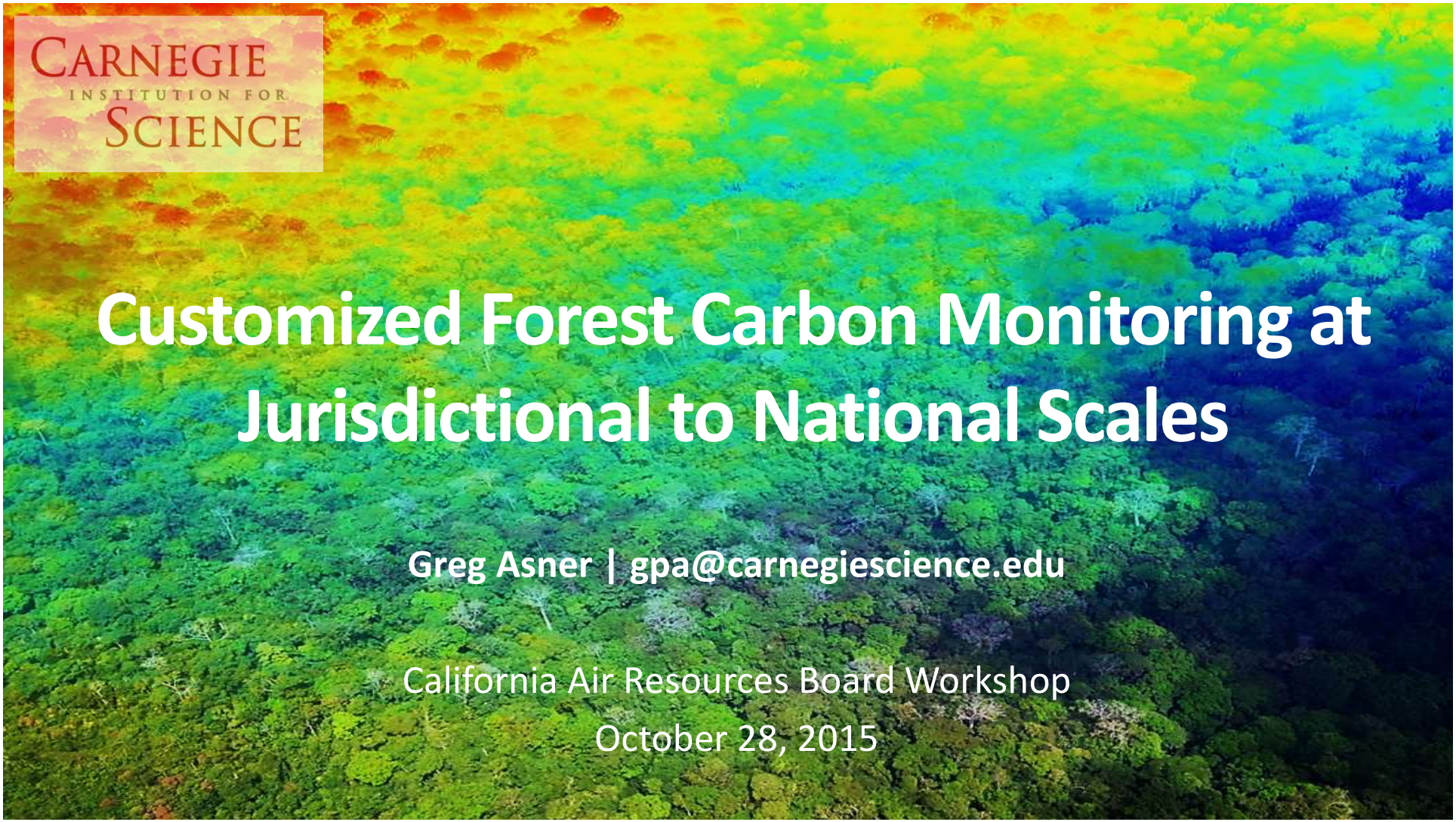


CARNEGIE INSTITUTION FOR SCIENCE

Customized Forest Carbon Monitoring at Jurisdictional to National Scales

