Earth Engine for Nature-based Climate Solutions

October 2023 | #GeoForGood23

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BOKU (Austria)
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The Nature Conservancy (US)

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NASA & Stanford University

Assessing leakage from carbon offset projects

Megan Ayers

October 2023 | #GeoForGood23

Agenda

01 **Intro to carbon offsets**
Why do entities purchase offsets? What is purchased?

02 **Evaluating carbon offsets**
What is a baseline, and what is additionality? How can GEE allow us to measure offsets?

03 **Carbon leakage**
What if decreasing emissions in one location causes increased emissions elsewhere?

04 **Measuring leakage with an RCT**
How could we perform an experiment with carbon credits to evaluate leakage?

05 **Takeaways**

Intro to carbon offsets

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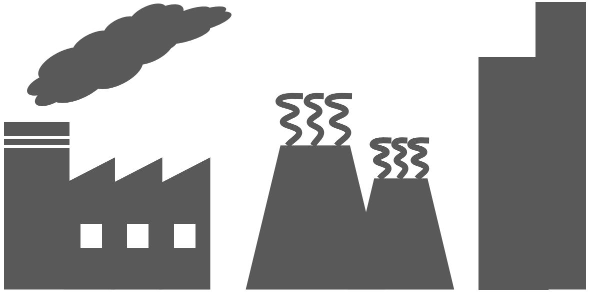
Who is purchasing carbon offsets?

Individuals, companies, and governments producing emissions beyond their targets



Emitting entities purchase carbon offset units

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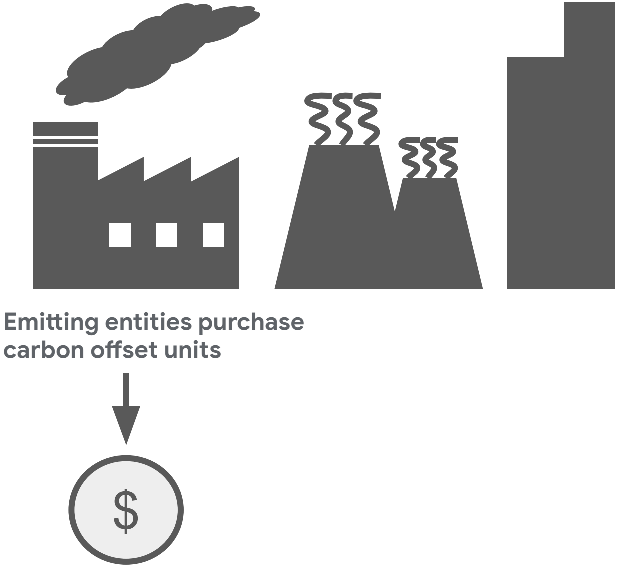
What is being purchased?
A waiver allowing the buyer to emit a certain amount of CO2



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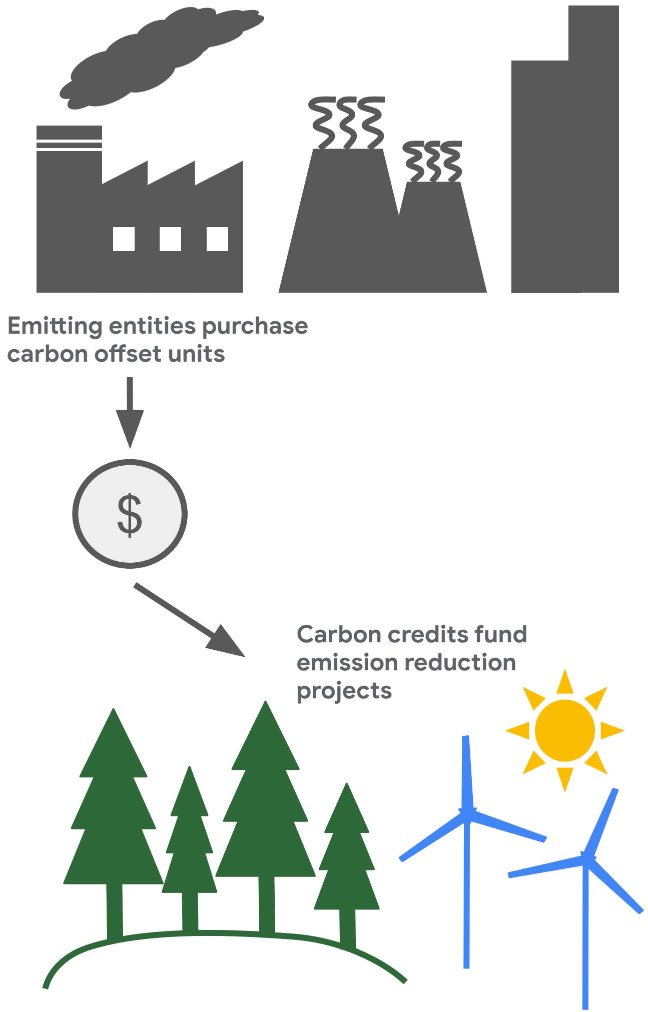
Where does the offset come from?
Projects receive carbon credits in exchange for preventing CO_2 emissions or sequestering carbon



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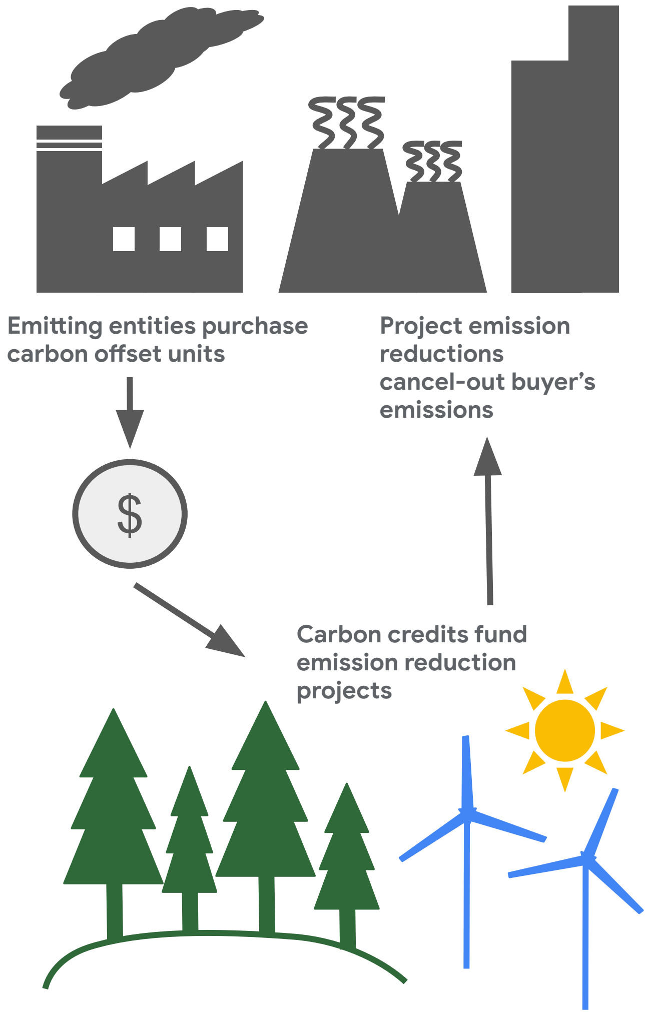
Why are the credits purchased?
To “offset” the buyer’s ongoing emissions



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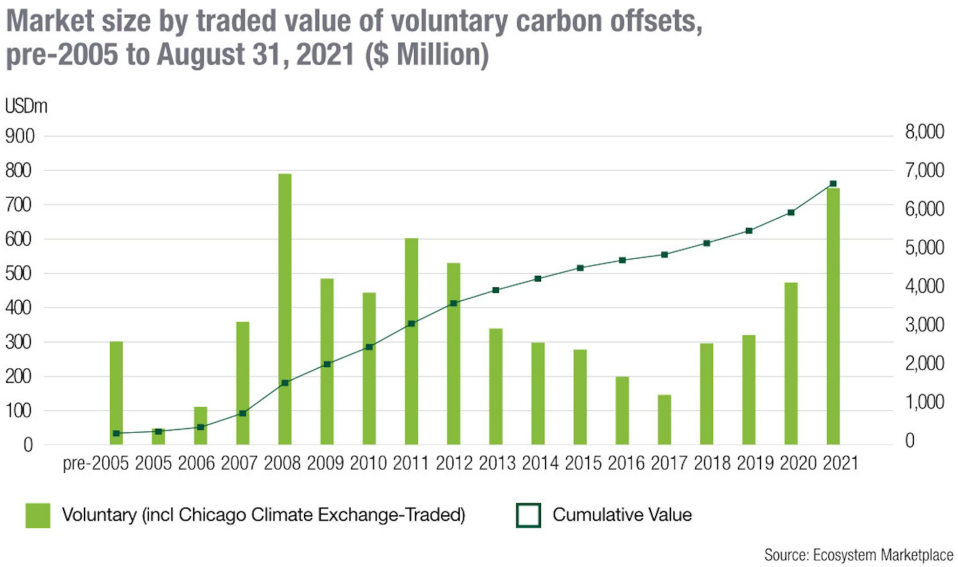

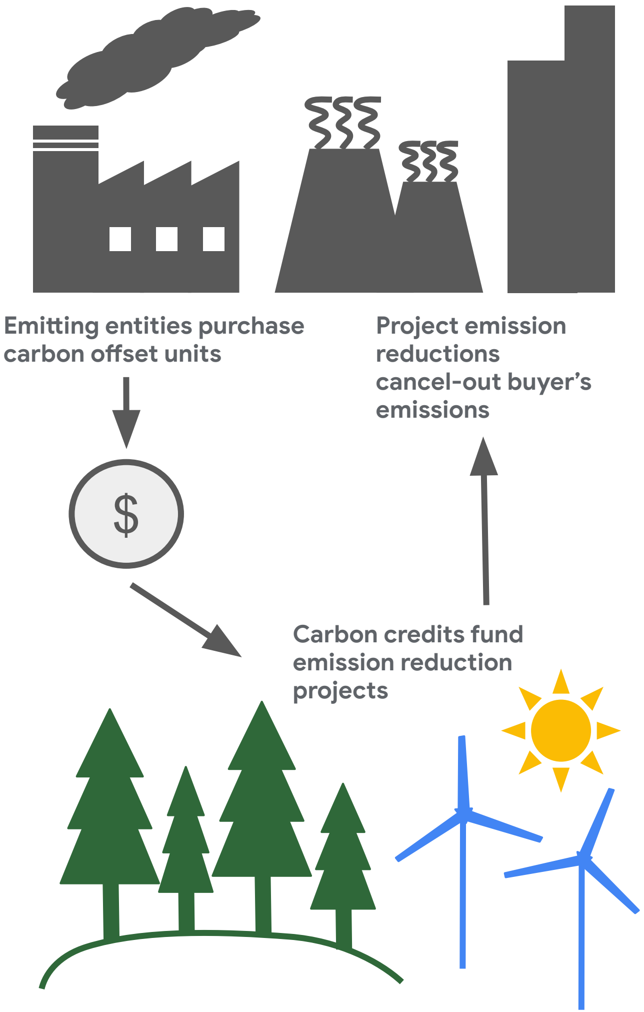

Measuring carbon offsets

How are offsets calculated?

Baseline and additionality

Offsets rely on claims about a counterfactual scenario.

