Automating Electricity Access Prediction using Satellite Imagery

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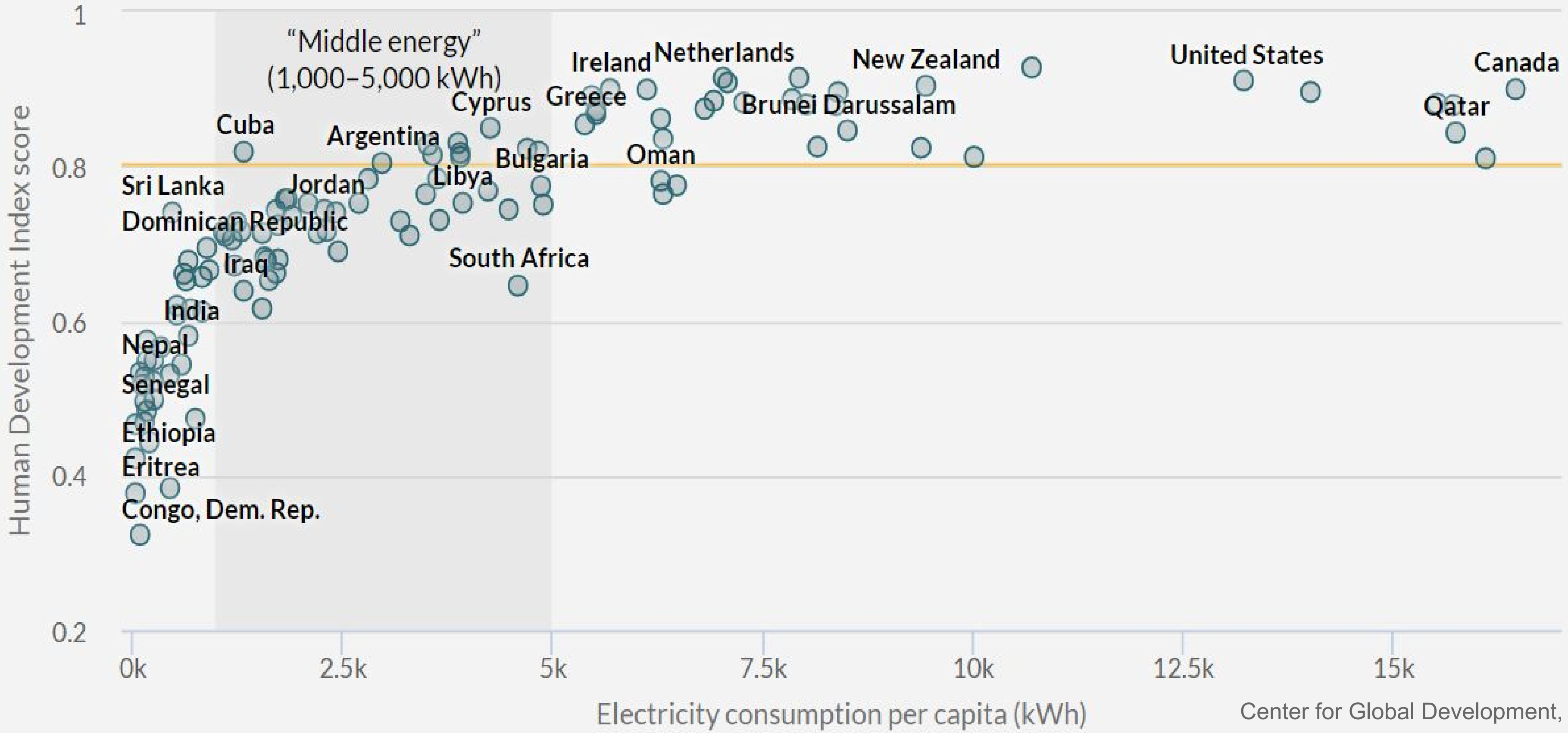
Presentation Roadmap

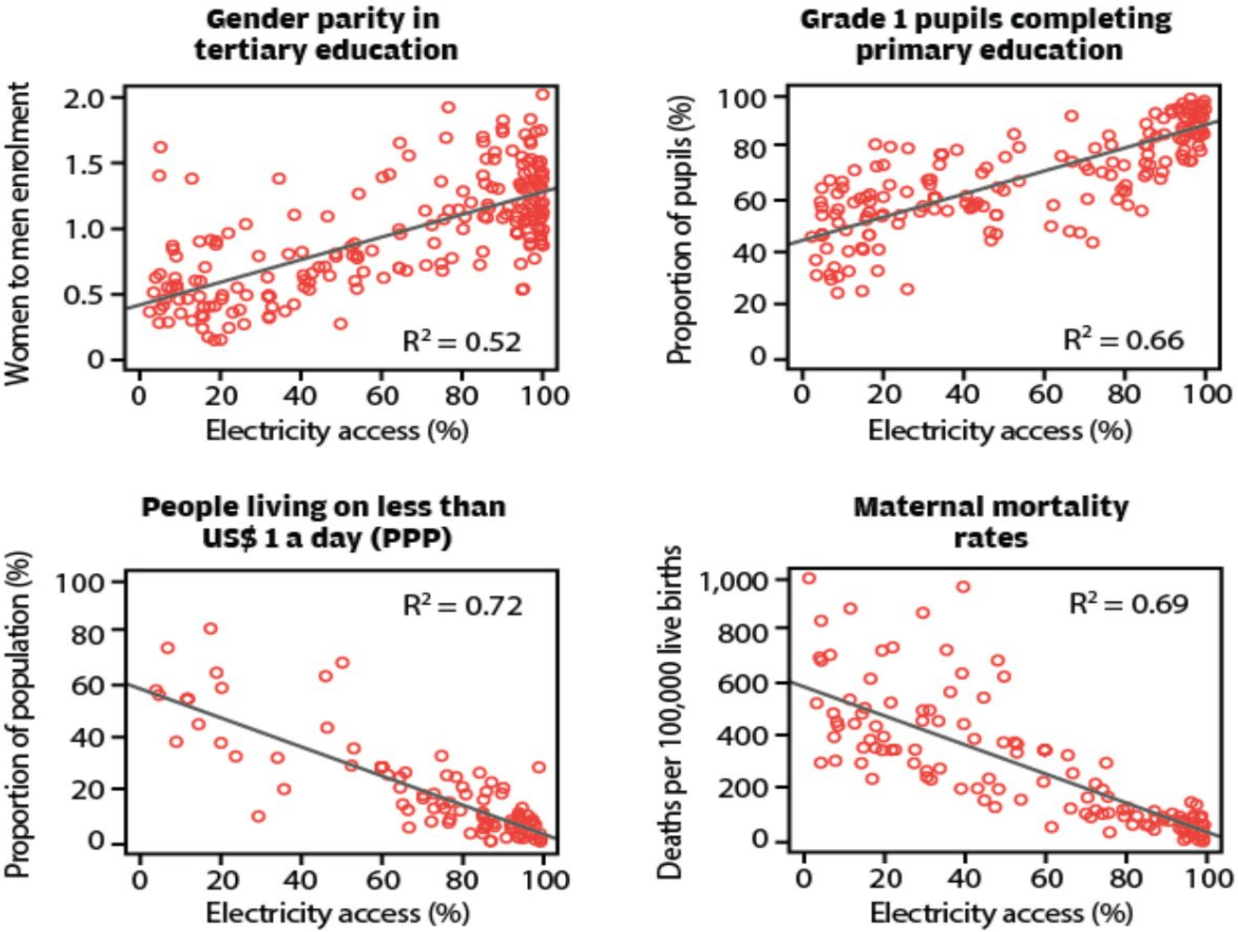
1. The Importance of Electricity
2. The Problem in Developing Countries
3. Our Team's Goal & Approach
4. Results
5. Future Work

