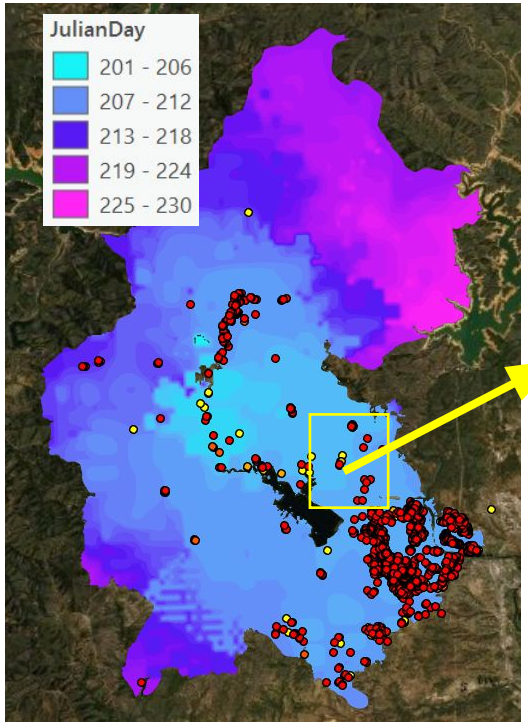
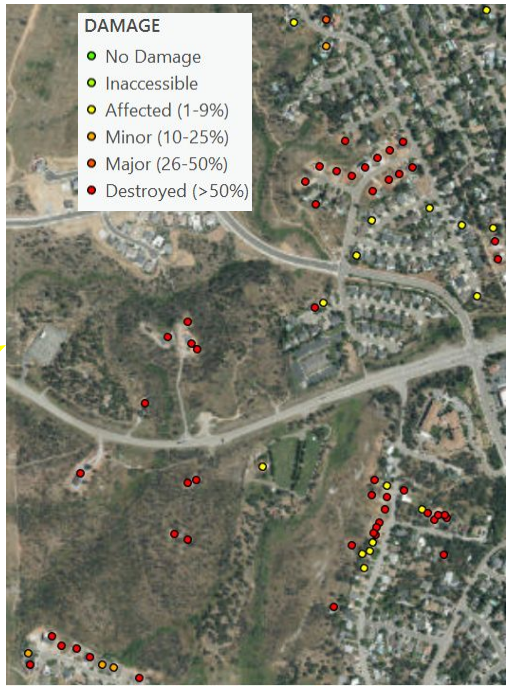


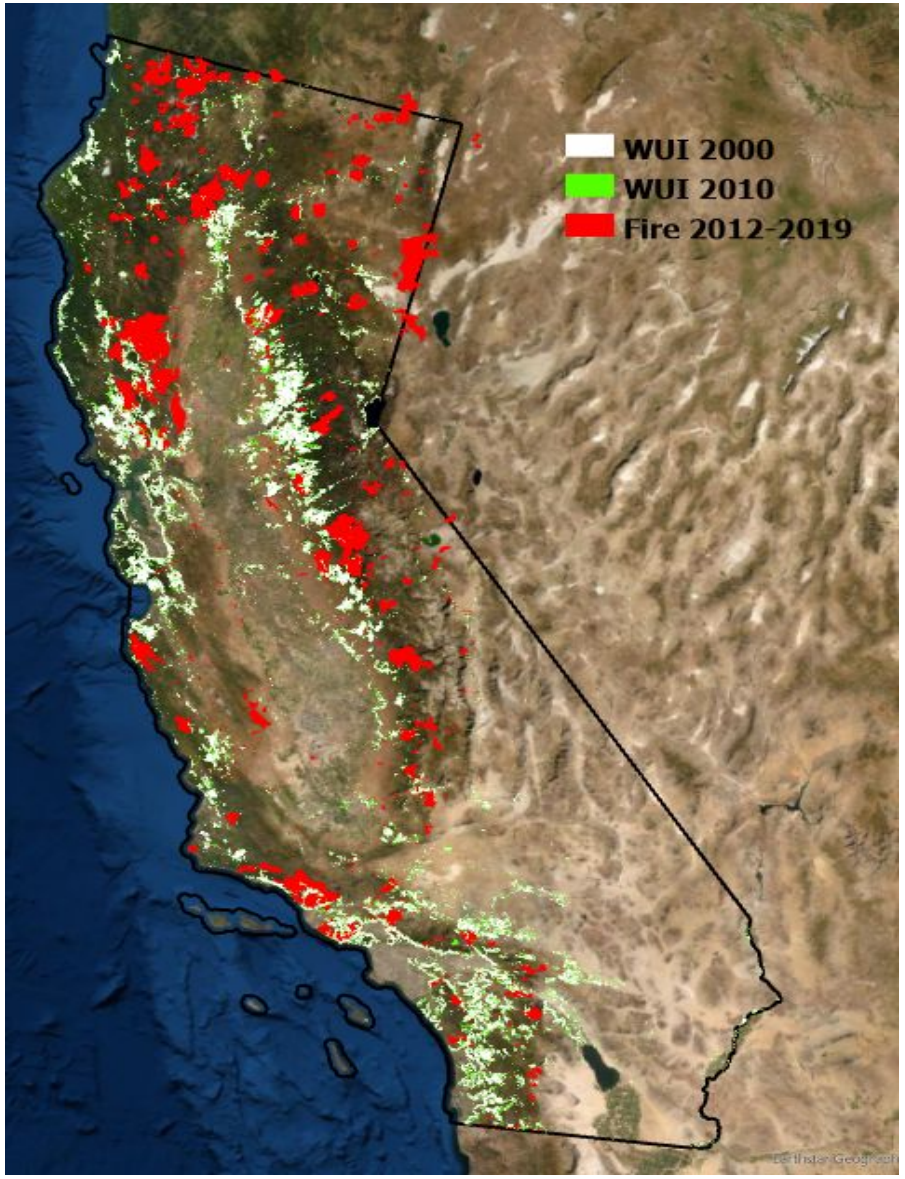


Multi-Source WUI Characterization Enhanced with Machine Learning: Dynamics and Hazard Assessment

Yufang Jin, Dan Dixon, and Yuhan Huang
University of California, Davis

Yong Jae Lee & Yuheng Li
University of Wisconsin - Madison

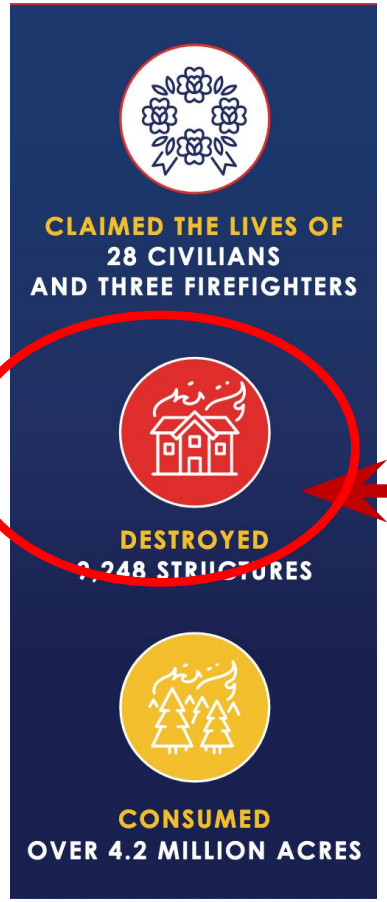
Increasing community vulnerability to wildfires at WUI

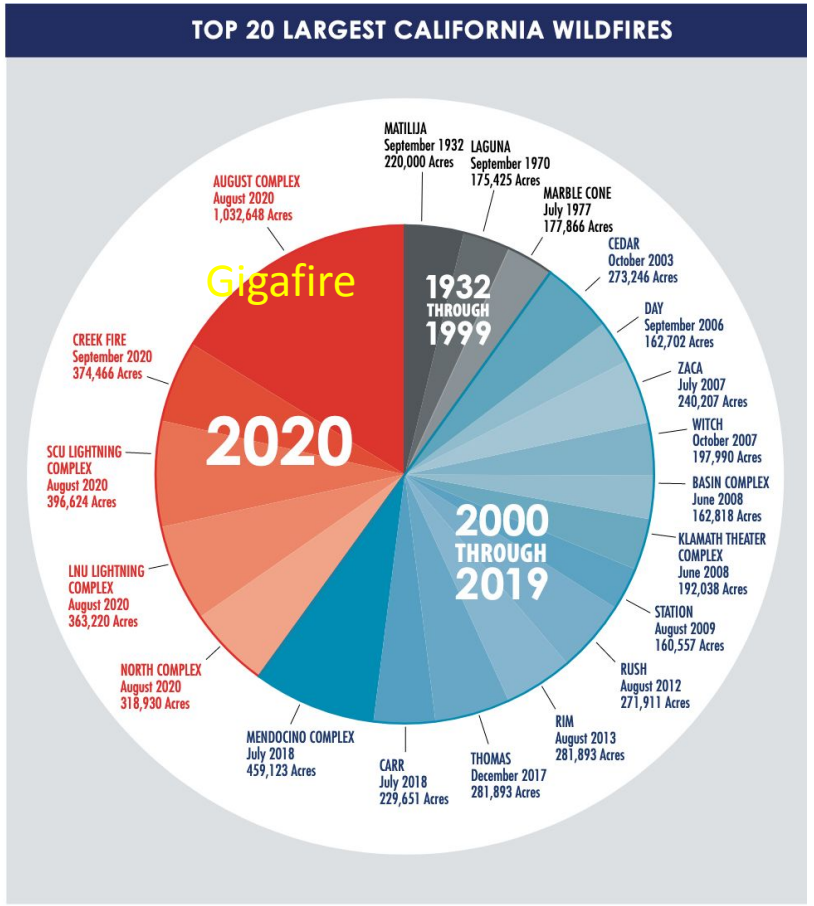


Increasing wildfires in California (**17** after 2000**, 5** largest in 2020)

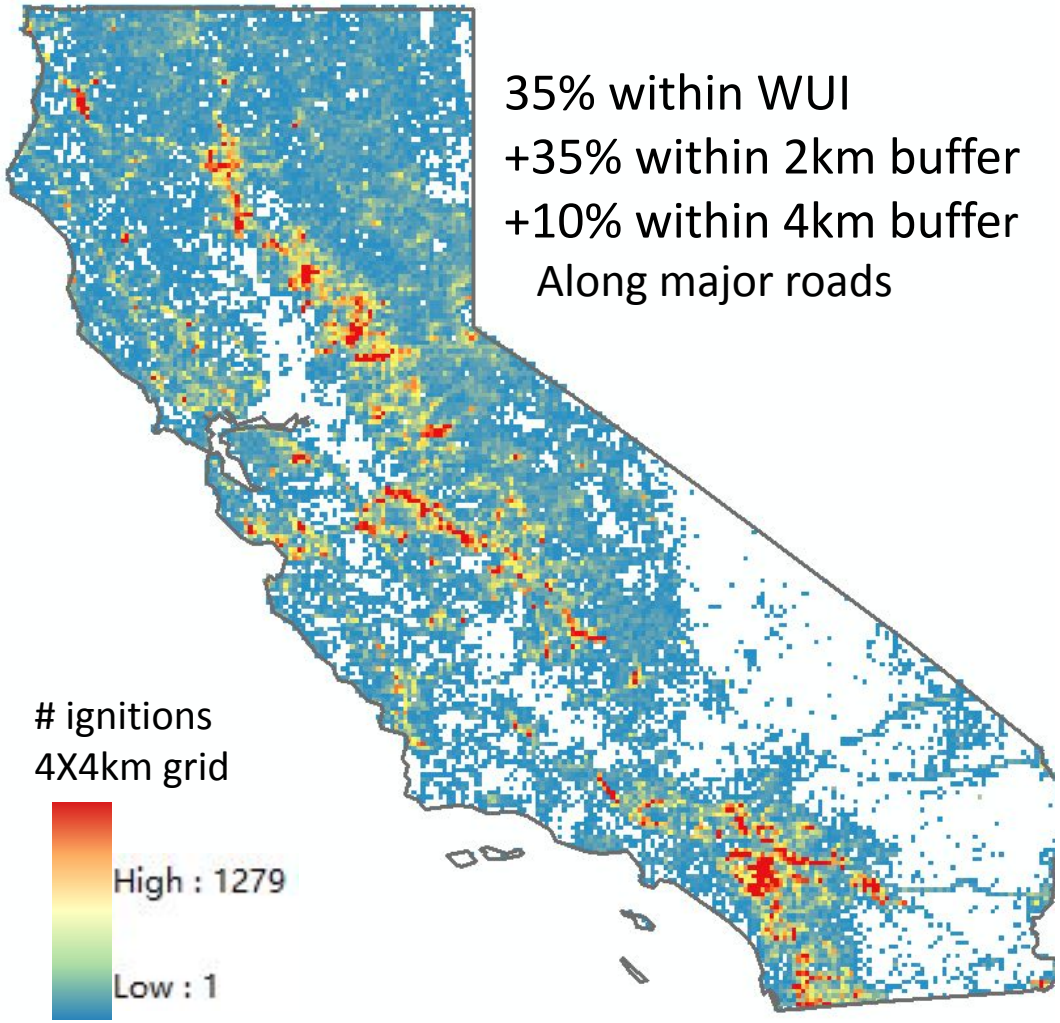
Expansion of housing development into the wilderness

