NLT New Light Technologies

IEG Independent Evaluation Group | WORLD BANK GROUP World Bank • IFC • MIGA

March 17, 2021

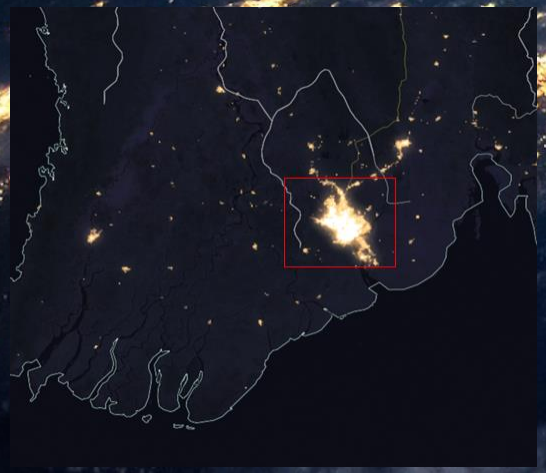
SATELLITE DATA FOR DECISION MAKING

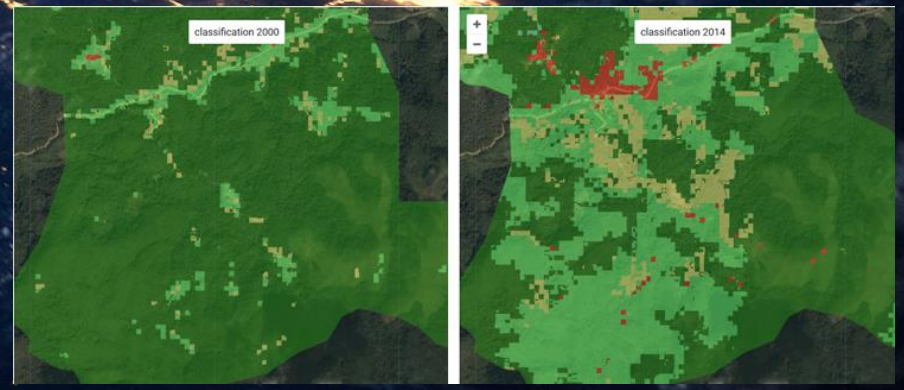
SEEING EARTH FROM 800KM ABOVE GROUND

Assessing outcomes and impacts

Ran Goldblatt, Ph.D.

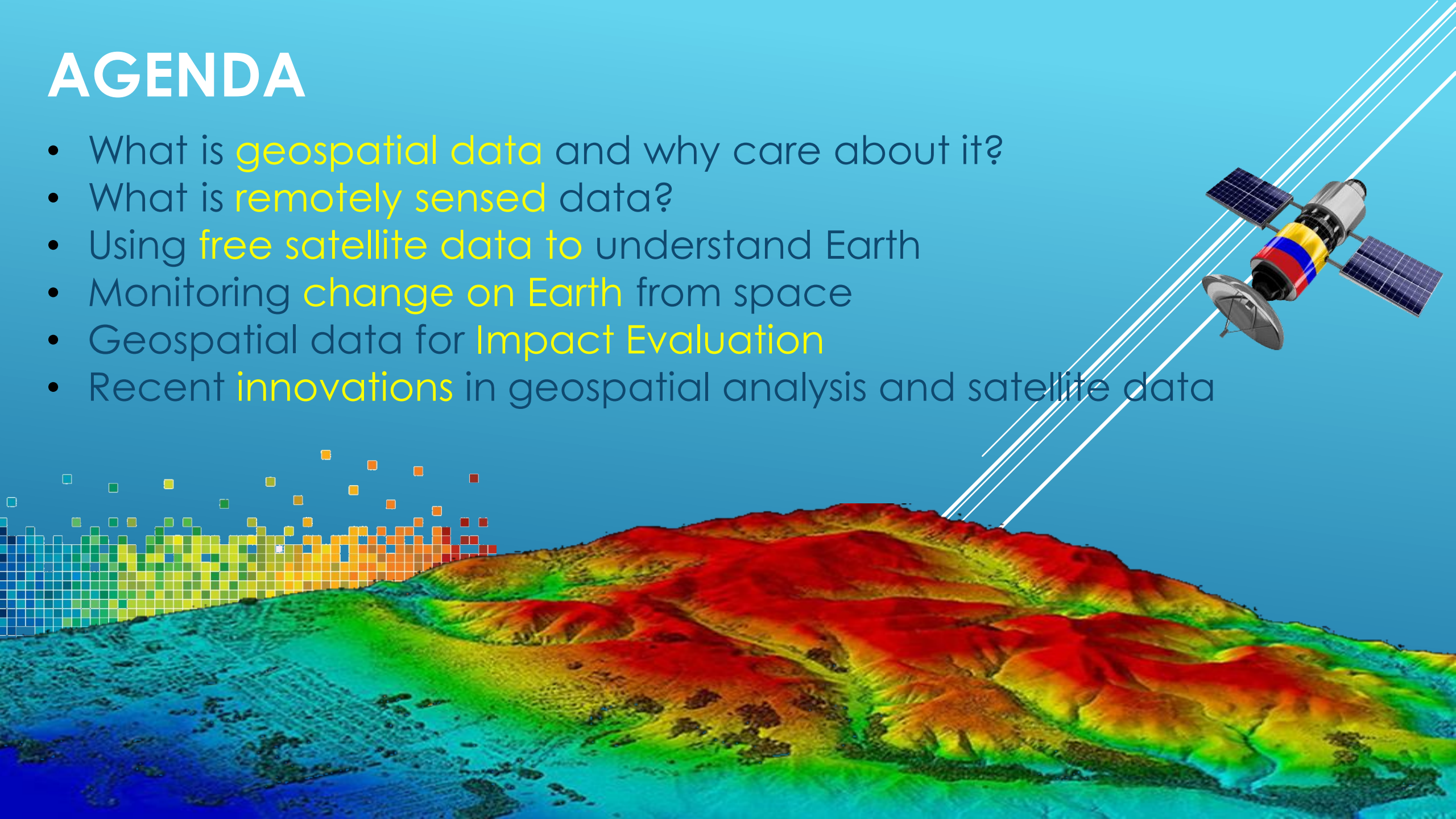
Chief Scientist, New Light Technologies Inc.





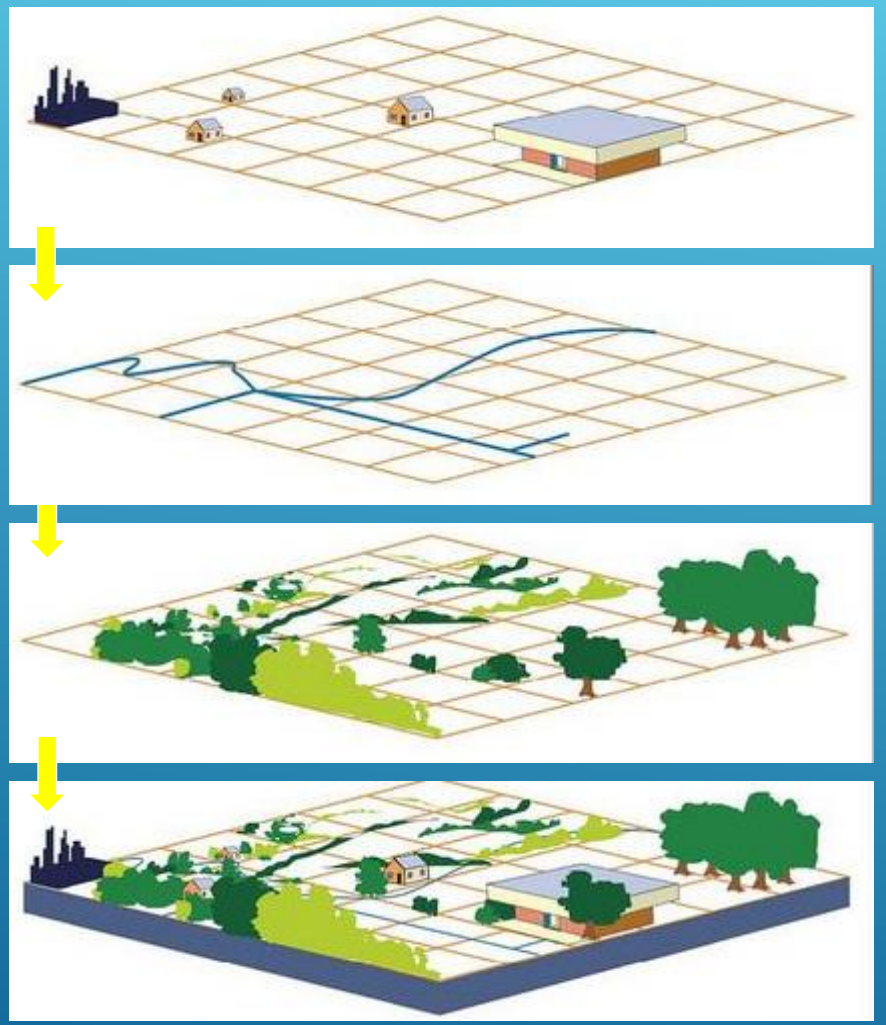
AGENDA

- What is geospatial data and why care about it?
- What is remotely sensed data?
- Using free satellite data to understand Earth
- Monitoring change on Earth from space
- Geospatial data for Impact Evaluation
- Recent innovations in geospatial analysis and satellite data

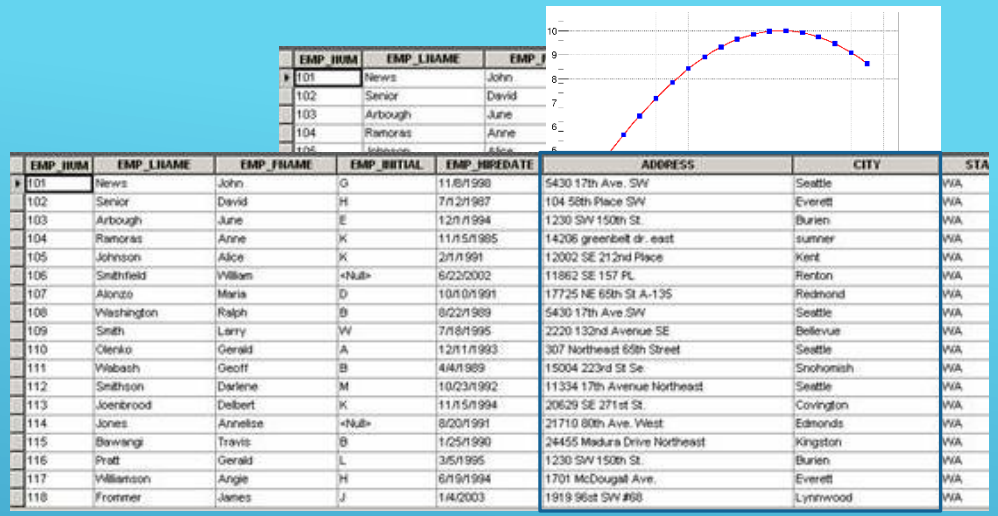


WHAT IS SPATIAL DATA?

The real world

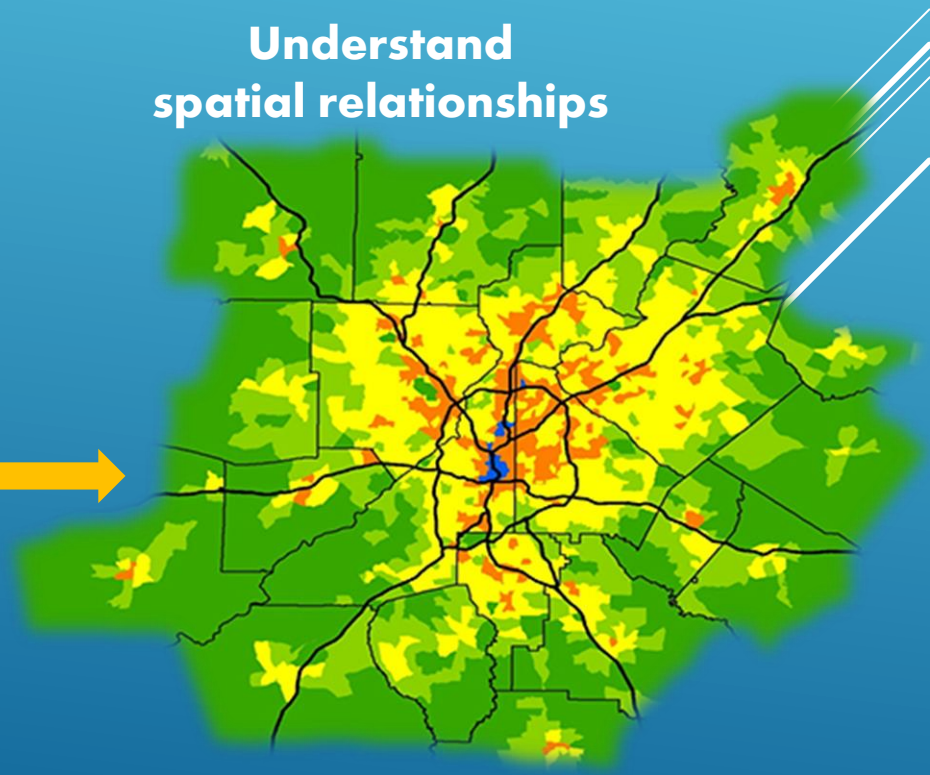


Entities that hold
spatial information



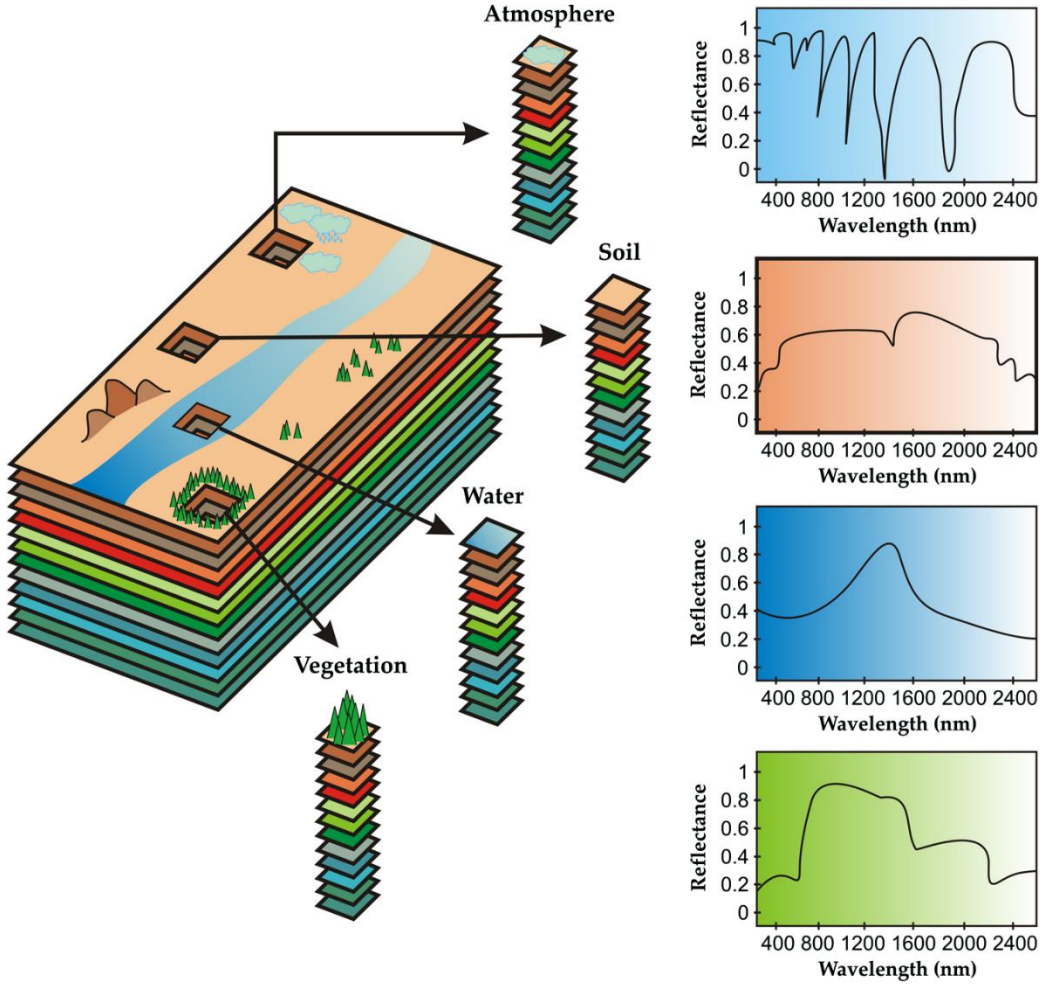
EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIREDATE	ADDRESS	CITY	STA
101	News	John	G	11/8/1998	5430 17th Ave. SW	Seattle	WA
102	Senior	David	H	7/12/1987	104 58th Place SW	Everett	WA
103	Arbough	June	E	12/1/1994	1230 SW 150th St.	Burien	WA
104	Ramoras	Anne	K	11/15/1985	14206 greenbelt dr. east	sumner	WA
105	Johnson	Alice	K	2/1/1991	12002 SE 212nd Place	Kent	WA
106	Smithfield	William	<Null>	6/22/2002	11862 SE 157 PL	Renton	WA
107	Alonzo	Maria	D	10/10/1991	17725 NE 65th St A-135	Redmond	WA
108	Washington	Ralph	B	8/22/1989	5430 17th Ave SW	Seattle	WA
109	Smith	Larry	W	7/18/1995	2220 132nd Avenue SE	Bellevue	WA
110	Olenko	Gerald	A	12/11/1993	307 Northeast 65th Street	Seattle	WA
111	Wabash	Geoff	B	4/4/1989	15004 223rd St Se	Snohomish	WA
112	Smithson	Darlene	M	10/23/1992	11334 17th Avenue Northeast	Seattle	WA
113	Joenbrood	Delbert	K	11/15/1994	20629 SE 271st St.	Covington	WA
114	Jones	Annelise	<Null>	8/20/1991	21710 80th Ave. West	Edmonds	WA
115	Bawangi	Travis	B	1/25/1990	24455 Madura Drive Northeast	Kingston	WA
116	Pratt	Gerald	L	3/5/1995	1230 SW 150th St.	Burien	WA
117	Williamson	Angie	H	6/19/1994	1701 McDougall Ave.	Everett	WA
118	Frommer	James	J	1/4/2003	1919 96st SW #68	Lynnwood	WA

