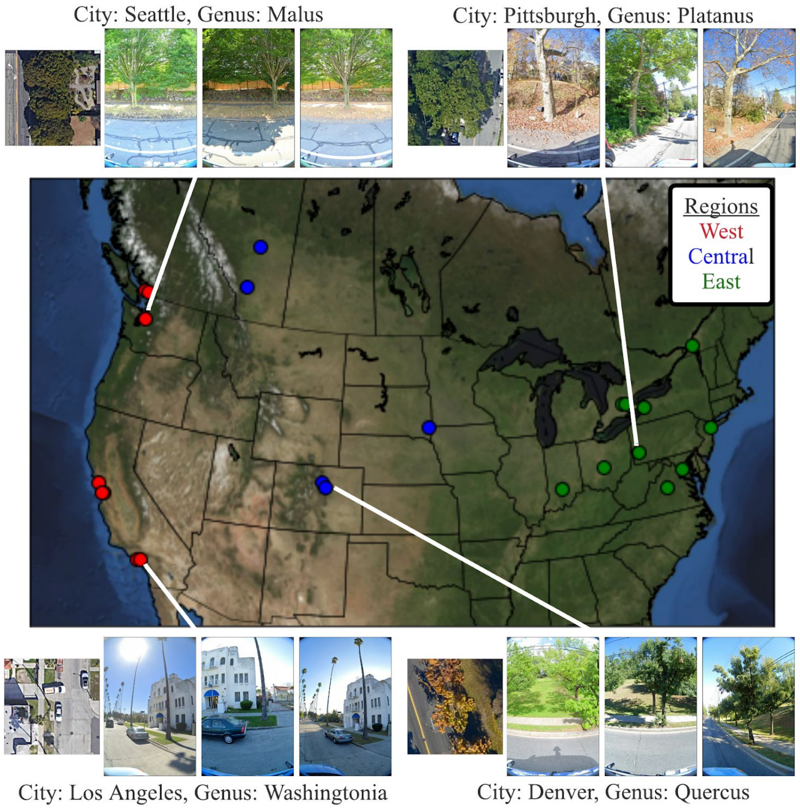
Tree canopy prediction is not enough

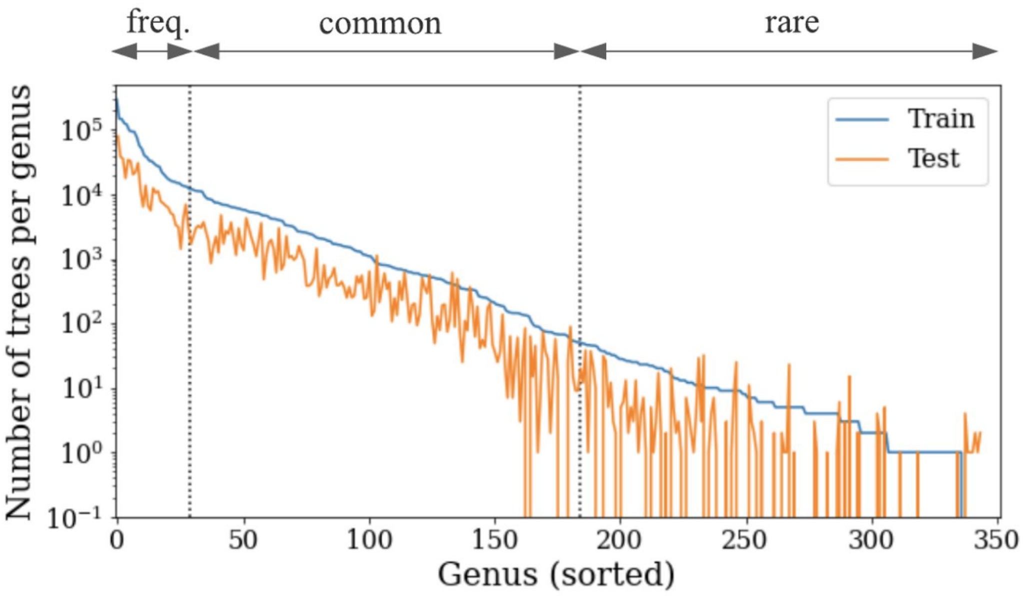
Instance locations and species identification is needed to:

- Estimate water retention
- Estimate carbon sequestration
- Estimate potential heat reduction
- Monitor species' reaction and resilience to our changing climate at scale
- Strategically plan planting to maximize biodiversity

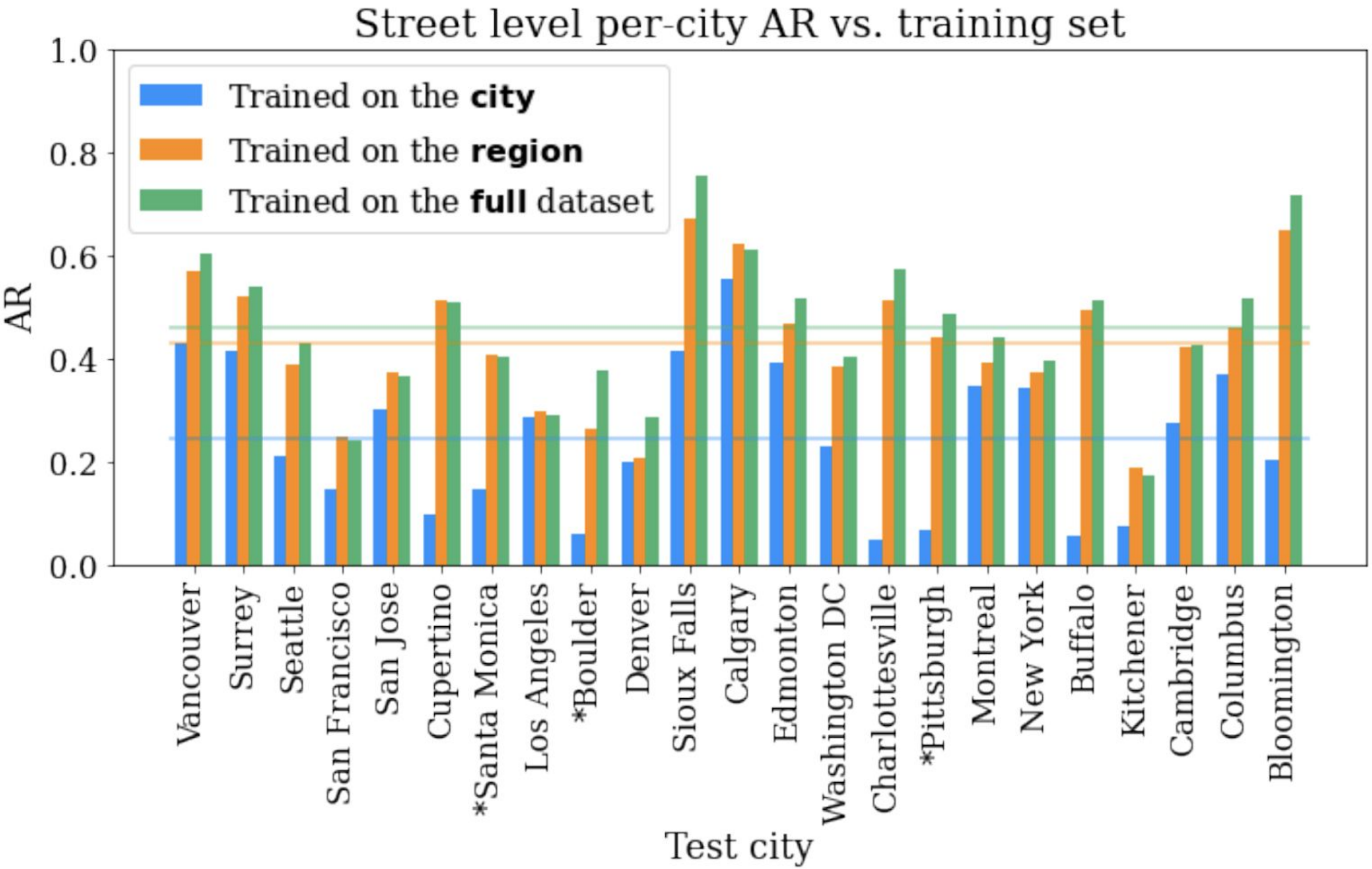
The Auto Arborist Dataset:

23 cities, 344 genera, 2.6M tree records, >1M trees w/ imagery



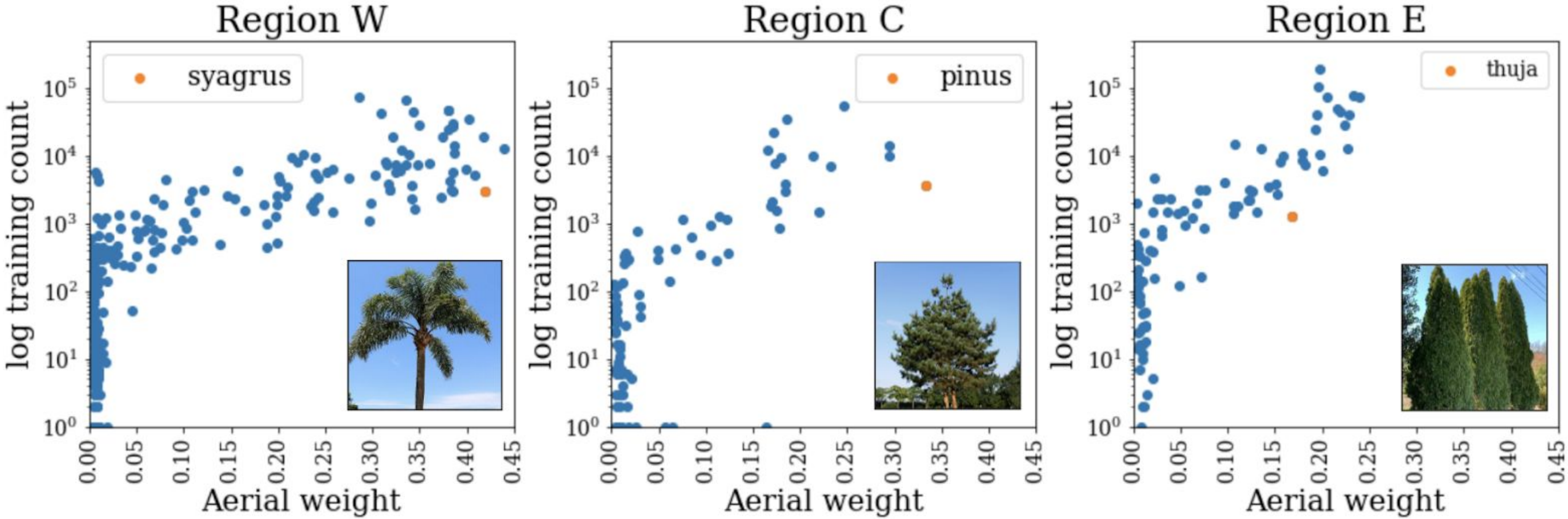


Models trained on the full dataset *often* outperform city-specific or region-specific models, *but not always*



Combining information across data modalities achieves best results

Train Set	Aerial	1 SL	3 SL	A+SL
Region W	20.63	41.53	45.12	**46.07**
Region C	18.8	44.77	46.91	**47.12**
Region E	17.54	43.25	45.13	**46.21**
Full	18.7	46.13	49.0	**49.23**
Full w/ Regional MoE				**49.96**