NASA, 2012

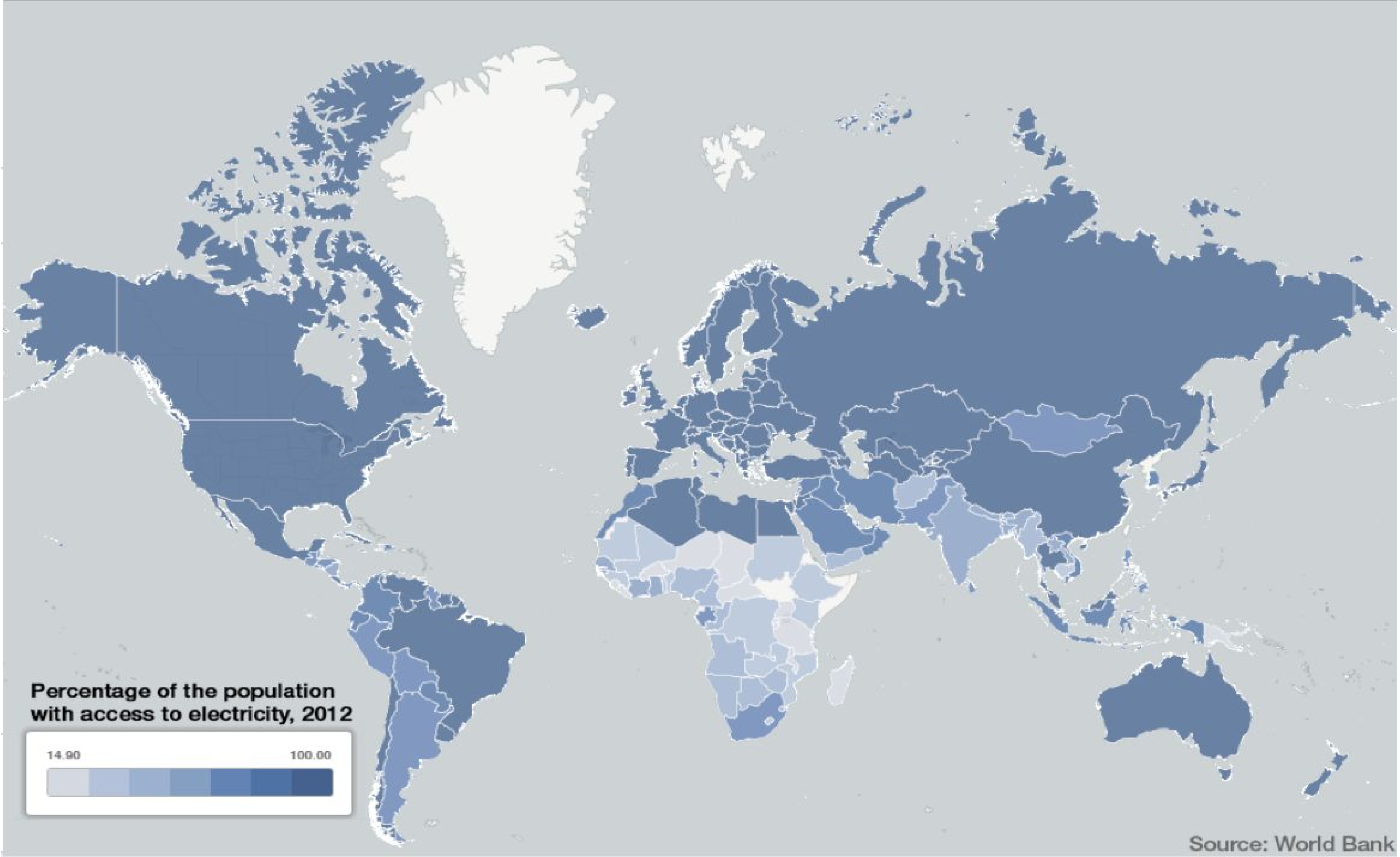
Higher electricity consumption is correlated with higher development and human welfare indicators



Center for Global Development, 2016



Daniel M. Kammen, 2016


Percentage of the population
with access to electricity, 2012
14.90
100.00
Source: World Bank

Why a data & satellite image based approach?

Data Needed

- Continuous
- High resolution
- Cheap
- Reliable
- Automatic
- Complete coverage