Understand
spatial relationships



REMOTE SENSING

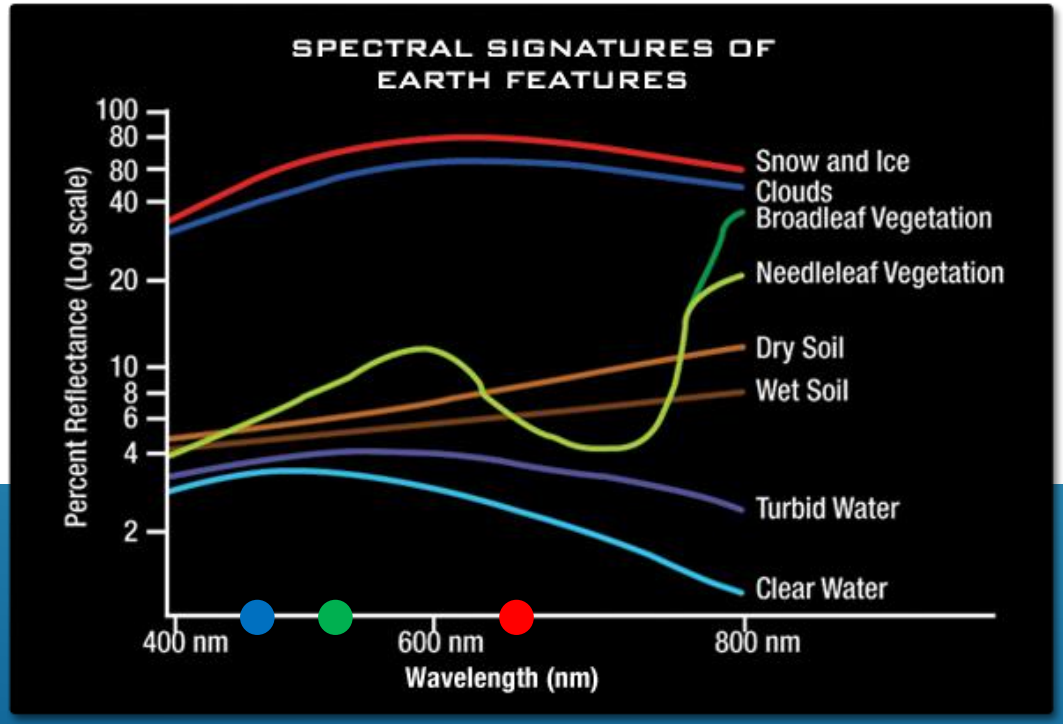
- The science of **IDENTIFYING**, **OBSERVING**, **COLLECTING** and **MEASURING objects without** coming into **direct contact** with them.
- Accomplished by humans and animals with the aid of **eyes**, or other **senses**.
- Satellites record the ***electromagnetic energy*** reflected or emitted from objects on Earth.



https://www.battelleecology.org/plot-spec-sig-python

RS: Learn about objects by studying the radiation **REFLECTED** and/or **EMITTED** by them.

Different types of land cover and land use on Earth have different characteristics



Spectral indices based on the spectral signature

NDVI

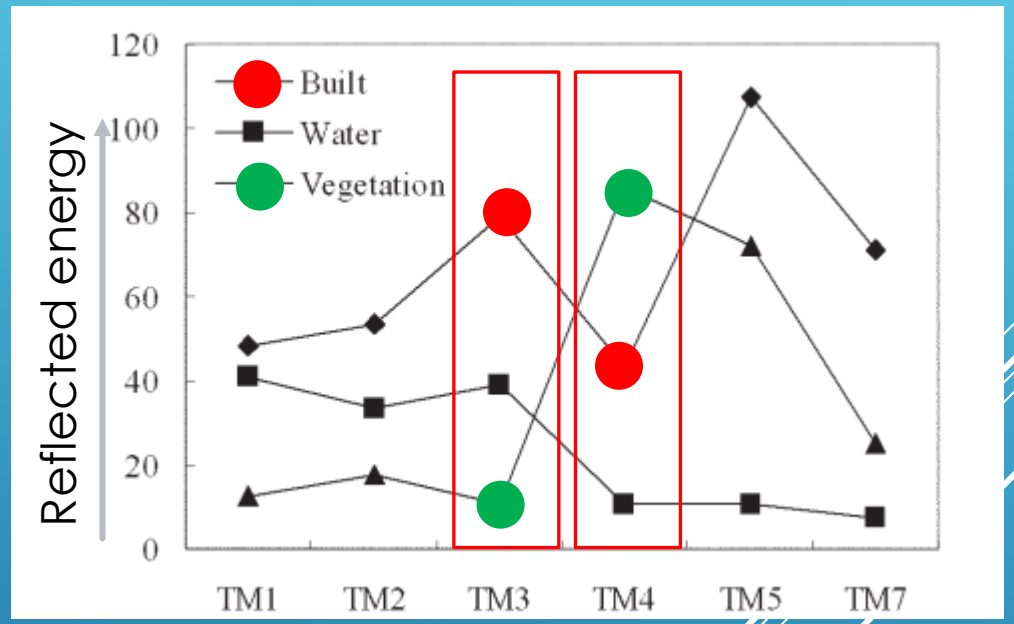
Normalized Difference Vegetation Index

NIR and RED bands

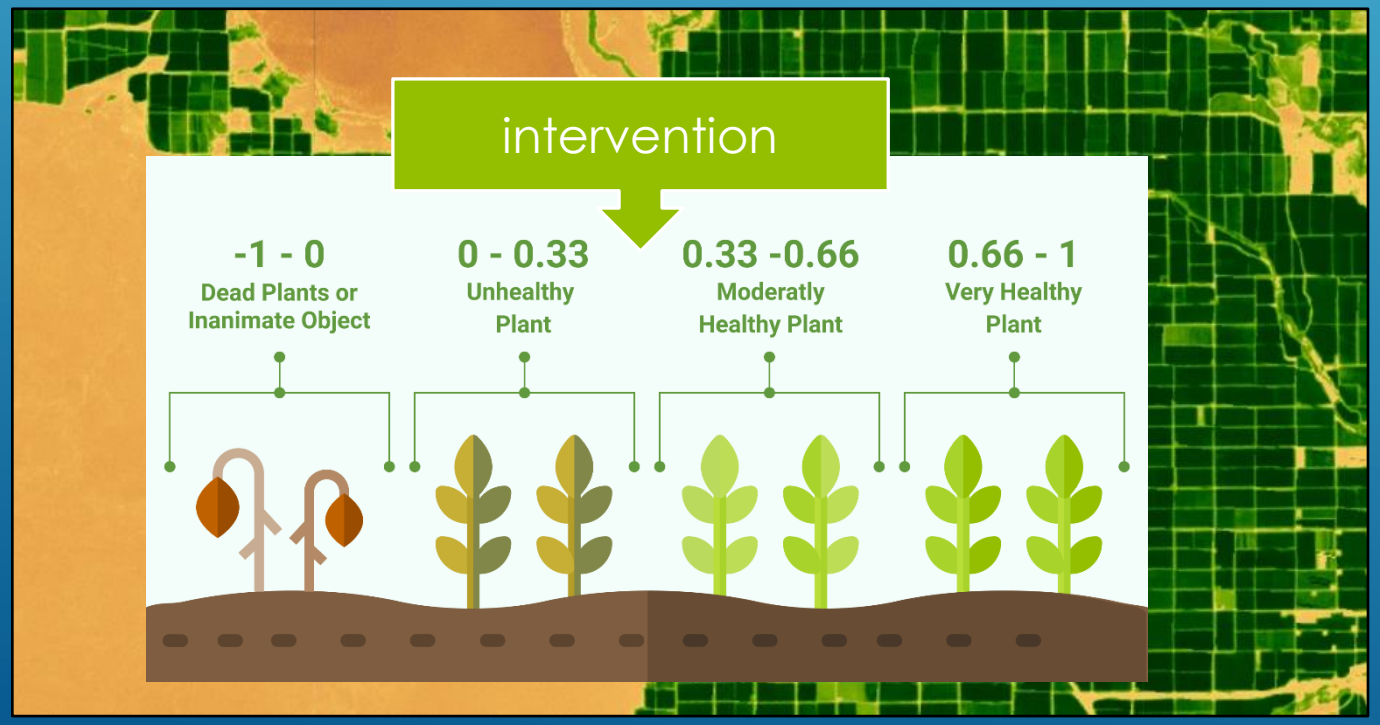
$$NDVI = (NIR - RED)/(NIR + RED)$$

H	L
Much is reflected	Much is absorbed

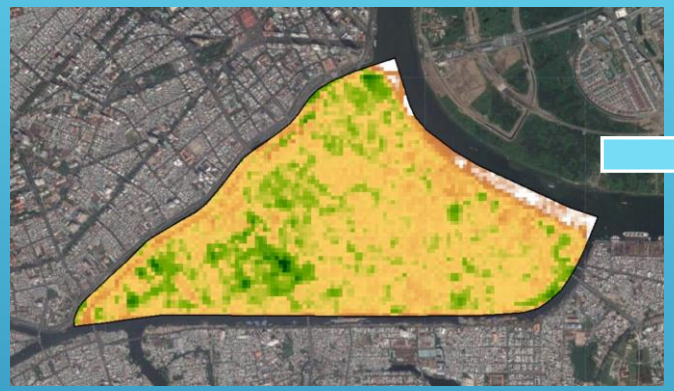
- Plants` chlorophyll **absorbs** the red light
- The leaves **reflect** the NIR light



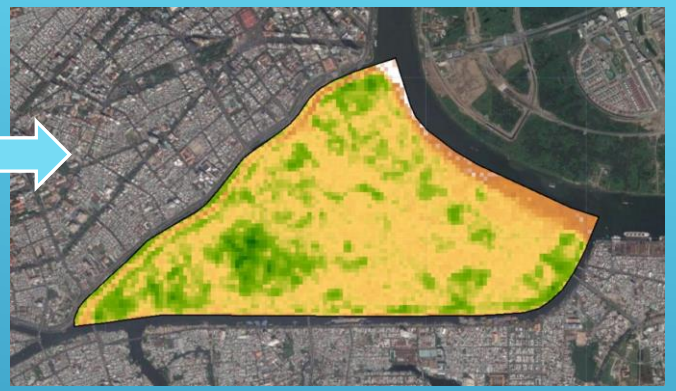
Xu, 2007

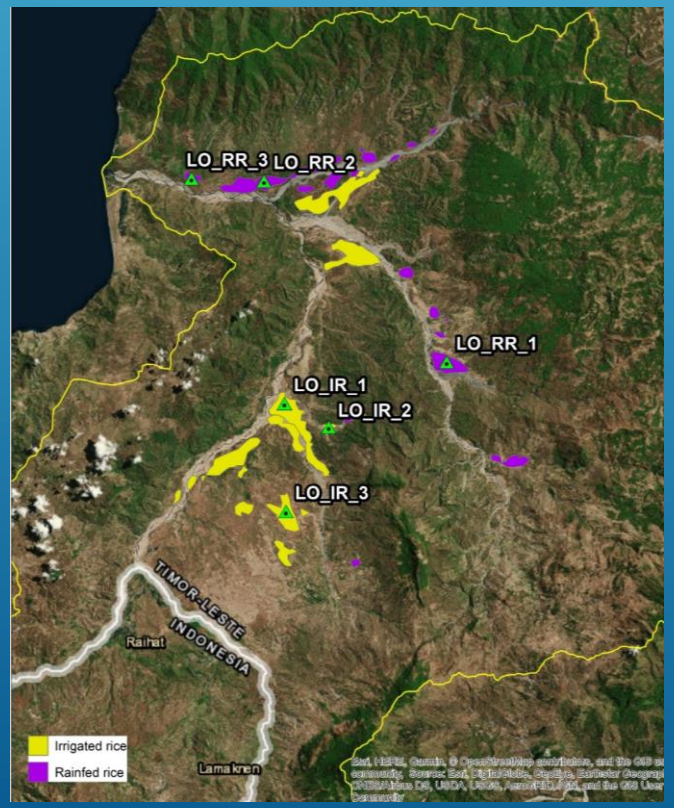


NDVI, 2000

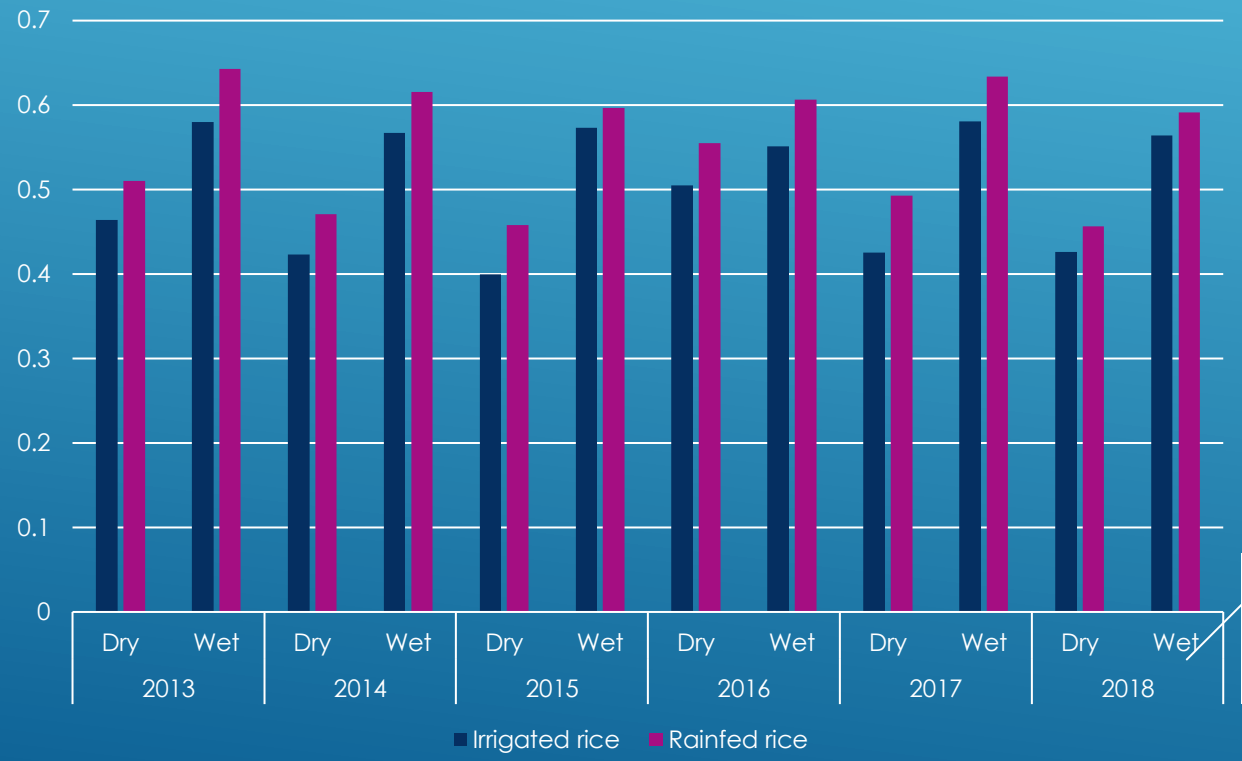


NDVI, 2016





Average NDVI (irrigated vs. rainfed rice fields)