- Creating larger WUI areas
- More than 20 million properties susceptible to wildfires



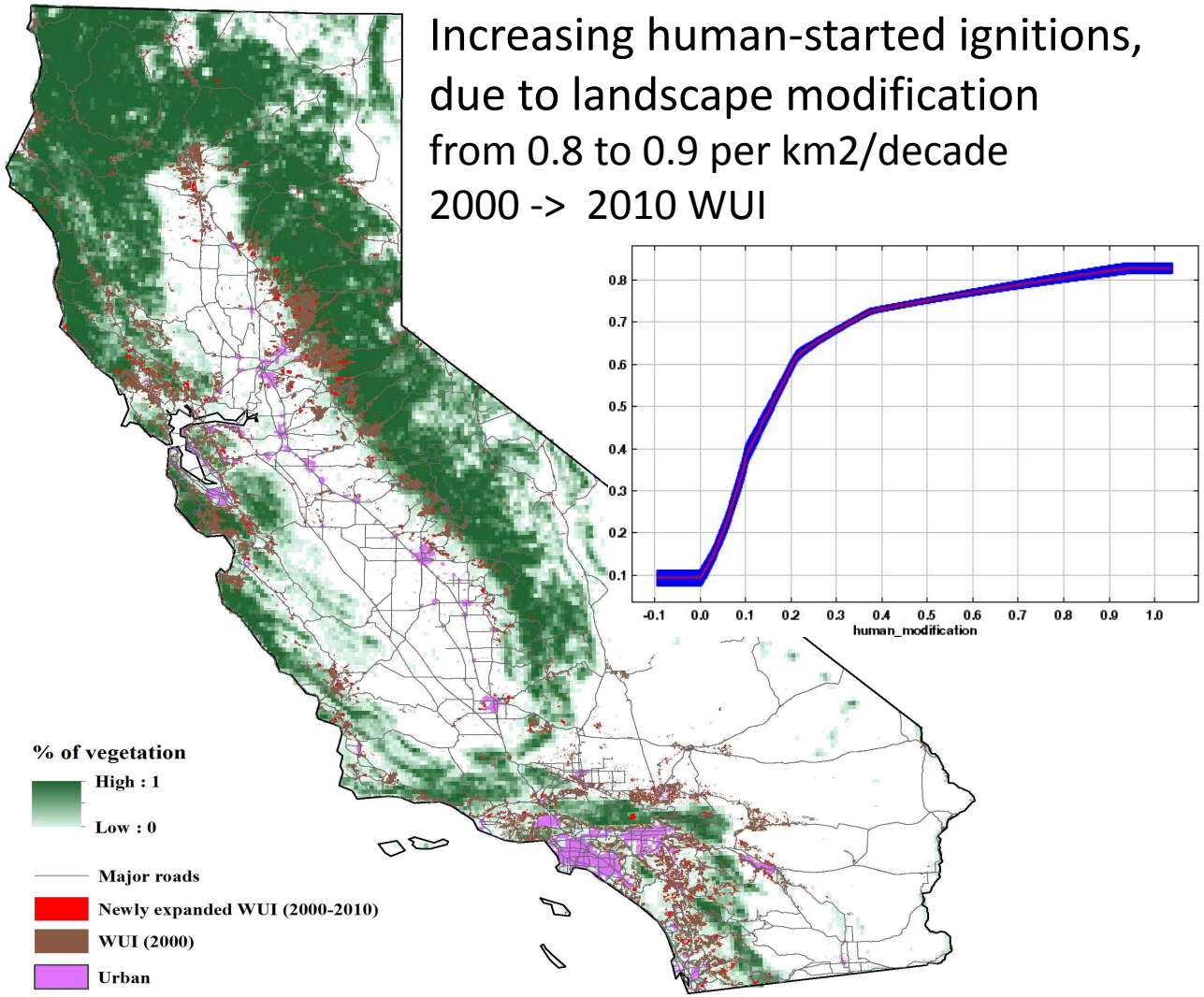


Majority of wildfire ignition started in/around WUI



35% within WUI
+35% within 2km buffer
+10% within 4km buffer
Along major roads

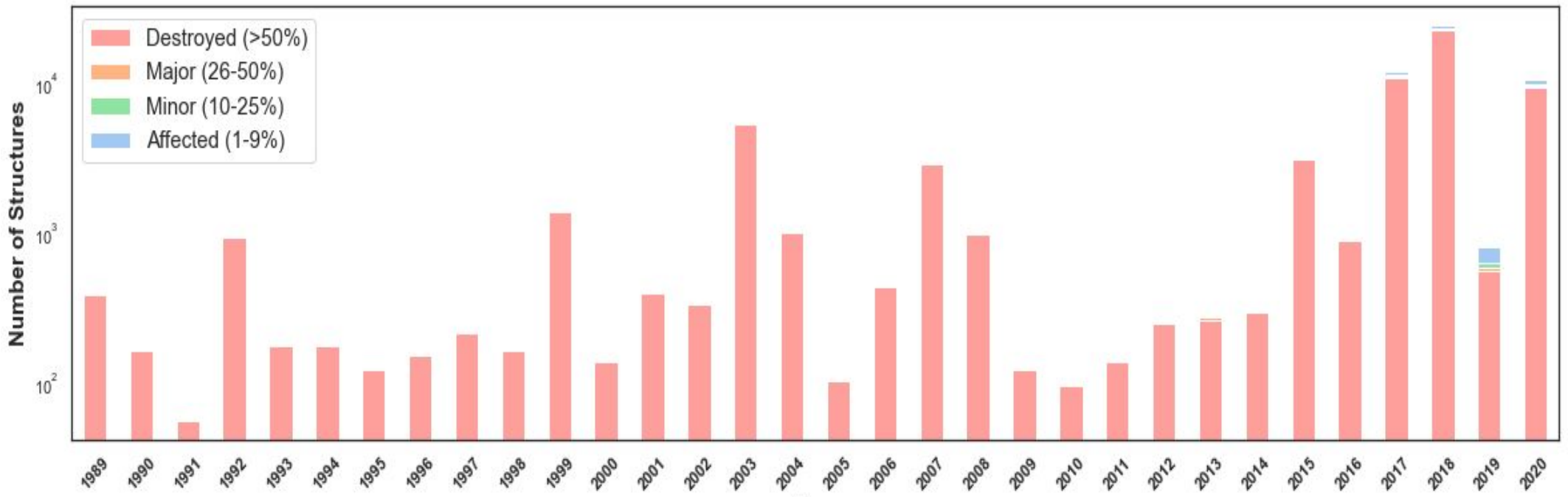
1992-2015



Increasing human-started ignitions,
due to landscape modification
from 0.8 to 0.9 per km2/decade
2000 -> 2010 WUI

Chen and Jin, 2022

Increasing structure damages by WUI wildfires in California

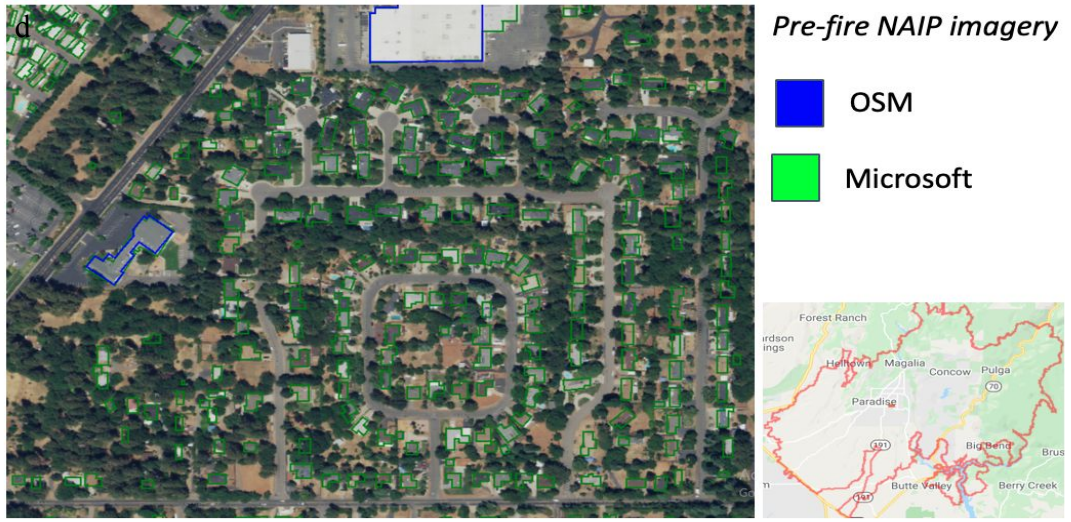


15 out of 20 most destructive fires occurred since 2015

More than half in the past 5 years
(2021 Dixie fire >1300;
2020 North Complex > 2000;
2018 Camp fire >18,000)

Challenging for fire risk assessment in WUI

- Heterogeneous, dynamic landscapes with human modification
- Challenging for fire behavior modeling and risk assessment



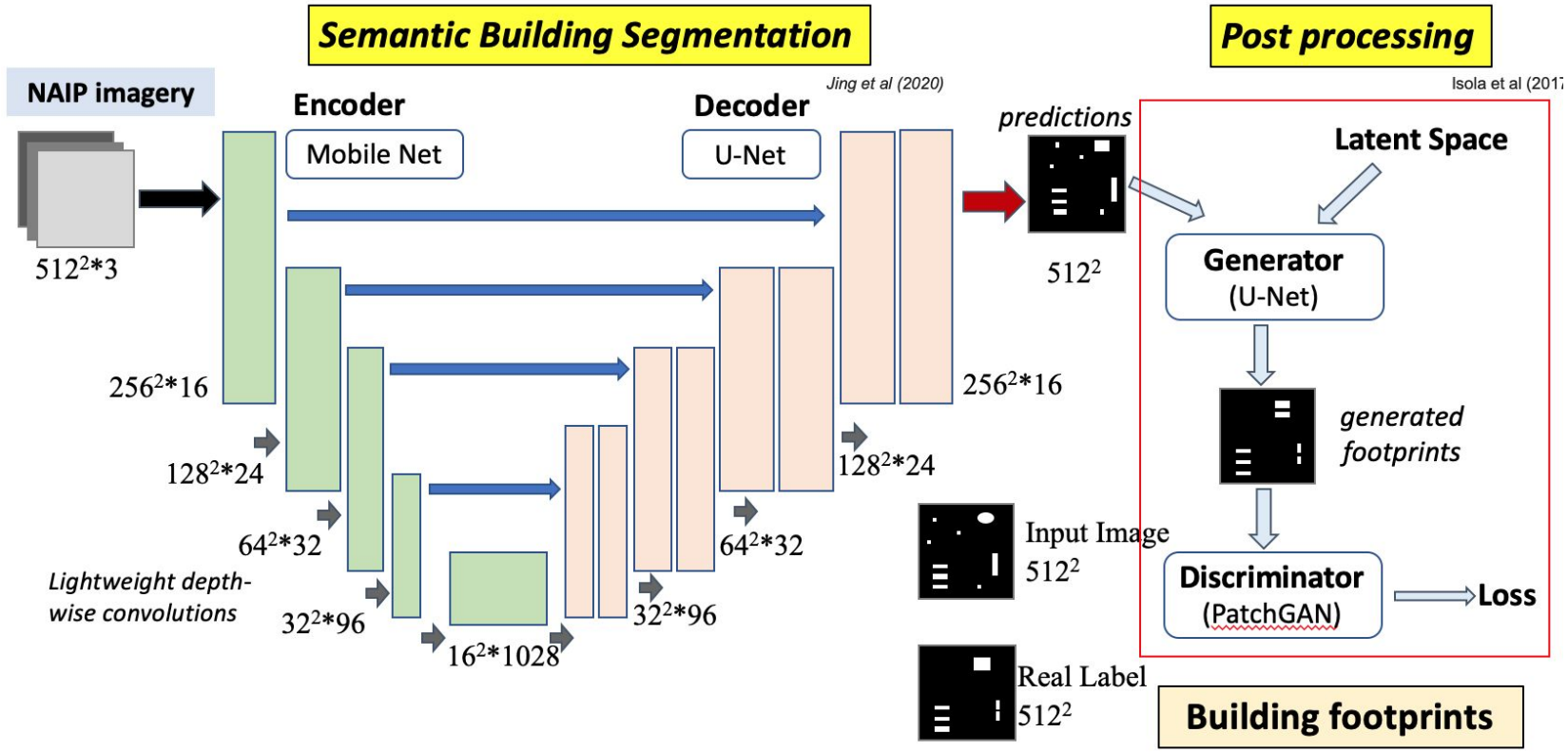
- Goal: Multi-sensor monitoring and community fire risk assessment