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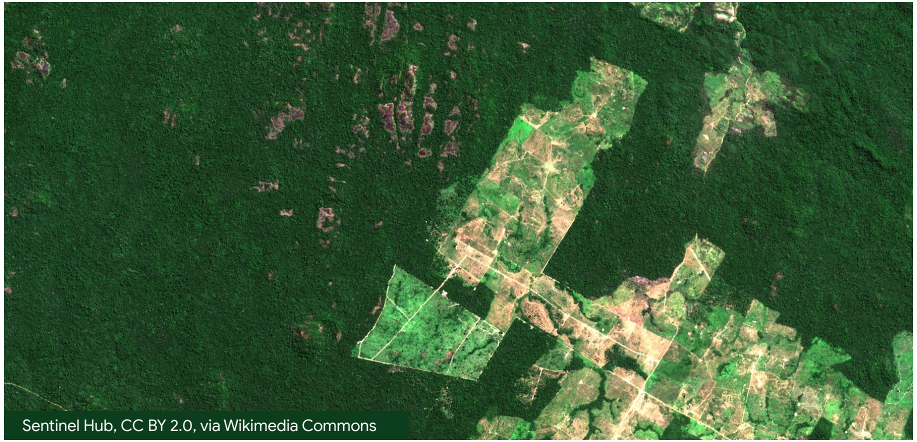
Example: Forest after carbon crediting



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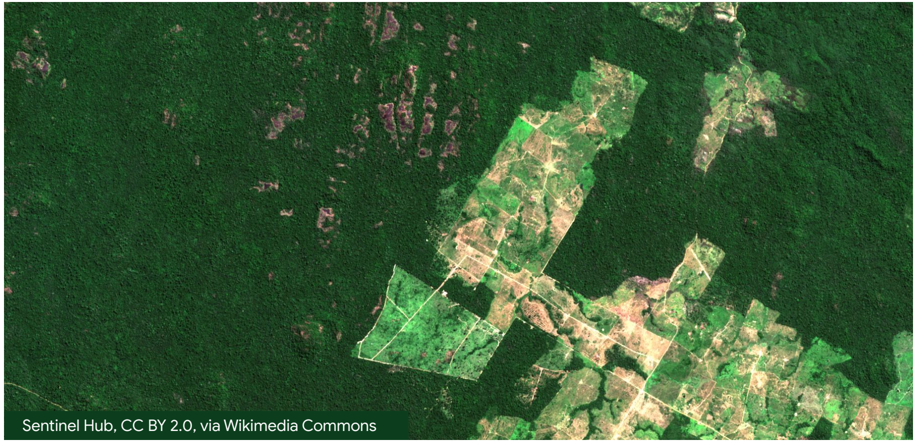

More deforestation?

(Additionality)

The same?

What would have happened without carbon crediting?

Remote sensing methods

Remotely sensed outcomes help evaluate offset projects

Good guesses about counterfactual ("baseline") scenarios require good data!

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Google Earth Engine provides tons of remotely sensed and geospatial data that is necessary for this kind of work.

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Offsets justify ongoing emissions. Empirical validation is necessary to ensure their climate benefits.

Carbon leakage

Carbon leakage: an overlooked issue

Additionality isn't enough to guarantee effective carbon offsets

Accurate baselines are critical for effective carbon offsets.

"Additionality" is the main focus of recent work: West et al. (2020), Badgley et al. (2021), Guizar Coutiño et al. (2022), West et al. (2023).

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Ex. preventing deforestation on one parcel of land could cause increased deforestation on unprotected land.

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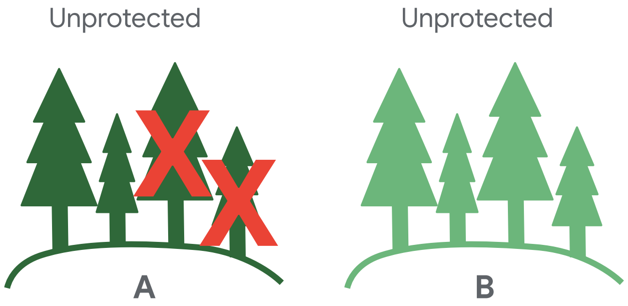

Baseline scenario (no carbon credits)

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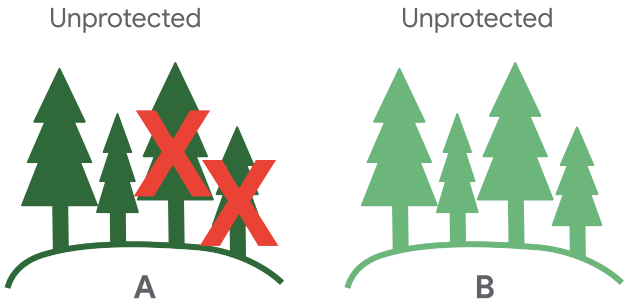

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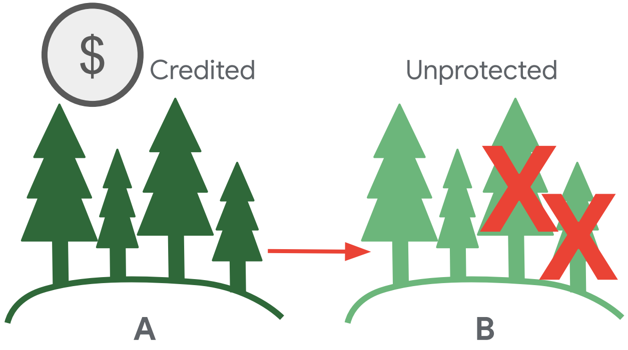

Project scenario

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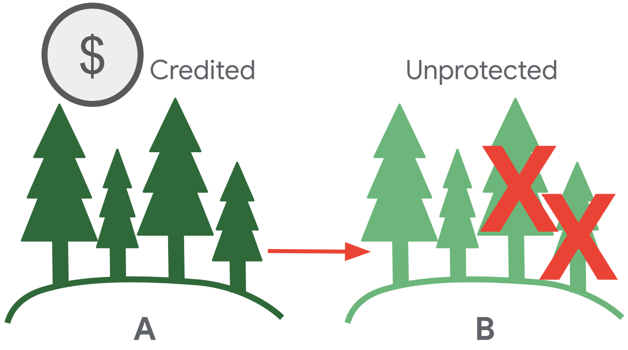
Leakage would undermine the climate benefits of carbon offsets.

Carbon protocols know this. Without quantitative evidence, most implement fixed leakage deductions.

Baseline scenario (no carbon credits)



Project scenario

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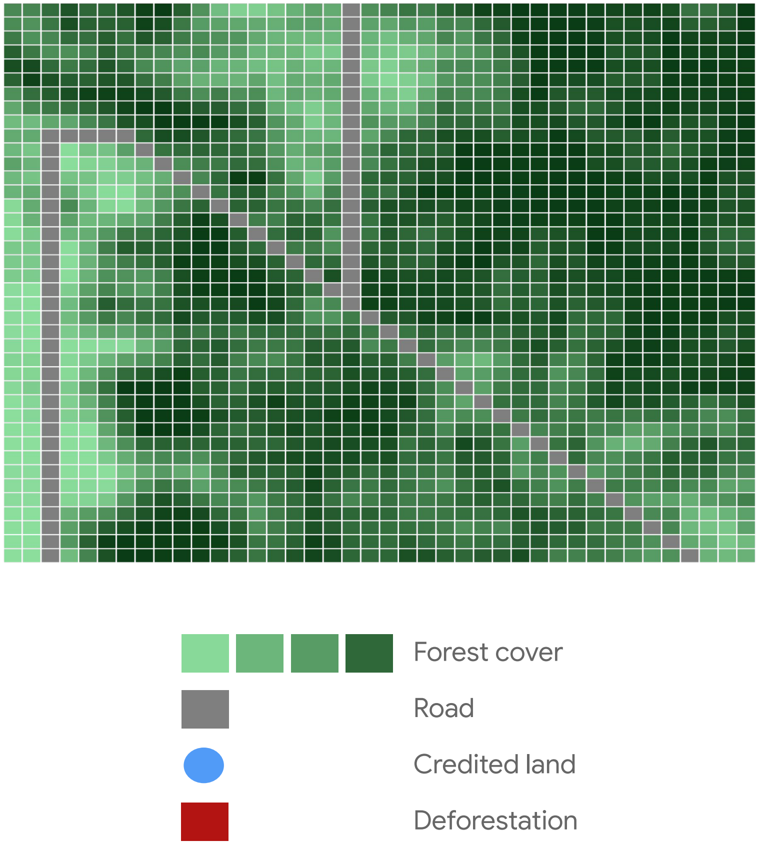
We want to change that!

Measuring leakage with an RCT

Measuring leakage



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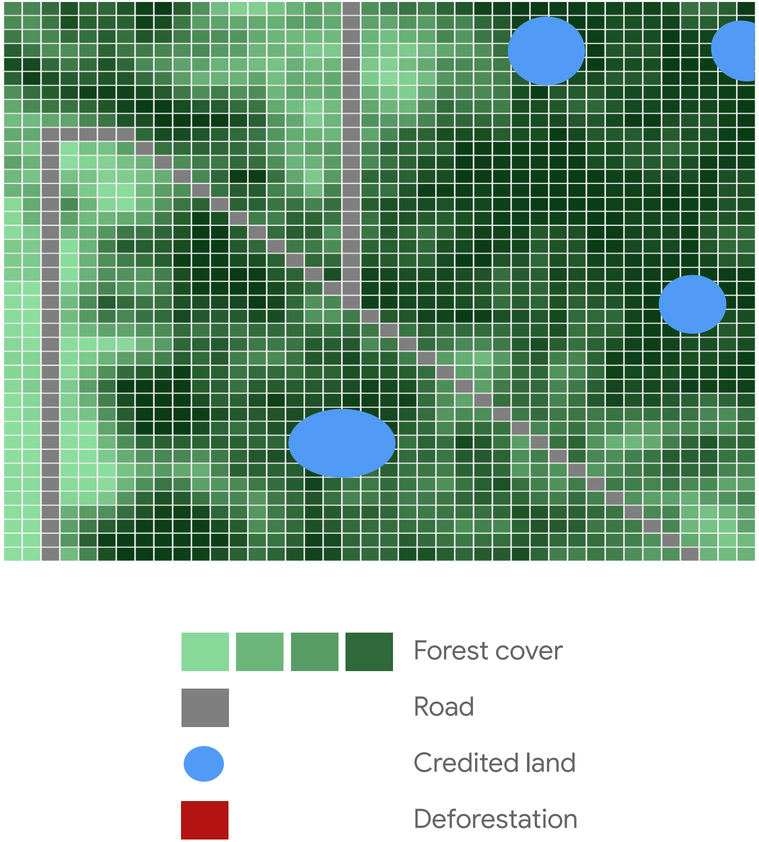

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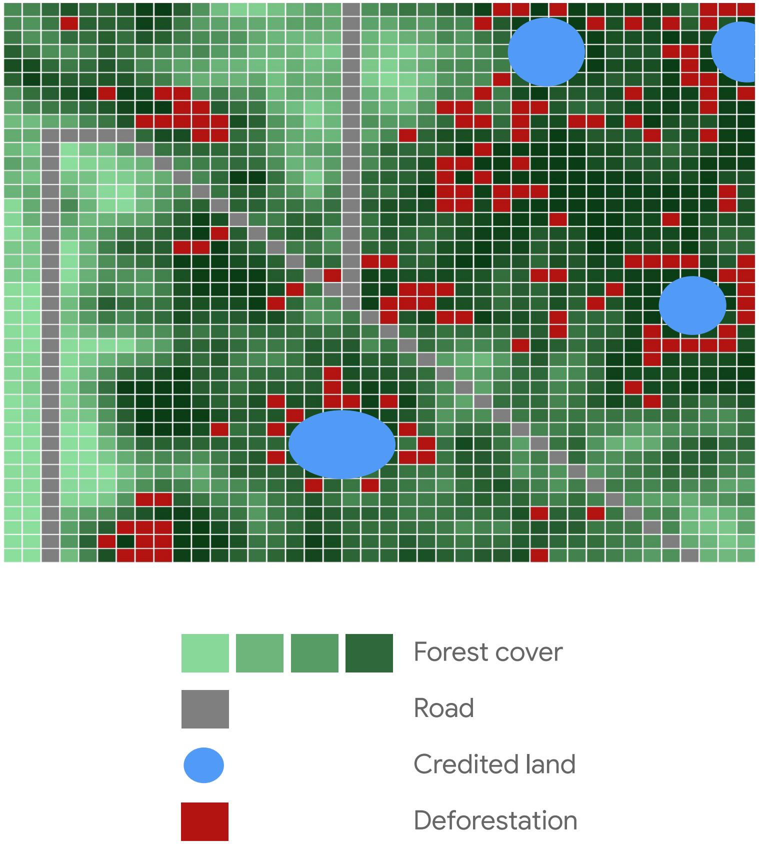