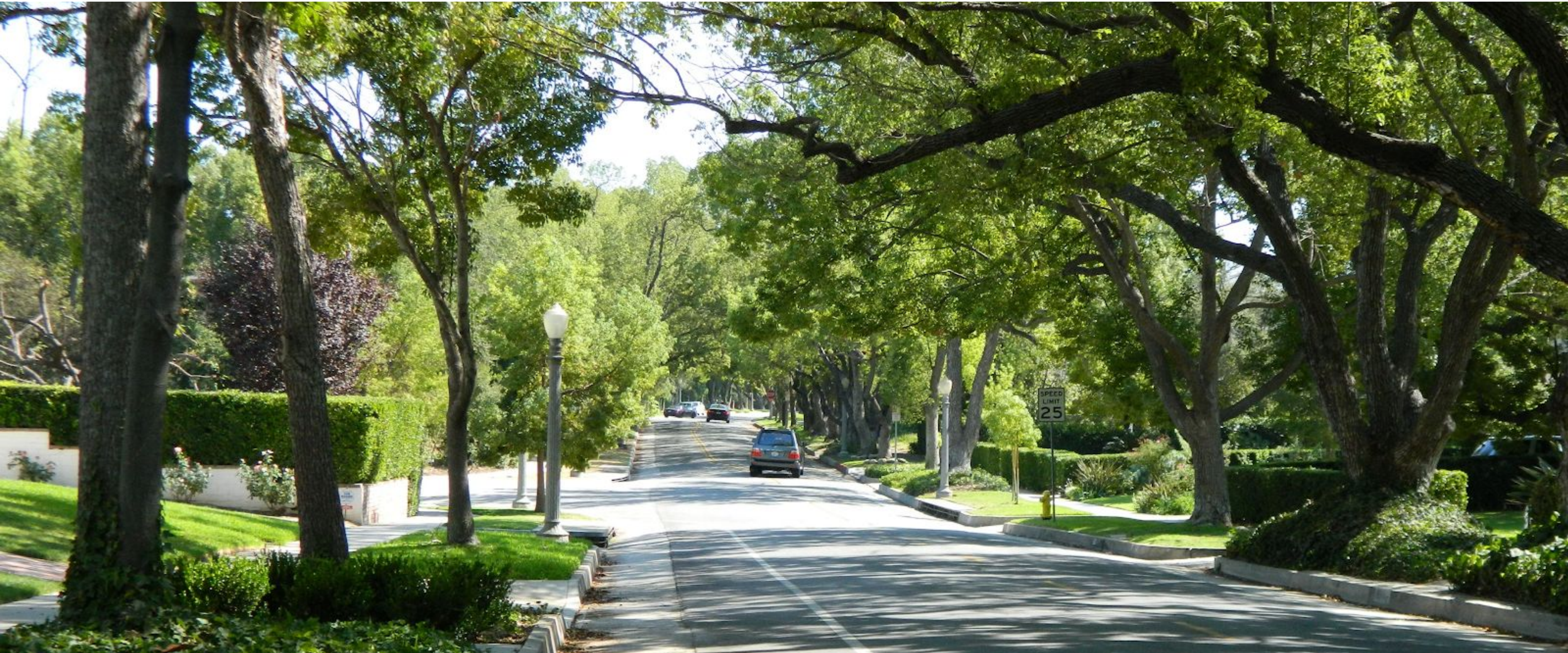


Dataset Release

https://google.github.io/auto-arborist/

Going beyond images-

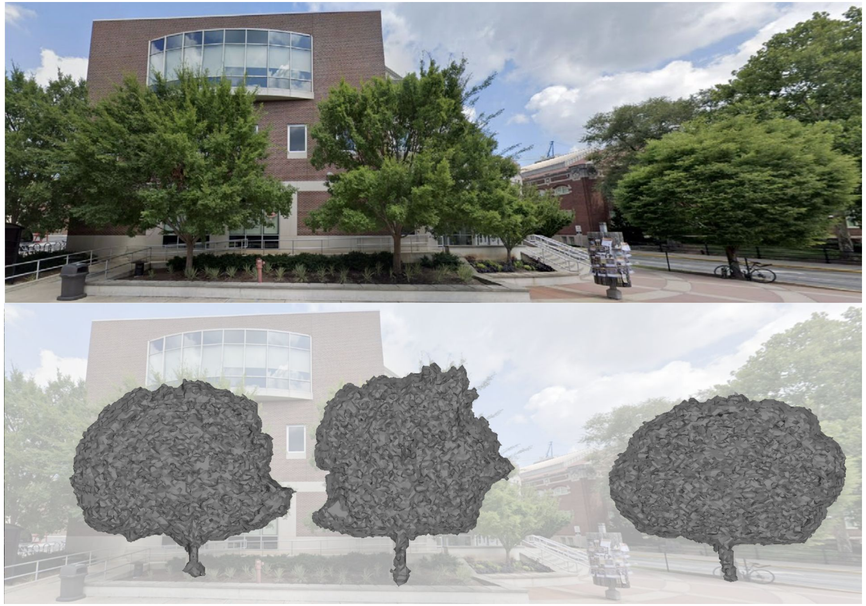