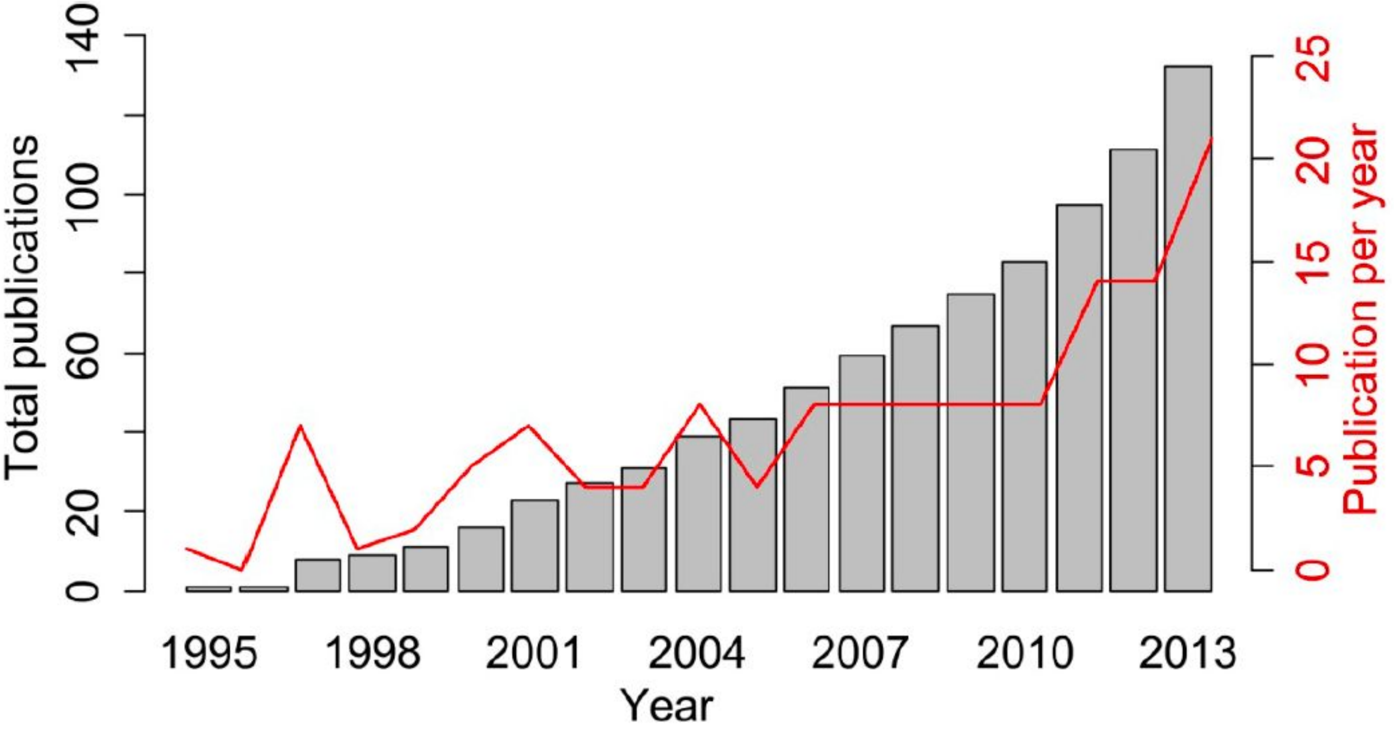
Issues

- Sporodic
- Low granularity
- Expensive
- Inaccurate
- Based on manual surveys
- Little data for remote regions

Solution

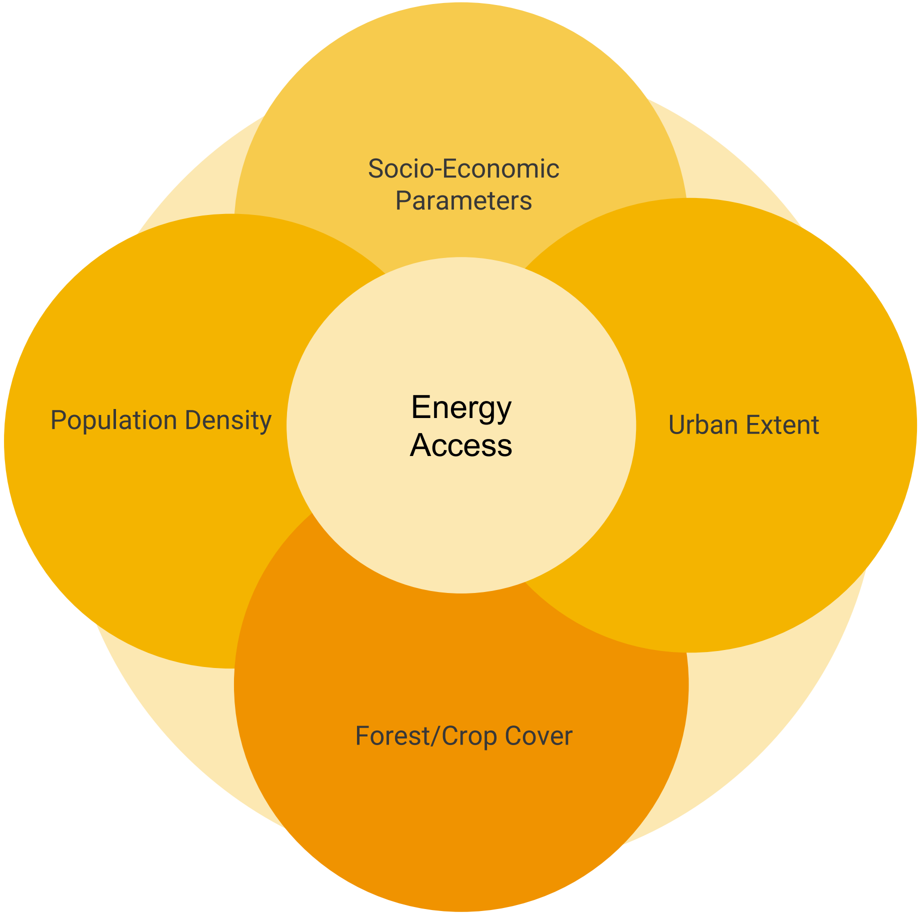
- Visit time - 12 hours
- High resolution images
- Satellite images widely available
- No bias, 100% accurate
- ML based approach
- Total coverage