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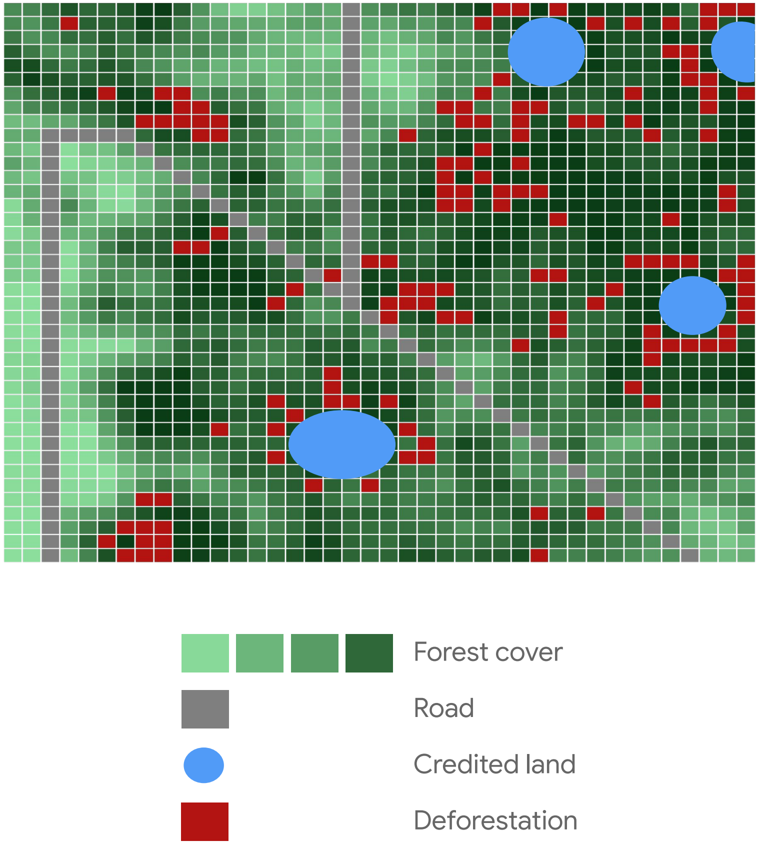
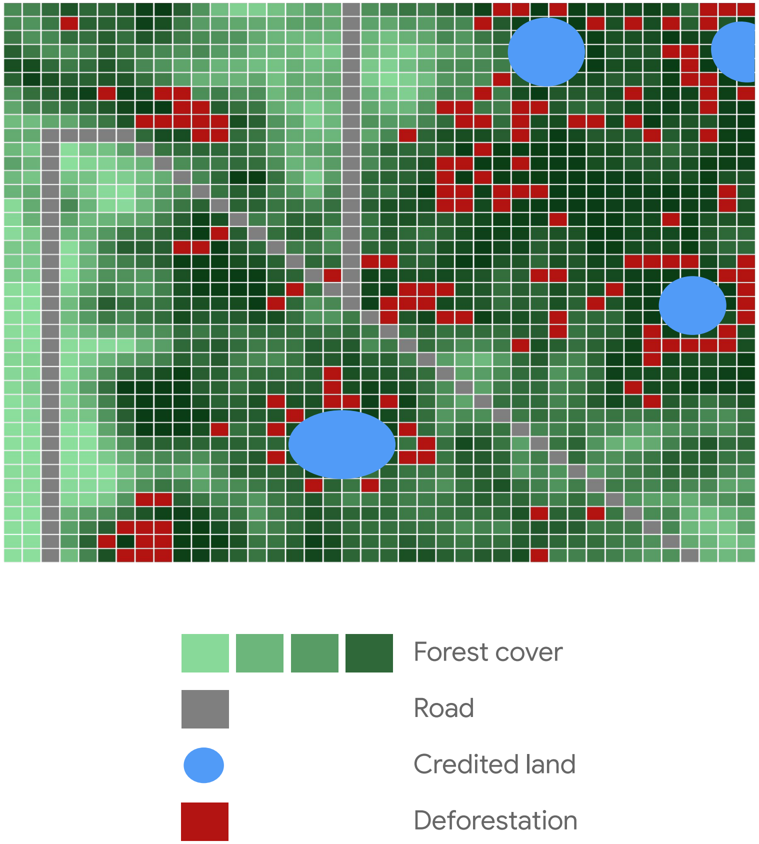


How much of this deforestation would have occurred without the presence of carbon offset projects?

Measuring leakage experimentally

RCTs are the gold standard for estimating causal effects.



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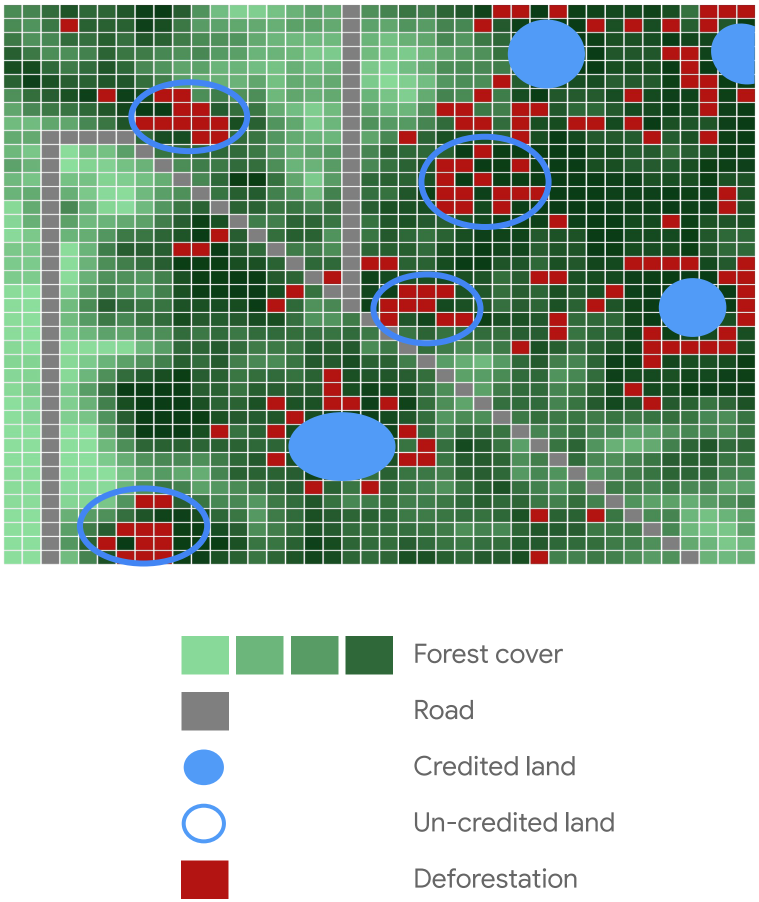

Why a randomized controlled trial?

We can be sure that credited and uncredited land is not systematically different (no adverse selection).

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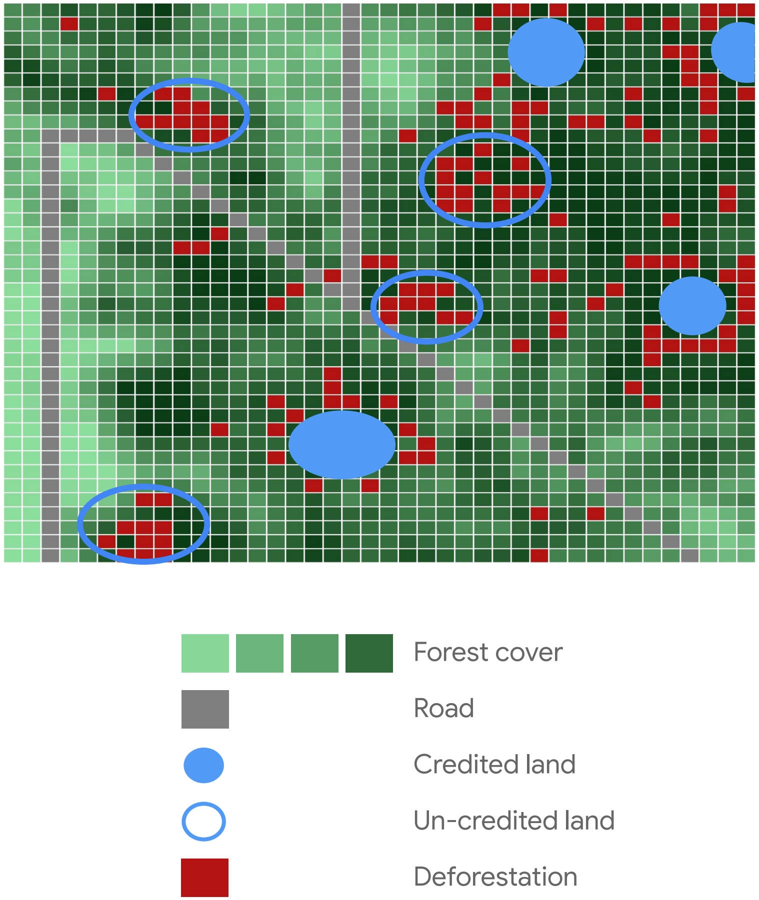

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Causal inference when units can interact

Leakage is an example of a more general problem in causal inference, called “interference.”

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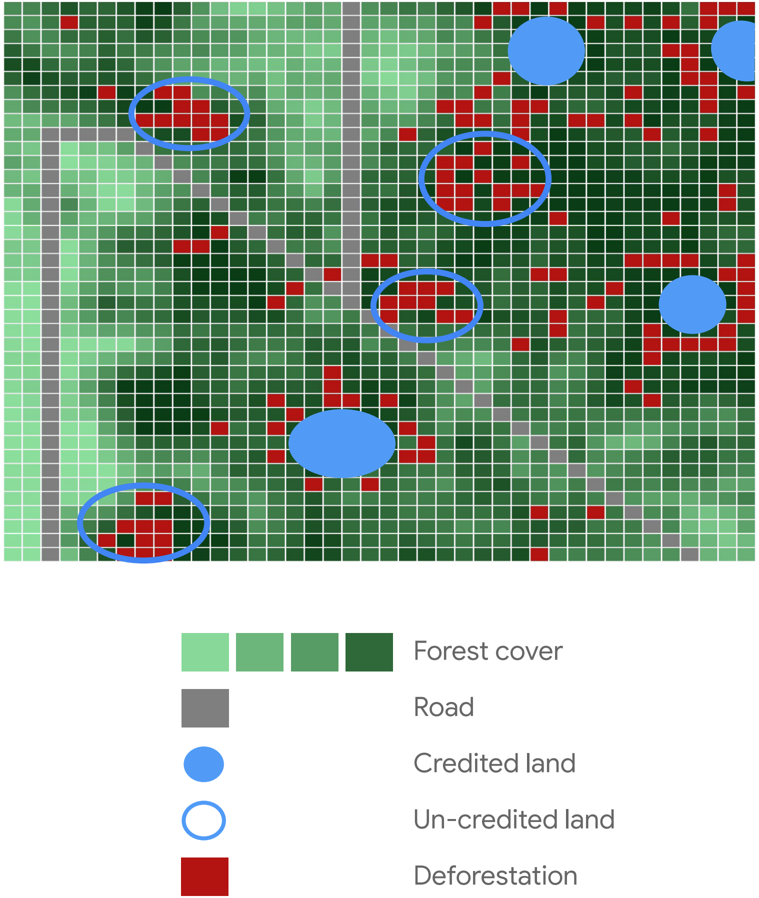

Why a randomized controlled trial?

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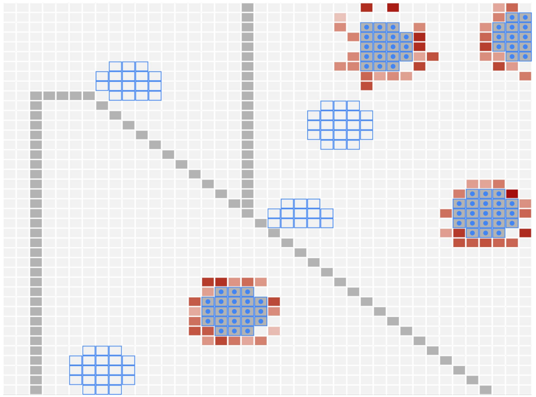
Causal inference when units can interact

Leakage is an example of a more general problem in causal inference, called “interference.”

We can extend recent methodological advancements for estimating “indirect” effects between units.

Leakage effects are likely to be spatially complex

Understanding leakage structures spatially and with respect to other covariates will inform the design of future carbon protocols and evaluations.



Proximity leakage

Leakage may concentrate in unprotected land closest to credited projects.