  (1) fine grained annual WUI characterization (human settlements and vegetation)

  (2) improved understanding of WUI fire behavior and building damage

Mapping building footprints from VHR imagery via Deep Learning

- NAIP VHR imagery at 0.6m to 1m every two years since 2009
- integrated Mobile-UNet and generative adversarial network (GAN)

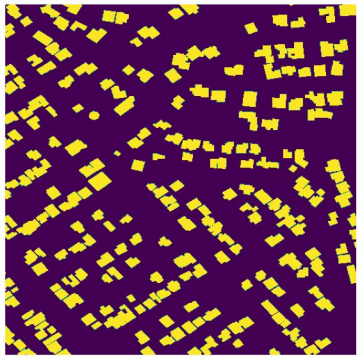
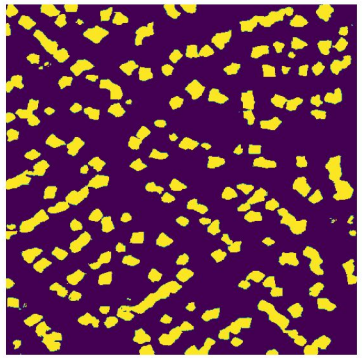


Building footprints identified from NAIP aerial imagery

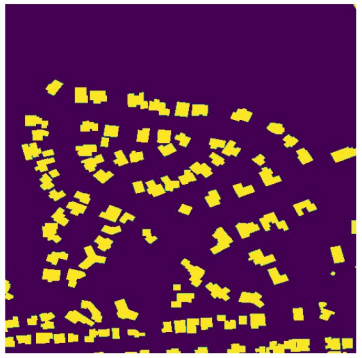
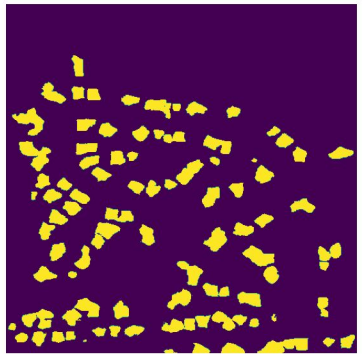
Input Image | Ground Truth | Predicted Image



Input Image | Ground Truth | Predicted Image

Input Image | Ground Truth | Predicted Image

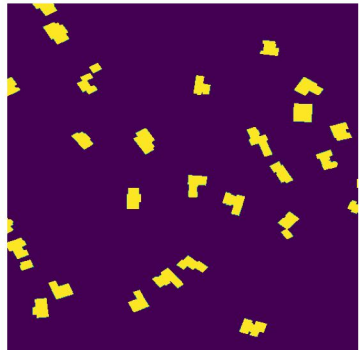
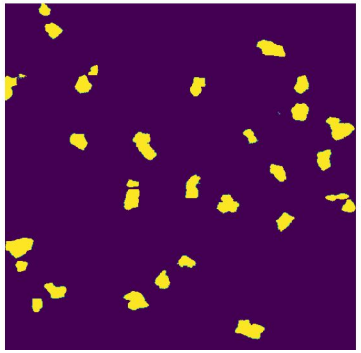




Urban and Interface WUI

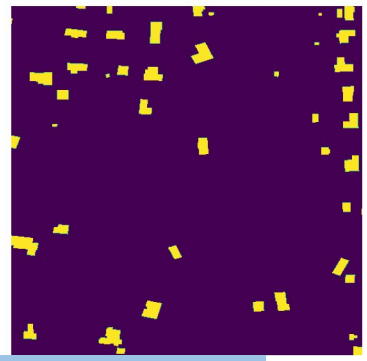
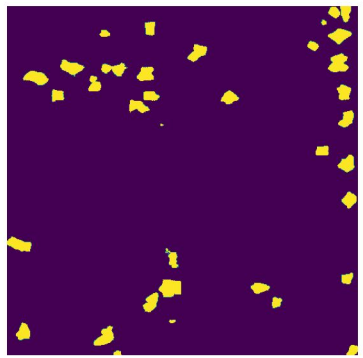
Input Image | Ground Truth | Predicted Image



Input Image | Ground Truth | Predicted Image

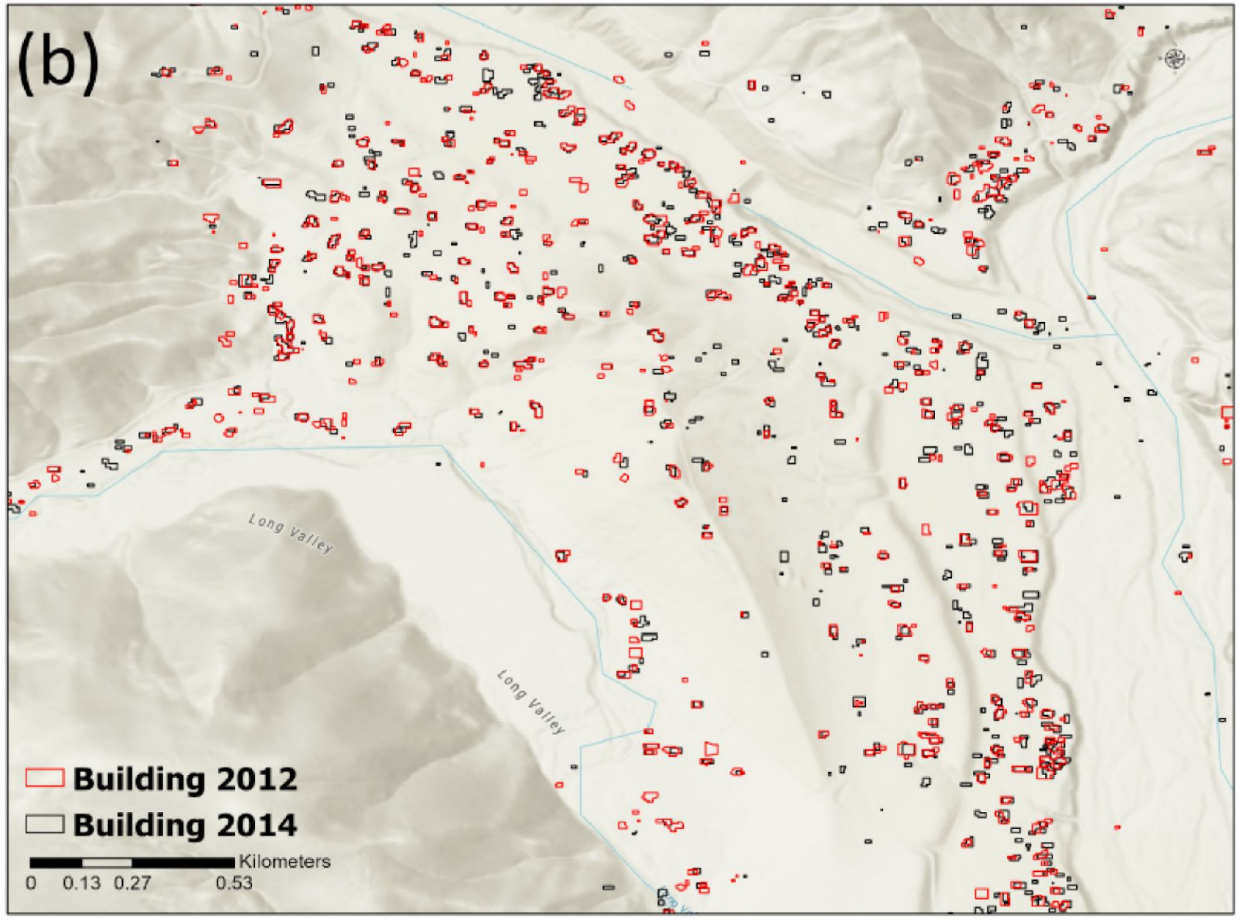




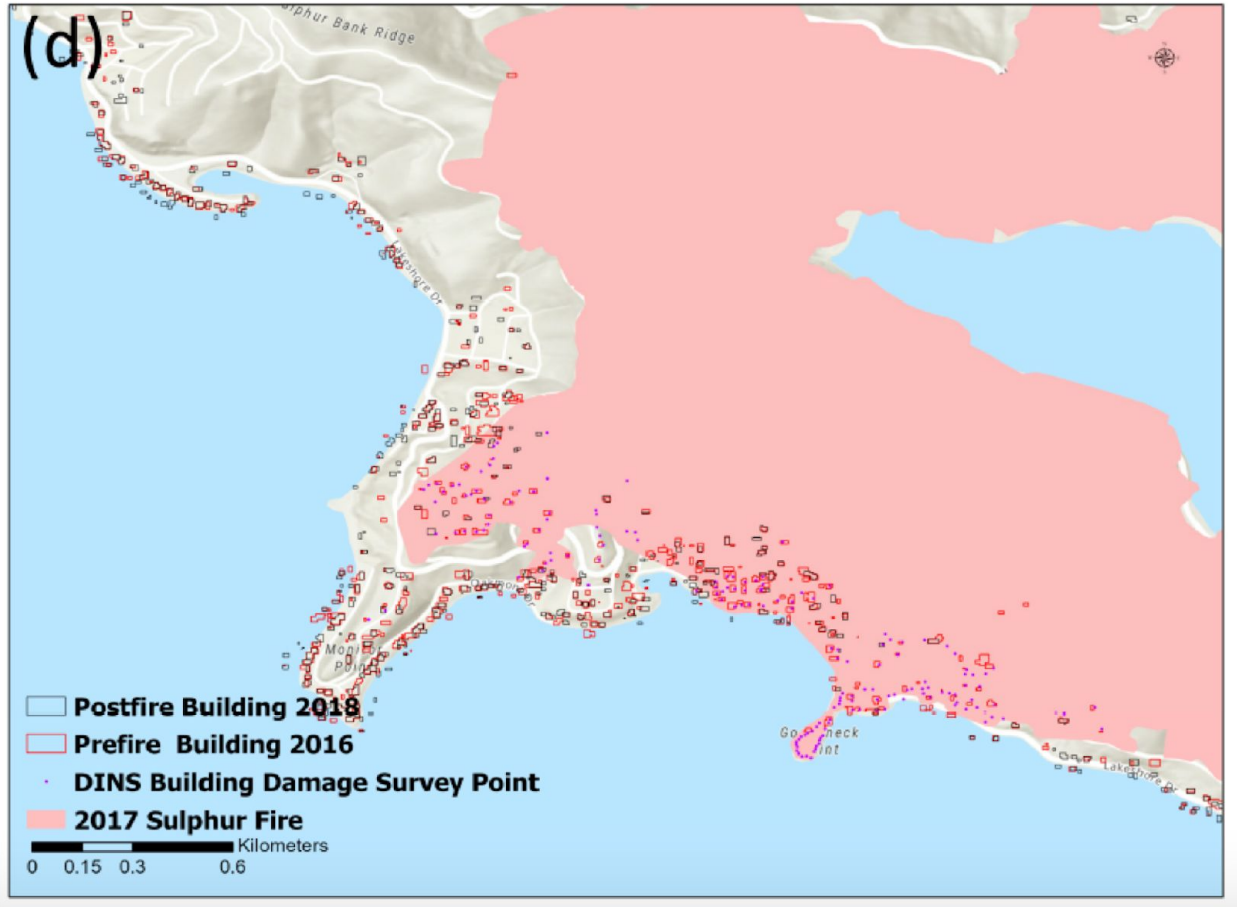
Input Image | Ground Truth | Predicted Image