Nighttime Lights Expanding Literature

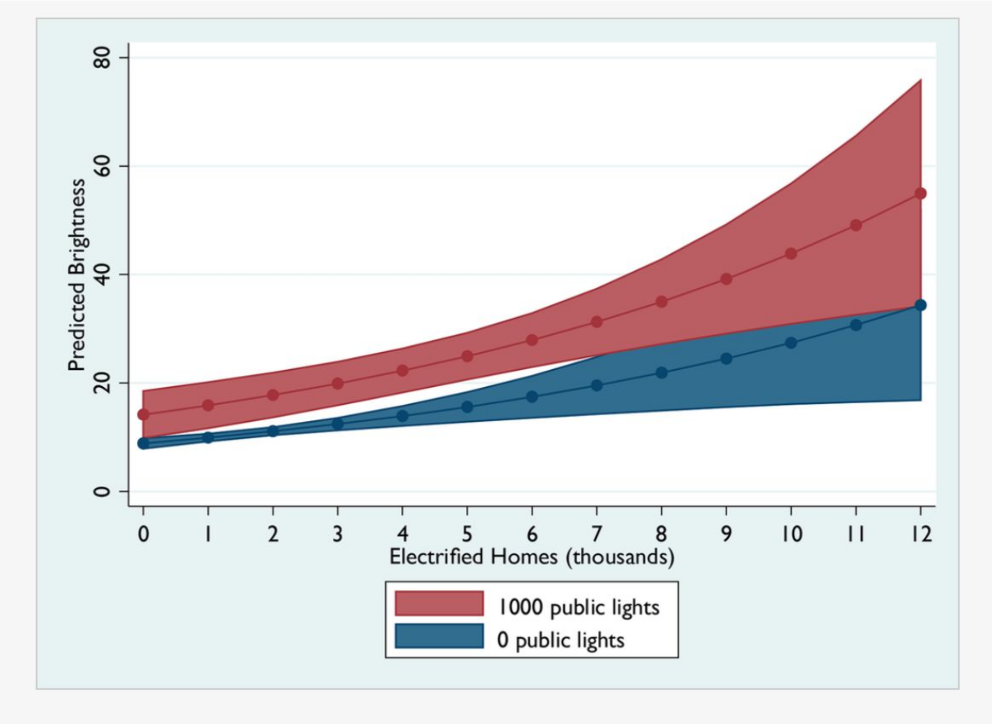


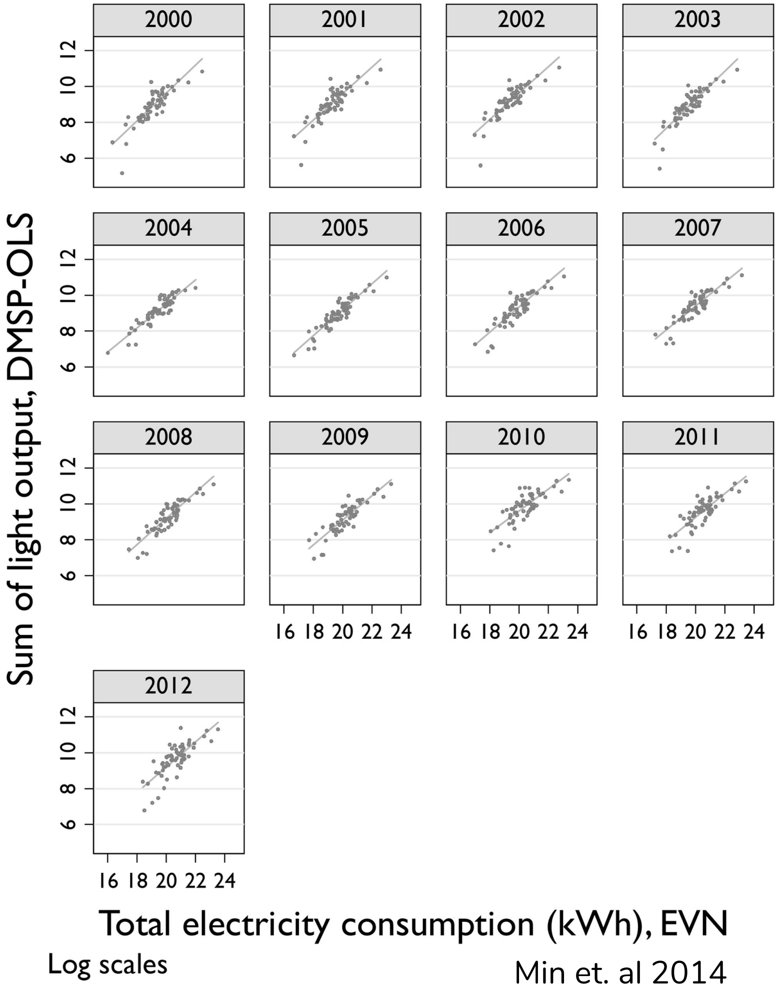
Huang et al., 2014

Nighttime Lights Data Uses

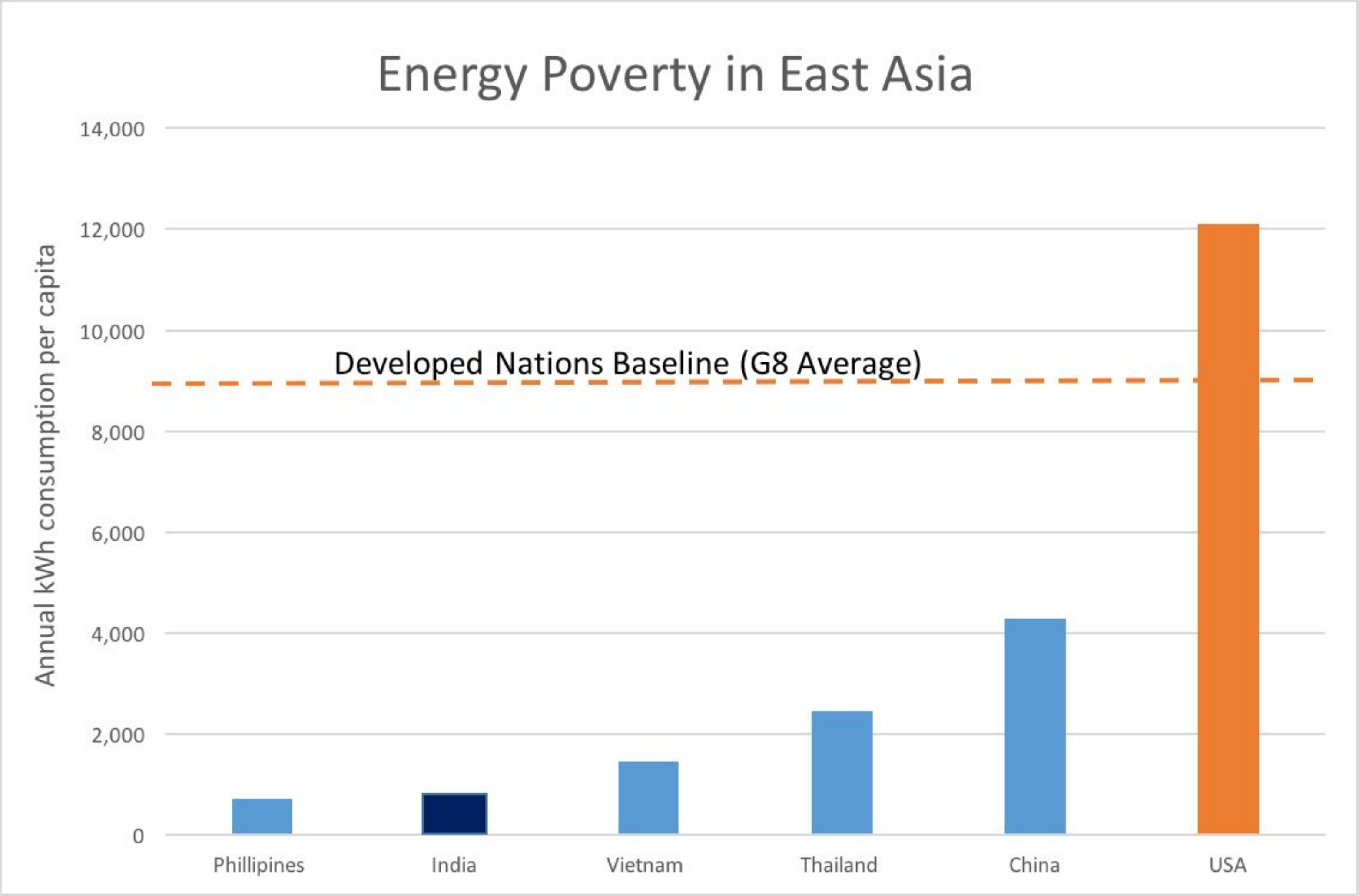


Literature Review





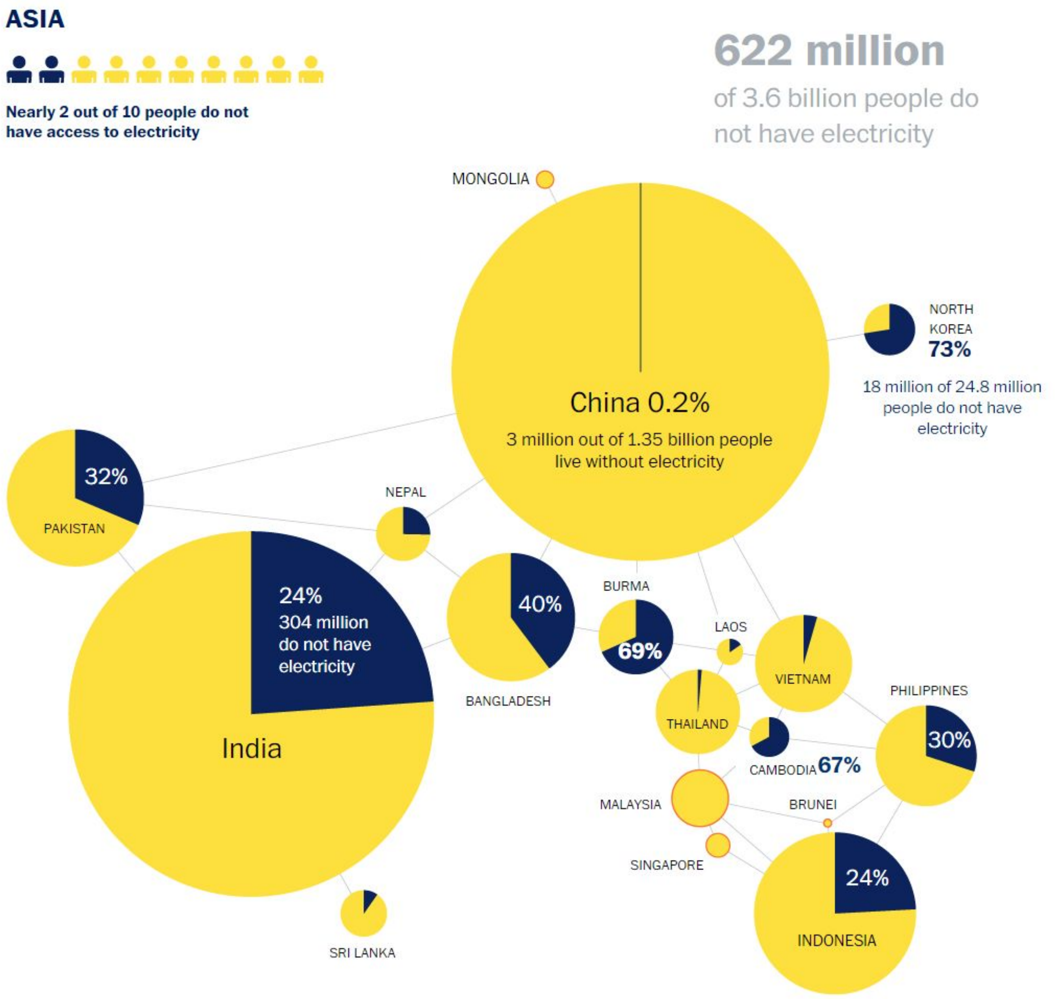
Min et. al 2014



Source: CIA World Factbook, 2016

Why India?
Why Bihar?

- Large Electricity Access Problem
- Narendra Modi's $2.5 Billion Power Plan to bring 100% electricity access
- GARV data- useful baseline



*Source: Washington Post. Source does not define electricity access

GARV Data

Census 2011	Village Name	District Name	State Name	Number of Households	Number of Electrified Households
215990	Bhaisalotan	Pashchim Champaran	Bihar	-9	-9
215989	Kalapani	Pashchim Champaran	Bihar	445	42
215991	Tharhi	Pashchim Champaran	Bihar	339	214
216180	Naurangia	Pashchim Champaran	Bihar	-9	-9
216179	Gardi	Pashchim Champaran	Bihar	-9	-9

Valuable for:

- Calculating Percentage Electrification for Lights at Night Villages
- Ground Truth Data; Useful for Training and Validation

Living in the Dark: 240 Million Indians Have No Electricity