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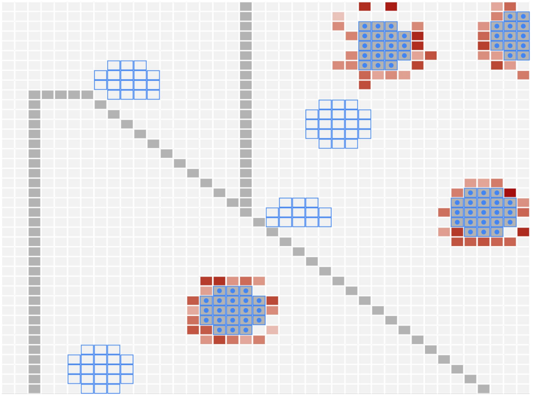

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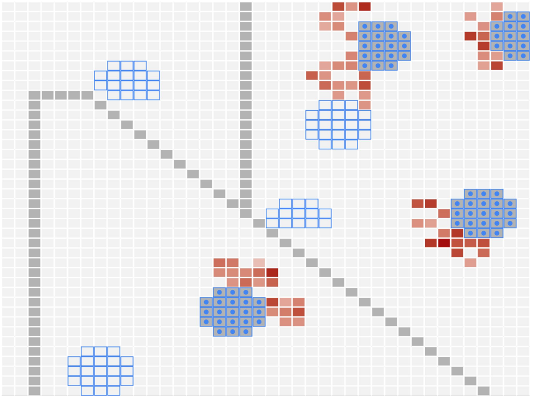

Strategic proximity leakage

Land as close or closer to roads than credited projects may be more vulnerable to leakage.

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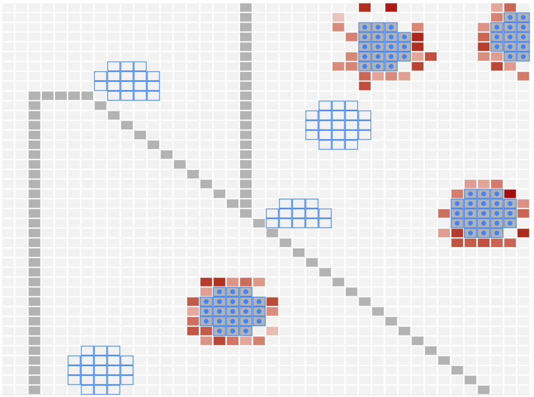

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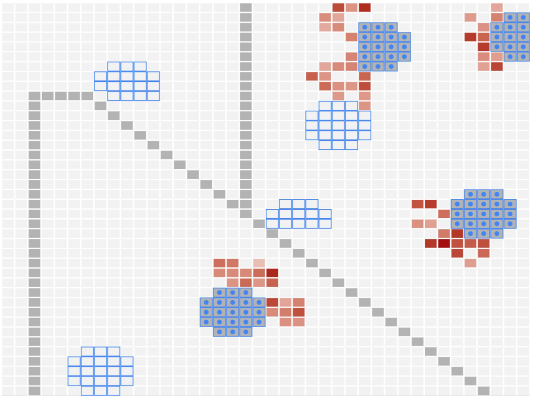

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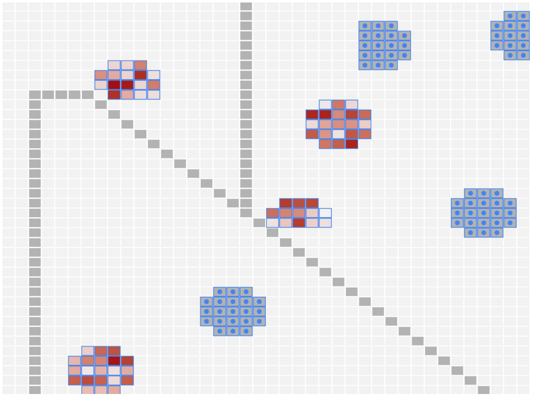

Similarity leakage

Land that is very similar to credited projects ("control" land) may be the first targets for leakage.

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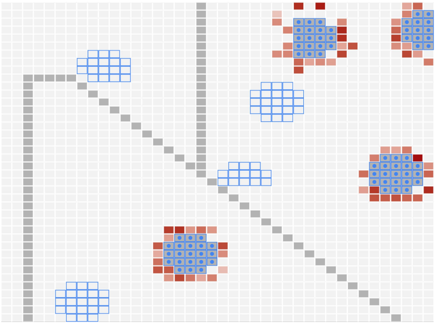

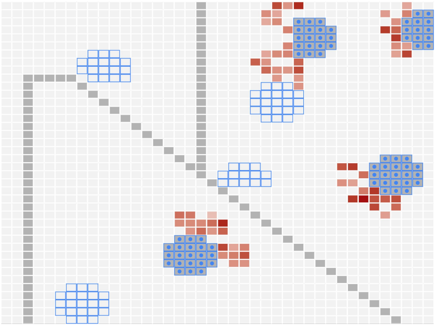

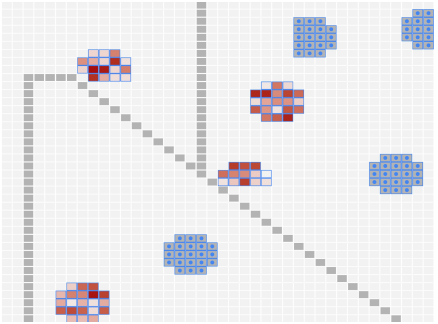

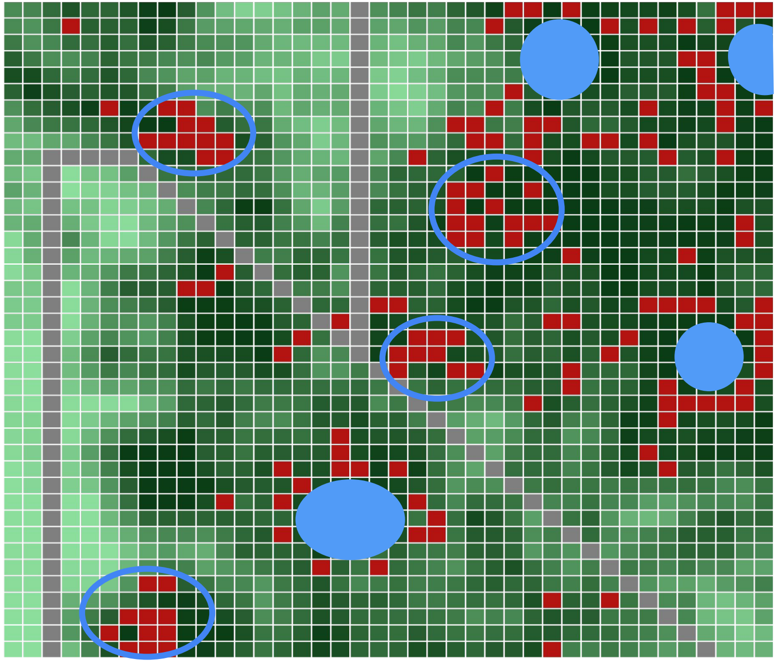

Takeaways

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Carbon crediting can have a valuable role in nature-based climate solutions.

Carbon leakage could undermine positive impacts of carbon credits.

A randomized study of carbon credits will help us understand leakage and minimize it in the future.

We are seeking partnership with interested stakeholders!

Please reach out to continue the conversation about carbon leakage and implementing RCTs to measure it.

Thank you!

Megan Ayers: m.ayers@yale.edu
Luke Sanford: luke.sanford@yale.edu
Fredrik Sävje: fredrik.savje@yale.edu

Leveraging Earth Engine for Transforming Land Cover & Above Ground Biomass into Greenhouse Gas Emissions Ensembles

Emil A. Cherrington, Ph.D. [*with contributions from Christine Evans, Africa Flores, and Ashutosh Limaye*]

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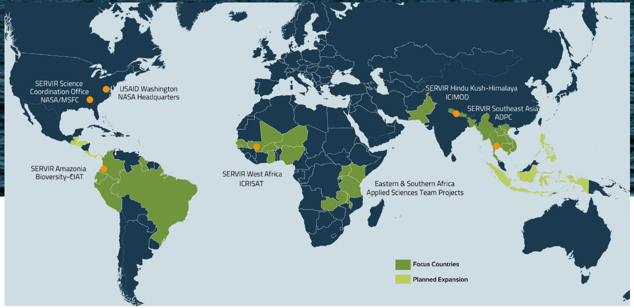
SERVIR

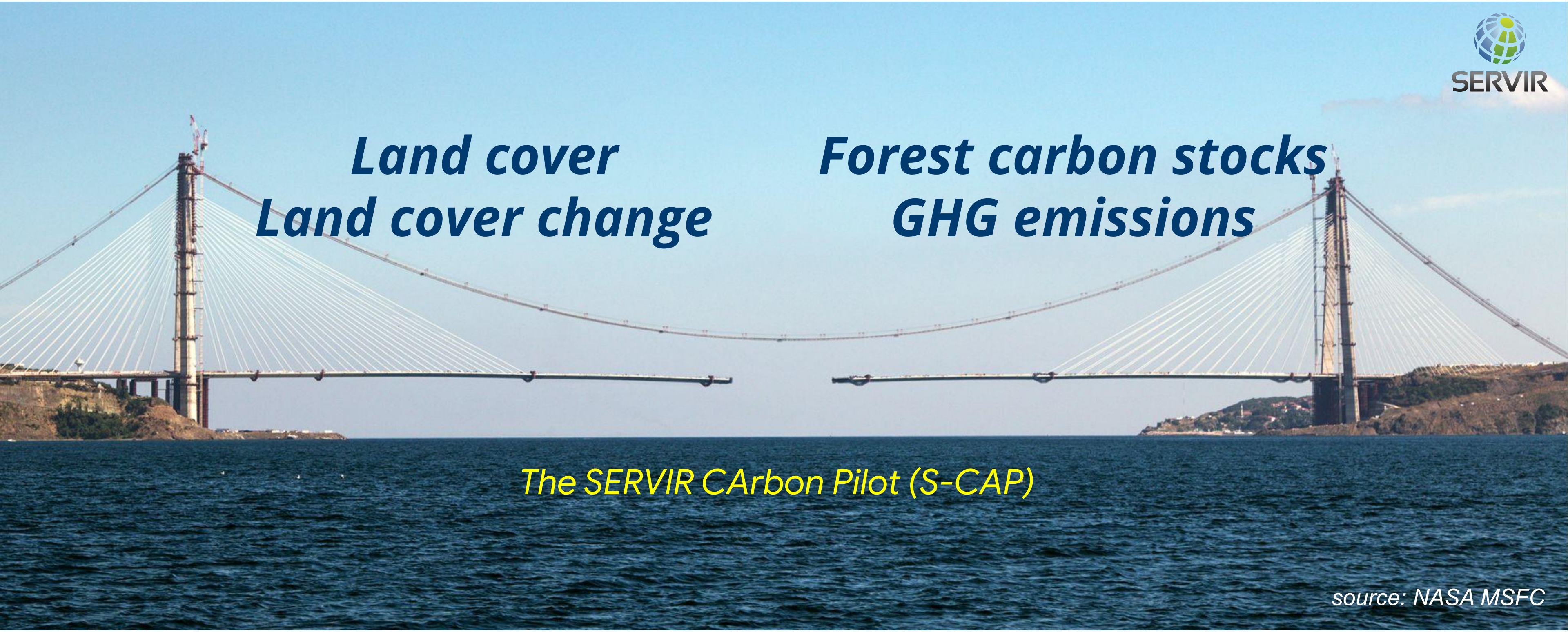
slide template source: Google

Bridging the Divide (1)



Bridging the Divide (2)