Rural and Intermix WUI

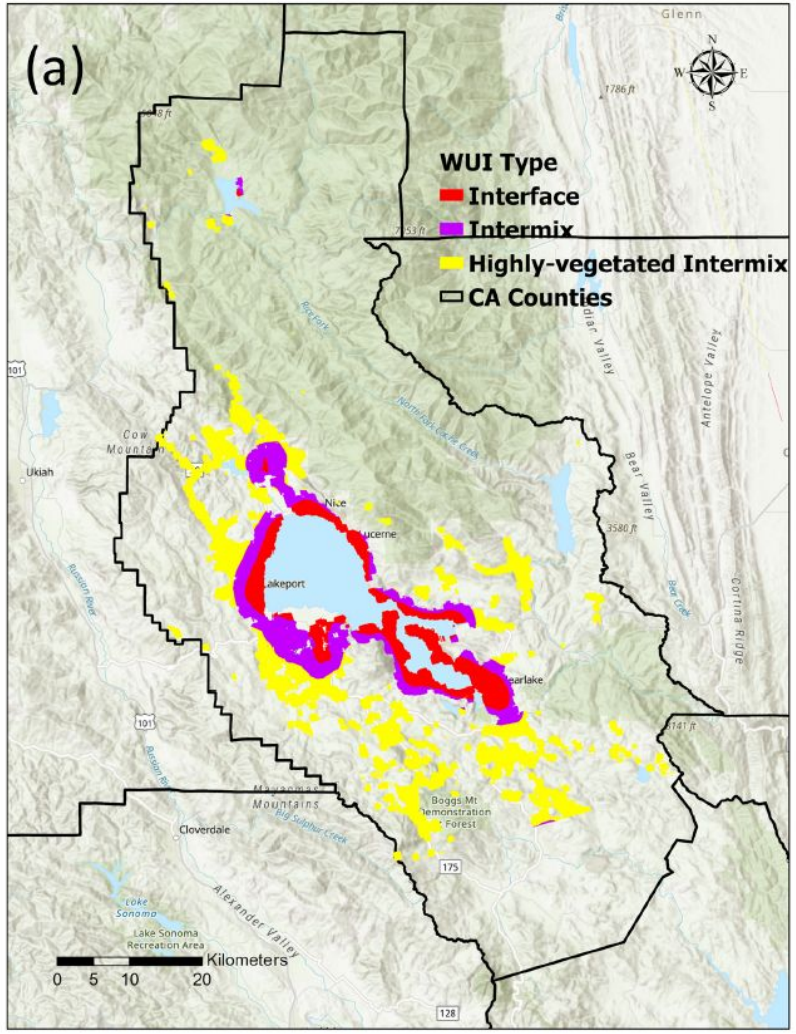
Tracking new housing development and structure damage every two years