50 million rural homes without power despite idle generation.

Power To The People: India Plans To Electrify 40 Million Households By 2018

In 2 years, BJP govt electrified 13523 villages; only 8% were completely electrified

Fateh Nagla, Uttar Pradesh- less than 10% electrification

Background: Bloomberg
Headlines: Hindustan Times, Bloomberg, Forbes

The Goal

Build an automated, scalable mechanism for predicting electrification using aerial imagery

What can we do with this?

- Identify target areas currently deprived of electricity with ease
- In long term: Assist researchers, policymakers in placement of energy expansion efforts (pre grid-expansion)
- Longer term: Evaluate success and effectiveness of energy expansion efforts, hold accountable (post grid-expansion)

Source: Descartes Labs, Forbes

Our Approach

Find a method to determine village-level electricity access in Bihar

Create machine learning model that predicts if a village is electrified and refine this model

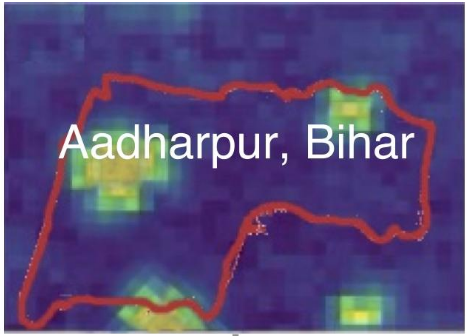
Use lights at night data as input and Indian Government Electricity Access Data to train machine learning model