Case study: Timor-Leste (work funded by the World Bank)

Irrigated rice field

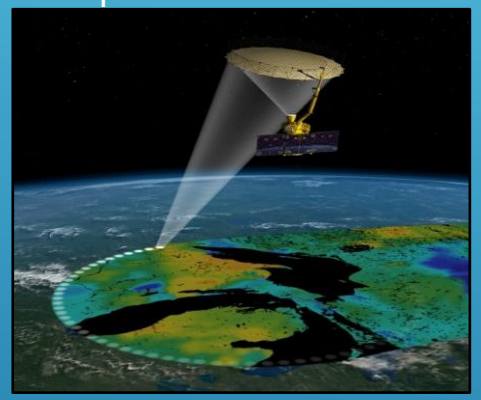
Rainfed rice field

- **1,419 active satellites**, both government and private.
- **374** specifically for **Earth observation/science**

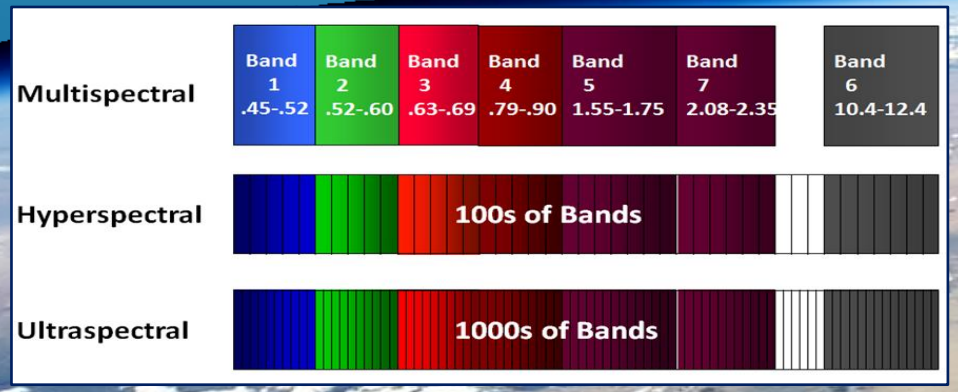
"FIT FOR PURPOSE" TECHNOLOGIES

Spatial resolution

Temporal resolution

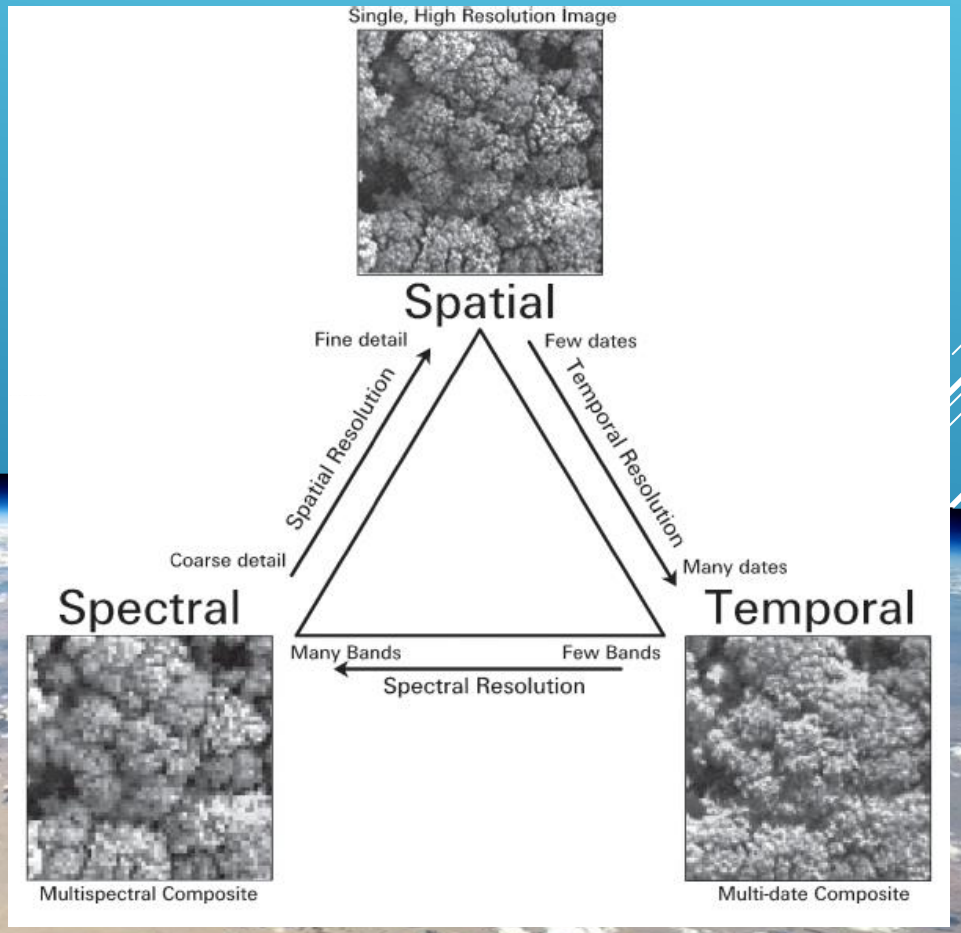


Spectral resolution



Price

Many things to consider when using…



Warner et al., 2009

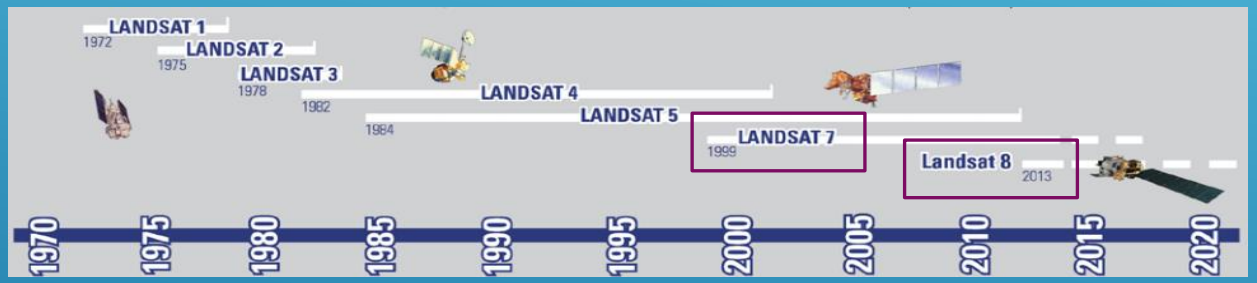
A CHANGE IN THE SATELLITE INDUSTRY

FROM *expensive*, *high-res*,
project specific satellite data TO
"Free", *medium-high* spatial resolution,
in *global scales*.

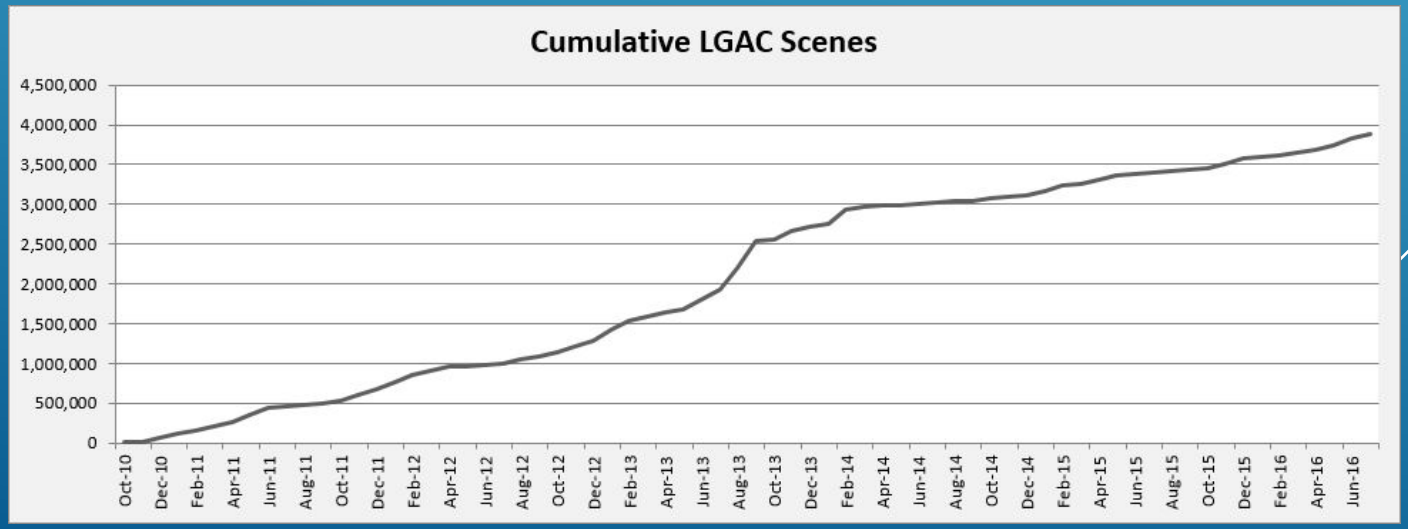
LANDSAT Mission - Mid 1960s:

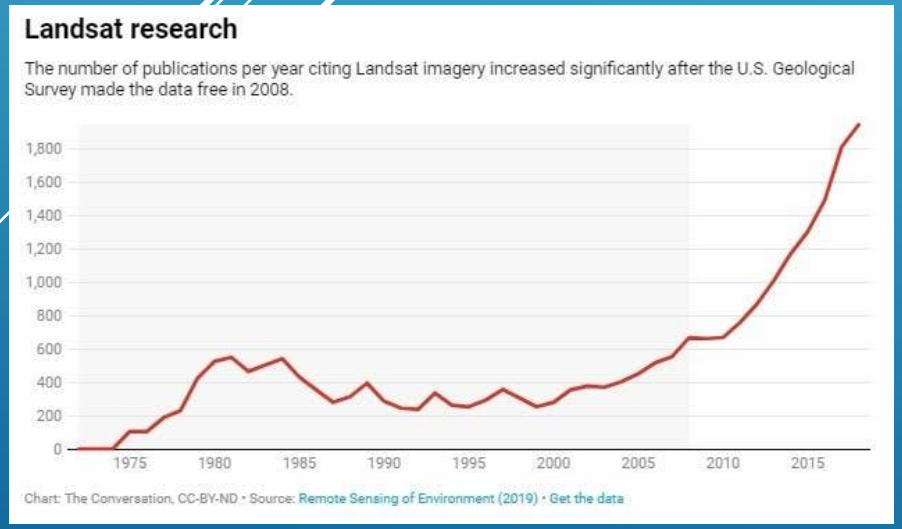
US effort to develop and launch the first **civilian Earth observation satellite**.

The Earth Resources Technology Satellite – **Landsat.**



- Orbit altitude: 705 Km
- Revisit period: every 16 days
- Spatial resolution: >30m
- Spectral resolution: 8/11 bands





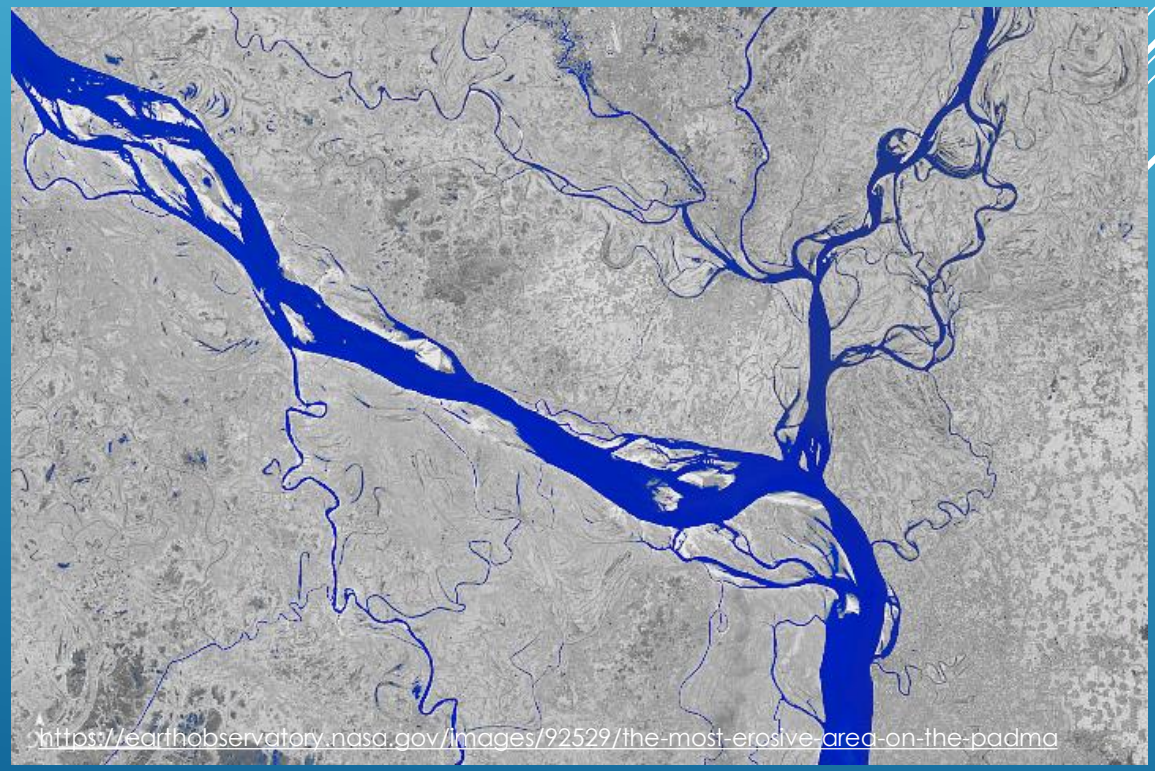
45 YEARS OF LANDSAT IMAGERY

https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/landsat-8-ldcm

https://news.mongabay.com/2013/05/google-time-lapse-offers-view-of-earth-over-3-decades/

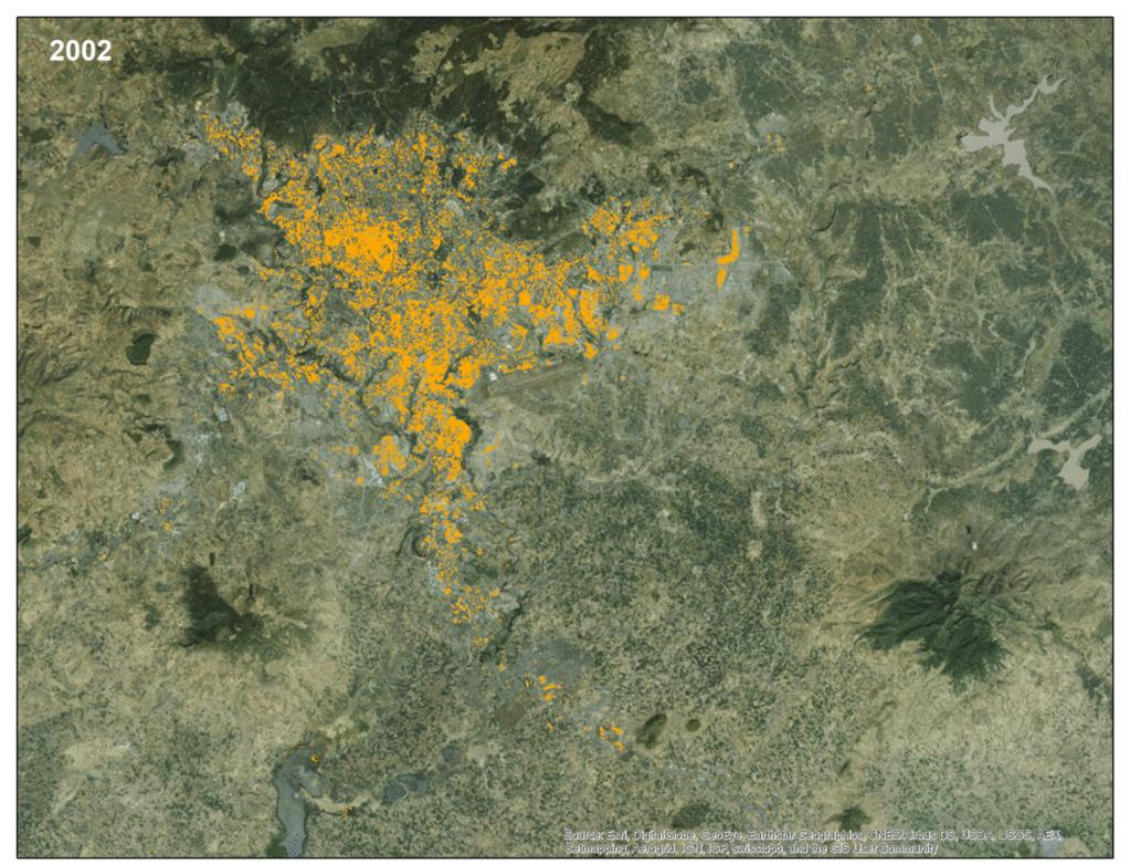
https://news.mongabay.com/

14 false-color images of the **Padma river** between 1988 and 2018 taken by the Landsat 5 and 8 satellites