Understanding urban forests in 4D



Generate tree structure from images

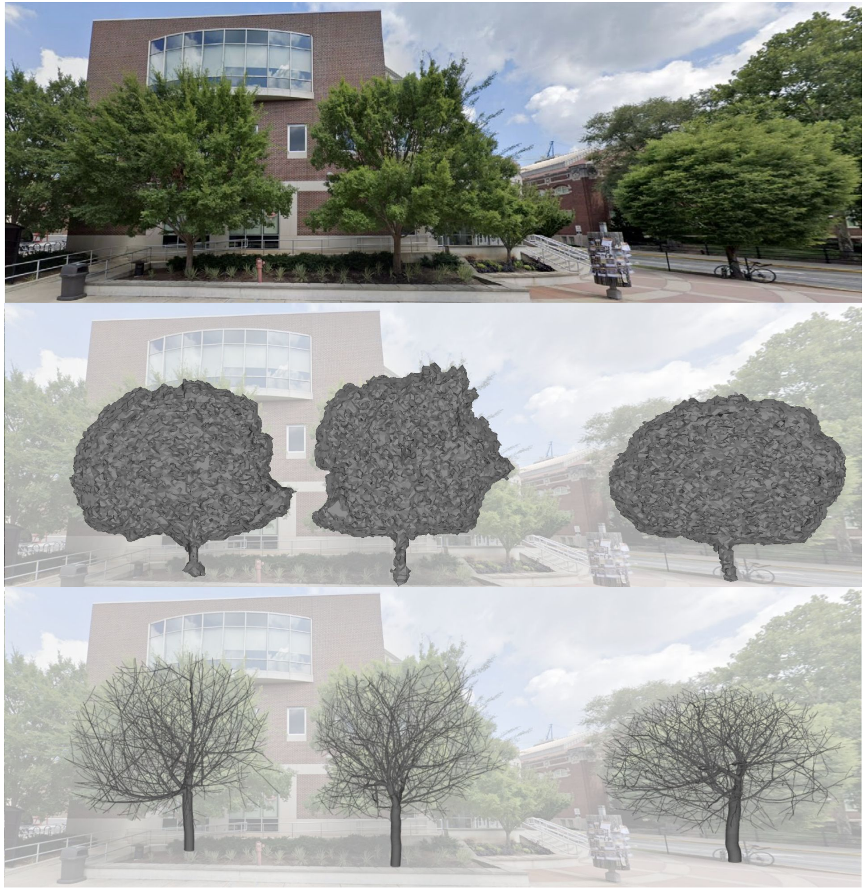
Work with researchers at Google and Purdue