Data Collection

Feature Extraction

Prediction

Output and Validation



Village	Aadharpur
Mean Radiance	0.43
Max Radiance	0.87

Machine Learning Model

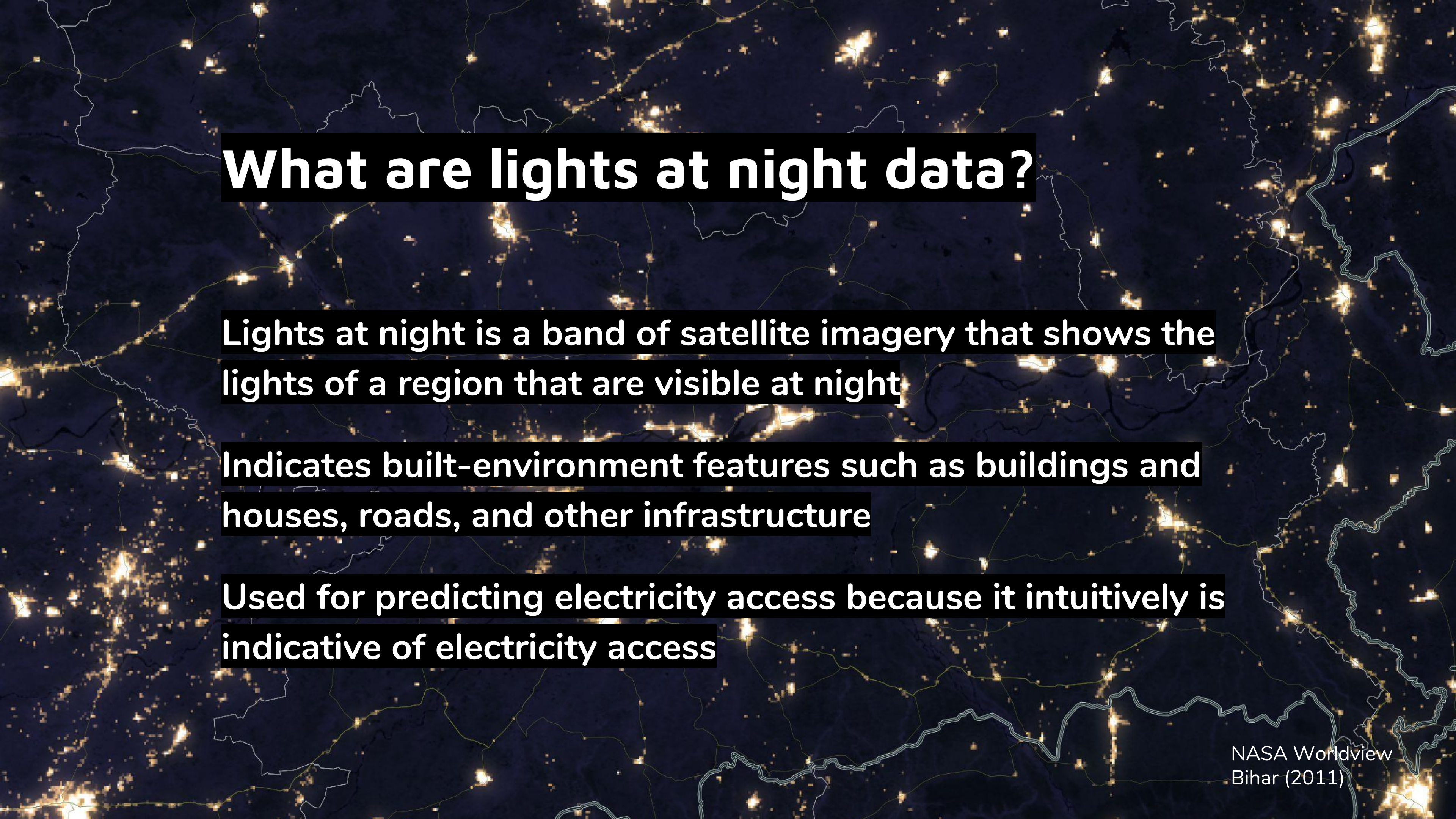
Village	Aadharpur
Predicted	Electrified
Ground Truth	Electrified
Correct?	TRUE

What are lights at night data?

Lights at night is a band of satellite imagery that shows the lights of a region that are visible at night

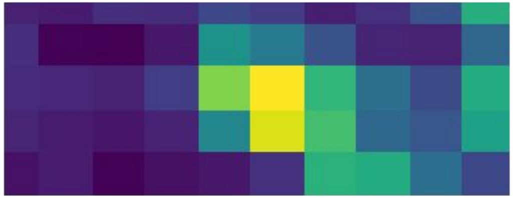
Indicates built-environment features such as buildings and houses, roads, and other infrastructure

Used for predicting electricity access because it intuitively is indicative of electricity access



NASA Worldview
Bihar (2011)

Image Processing



Lights at night

Village boundaries

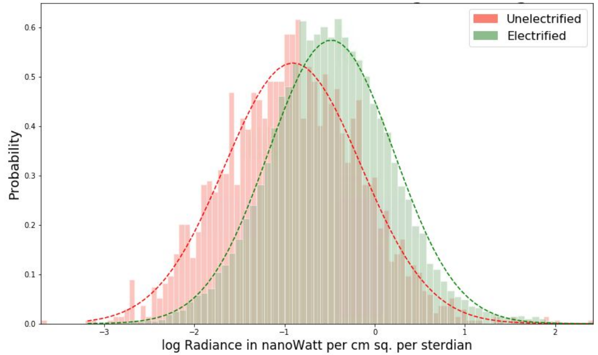
Combined data

0.27	0.32	0.43	0.56	0.76	0.99	2.24	2283.31
10th Percentile	25th Percentile	50th Percentile	Mean	75th Percentile	90th Percentile	Max	Total Night Lights

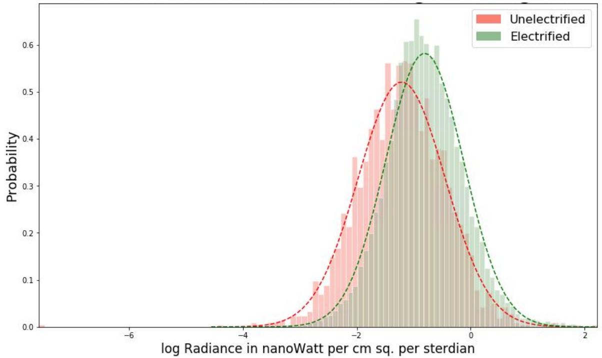
Data Distribution

Max, mean, 10th Percentile, 25th Percentile, Median, 75th Percentile, 90th Percentile of radiance per pixel