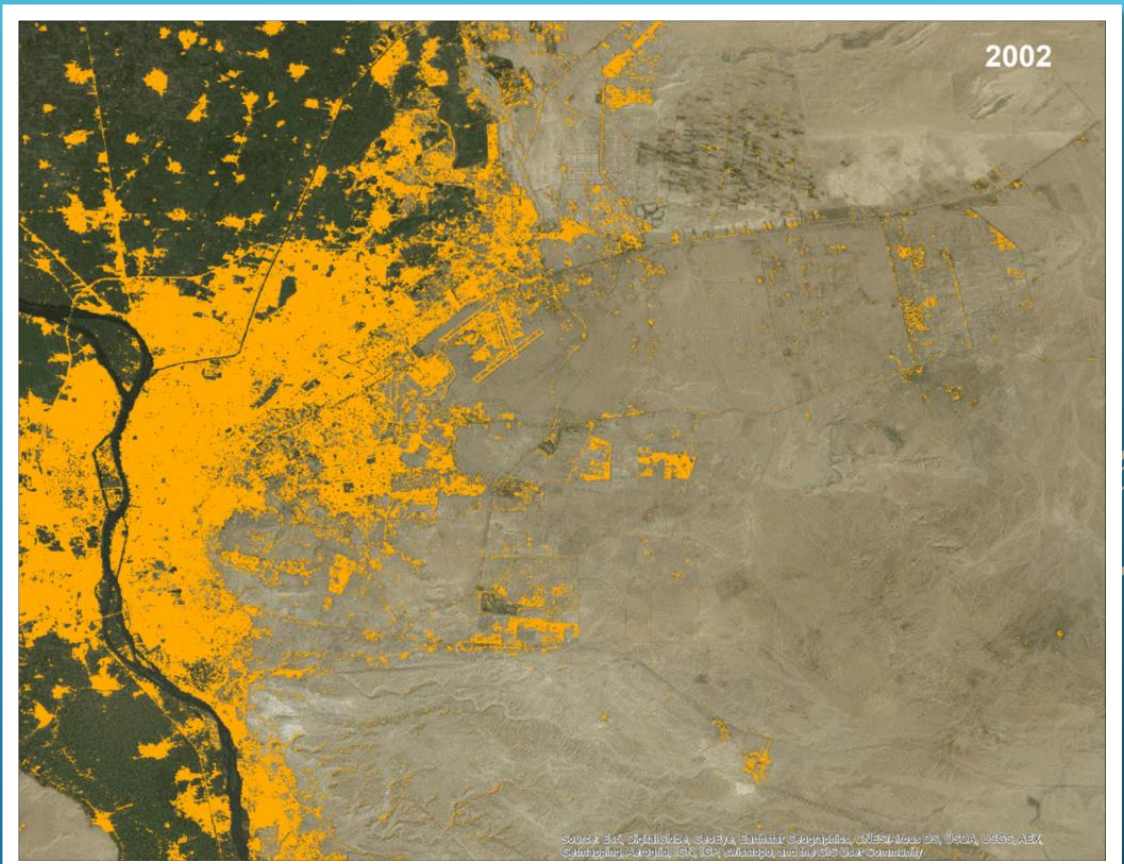


https://earthobservatory.nasa.gov/images/92529/the-most-erosive-area-on-the-padma

Addis Ababa, Ethiopia



Cairo, Egypt



LAND SURFACE TEMPERATURE (LST)

Open Access Article

Utilizing Remotely Sensed Observations to Estimate the Urban Heat Island Effect at a Local Scale: Case Study of a University Campus

by Abdullah Addas [1,*], Ran Goldblatt [2] and Steven Rubinyi [3]

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[2] New Light Technologies Inc., Washington, DC 20005, USA
[3] Urban, Disaster Risk Management, Resilience, and Land Global Practice, The World Bank, Washington, DC 20433, USA
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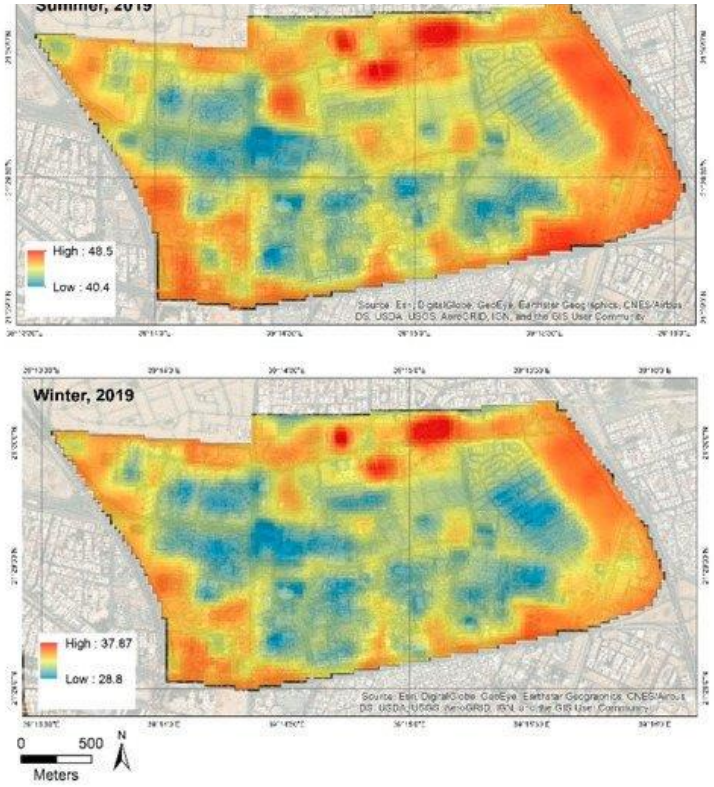
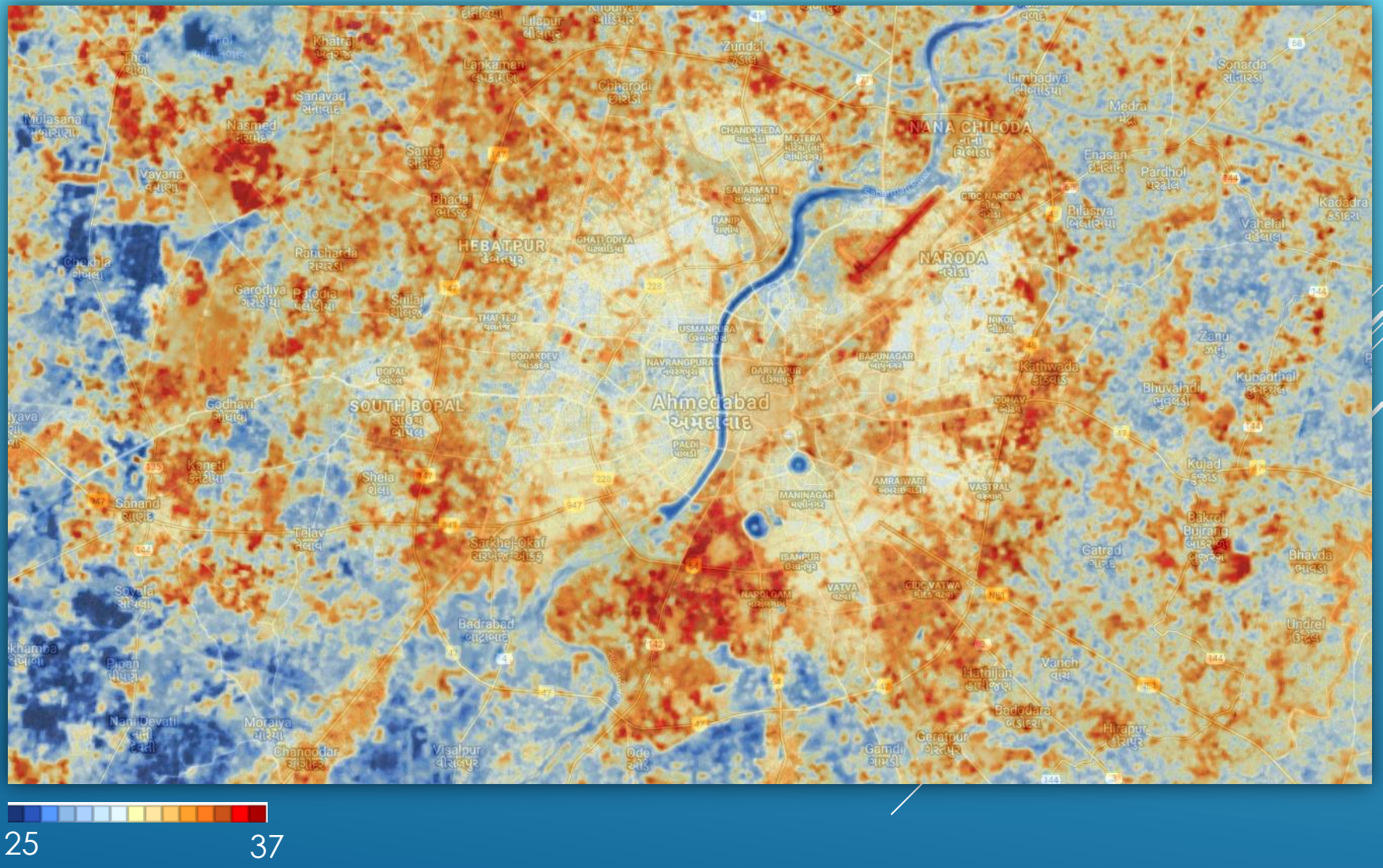
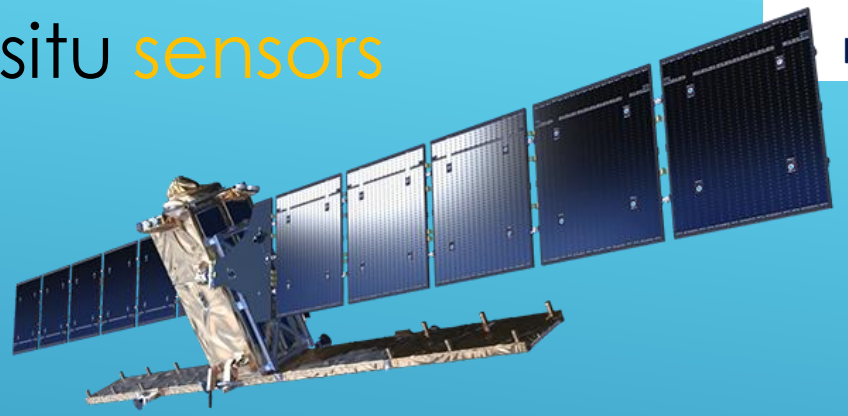




Copernicus Program (ESA)- 2010s:

Earth observation satellites and in-situ sensors



Sentinel-2 (First launched: 6/2015)

Multispectral *high-resolution imaging*

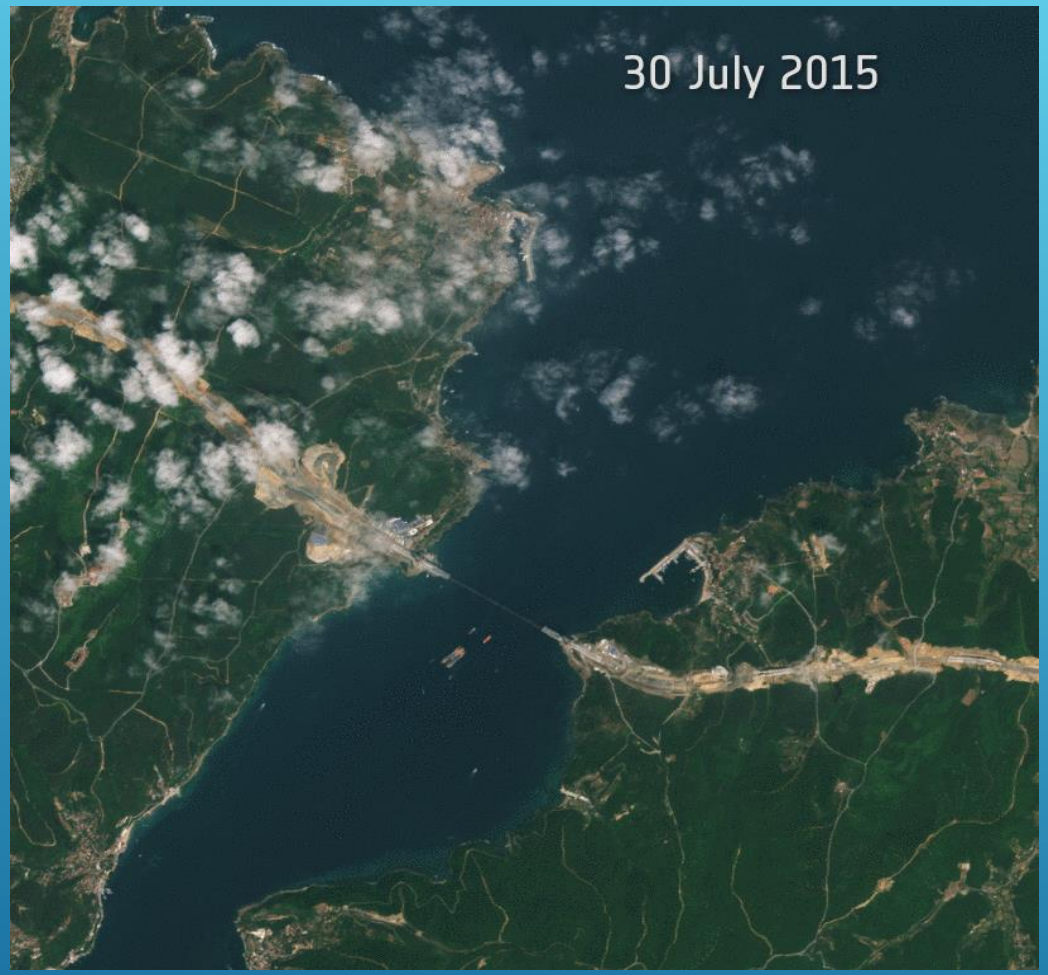
- Revisit period: 5 days at equator
- Spatial resolution: 10m-30m
- Spectral resolution: 13 bands
- Includes 3 bands in the 'red edge' (e.g. determining vegetation state).