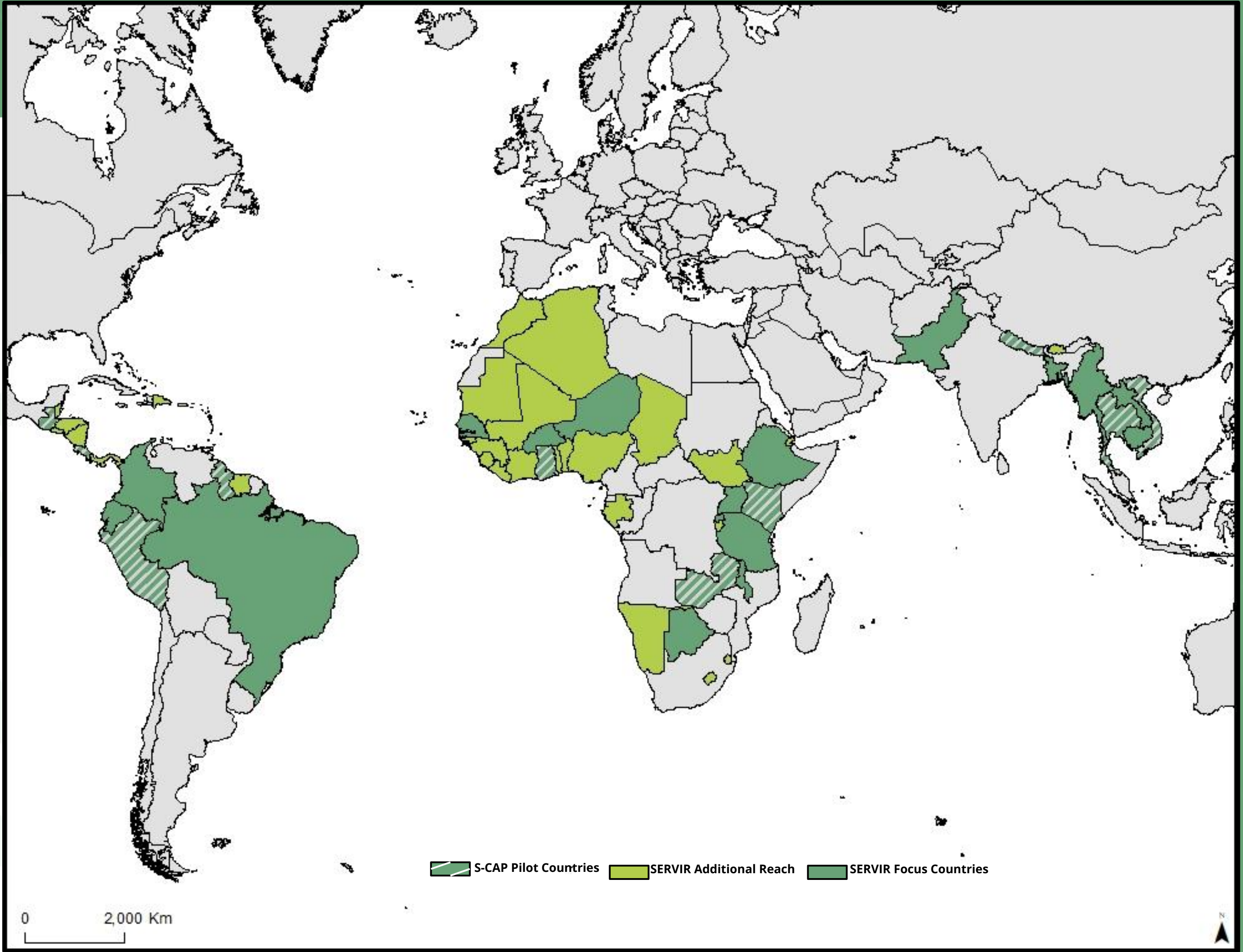
From land cover / change to forest carbon stocks and GHG emissions



SERVIR CArbon Pilot (S-CAP) research questions:

1. What do we know about **forest cover** in our area of interest (AOI)?
2. What do we know about **forest cover change** in that AOI?
3. What do we know about **carbon sequestered** in that AOI?
4. What do we know about **carbon dioxide emissions** from deforestation in that AOI?

source: SERVIR SCO, modified from NASA SVS



S-CAP pilot countries

Americas

- Colombia
- Costa Rica
- Guatemala
- Guyana
- Peru

Africa

- Côte d'Ivoire
- Ghana
- Kenya
- Zambia

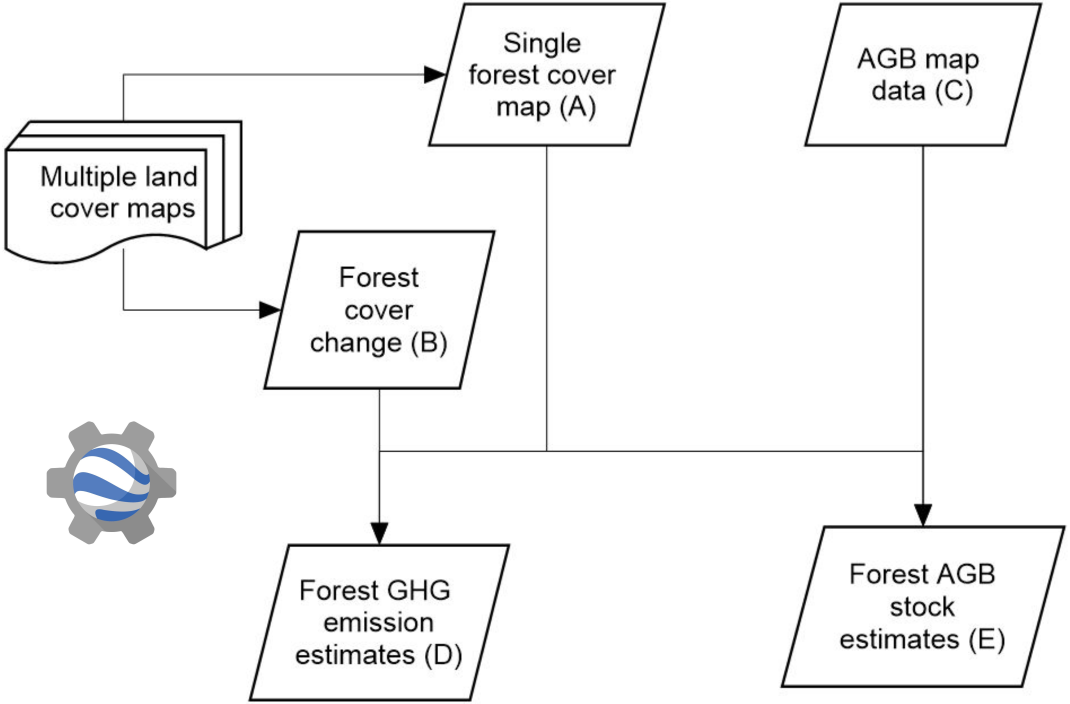
Asia

- Bangladesh
- Bhutan
- Cambodia
- Nepal
- Thailand
- Vietnam

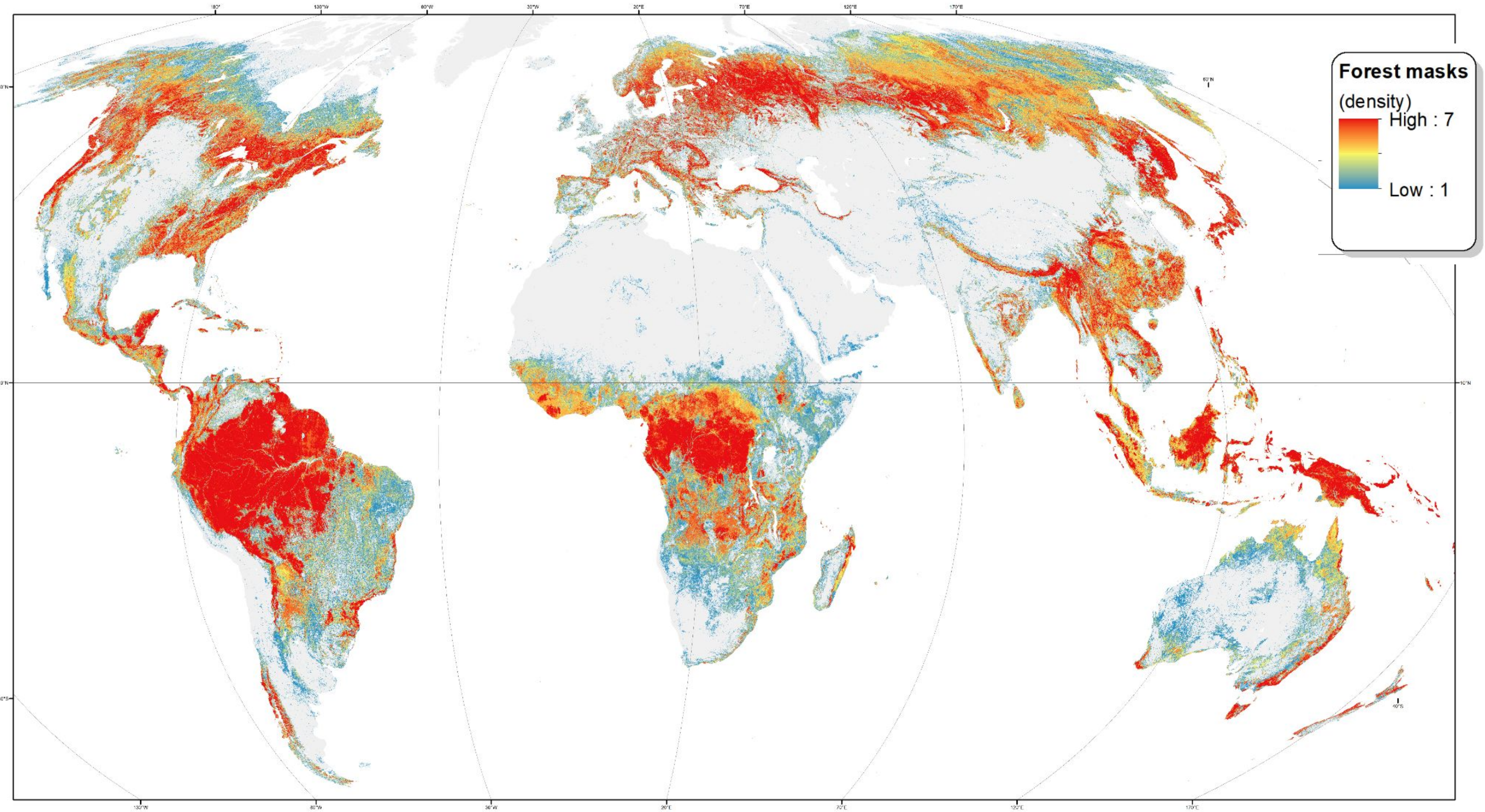
Map source: Christine Evans, UAH/NASA SERVIR

Methods: Ensemble development

Optional eyebrow



source: Cherrington et al. (in prep.)



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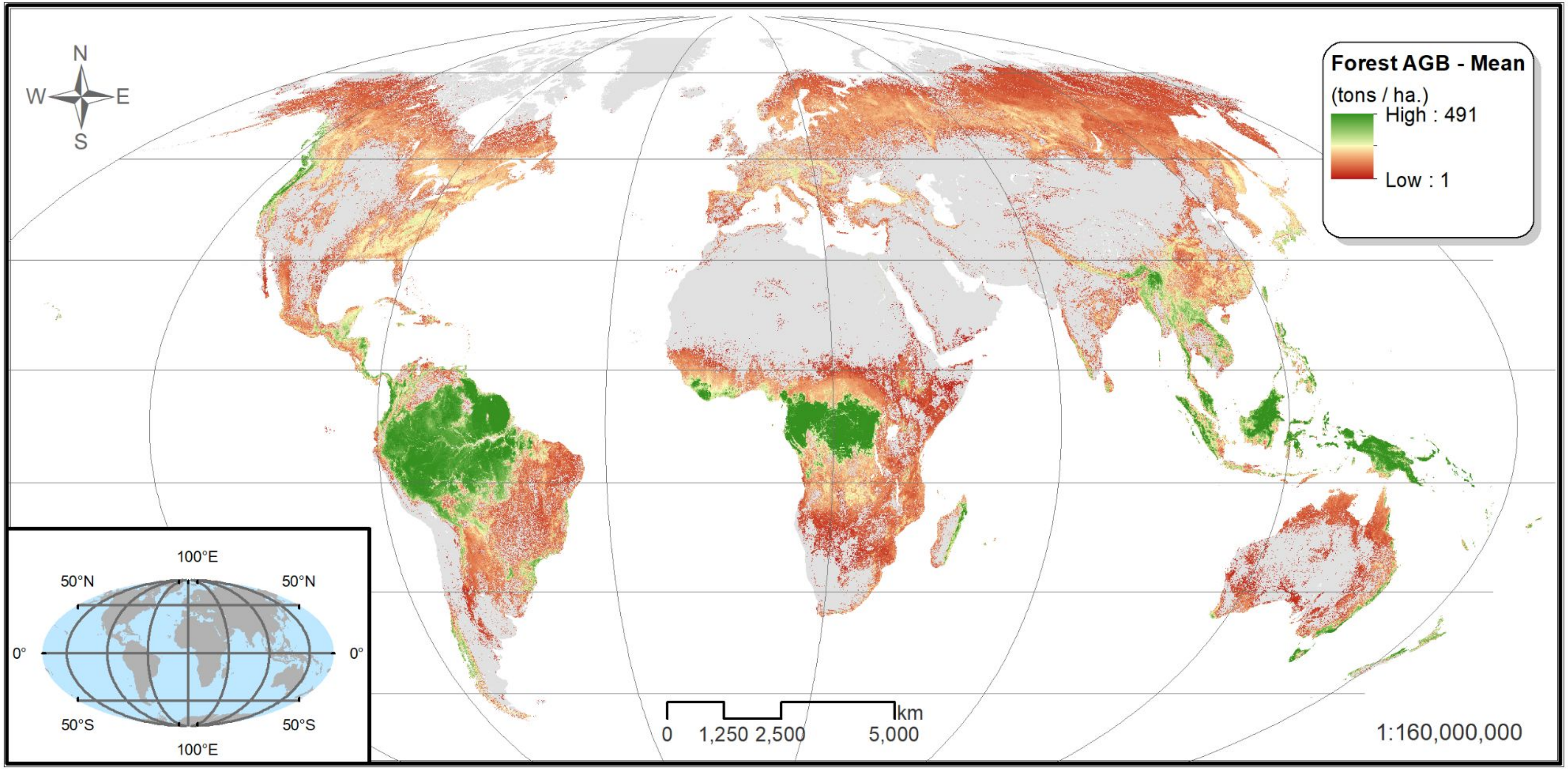