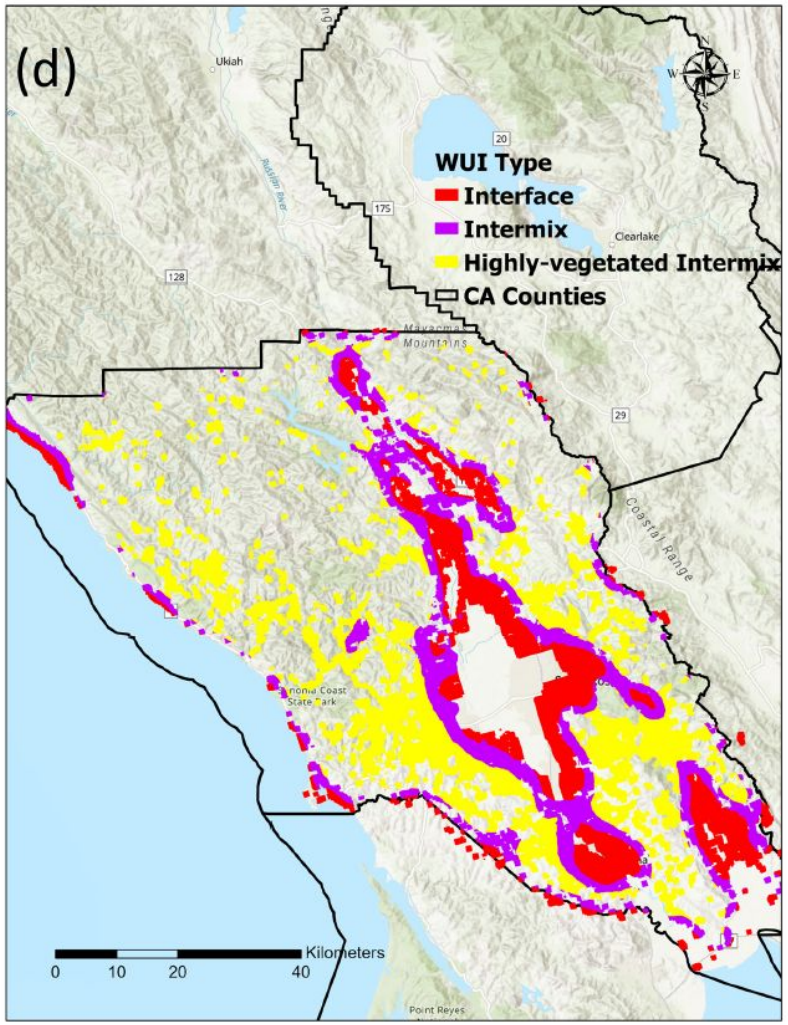


Huang et al., 2022

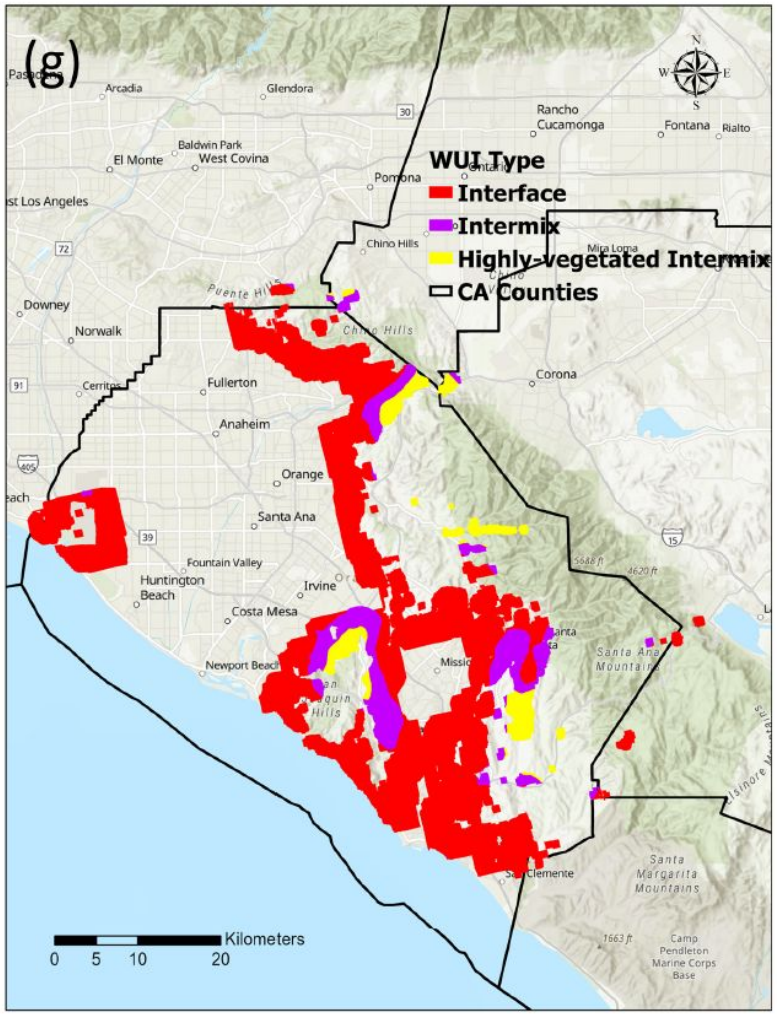
Improved mapping of WUI patterns



Lake County

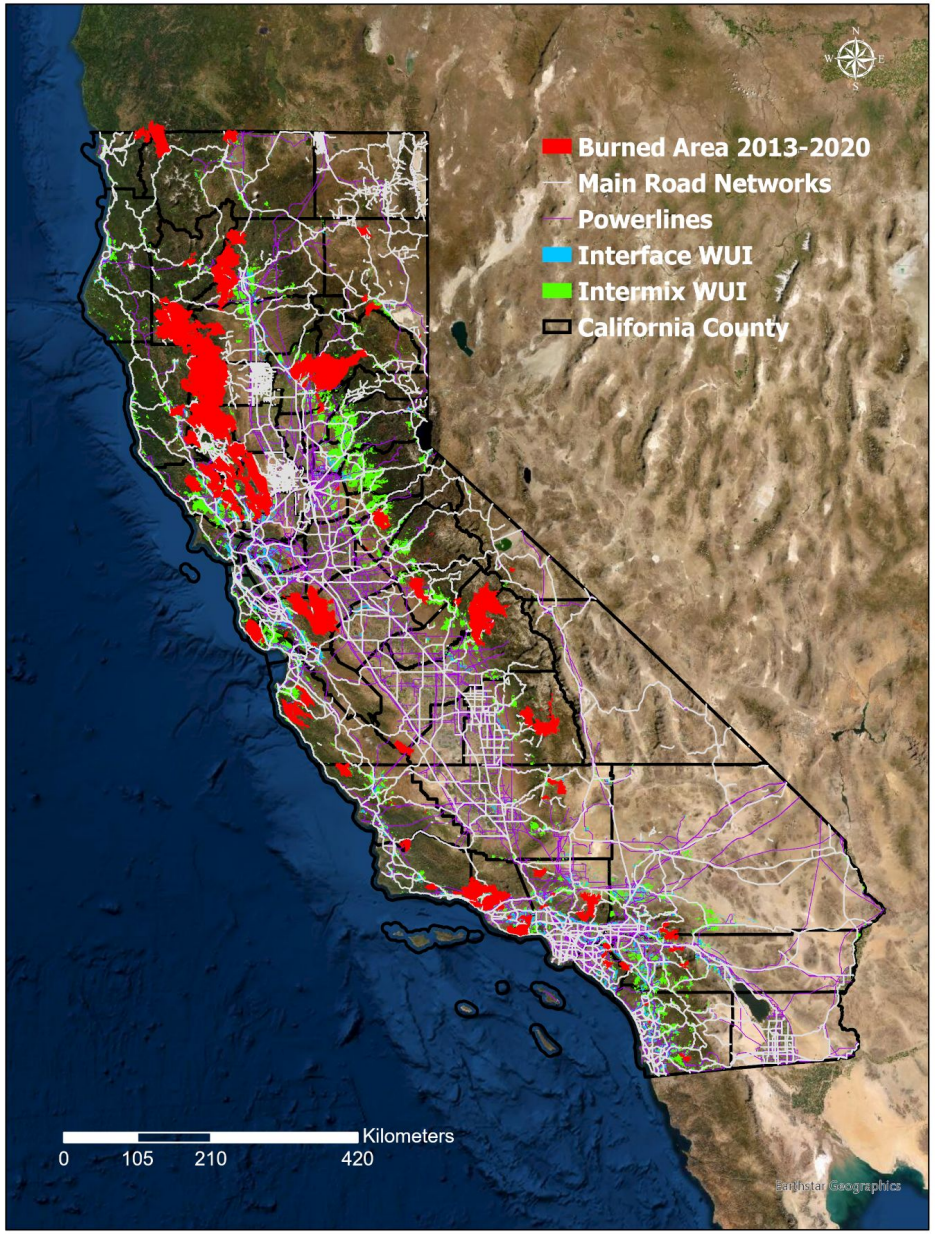


Sonoma County



Orange County

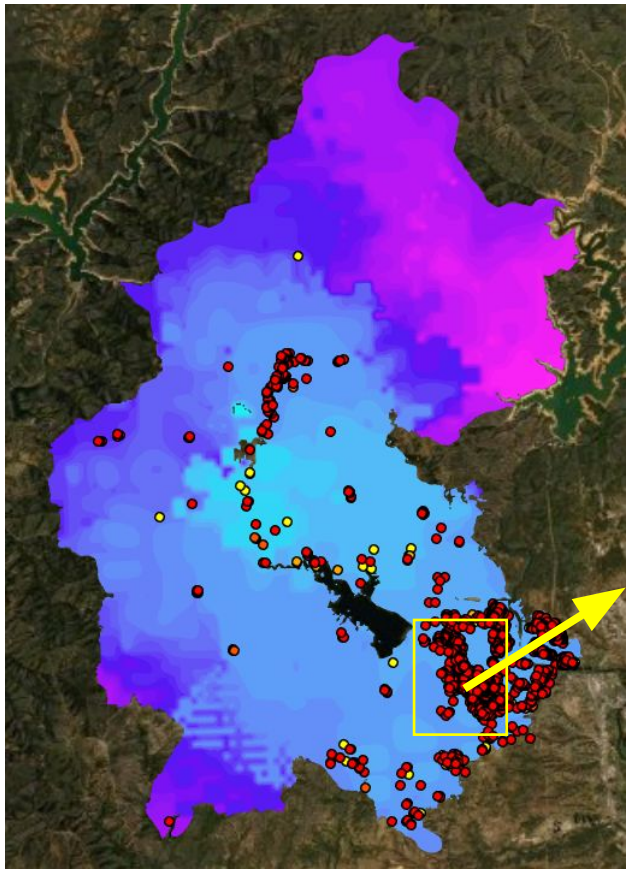
Huang et al., 2022



VUI fire risk and structural damage

All WUI fire days from 2003 – 2020

Machine learning: modeling probability of building damage



Modeling risk of structure damage by wildfires

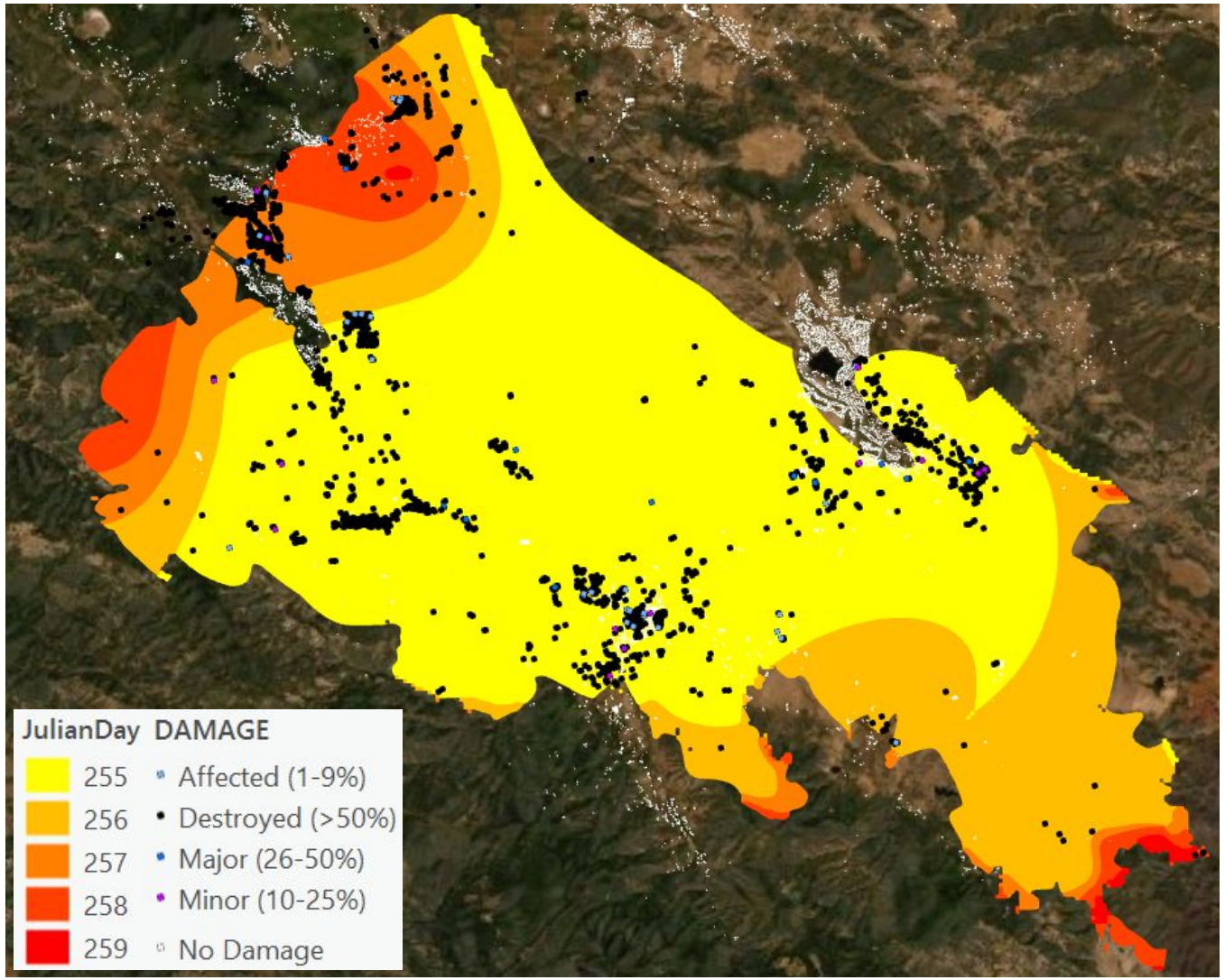
Daily fire perimeters

Pre-fire
Building footprints

Post-fire
Damage Survey

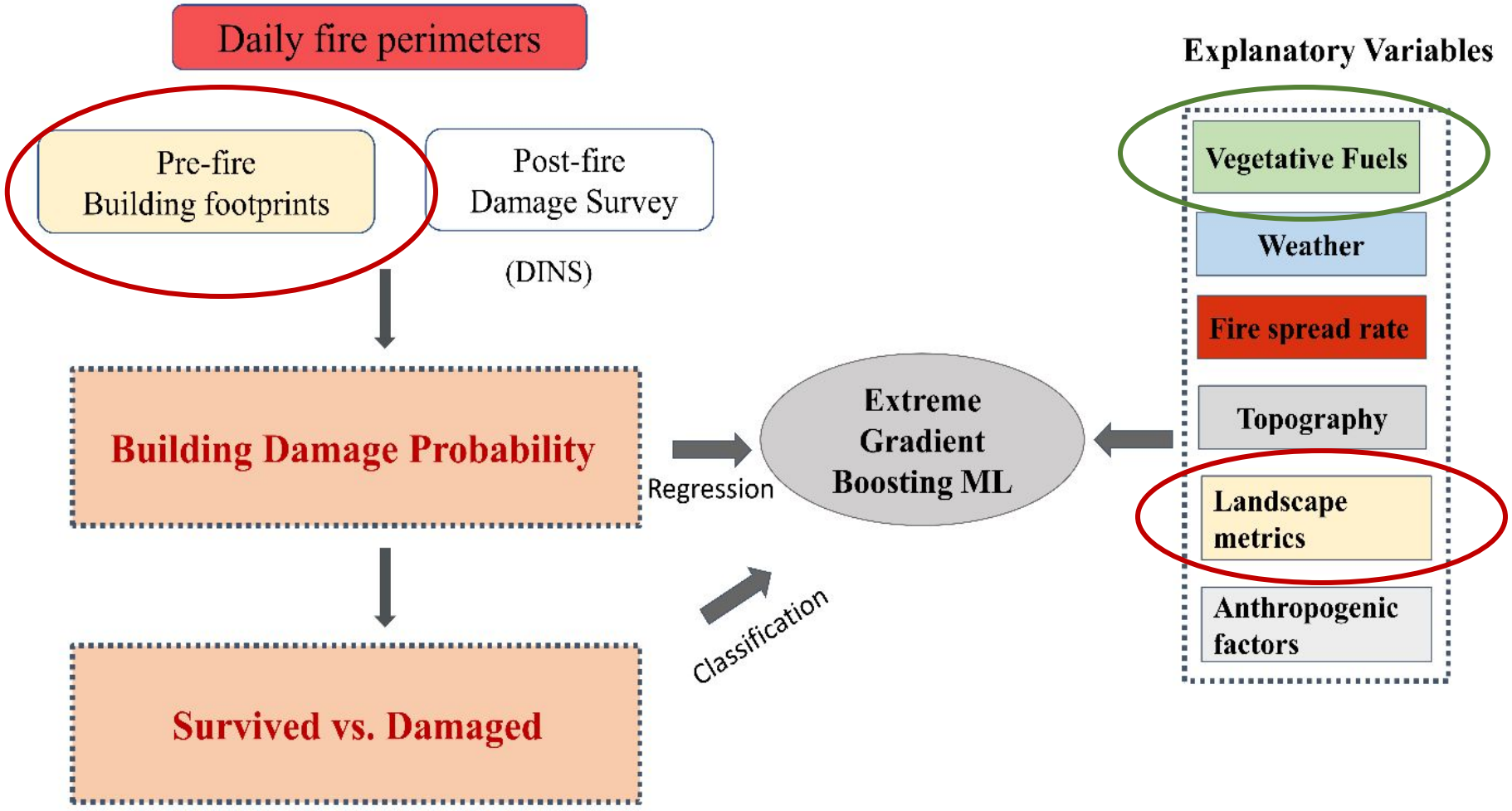
(DINS)

Building damage probability
(% = # damaged / # buildings)



* **Intermediate scale**: within daily fire perimeter

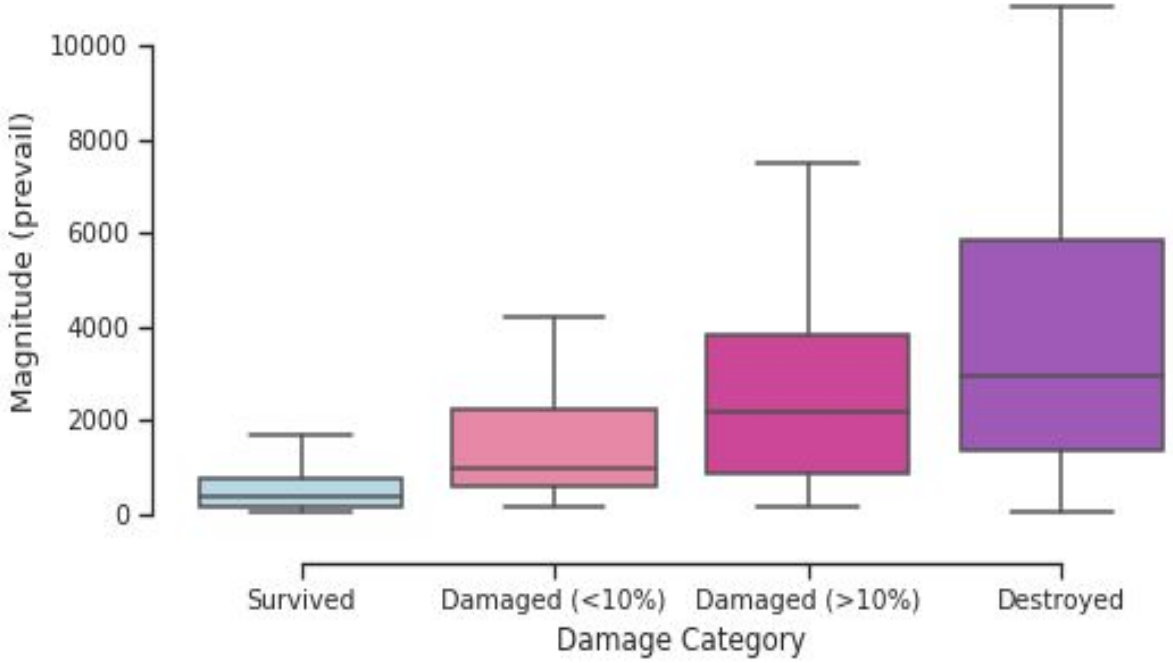
Wildfire-caused building damage risk evaluation