Sentinel-1 (First launched: 4/2014)

SAR imaging

- Revisit period: 6 days
- Spatial resolution: down to 5m
- Spectral band: C-band
- Land and ocean modes
- All-weather imaging of Earth's surface

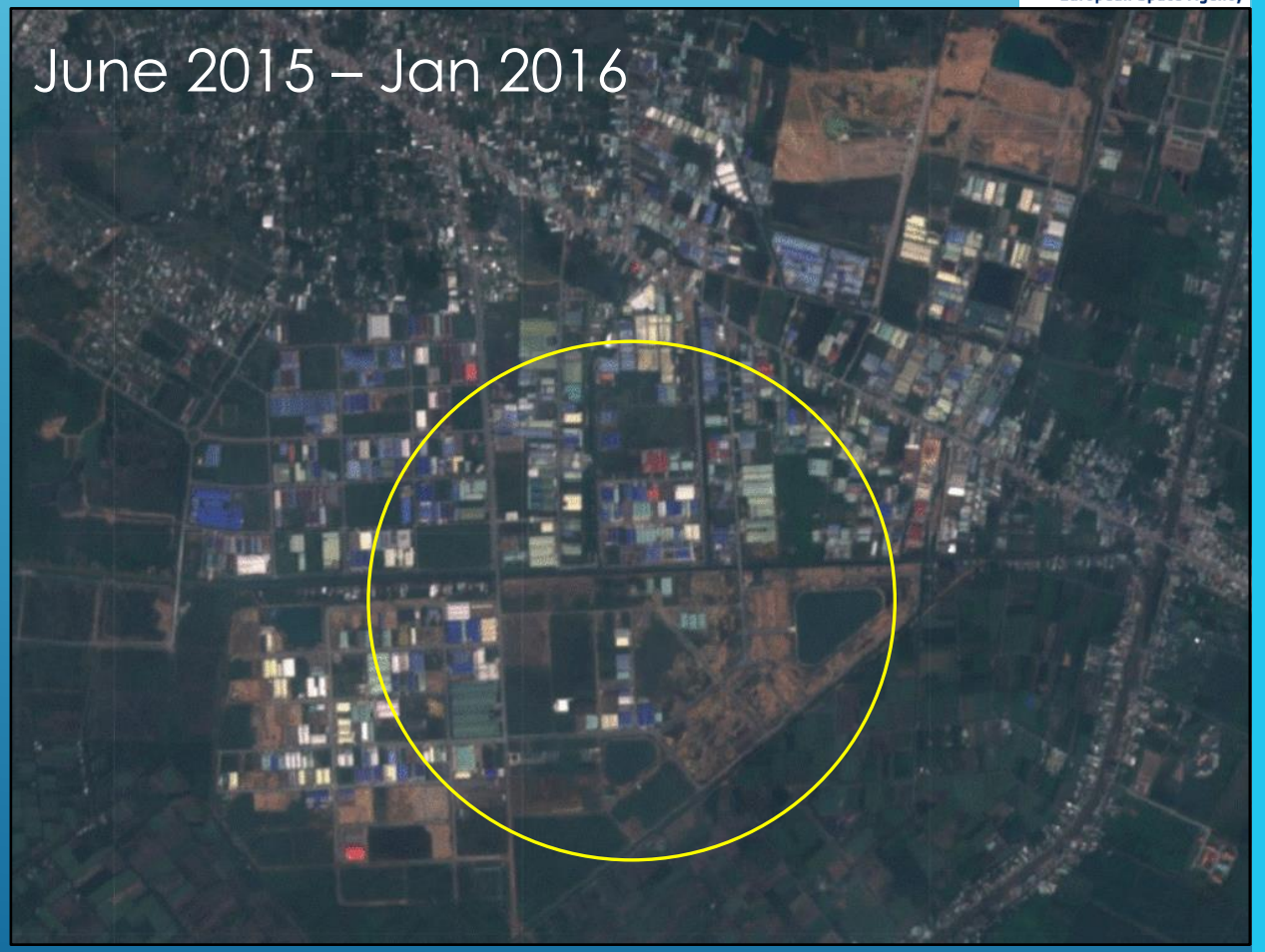
Sentinel-2



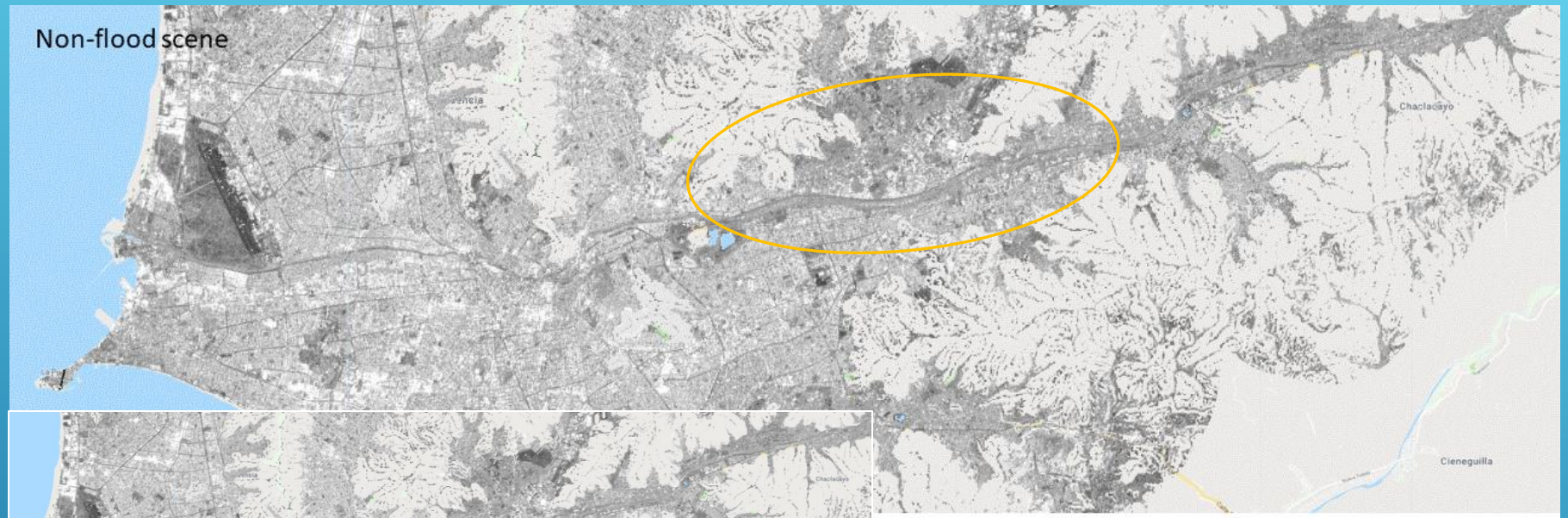
17 images from the Sentinel-2A satellite show a year of progress on the Third Bosphorus Bridge in Istanbul, Turkey

source:
http://www.esa.int/spaceinimages/Images/2016/08/Third_Bosphorus_Bridge_progress

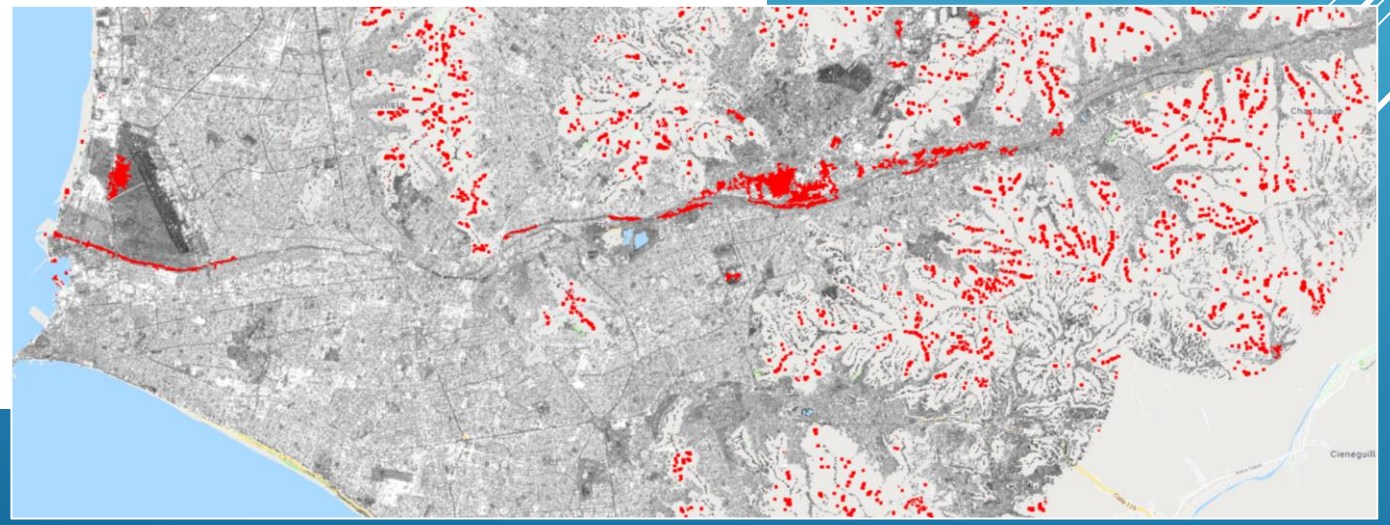
esa
European Space Agency



APPLICATIONS | SENTINEL-1



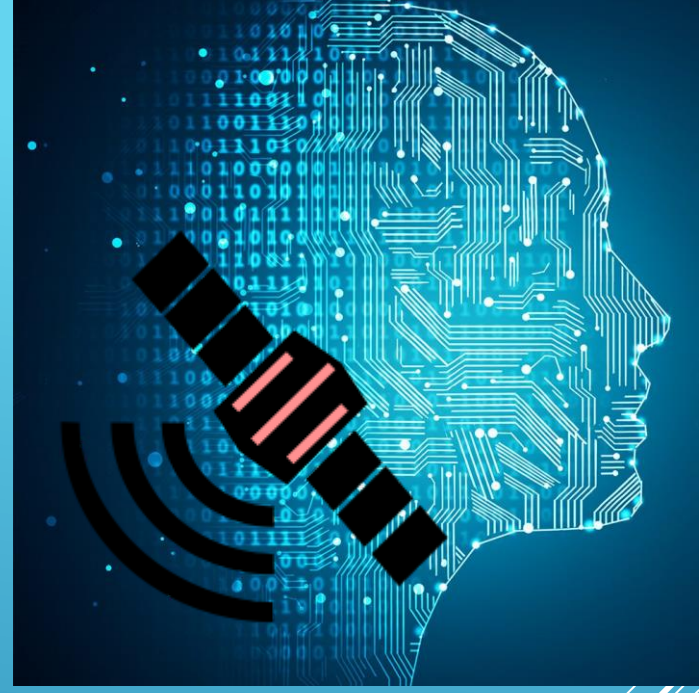
Lima, Peru. Flood event: March 2017



SAR backscatter change detection

REMOTE SENSING AND MACHINE LEARNING

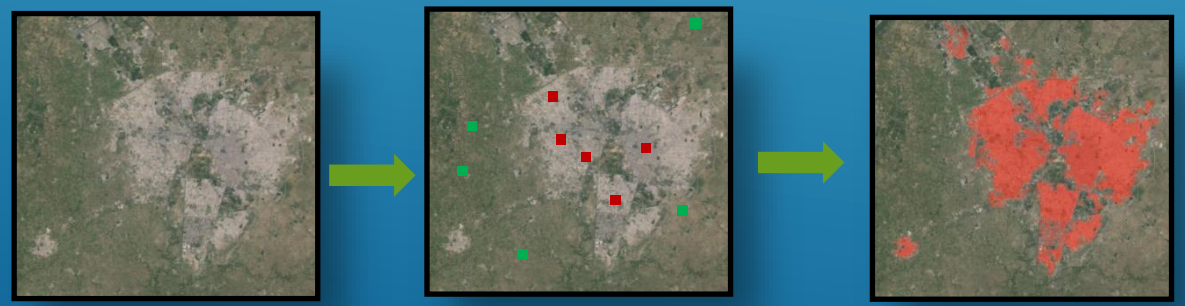
The domain of **MACHINE LEARNING** focuses on:
How machines learn rules from examples?



The goal:

- Learn patterns from examples;
- Be able to generalize them to new examples.

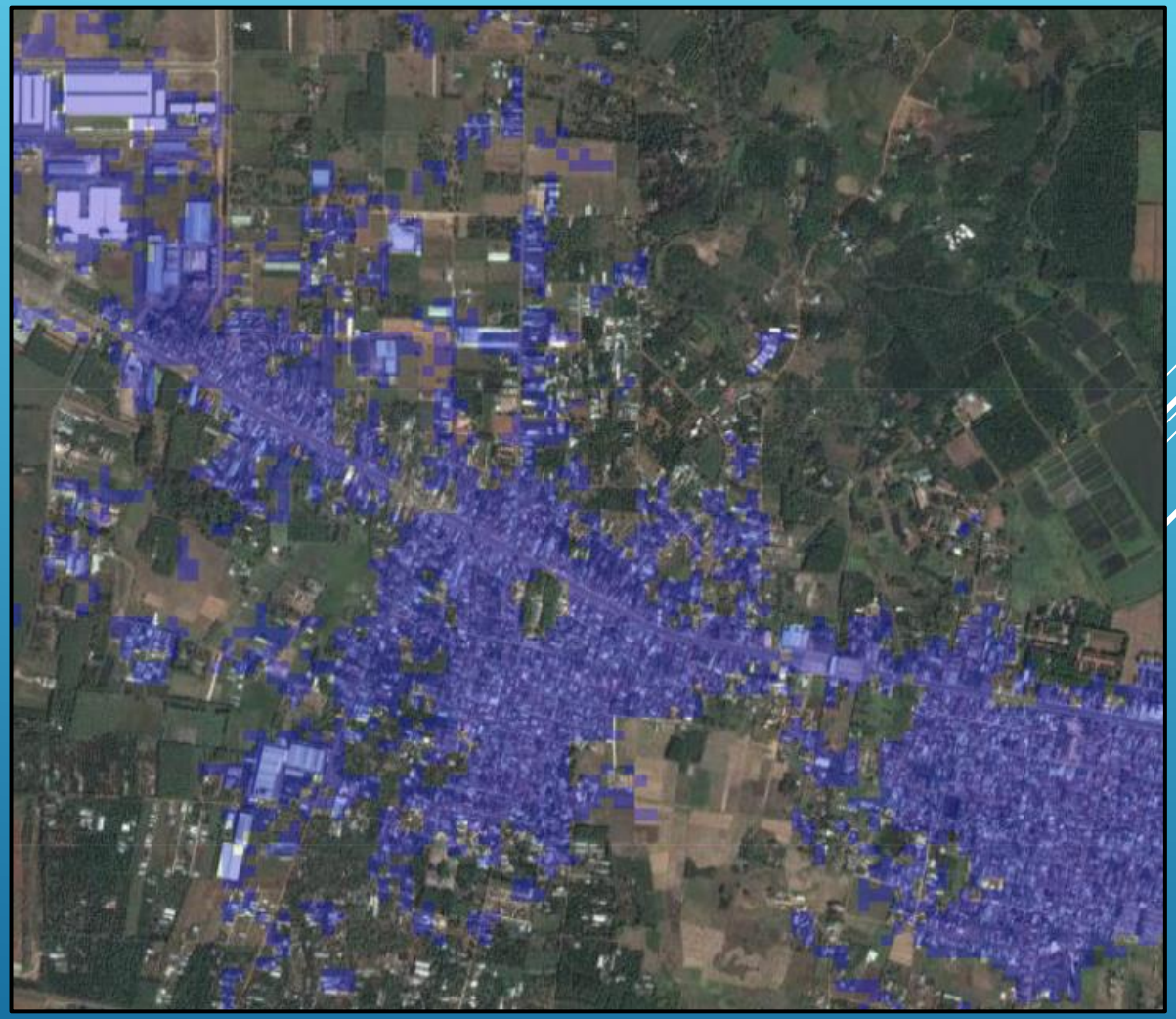
Supervised Image Classification



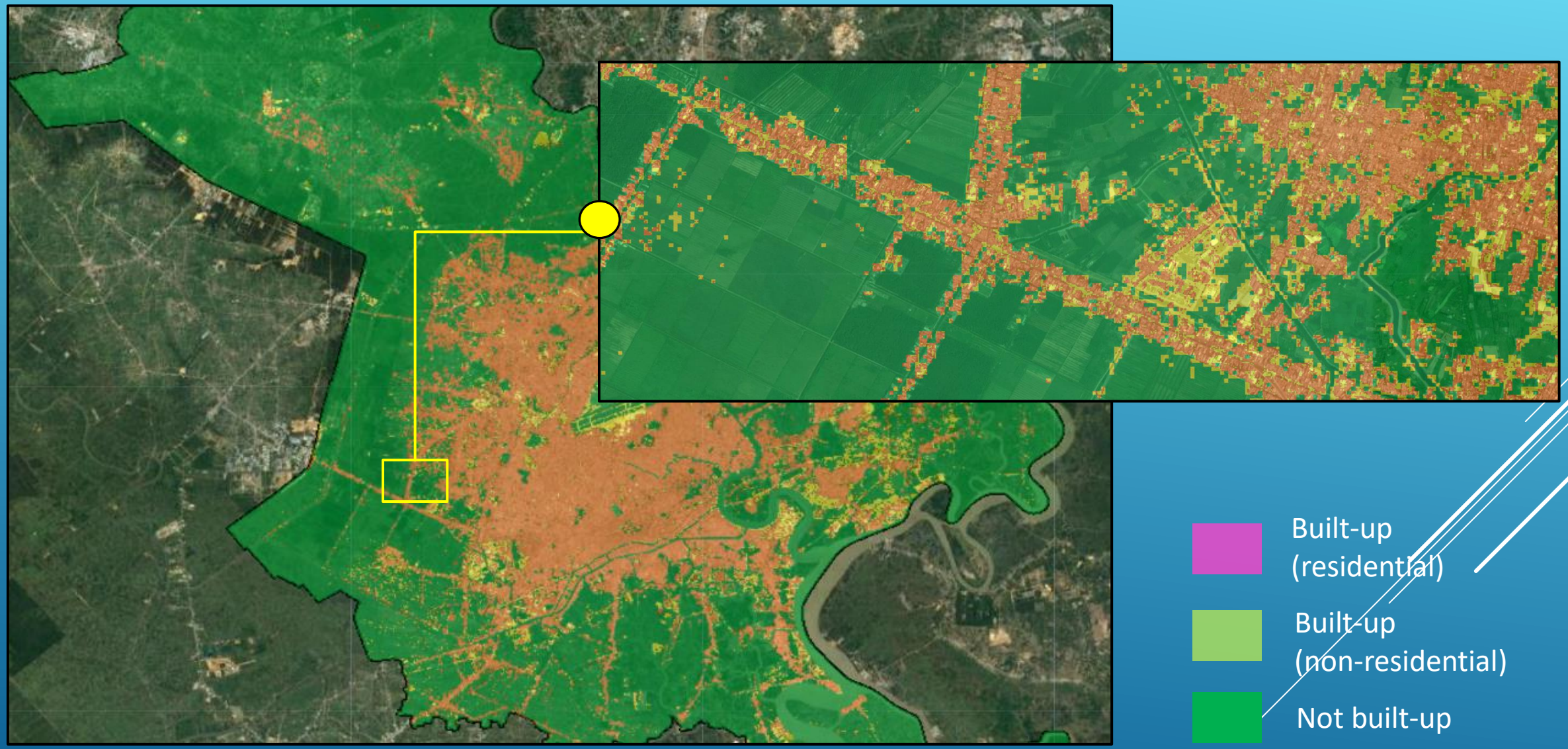
satellite image Real examples prediction