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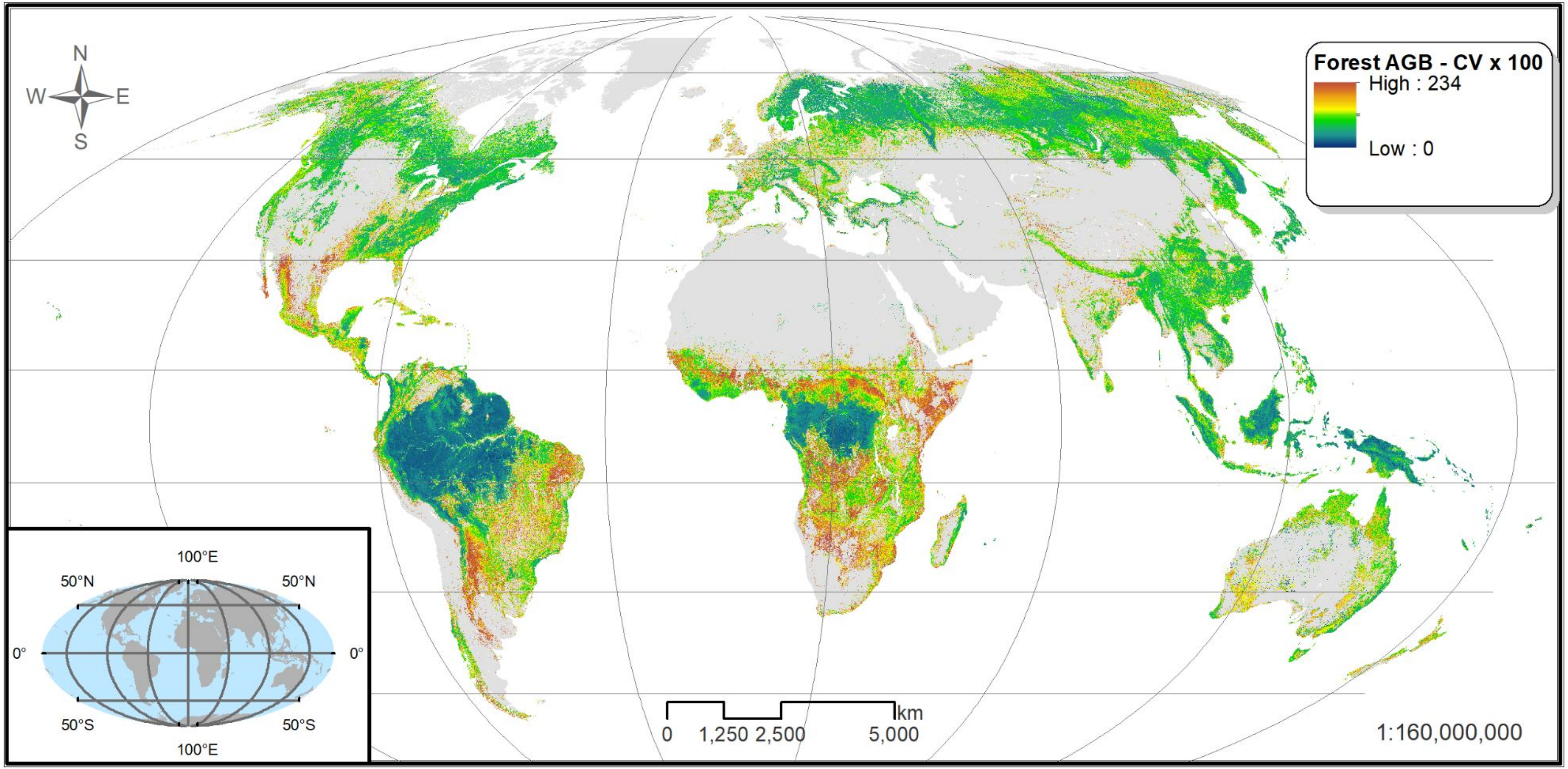


source: Cherrington et al. (in prep.)

SERVIR

Search places

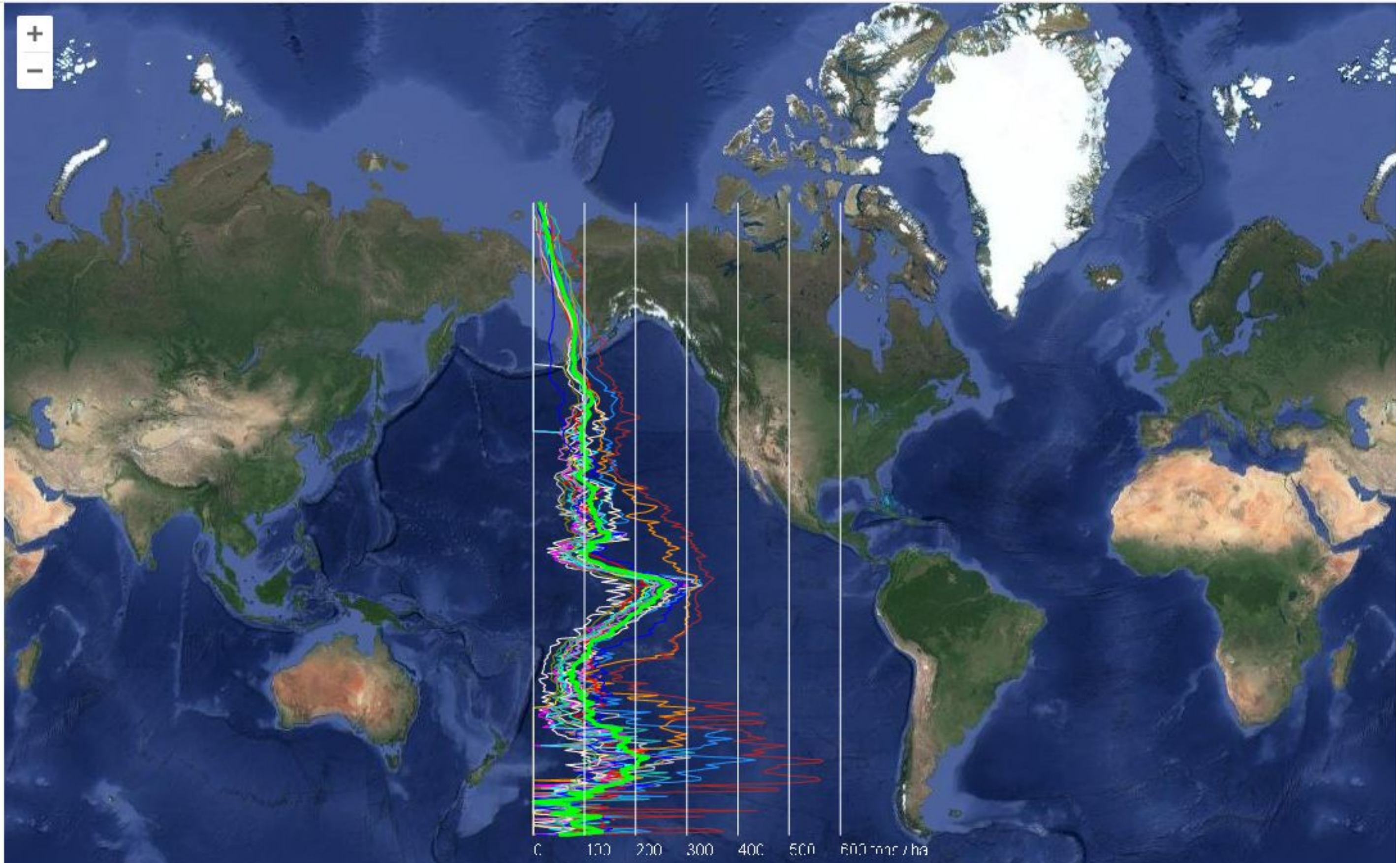
S-CAP: Interactive Forest AGB viewer

Selectable AGB averages per latitude:

- ☑ 0. AGB mean
- ☑ 01.
- ☑ 02.
- ☑ 03.
- ☑ 04.
- ☑ 05.
- ☑ 06.
- ☑ 07.
- ☑ 08.
- ☑ 09.
- ☑ 10.
- ☑ 11.
- ☑ 12.
- ☑ 13.
- ☑ 14.
- ☑ 15.
- ☑ 16.

* = tropics only

credits: Cherrington et al. / SERVIR SCO, July 2023



work based on Santoro et al. (2023)

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S-CAP capacity building activities

Upcoming trainings:

October 16-20 | Belize
November 13-17 | Ghana

Guatemala City, Guatemala (w/ SilvaCarbon)

Technical professionals from government, education and private institutions responsible for forest carbon accounting and deforestation monitoring.

Fundamentals, applications, and code for LandTrendr, CCDC-SMA, BULC-D, S-CAP with practical exercises applied in participants' areas of interest

Bangkok, Thailand - SERVIR Southeast Asia

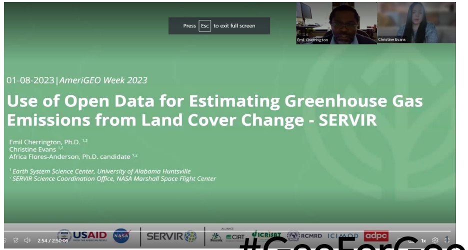
Technical professionals from government, education and private institutions responsible REDD+ reporting.

Focused on the role of geospatial technology in supporting REDD+ initiatives and the use of remote sensing for biomass estimation and mapping. Topics included fundamentals, applications, and code for LandTrendr, CCDC-SMA, S-CAP, and GEDI, with practical exercises applied in participants' areas of interest

Cali, Colombia - SERVIR Amazonia

GIS and technical specialists from Brazil, Colombia, Ecuador and Peru brought together to share progress of several ongoing services.

Intro presentation to the S-CAP concept before a GEE demonstration applying the algorithms / techniques covered to estimate carbon emissions



AmeriGEO virtual training

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Summary

SERVIR CArbon Pilot (S-CAP)

Open Science
- Replicable and transparent GHG methodologies, *enabled by Earth Engine*

Ensemble Approach
- Leveraging available LC + AGB data instead of reinventing the wheel
- *Synergistic* instead of *competitive* w/ other efforts

Uncertainties
- Guide users on which datasets might be the most appropriate for their area

Capacity Building
- Focus on strengthening SERVIR hub and partner country capacities
- Provide technical trainings on how to estimate CO_2e using different datasets
- Incorporate these methods into SERVIR hubs' current land cover services

Economic assessment
- Estimation of financial value of forest C stocks and historical emissions

Web Platform
- Earth Engine-based, *in development*

Thank you!

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@BzGEO

Mapping the Invisible: High-Accuracy Carbon Flux Estimation at Scale with GEE.

Álvaro Moreno-Martínez & Nathaniel P. Robinson

October 2023 | #GeoForGood23

Universitat de València
The Nature Conservancy

Nature Based Climate Solutions are a Key Solution

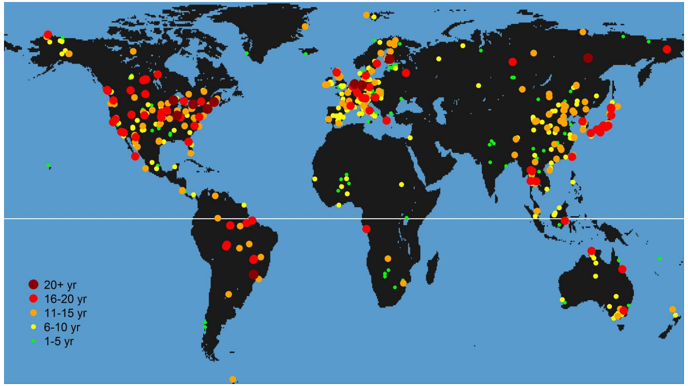
NATURE CAN PROVIDE A THIRD OF THE SOLUTION

11 $GtCO_2e$ from NCS

Griscom, Bronson W., et al. "Natural climate solutions." Proceedings of the National Academy of Sciences 114.44 (2017): 11645-11650.