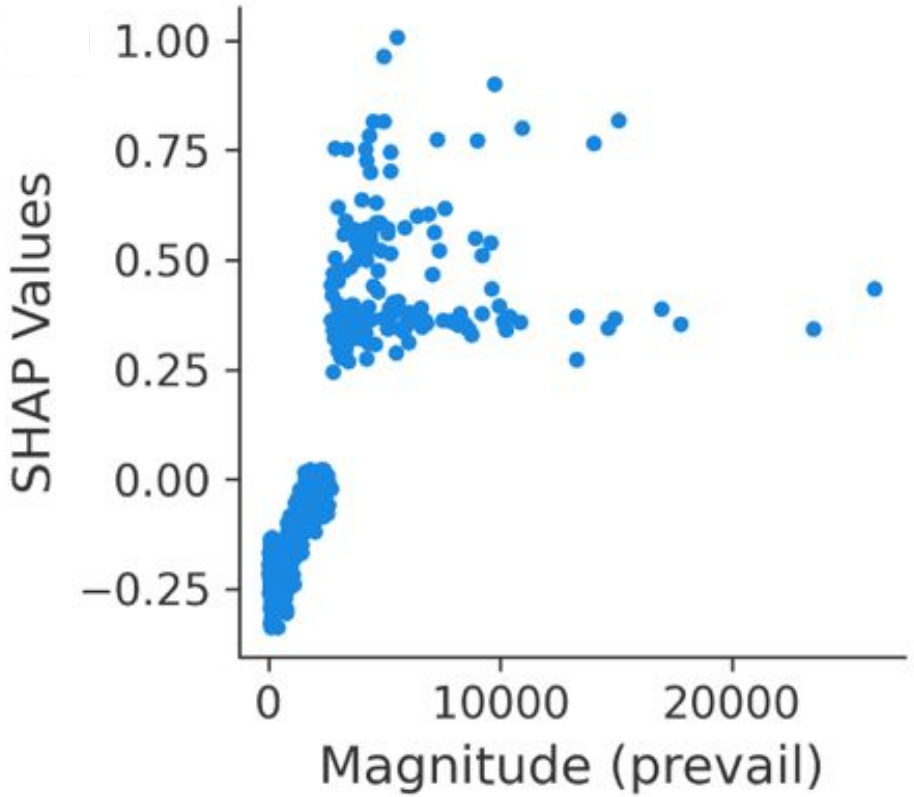


All WUI fire days from 2003 – 2020

Machine learning: modeling probability of building damage

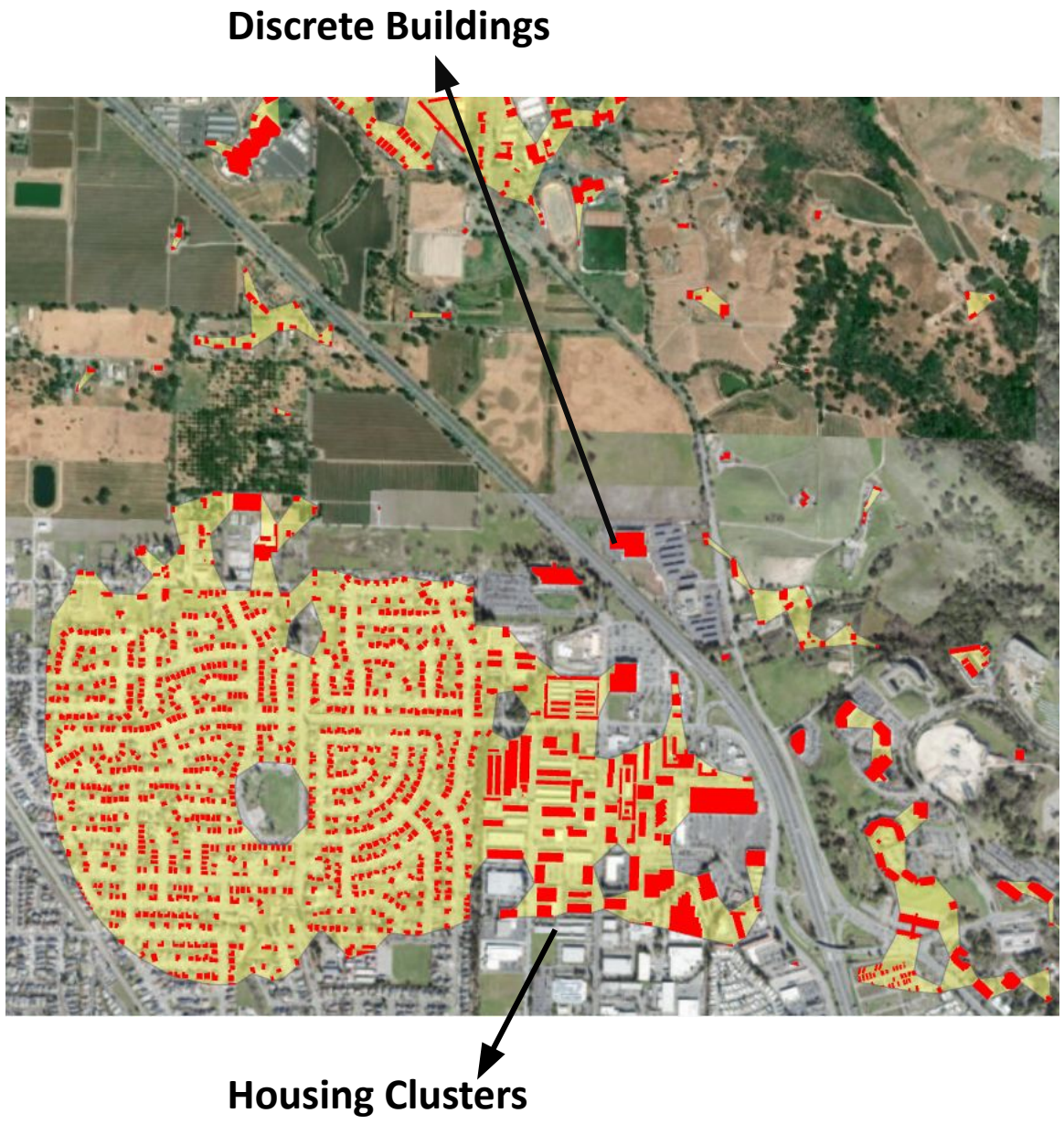
Fast moving fires caused higher building damage probability

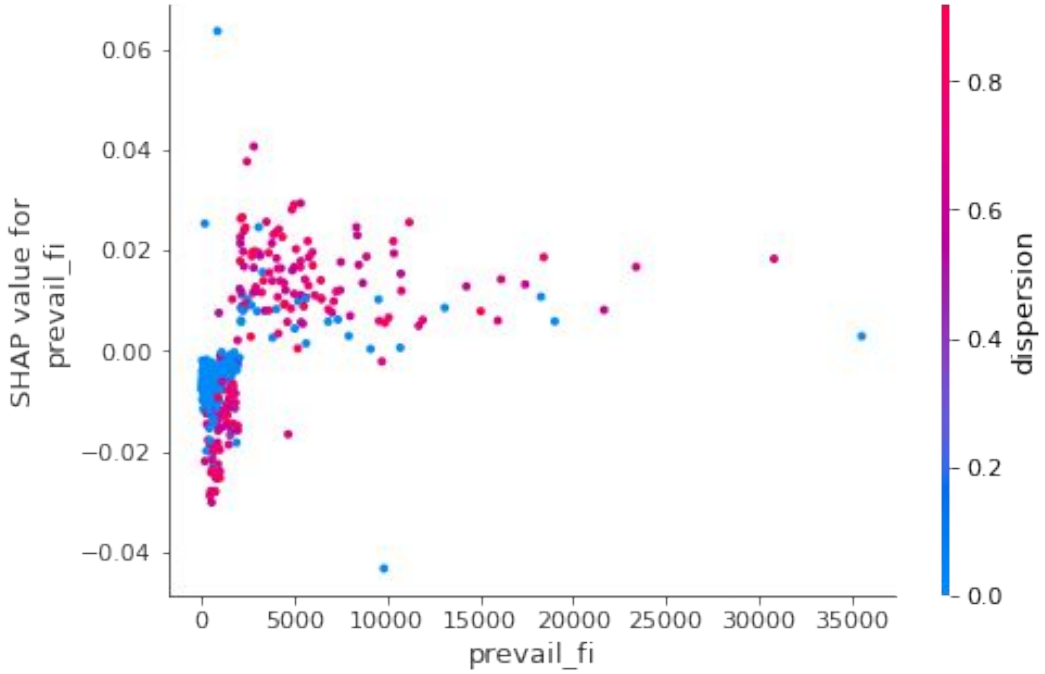




Huang et al., in prep

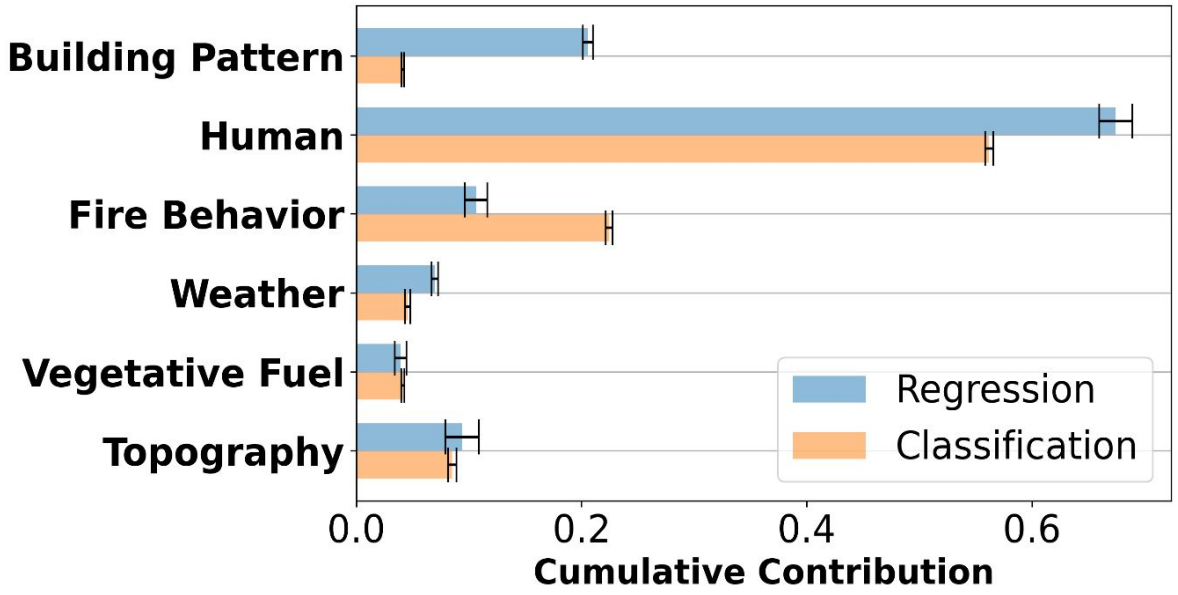
Impacts of building patterns on Structural Damage

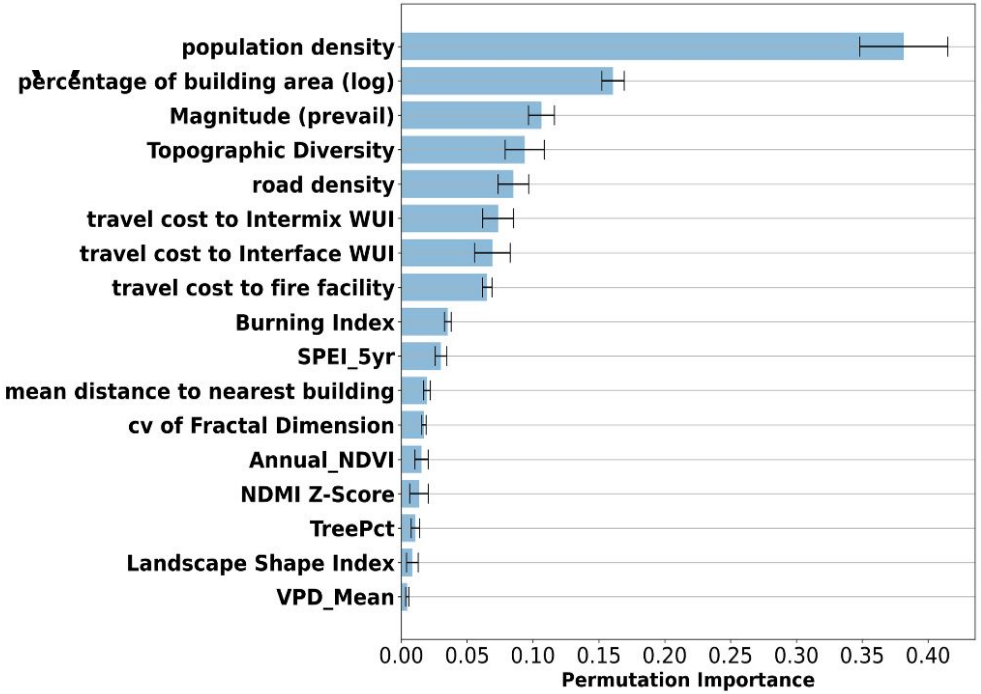




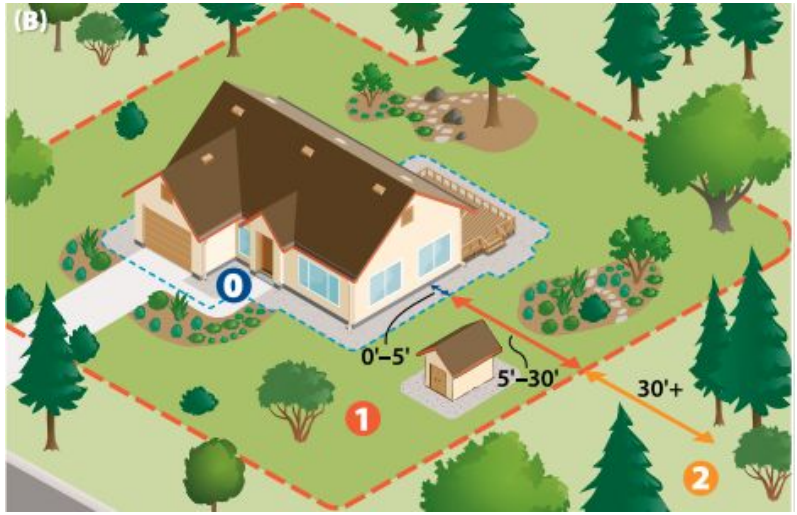
Higher risk for clustered buildings than dispersed community, especially when fire spreads relatively slowly.