From DATA to INSIGHTS

Built-up LC



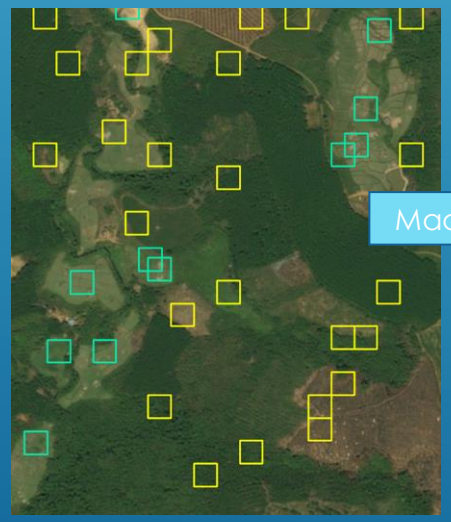
“BUILT-UP” RESIDENTIAL AND NON-RESIDENTIAL



Ho Chi Minh City, Vietnam
Funded by the World Bank

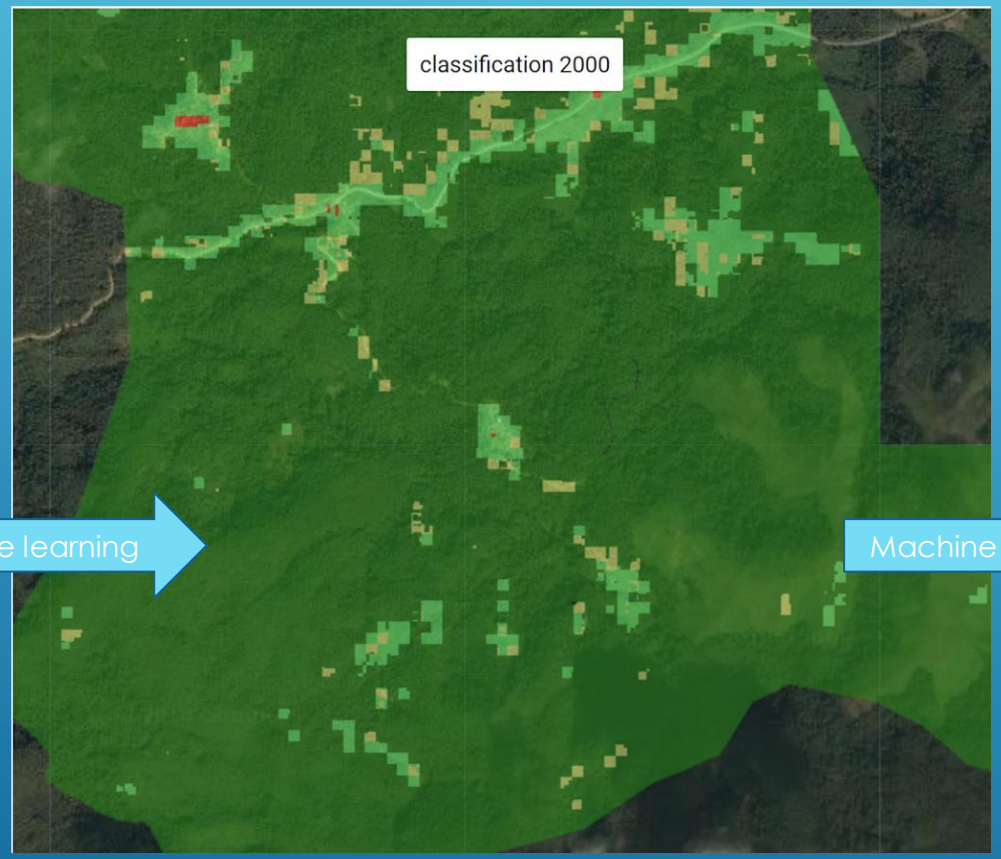
IMAGE CLASSIFICATION OF **LAND USE** AND **LAND COVER**

An automated and easy-to-use methodology for mapping annual land cover changes

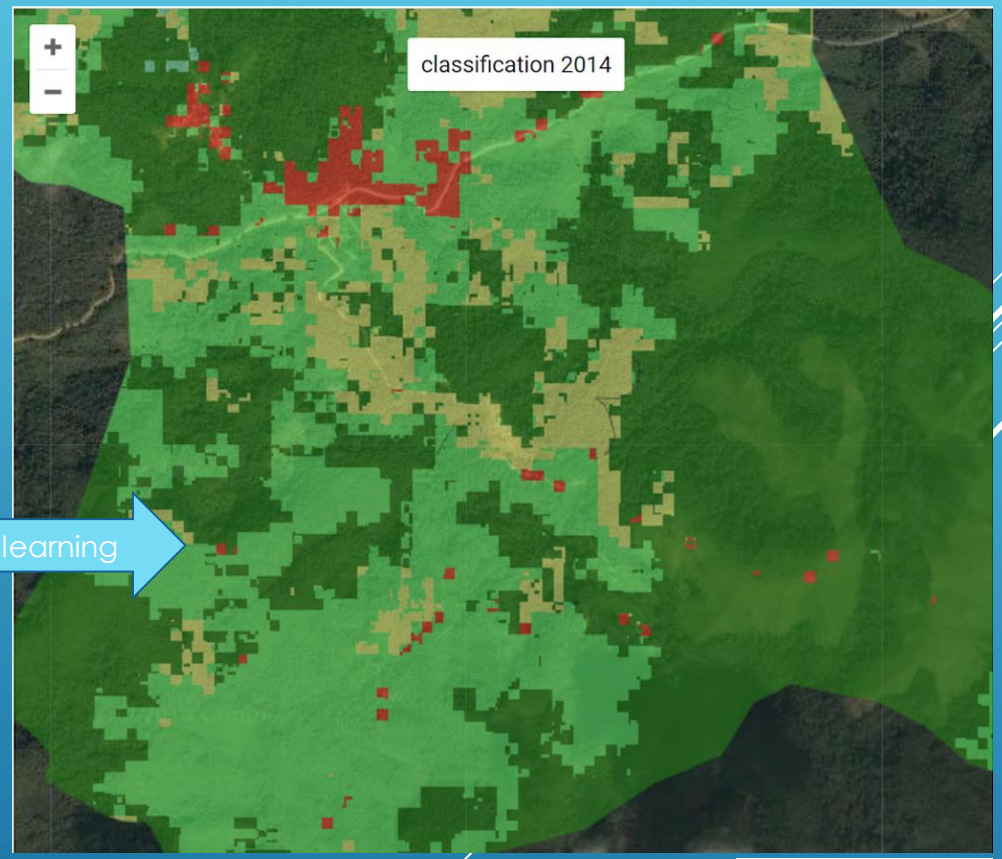


Several thousands of hand-labeled examples

Machine learning

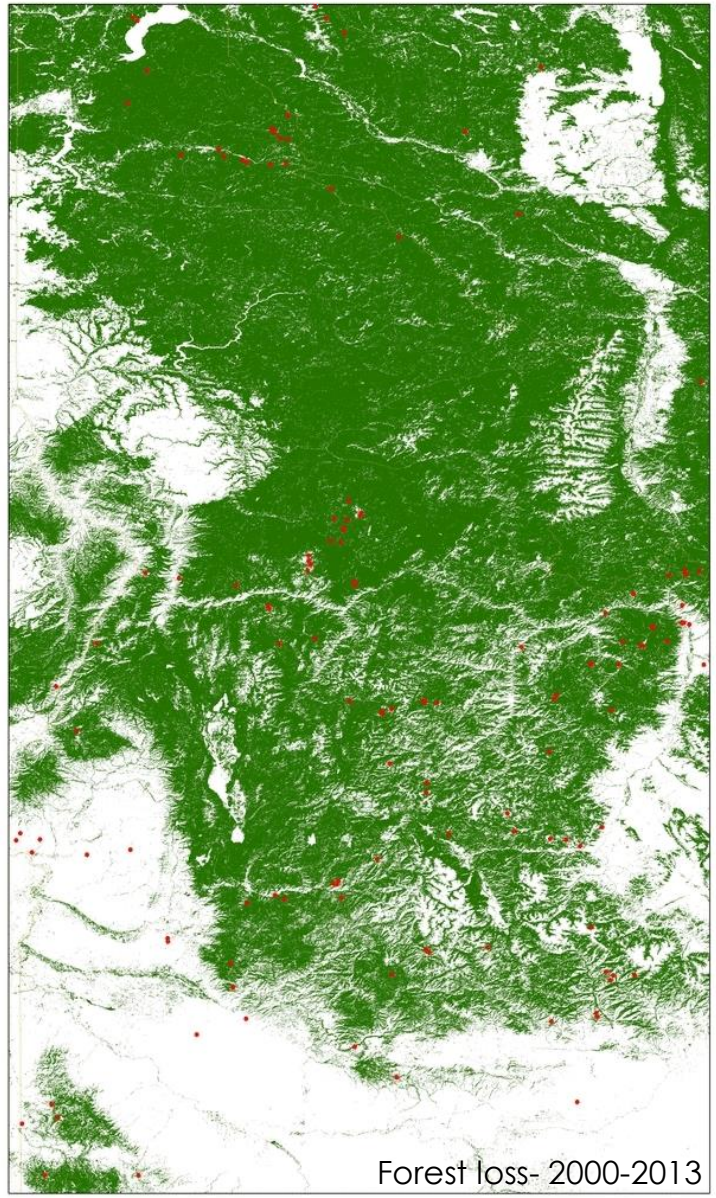


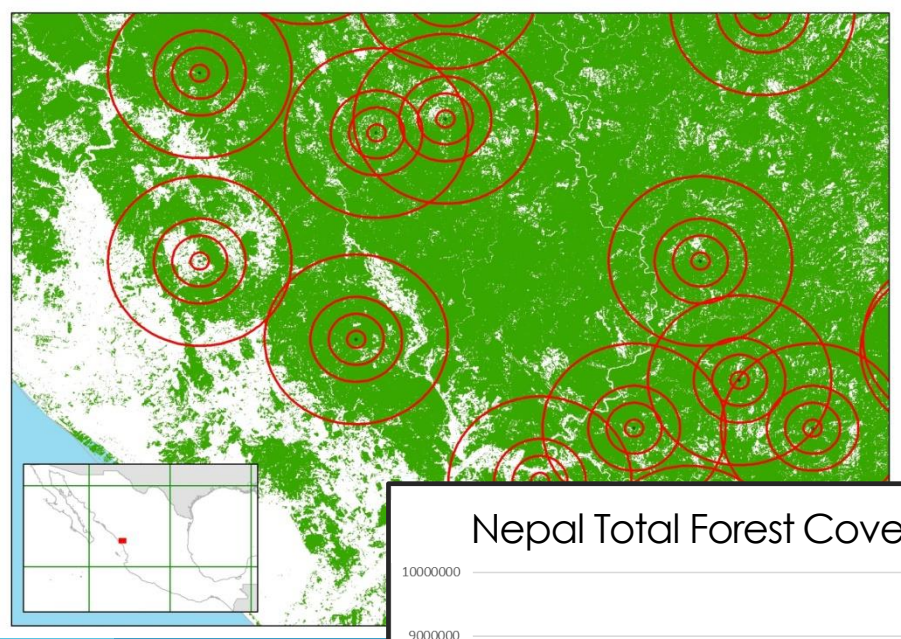
Machine learning



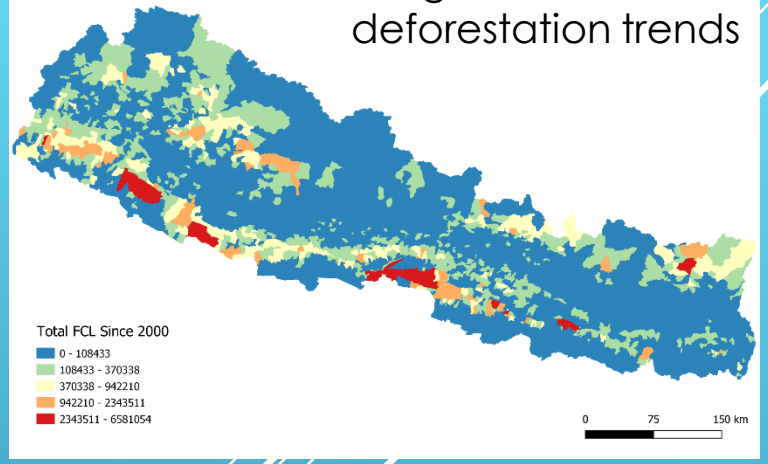
Conversion from
natural forest cover to agriculture land