Generate tree structure from images



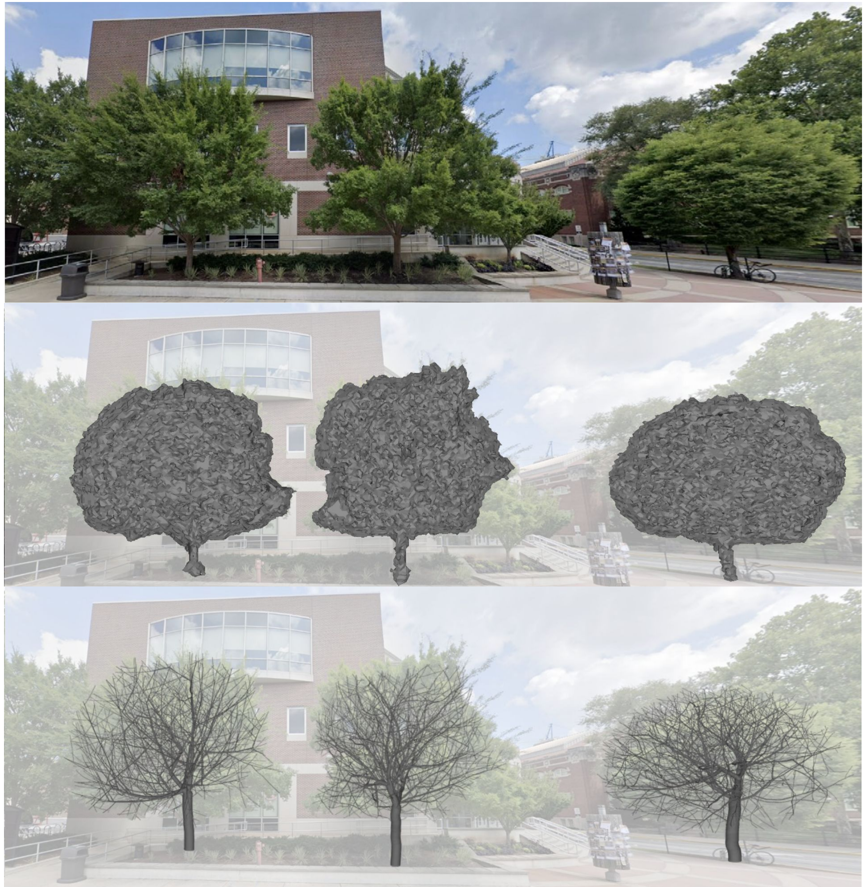
Work with researchers at Google and Purdue

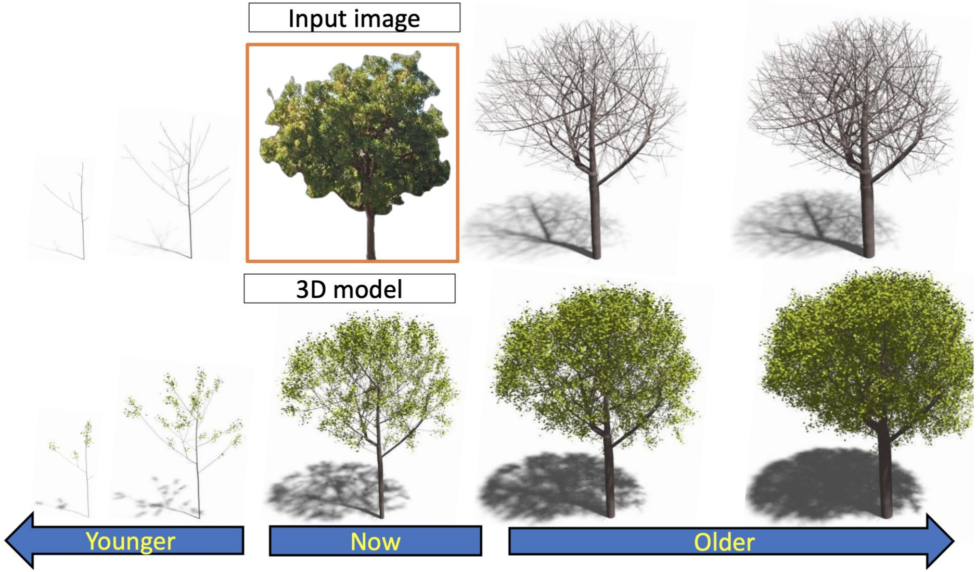
Generate tree structure from images



Work with researchers at Google and Purdue

Measure and predict urban forest change





Work with researchers at Google and Purdue

Open challenges in CV4Ecology

- Global and local distribution shift
- Long-tailed distributions
- Sparse, low-quality, biased data
- Interactive ecologist-AI systems
- Multimodal, multiview systems
- Detecting and categorizing change
- Limited Interdisciplinary capacity

Interested? Join our slack channel by emailing aiforconservation@gmail.com

Thanks!
Questions?