Variable importance for building damage risk





fuels



Multi-sensor fine scale WUI fuel mapping

- Woody canopy fuels (shrub/tree crowns)

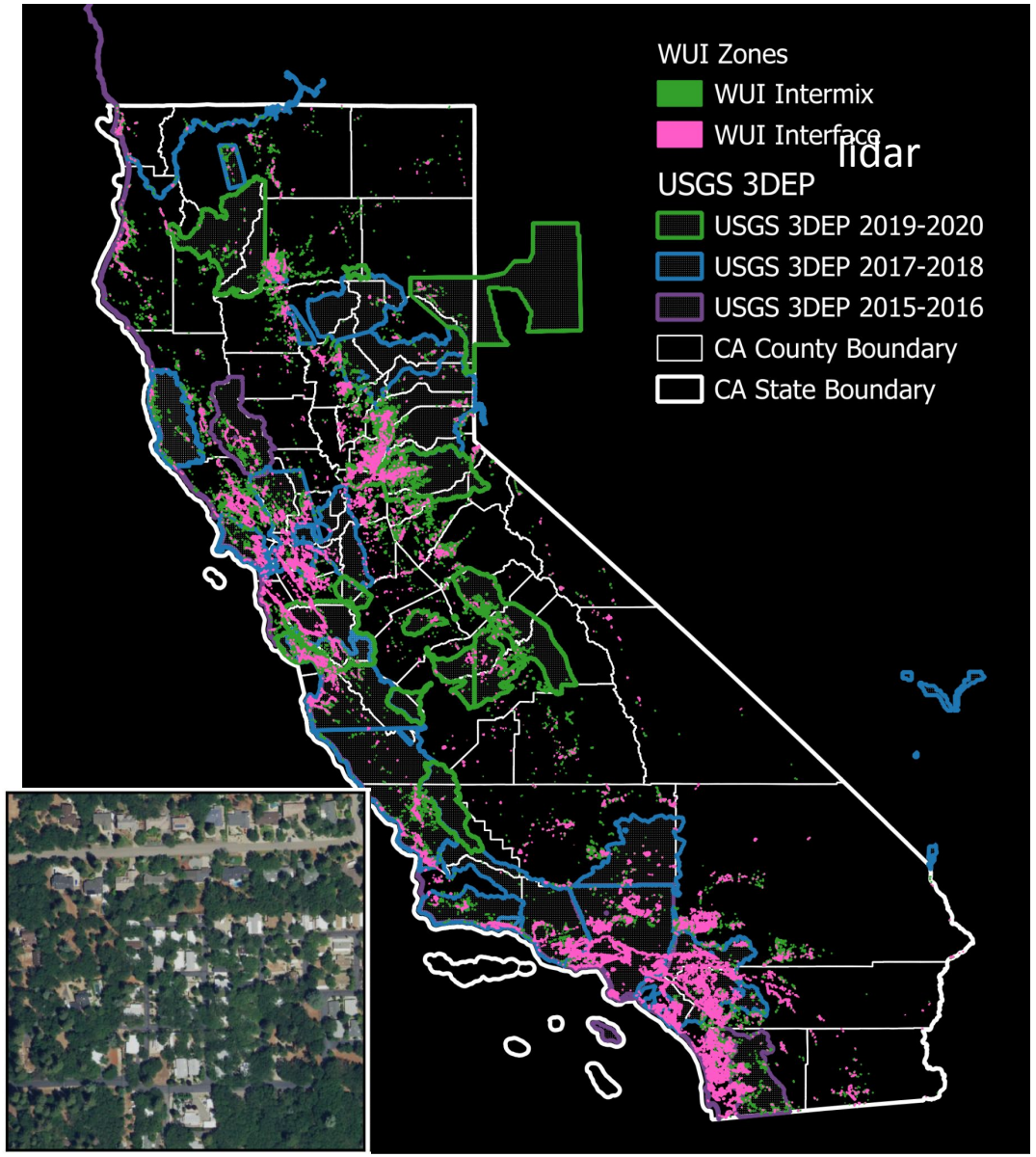
  NAIP imagery at 0.6-1m since 2009
  PlanetScope at 3m since 2017
  NAIP + PlanetScope

- Fuel structure

  Aerial lidar – Radar + GEDI

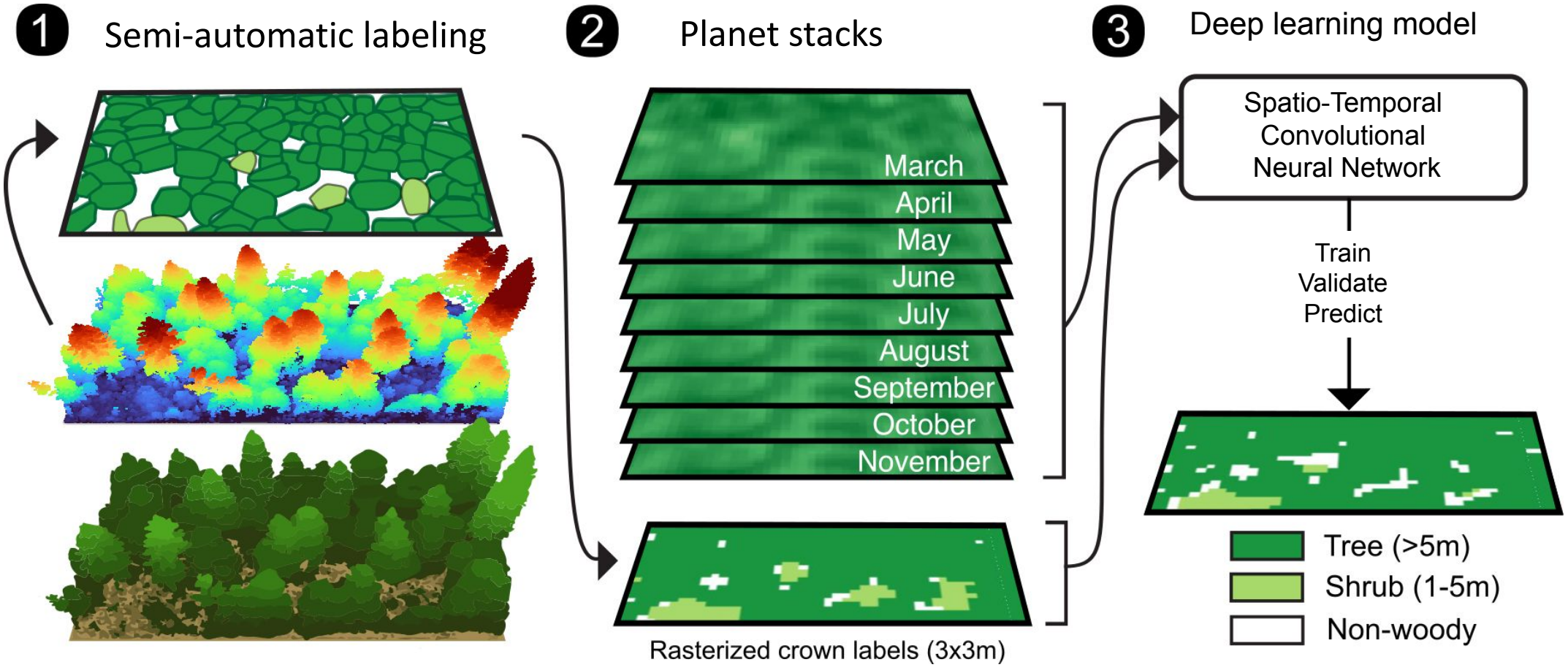
-> Quantify fuel characteristics

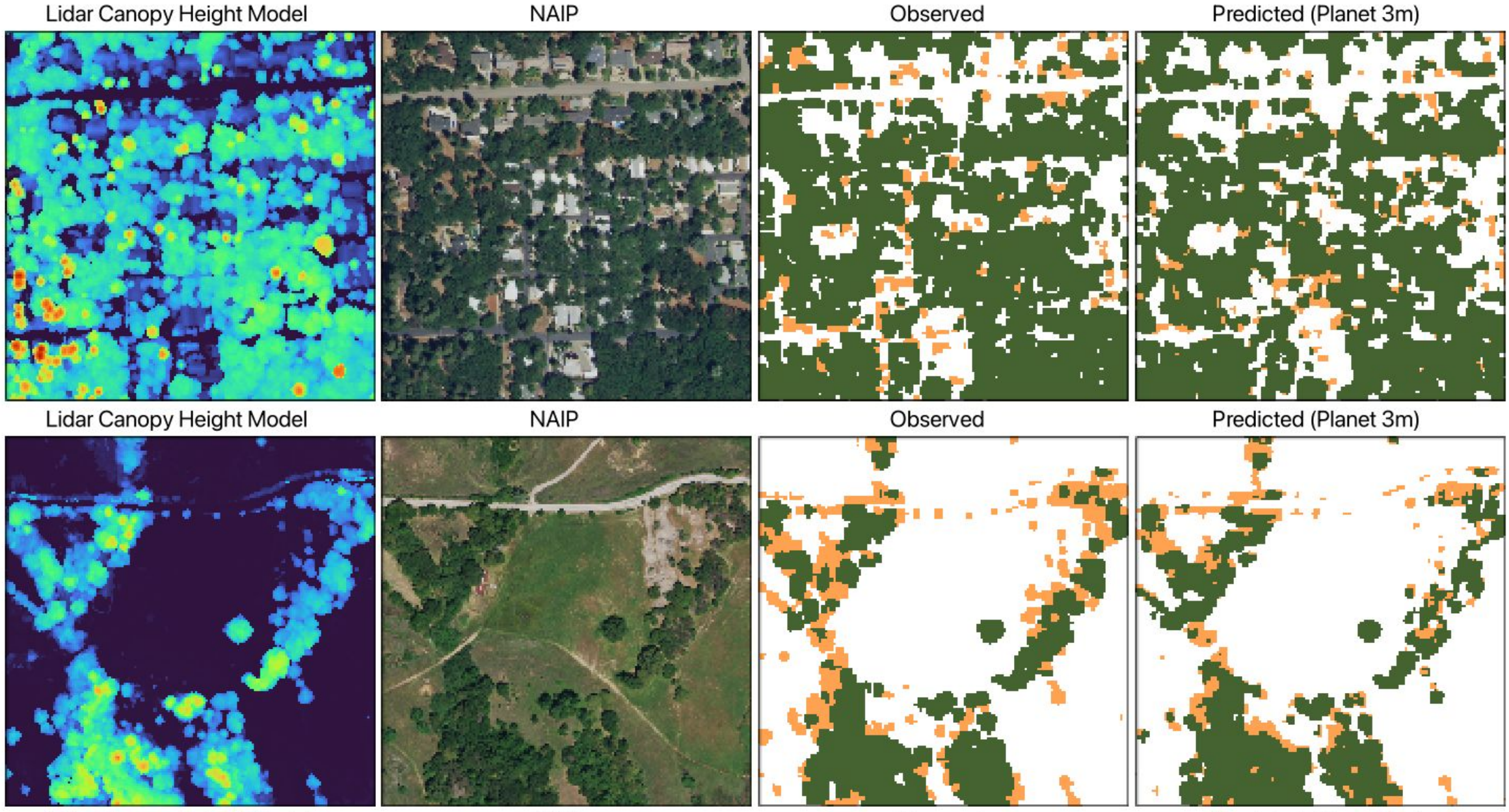
-> tracking fuel treatment (e.g., thinning, defensible space around houses)

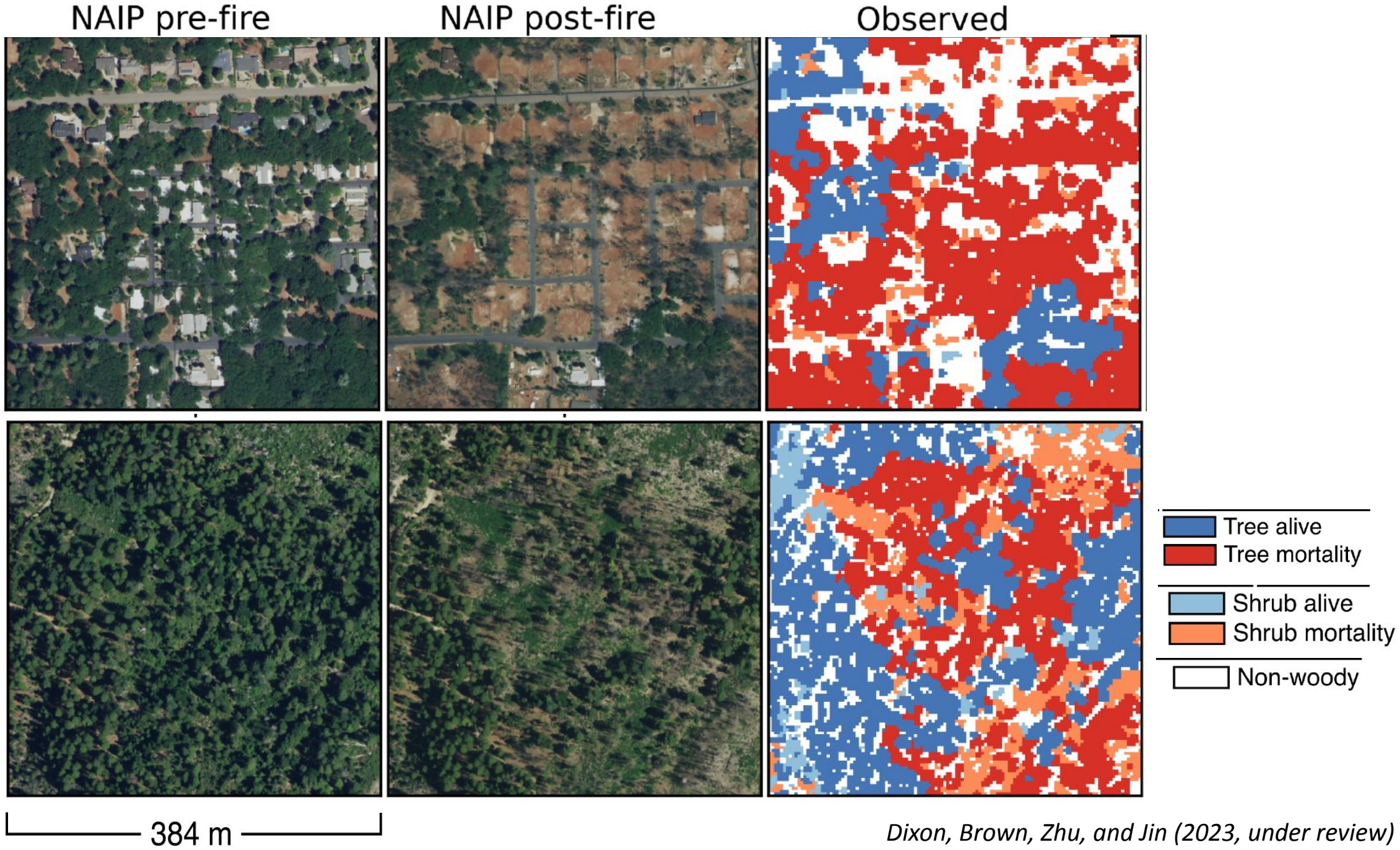


Fine scale WUI canopy fuel mapping: Planetcope

- 3D convolutional neural network (CNN)