Forest cover and mining activity

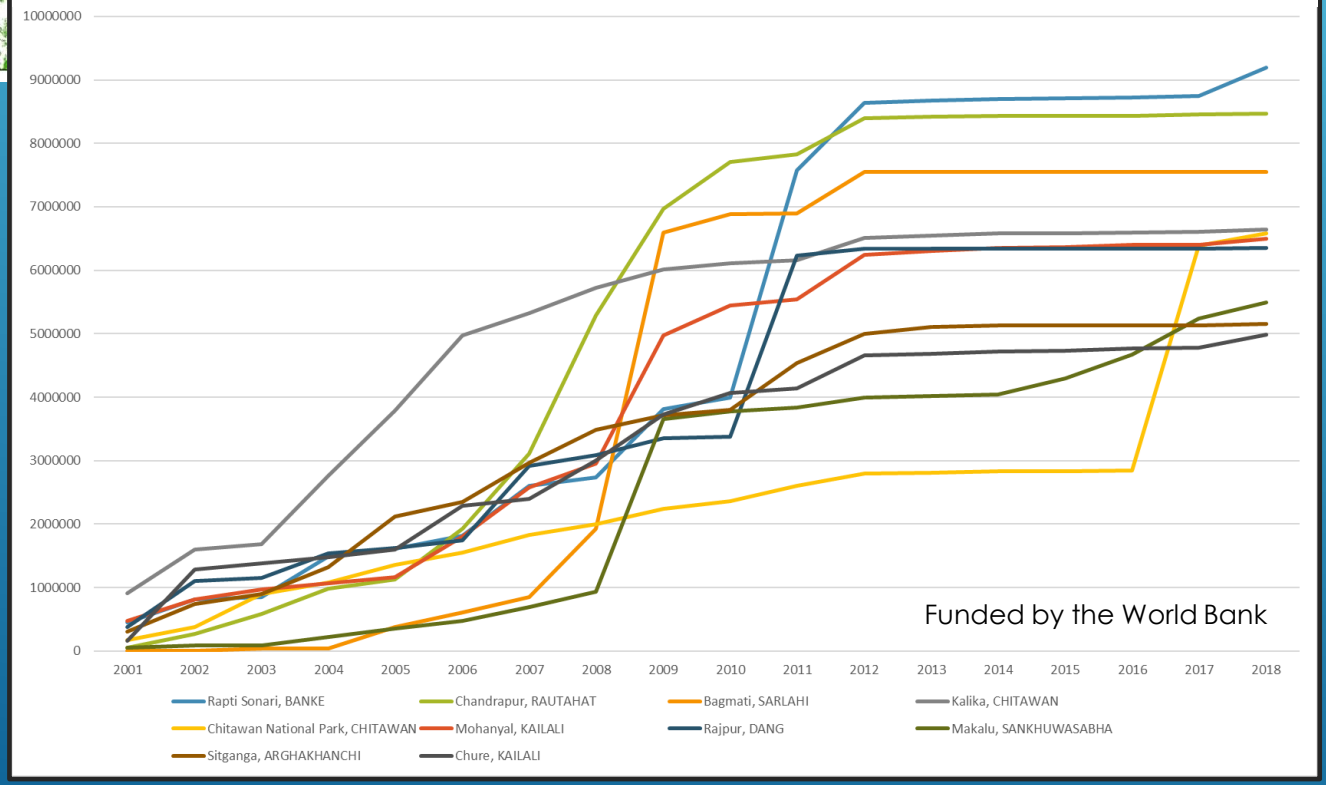




Regional and local deforestation trends



Nepal Total Forest Cover Loss Since 2000 Administrative District 3

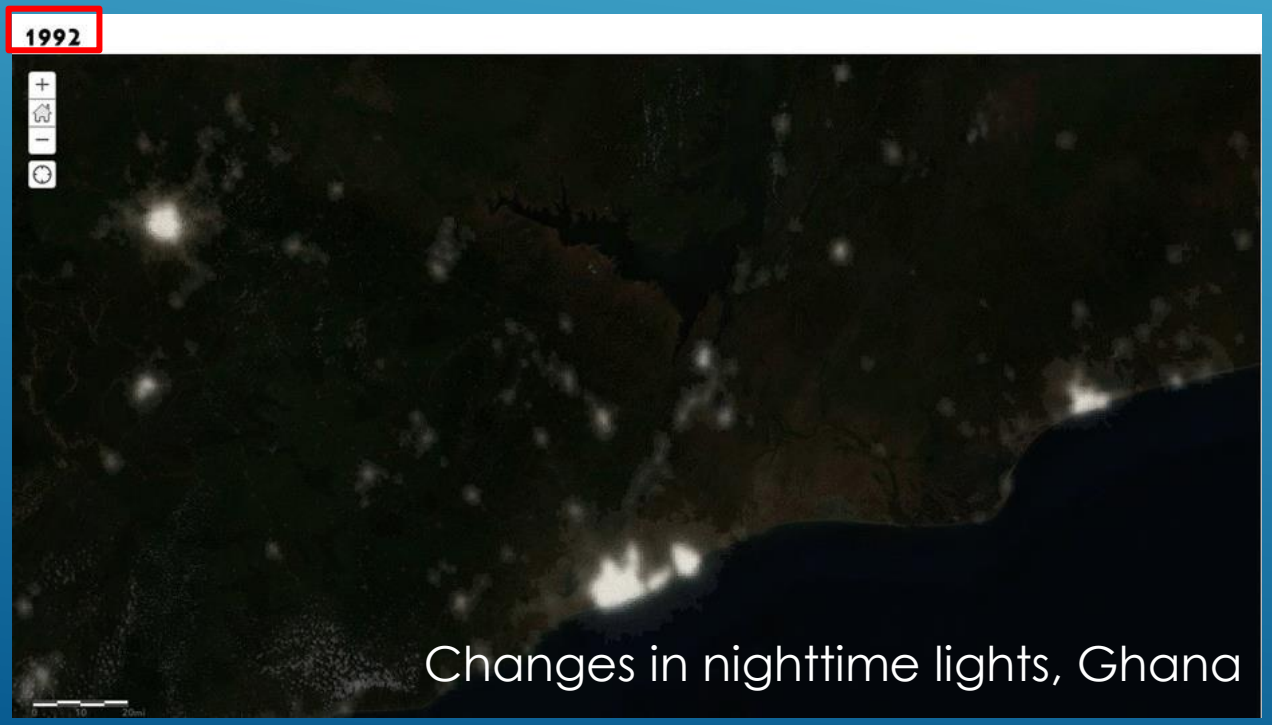


Funded by the World Bank

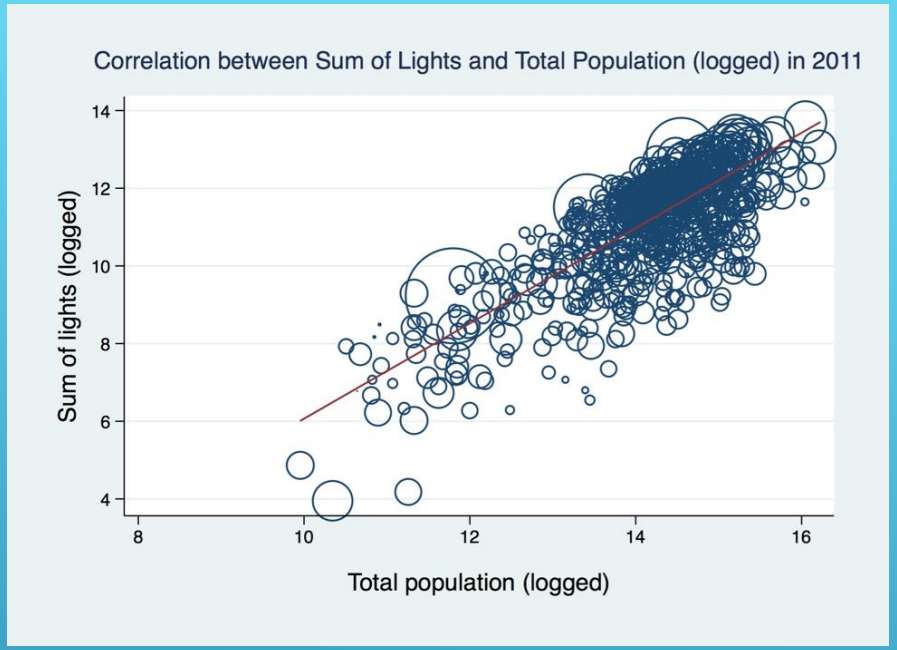
Google

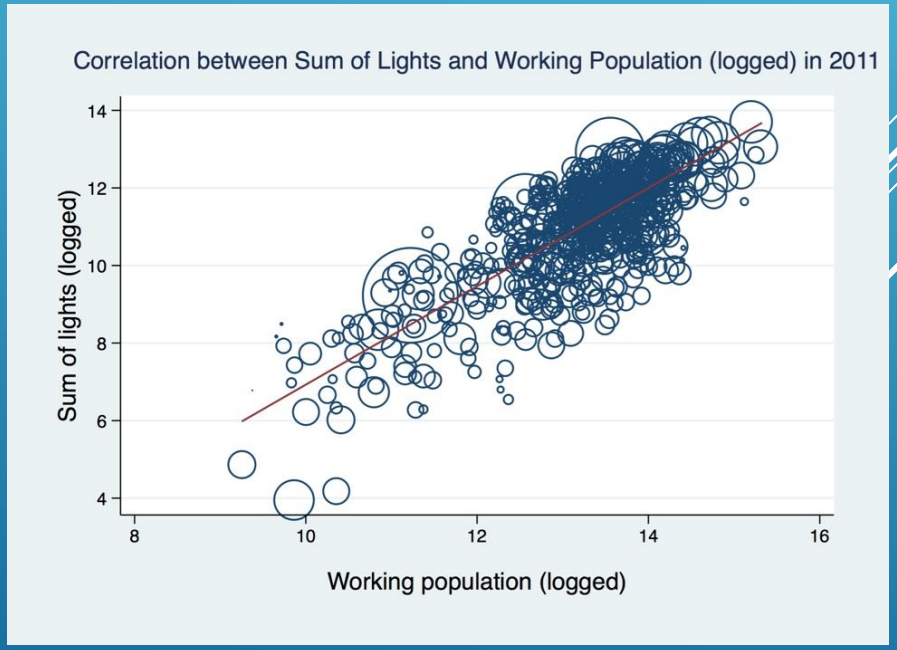
India night light

Google Search I'm Feeling Lucky

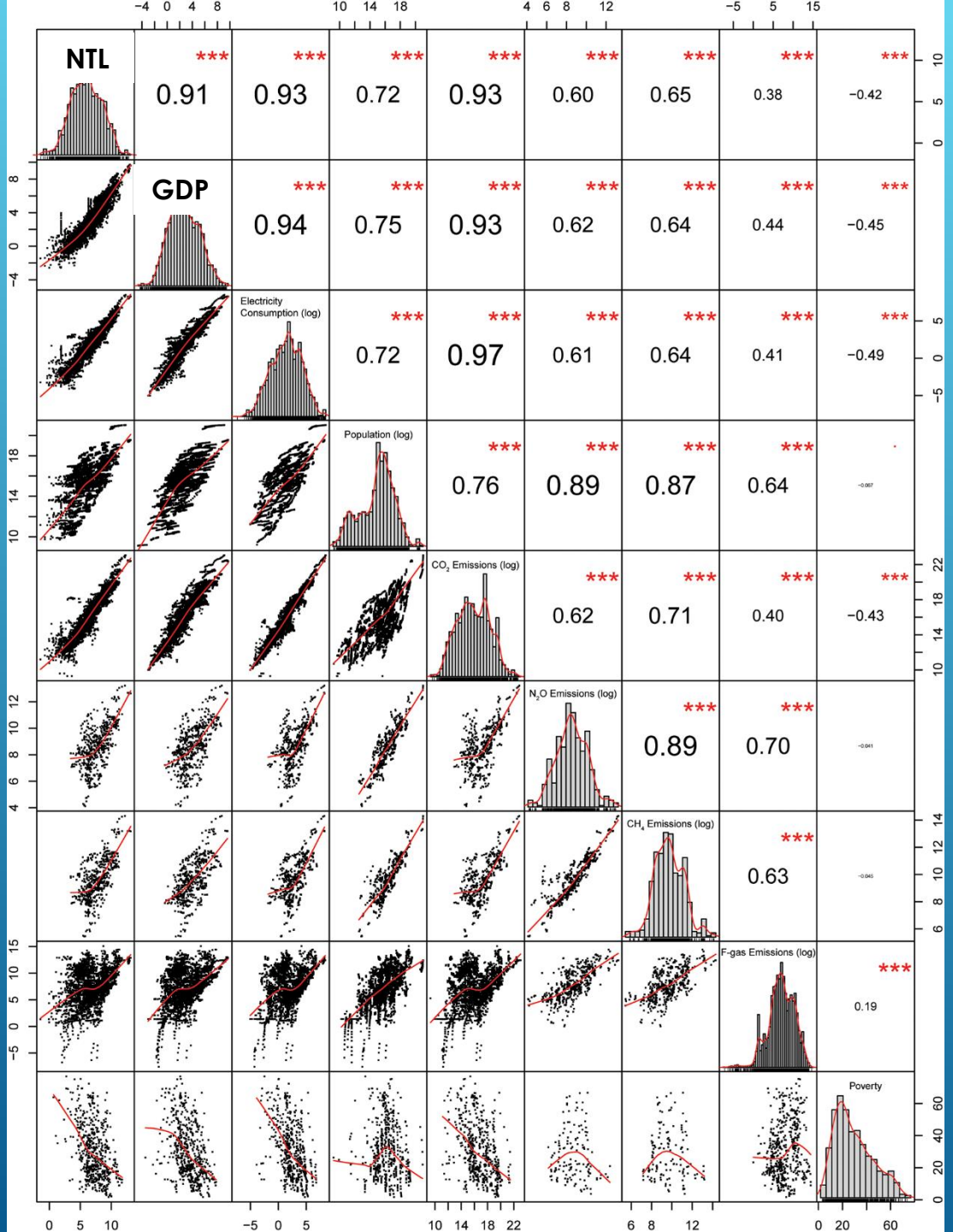


Changes in nighttime lights, Ghana





Henderson et al., 2017



Night-time lights: A global, long term look at links to socio-economic trends

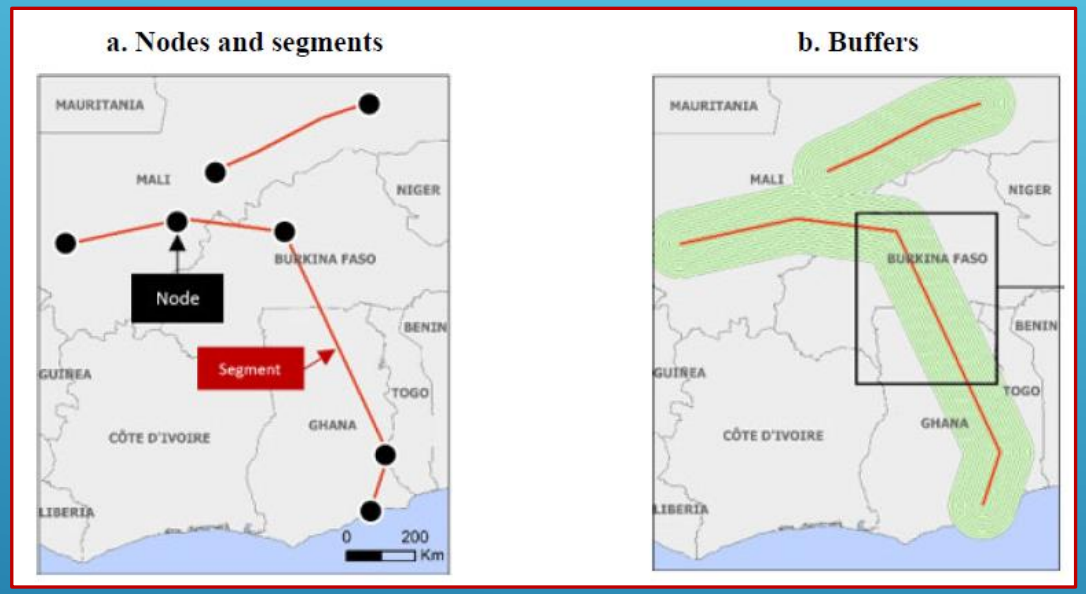
Jeremy Proville, Daniel Zavala-Araiza, Gernot Wagner

Published: March 27, 2017 • https://doi.org/10.1371/journal.pone.0174610

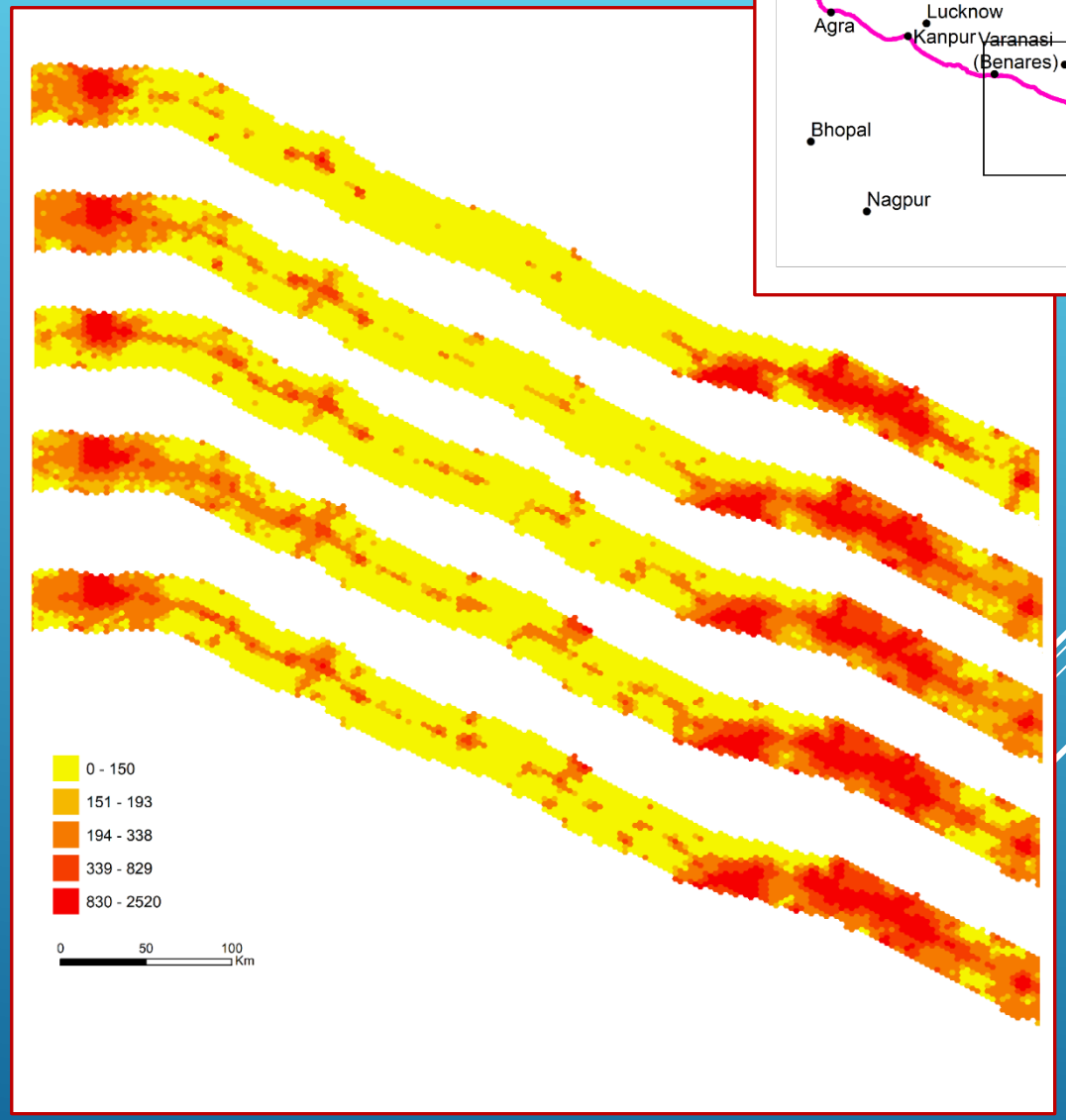
Correlation between area lit and a collection of socio-economic indicators.