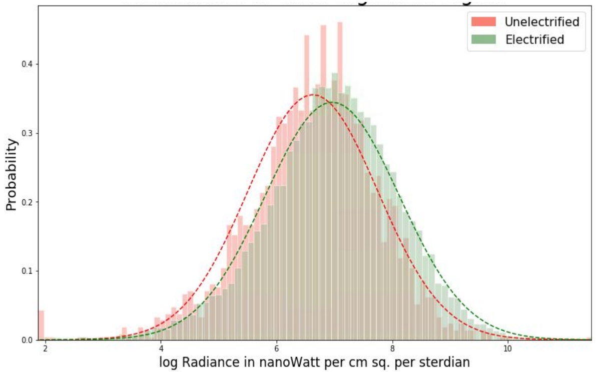
50th Percentile



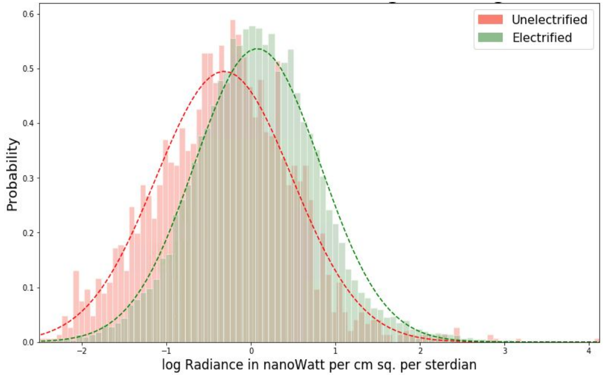
10th Percentile



Total Night Lights



Max

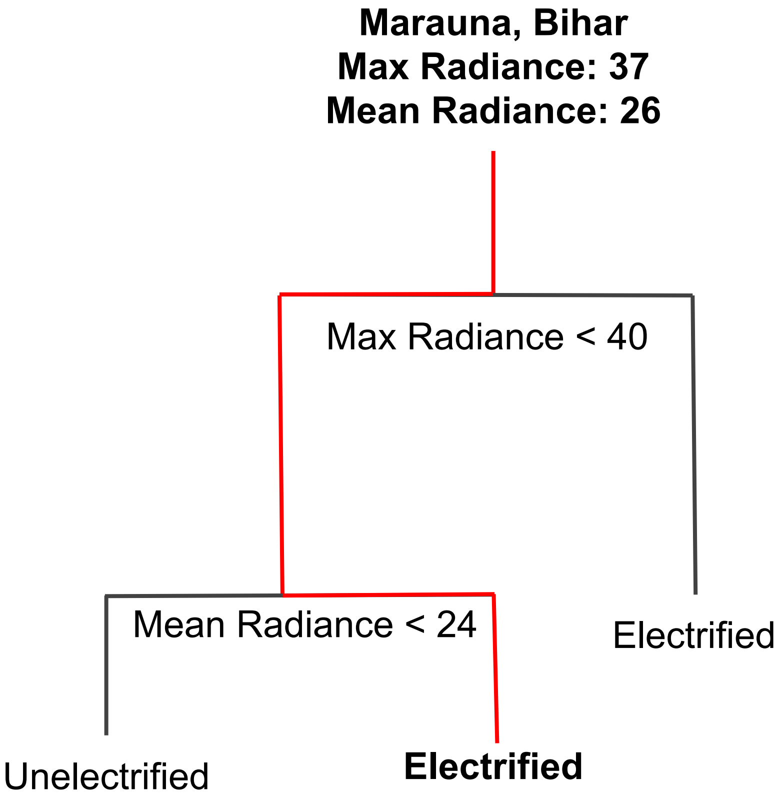


Classification Model

Gradient Boosting Tree Binary Classification Model was selected

Model uses many decision trees to classify villages based on the entire feature space

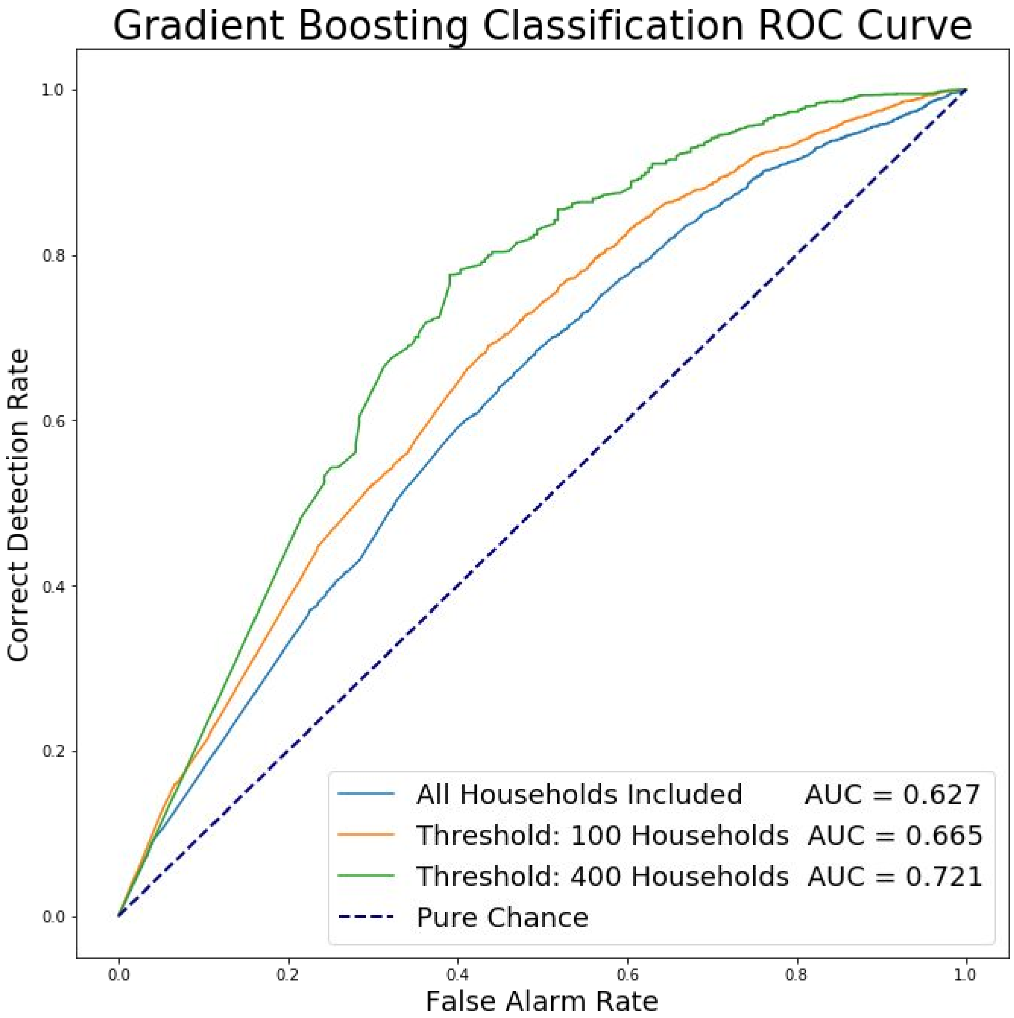
Decision trees use values of different predictors (such as mean radiance and max radiance) to intelligently group similar villages