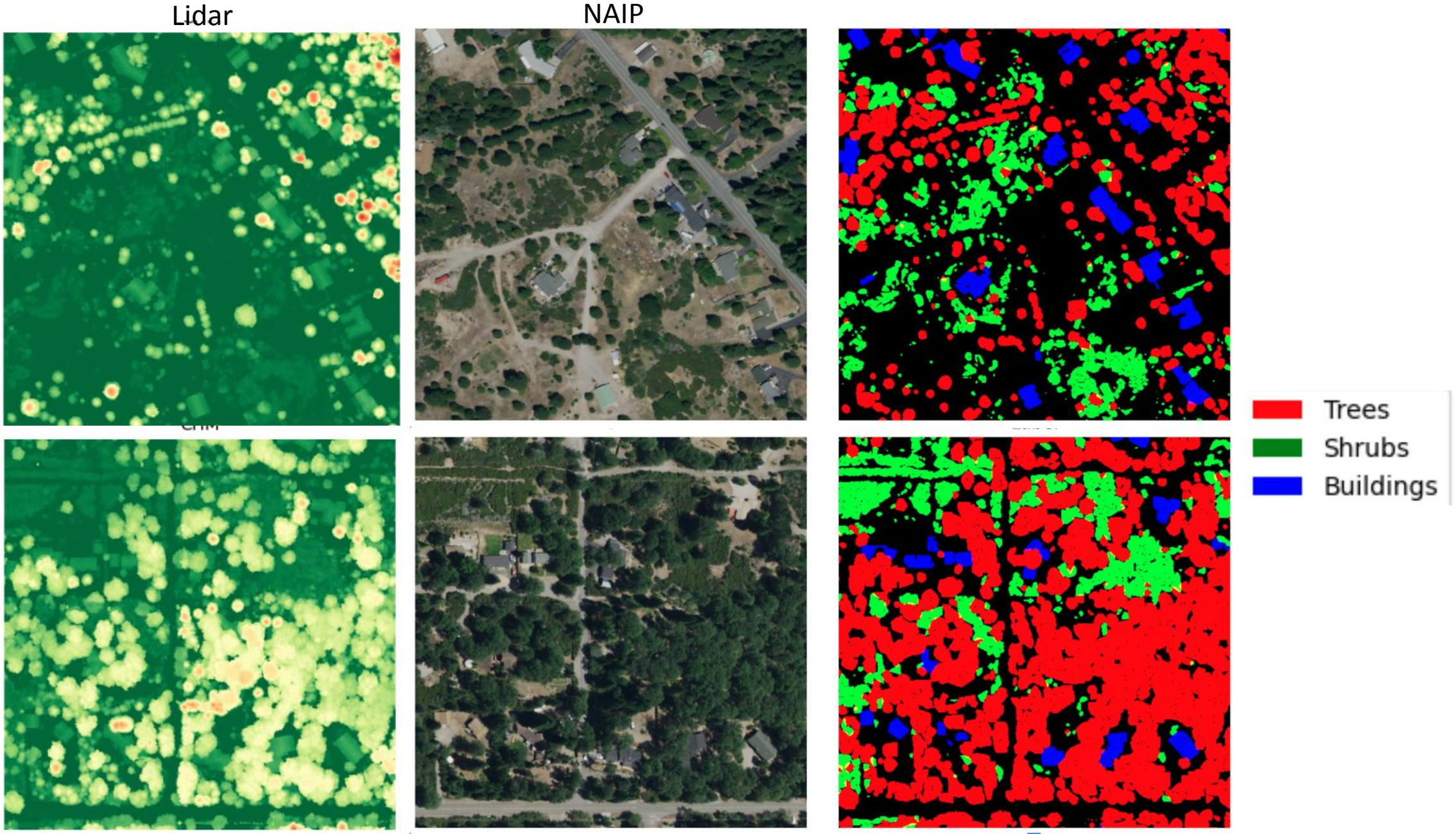



Lidar Canopy Height Model
NAIP
Observed
Predicted (Planet 3m)
Lidar Canopy Height Model
NAIP
Observed
Predicted (Planet 3m)

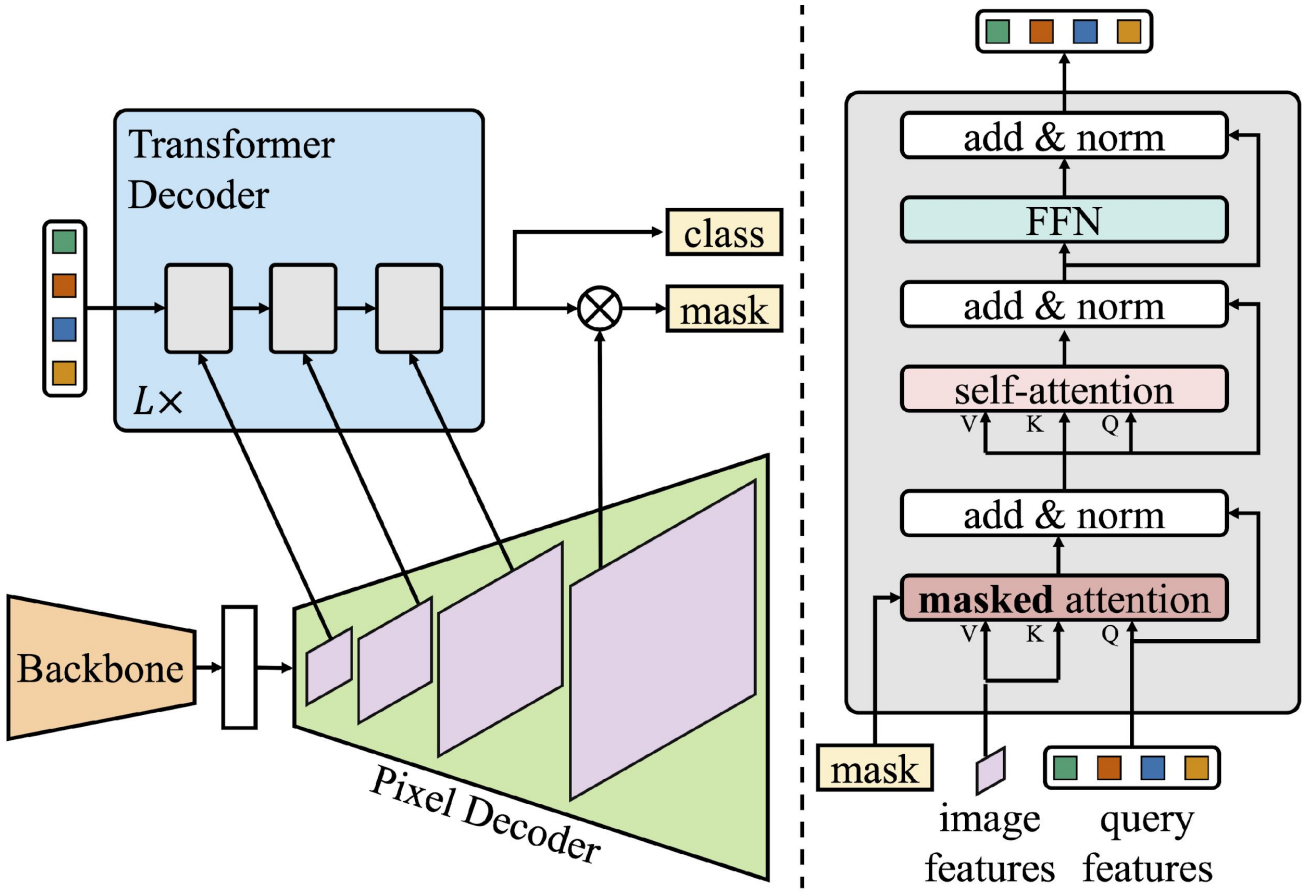


Dixon, Brown, Zhu, and Jin (2023, under review)

Crown scale canopy mapping from NAIP



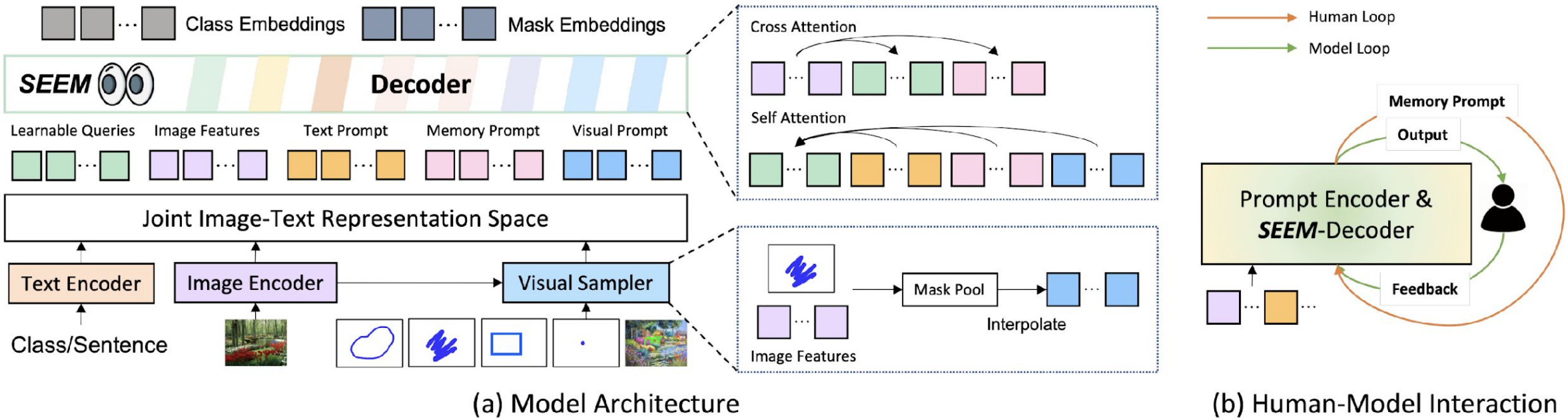
Mask2Former (Facebook AI Research)



- Masked-attention Mask Transformer (Mask2Former), a deep network capable of addressing any image segmentation task (panoptic, instance or semantic).
- State-of-the-art (SOTA) results on several segmentation benchmarks.

[Bowen Cheng, Ishan Misra, Alexander G. Schwing, Alexander Kirillov, and Rohit Girdhar. "*Masked-attention Mask Transformer for Universal Image Segmentation.*" CVPR 2022.]

Segment Everything Everywhere All at Once



(a) Model Architecture

(b) Human-Model Interaction

- Our model (SEEM) can perform any segmentation task, such as semantic, instance, and panoptic segmentation, in open-set scenarios.
- Supports visual, textual, and referring region prompts in any combination, allowing for versatile and interactive referring segmentation.

[Xueyan Zou, Jianwei Yang, Hao Zhang, Feng Li, Linjie Li, Jianfeng Gao, and Yong Jae Lee. "***SEEM:* Segment Everything Everywhere All at Once**." arXiv, 2023. (On going work)]

Conclusions and next steps

- Deep learning based building footprints detection from NAIP aerial imagery allows for tracking WUI building dynamics every two years.
- Crown scale woody fuels mapping with Planet and NAIP was enhanced with deep learning such as CNN.
- WUI building damage was driven by rapid fire spread, building patterns, and other community related variables.

- Next steps – toward fire-safe communities

Data fusion for scalable WUI characterization;

Adapting more advanced deep learning framework to improve object identification

Improved understanding of the linkages between fuels, fire behavior, and structure damage

Tools for community fire vulnerability assessment