Which are the best Carbon flux estimations we have?

Illustration of an Eddy Covariance (EC) flux tower



Location of the Cal/Val flux tower sites (Fluxnet 2015)

Having good site observations is nice, but we want/need maps!!!

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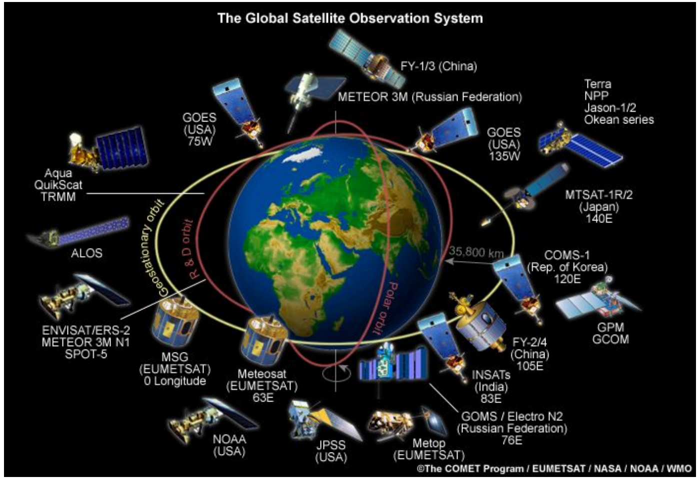
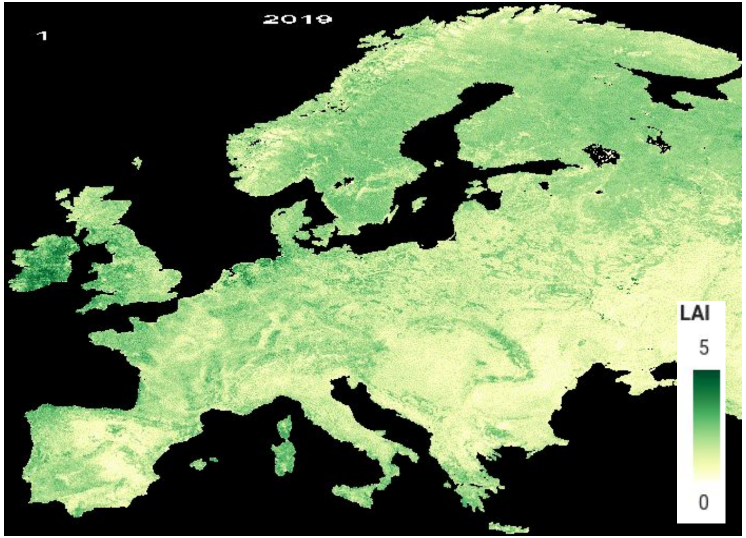
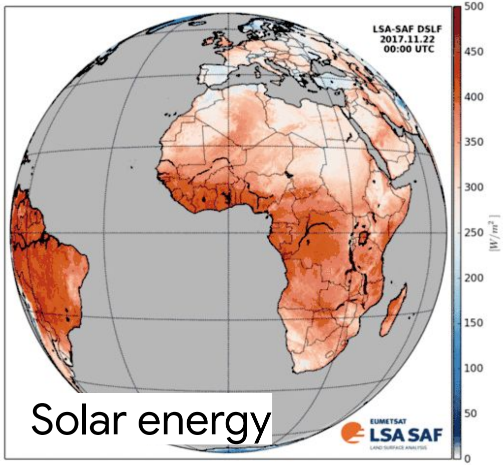
Remote Sensing (RS) data and GEE are critical to bridge the spatial gaps

RS provides spatial/temporal information about:

- Amount of vegetation (NDVI, LAI, FAPAR, FVC)
- Vegetation health
- Soil moisture
- Solar irradiation

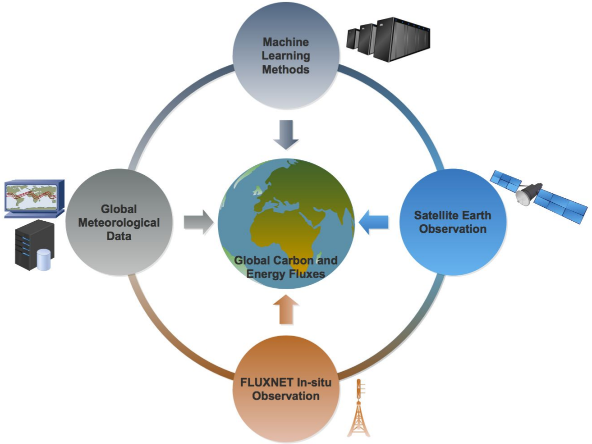


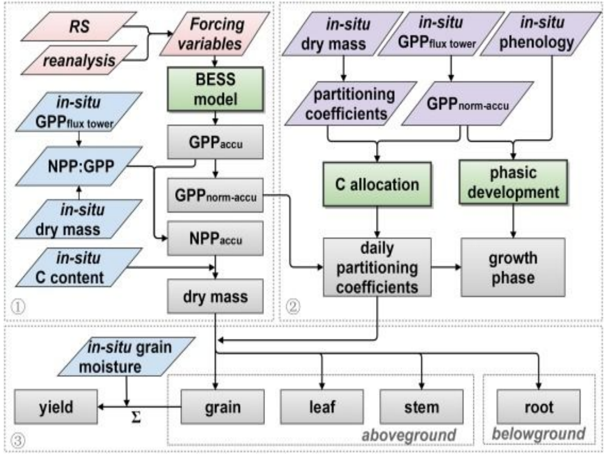


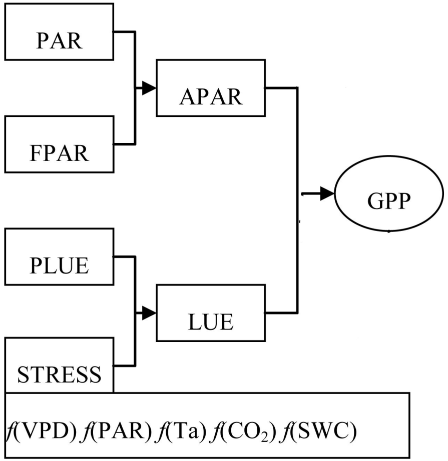


State-of-the-art methods to create maps from flux tower data

Typical approaches







Data driven methods

- Pure Machine Learning approaches (e.g. Fluxcom)
- Lots of data for proper calibration
- Almost no prior knowledge is needed

Mechanistic approaches

- e. g., Breathing Earth System Simulator (BESS), in GEE
- Complex models based on many submodels.
- Require a significant amount of input data.

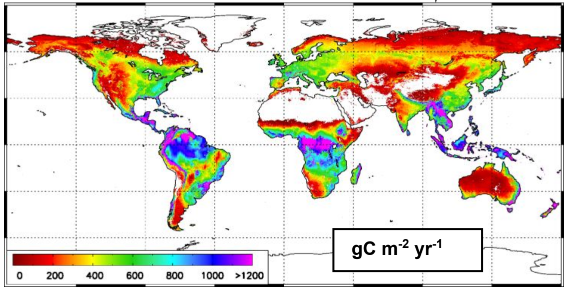
Semiempirical approaches

- Simpler logic but still physically based (e.g. MODIS)
- Sweet spot, easy calibration and less data demanding
- Widely used, computationally efficient

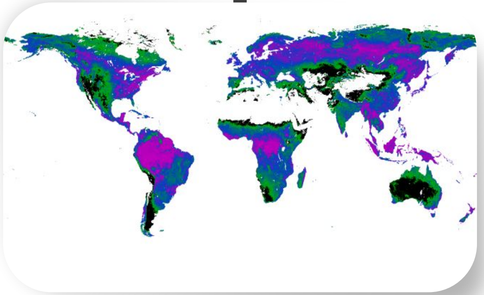
Semiempirical NASA MODIS (MOD17) approach

Gross Productivity = Light absorbed (APAR) x light use efficiency

$$GPP = APAR \times \varepsilon$$

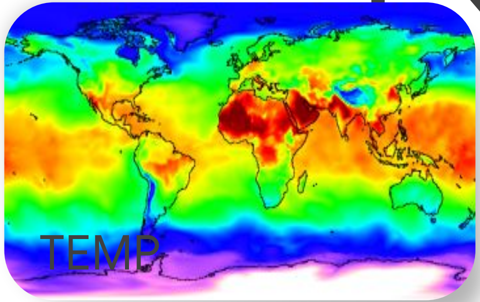


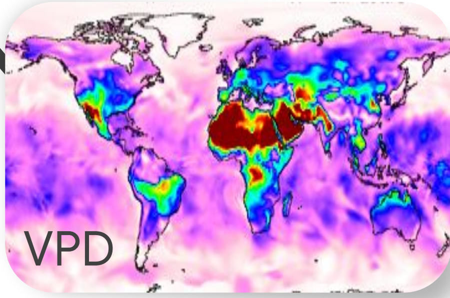
GPP



FPAR x PAR

ε_{max}





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GEE Carbon Flux Estimation

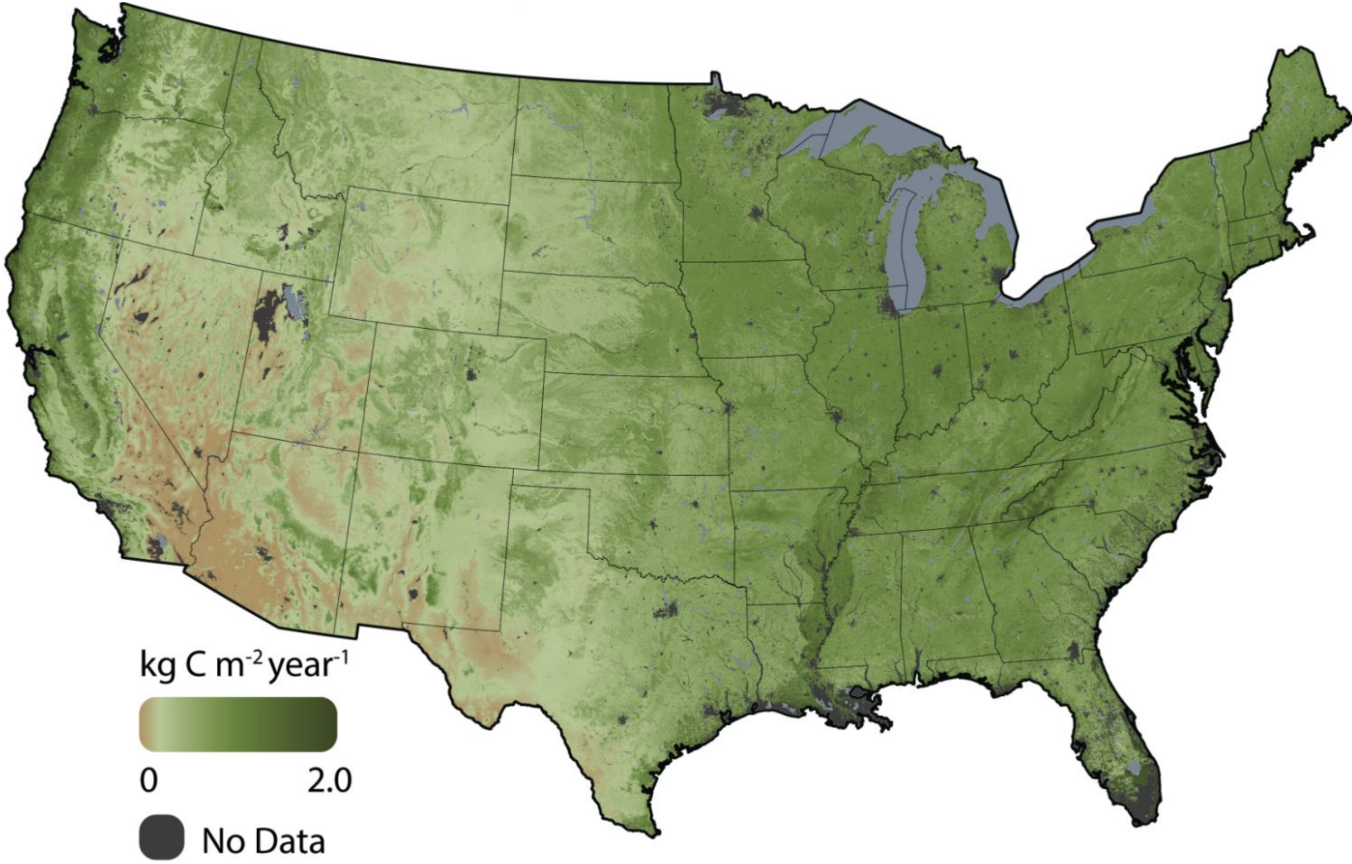
Implementing the MOD17 GPP/NPP Algorithm