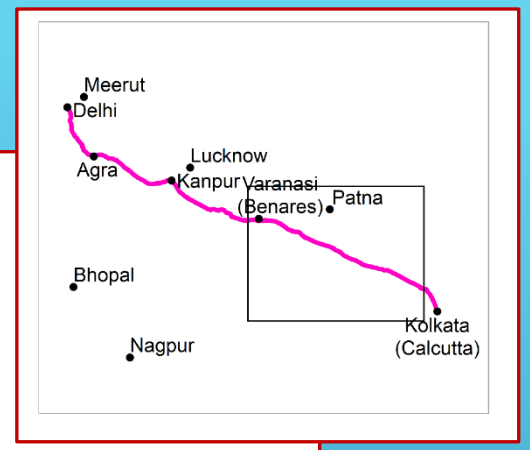
The matrix shows links between logarithms of Area Lit, **GDP**, **Electric Power Consumption**, **Population**, **CO_2** Emissions, **N_2O** Emissions, **CH_4** Emissions, **F-gas** Emissions, and non-log **Poverty Headcount Ratio**.

THE **ECONOMIC BENEFITS** OF INFRASTRUCTURE INVESTMENT



Case study: Golden Quadrilateral





1995

2000

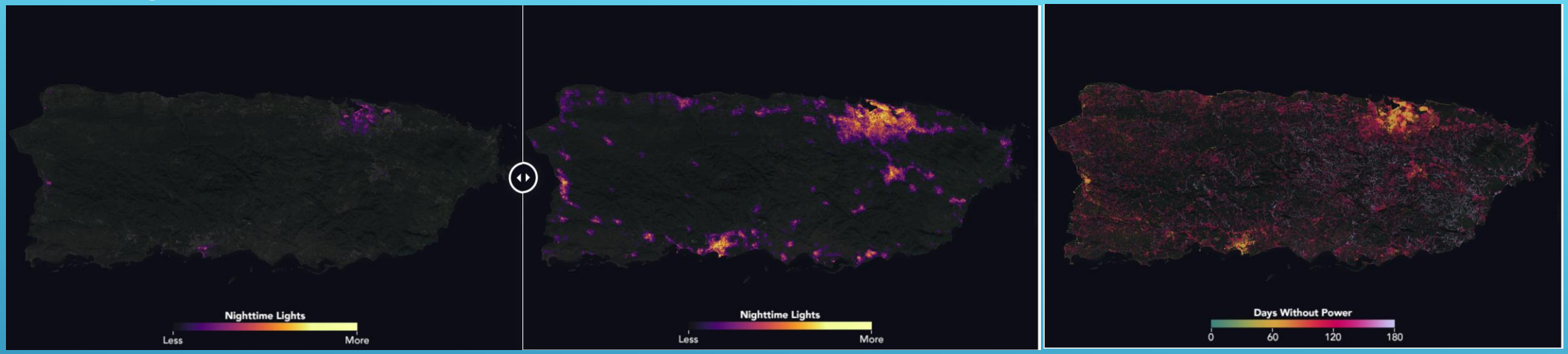
2005

2010

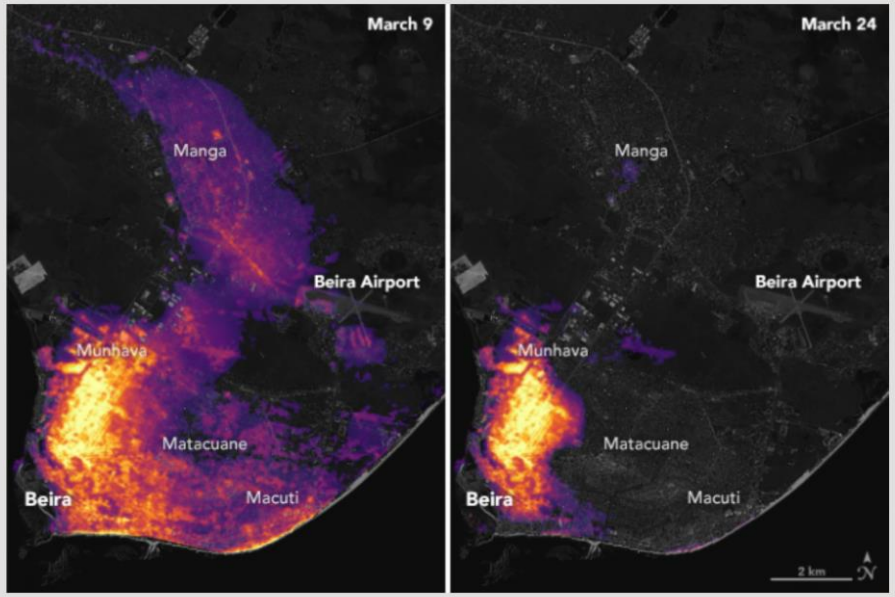
2012

Funded by the World Bank

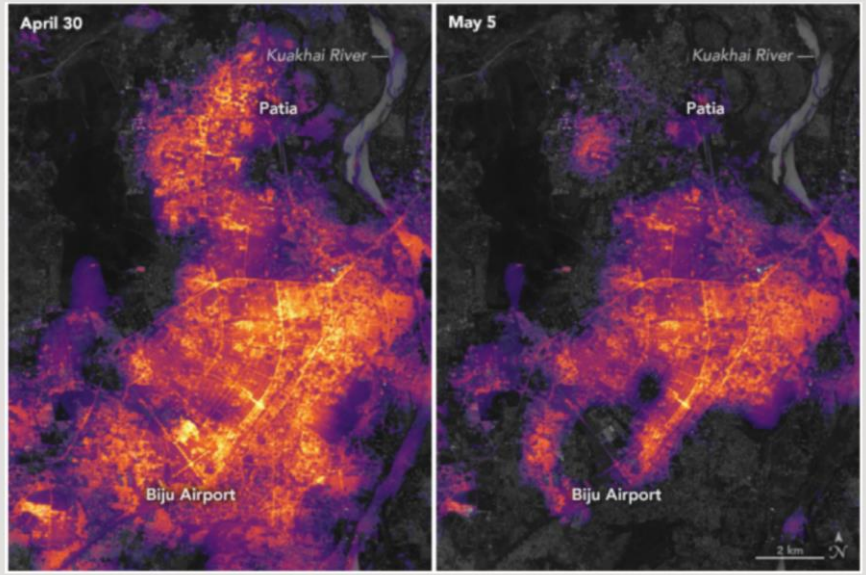
Recover post Hurricane Maria



https://earthobservatory.nasa.gov/images/144371/night-lights-show-slow-recovery-from-maria



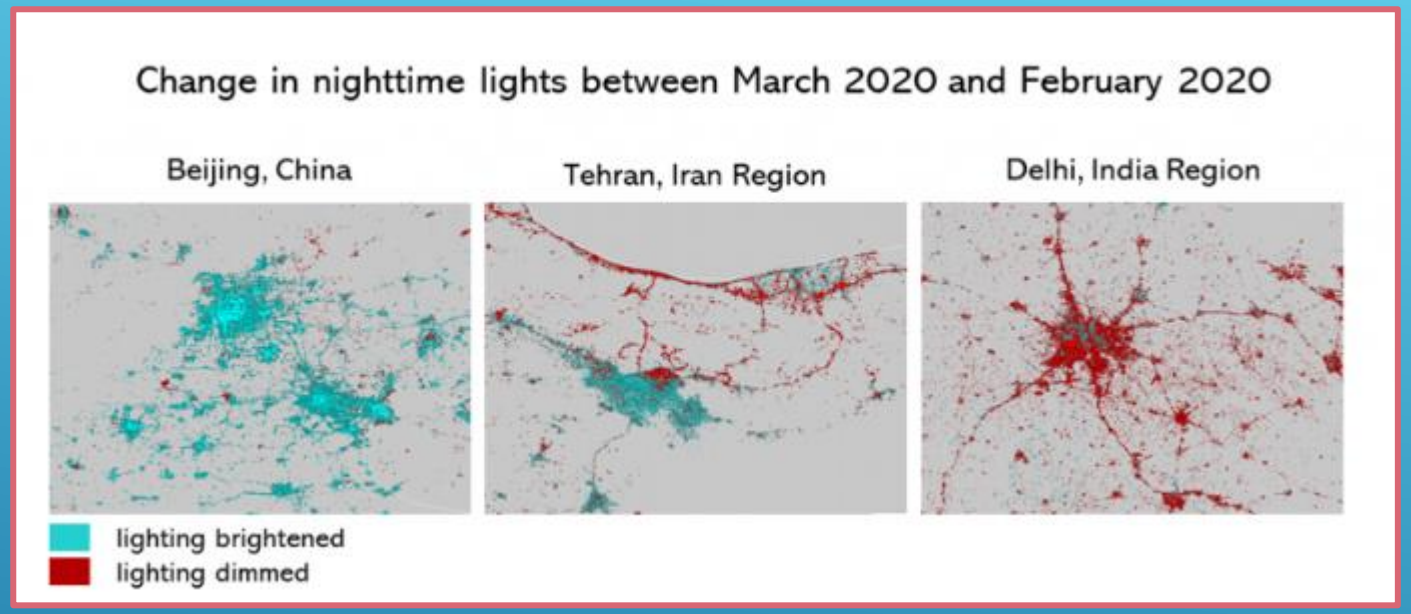
VIIRS Black Marble imagery of Mozambique comparing before (March 9th, 2019) and after (March 24th, 2019) flood impacts from Cyclone Idai.



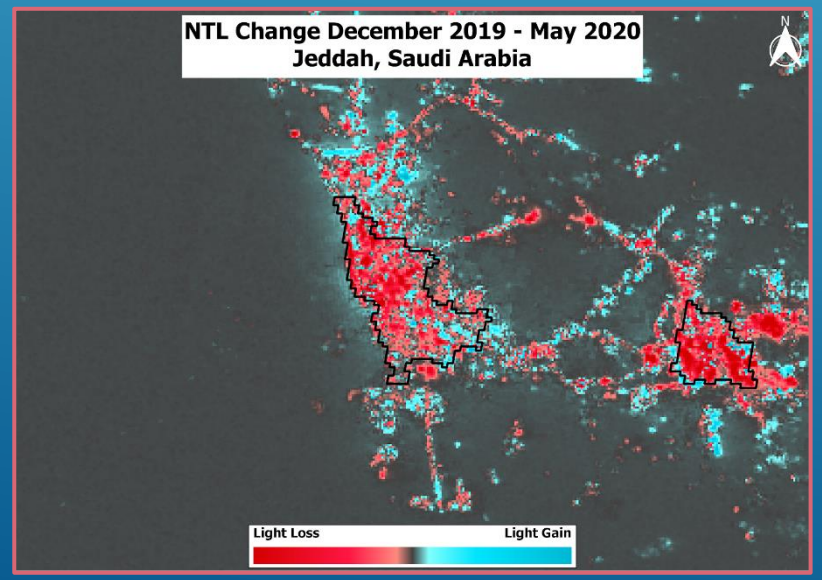
VIIRS Black Marble imagery of nighttime lights in Bhubaneswar India, comparing April 30th and May 5th 2019. Credit: NASA Earth Observatory, Ranjay Shrestha / NASA GSFC

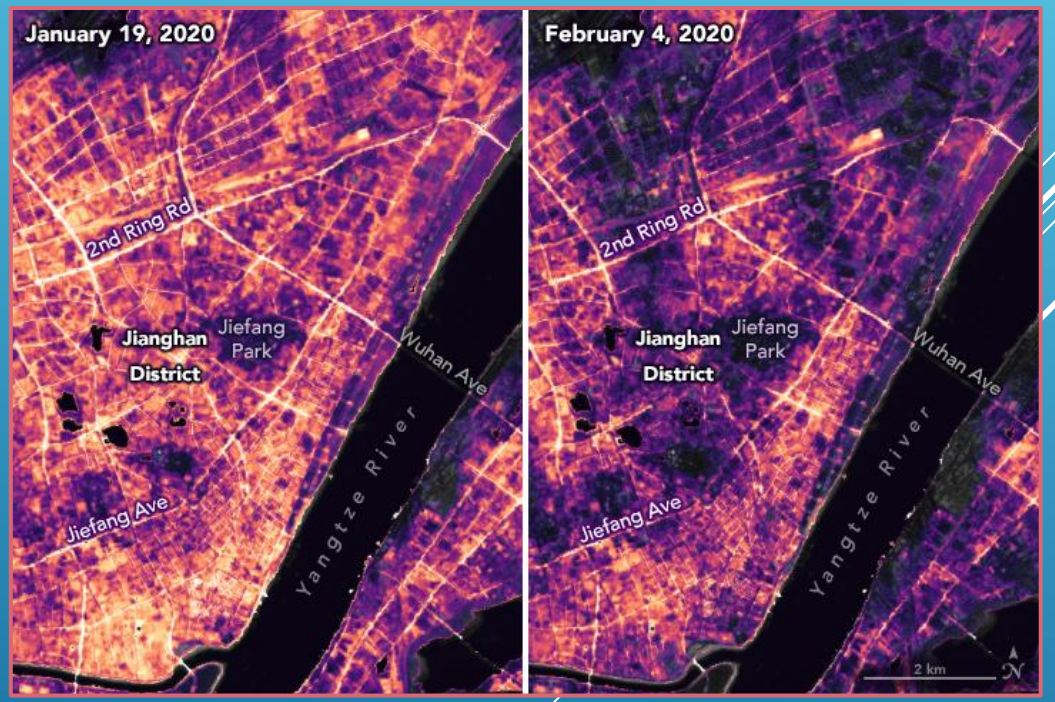
Black Marble data

THE ECONOMIC IMPACTS OF COVID-19



Changes in the intensity of nighttime lights can be used to illustrate pace of recovery. These images show changes in nighttime lights between March 2020 and February 2020. Cyan = lighting brightened, Red = lighting dimmed. Source: Elvidge et al., 2020. The Payne Institute for Public Policy.





Changes in activity around the city of Wuhan, China, between January 19 and February 4, 2020, as observed by nighttime lights. Source: NASA's Goddard Space Flight Center (GSFC) and Universities Space Research Association (USRA).

How can satellite data help improve IEs?

- **Measuring outcomes of interventions**

Examples: Measuring economic growth, GDP, poverty, wealth, infrastructure quality, population distribution, land productivity, ground water.

- **Constructing (unbiased) comparison groups**

Satellites continuously collect data (both temporally and spatially, thus data is **not susceptible to self-selection bias** like other sources of big data.

- **Long term impacts**

With satellite data it is possible to **collect pre- and post-program data**, including **follow-up data**, without the need for going to the field.
→ Allowing measurement of long-term program impacts, which can help analyze how the impacts evolve over time and how long they last.

Overcoming analytical challenges

- **Assessing pre-program trends**

Historical satellite imagery makes it possible to **evaluate parallel trend assumptions** and find pre-program similarities between treatment and control groups.

- **Controlling for covariates**

With satellite data it is possible to **control for local time-varying factors** through a **fixed effects approach** at the level of individual pixels and for time-invariant factors according to the **reflectance characteristics of individual pixels**. Reducing potential for an ***omitted variable* bias.**

- **Heterogeneous Effects**

Satellite data allows to **estimate heterogeneous effects** based on **observable baseline conditions** such as population density at the cell-level, etc. with sufficient power for **sub-group analysis**. Less reliance on the **average treatment effect** for an **entire treatment group .**

Overcoming analytical challenges (cont.)

➢ Robustness analyses

- Satellite data can help conduct robustness analyses by allowing **identification of multiple comparison groups** (expensive with traditional data collection methods).
- **Placebo tests can be conducted through testing the treatment effect** on the treated site(s) for an arbitrary pre-program date.

➢ External validity and generalizability

Satellite data are available not only for the program area, but also for the **country/regional context**. This allows evaluation of the external validity of the results by considering the broad spatial context.

Overcoming logistical challenges

- **Cost of data collection**

A fundamental challenge of IEs is the cost of survey data collection, which can reach up to USD 400k (according to 3ie). The survey alone can cost up to USD 200k. In comparison, the cost of a desk-based impact evaluation with free satellite data would be around USD 150k.

- **Retrospective, desk-based evaluation**

Historical time series satellite data allows retrospective assessment of programs already implemented and in most cases the evaluation can be implemented remotely.

TO SUMMARIZE

- Satellite data is revolutionizing how understand Earth
- Free satellite data is increasingly available at high spatial, spectral and temporal resolutions
- Cloud based computational platforms allows one to scale the analysis across space and time
- AI and ML approaches allows to translate the collected data into meaningful information that can be used for an informed decision making.
- Increasingly, sources of geospatial data and satellite imagery are being utilized to support and improve the process of IEs.

THANK YOU!

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