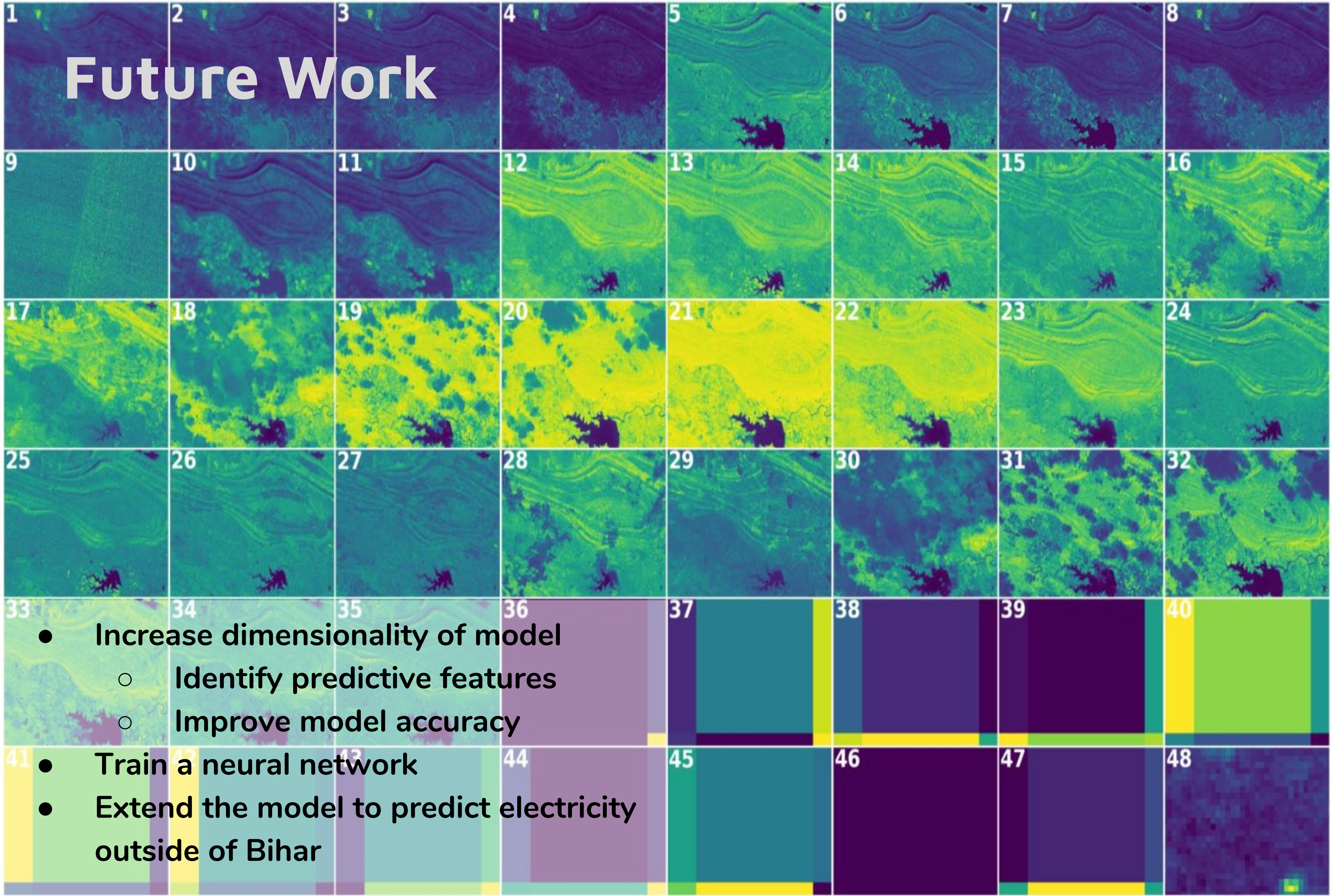
Results & Analysis

Improved results by increasing minimum # households

- AUC = 0.627 unfiltered
- AUC = 0.721 with threshold of 400 households



Future Work



- Increase dimensionality of model
  - Identify predictive features
  - Improve model accuracy
- Train a neural network
- Extend the model to predict electricity outside of Bihar

Bands

1: Coastal aerosol (0.43 - 0.45 µm)
2: Blue (0.45 - 0.51 µm)
3: Green (0.53 - 0.59 µm)
4: Red (0.64 - 0.67 µm)
5: Near Infrared (0.85 - 0.88 µm)
6: Short-wave Infrared 1 (1.57 - 1.65 µm)
7: Short-wave infrared 2 (2.11 - 2.29 µm)
8: Panchromatic (30-meter) (0.50 - 0.68 µm)
9: Cirrus (1.36 - 1.38 µm)
10: Thermal Infrared 1 (10.60 - 11.19 µm)
11: Thermal Infrared 2 (11.50 - 12.51 µm)
12-23: NDVI Jan-Dec 2016
24-35: green index Jan-Dec 2016
36-47: rainfall data Jan-Dec 2016
48: Nighttime lights

Acknowledgements

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Dr. Kyle Bradbury (Energy Initiative), Dr. Leslie Collins (Pratt), Dr. T. Robert Fetter (Nicholas Institute), Dr. Marc Jeuland (Sanford), Dr. Timothy Johnson (Nicholas)

Questions?


WE ARE THE CHAMPIONS!
WE ESCAPED!
CARLHACKS 2016
IT WAS HER FAULT
IT WAS HIS FAULT
GENIUS
YAS QUEEN
#FAIL

References

1. Alstone, P., Gershenson, D., & Kammen, D. M. (2015). Decentralized energy systems for clean electricity access. *Nature Climate Change*, *5*, 305.
2. Huang, Q., Yang, X., Gao, B., Yang, Y., & Zhao, Y. (2014). Application of DMSP/OLS Nighttime Light Images: A Meta-Analysis and a Systematic Literature Review. Remote Sensing, 6(8), 6844–6866.
3. Energy access database. (n.d.). Retrieved October 03, 2017, from http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/.
4. Khandker, S.R., Samad, H.A., Ali, R., & Barnes, D.F. (2012). Who Benefits Most from Rural Electrification? Evidence in India. *Policy Research Working Papers*. doi:10.1596/1813-9450-6095
5. Min, B., & Gaba, K. M. (2014). Tracking Electrification in Vietnam Using Nighttime Lights. Remote Sensing, 6(10), 9511–9529.
6. Shi, K., Yu, B., Huang, Y., Hu, Y., Yin, B., Chen, Z., Wu, J. (2014). Evaluating the Ability of NPP-VIIRS Nighttime Light Data to Estimate the Gross Domestic Product and the Electric Power Consumption of China at Multiple Scales: A Comparison with DMSP-OLS Data. Remote Sensing, 6(2), 1705–1724.