1. Build robust time series of Landsat or Sentinel Based LAI and FPAR.

2. Incorporate ever improving land cover datasets

3. Combine with high resolution meteorological data

4. Optimize parameters with the EC network data.



More Robust Tracking of NBS

Landsat or Sentinel Based Estimates of GPP/NPP

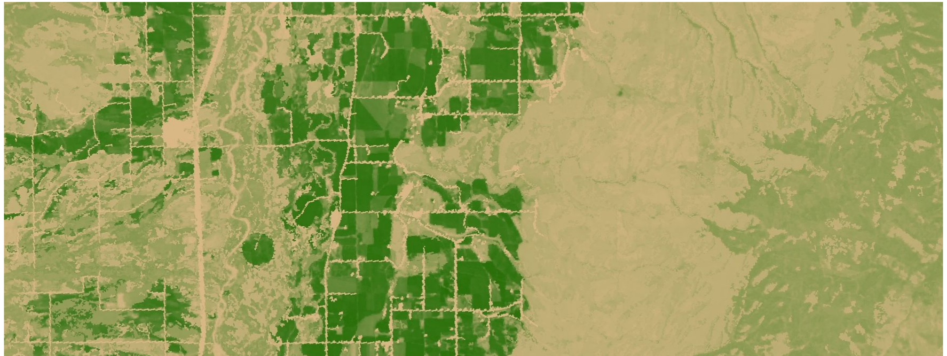
Data resolution better matches underlying processes

Scale of Data

GEE allow for the scaling of high resolution estimates across regions, continents, and ultimately global.

Units

Units are more meaningful — amount of carbon uptake by vegetation over a given time frame.



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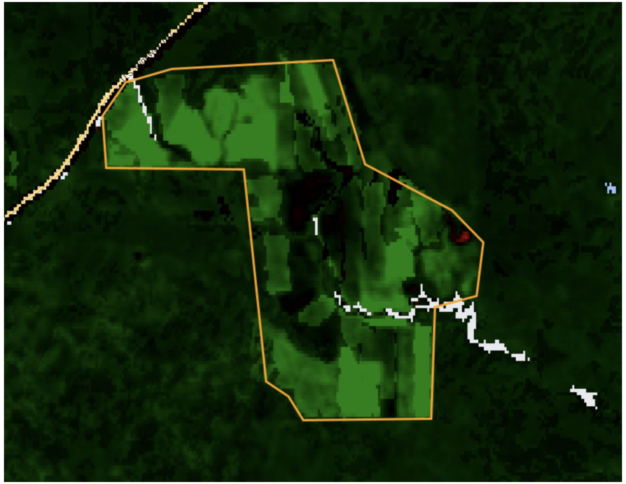
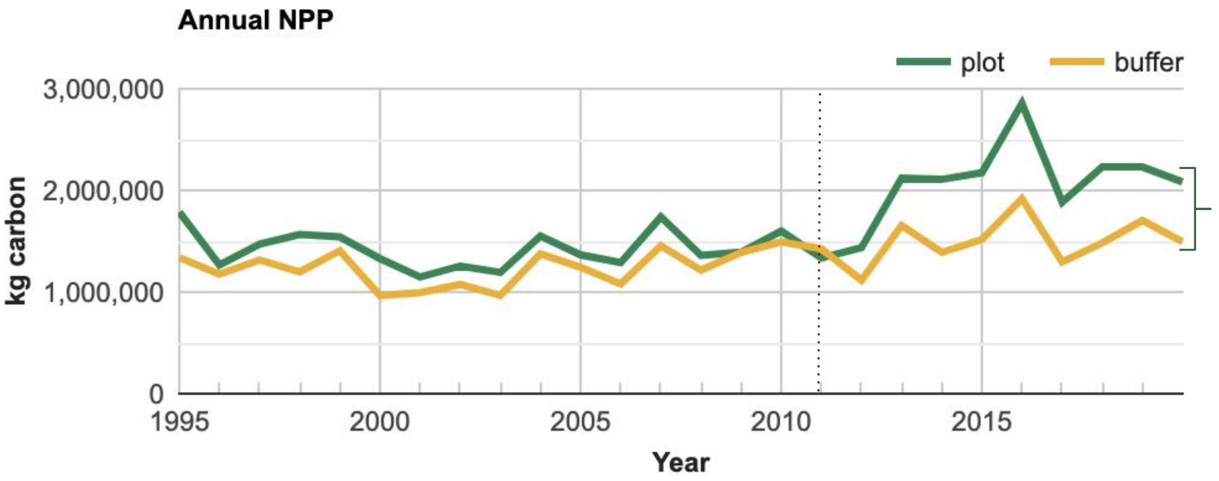
Impacts of NBS at grazing allotment scale





Thank you!

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Marrying Mangroves with Megacities: Pioneering Coastal Ecosystem Valuation & Monitoring Systems across India

Liza Goldberg

October 2023 | #GeoForGood23


Thani Creek, Mumbai

For a drowning city, mangroves could be a win-win solution.

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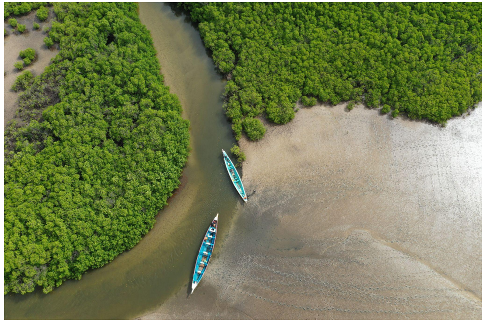
State of India’s Coastal Wetland Policy



Mission Amrit Dharohar

Encourage optimal use of wetlands in Ramsar Sites, enhance biodiversity, carbon stocks, ecotourism opportunities, and income generation for local communities.

MISHTI Scheme

Promote the reforestation of 540 sq. kms of mangroves across 11 states and 2 union territories from 2023-2027.

MoEFCC Green Credits

Award individuals, corporations, and public institutions for undertaking eight “environmental interventions.”

Can we prevent greenwashing through establishing space-based transparent monitoring and accountability systems for each policy initiative?

Chennai, India 2022

Ecosystem Services Valuation Part I

InVEST Coastal Vulnerability Model

- Coastal geomorphology
- Distribution of seagrass, kelp, wetlands
- Rates of observed net sea level rise
- Digital Elevation Models (DEMs)
- Observed wind speed and wave power

InVEST
Integrated Valuation of Ecosystem Services and Tradeoffs

- Regions that currently benefit most / could potentially benefit from wetlands to prevent storm surge impacts

Coastal Blue Carbon Model

- Distribution of coastal vegetation
- Habitat-specific carbon stock data
- LCLUC maps
- Market price of carbon

InVEST
Integrated Valuation of Ecosystem Services and Tradeoffs

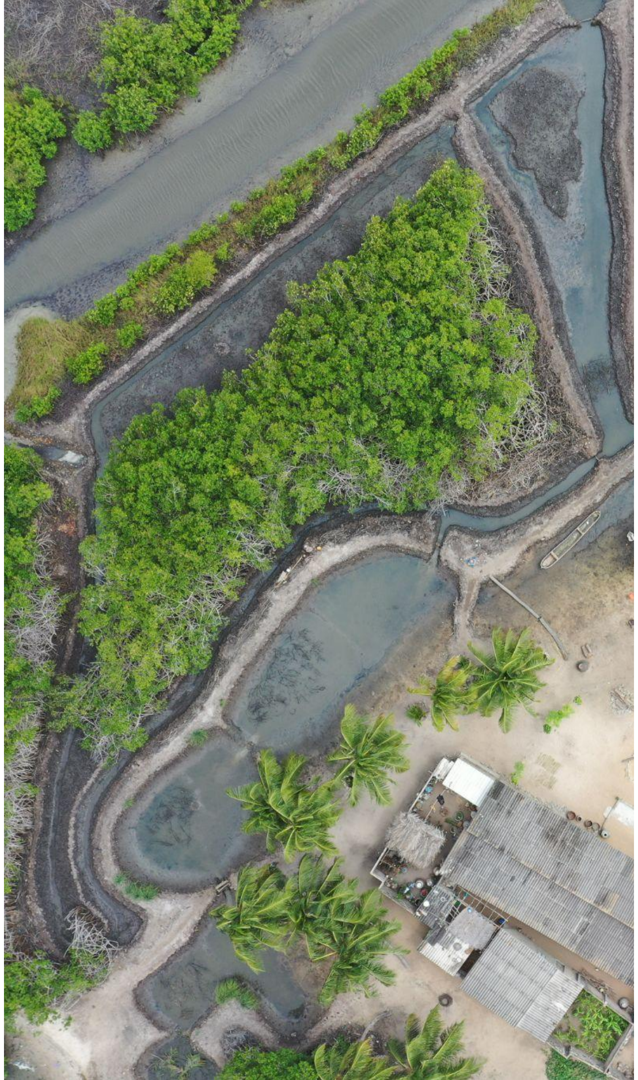
- Marginal monetary value of carbon stored and sequestered

\+ **Urban Flood Risk Mitigation Model, Recreation Model, Urban Stormwater Retention Model**

Ecosystem Services Valuation Part 2

Our ecosystem service models will allow us to generate a **quantifiable understanding of potential losses/damages and physical risks** avoided by mangrove restoration and conservation plans.

Our partners in the insurance and real estate sectors will then **integrate these valuations into premium calculations and urban planning** in Mumbai, Calcutta, and Chennai.



Wetland Report Card Development

Indicator	Measurement Type
Area	- % Wetland area converted to non-wetland by either human activities of climatic stressors (RS + Field)
Hydrology and Catchment	- Water quality (RS + Field) - Number of natural outlets choked and diverted (RS + Field)
Biodiversity	- % Wetland area covered by invasive species (RS + Field) - Annual waterbird count (Field)
Governance	- Quality of wetlands management plan & level of protection (Field) - Collaborative community management plans (Field)

National Indian Mangrove Monitoring Portal

Thani Creek, Mumbai 2015 to 2022

- Real-time **loss and gain monitoring** using Landsat, Sentinel, monthly NICFI data
- Central hub for submission of **field data from community collaborators**, especially on water quality and ground images of land cover
- Reporting of relevant real-time **local environmental variables**, particularly air pollution, monsoon projections, and sea level rise reports

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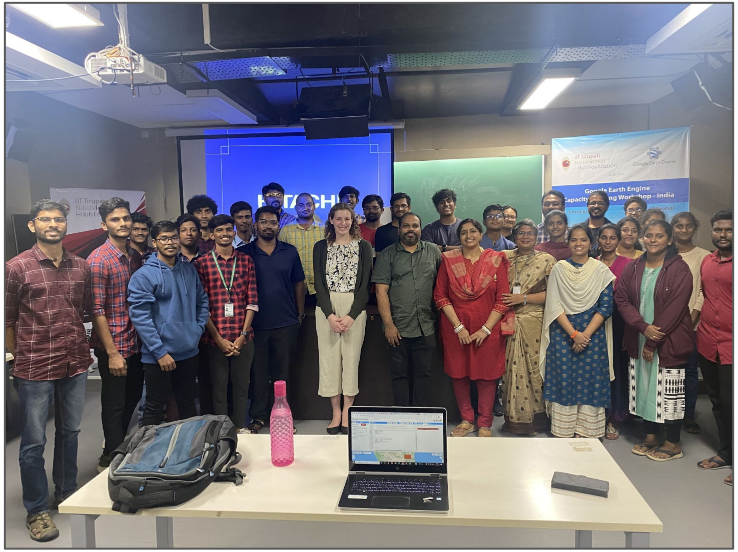
Capacity Building Programs

Bangalore 2022



Tirupati 2022

We seek to democratize remote sensing tools to those on the frontlines of our planet's greatest climate threats.

#GeoForGood23

We seek to set revolutionary standards of data openness and transparency for a nation defining the future of sustainable development.

Shillong, Assam, India 2023

Thank you!

lizagold@stanford.edu