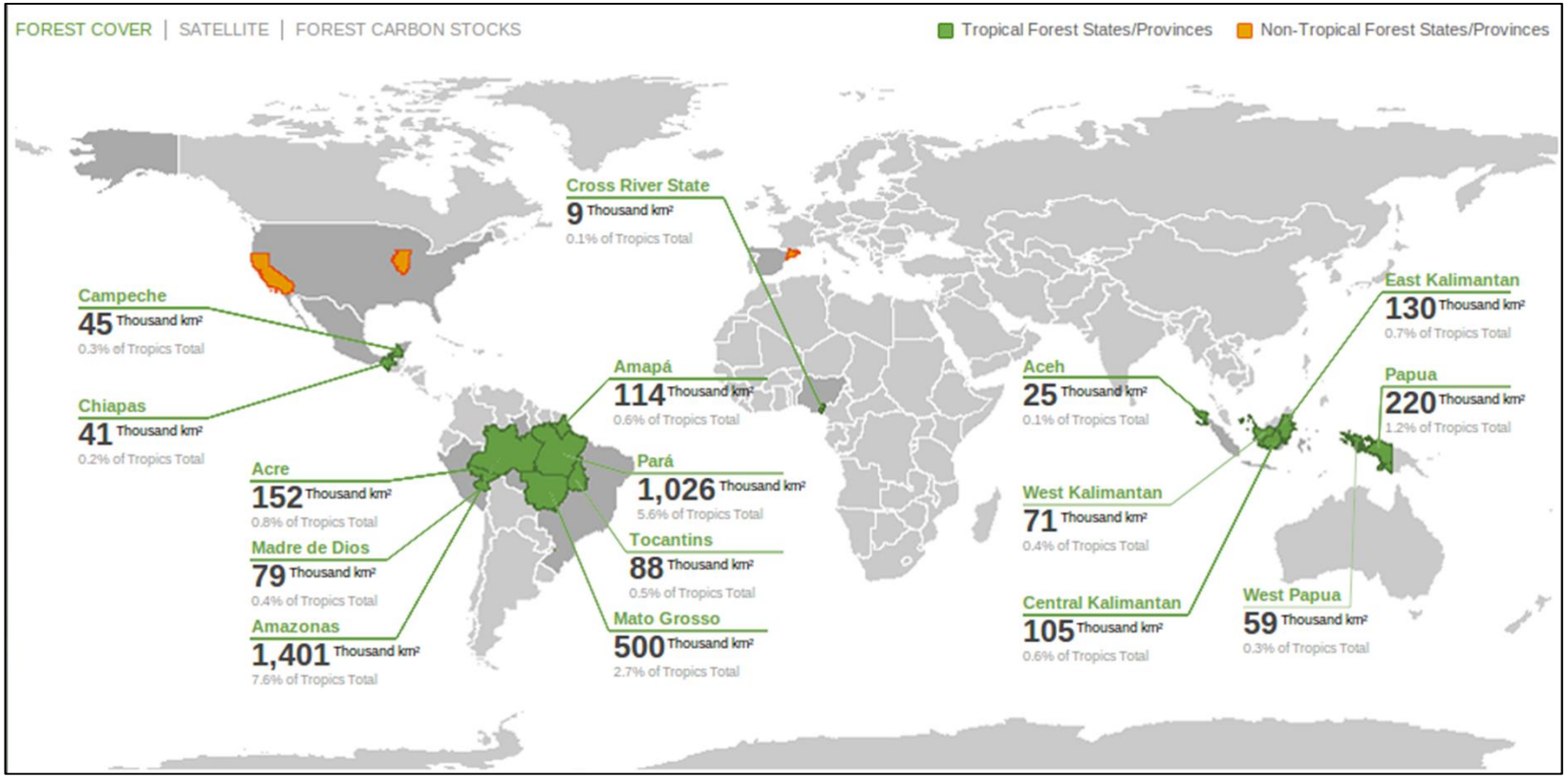
Greg Asner | gpa@carnegiescience.edu

California Air Resources Board Workshop

October 28, 2015

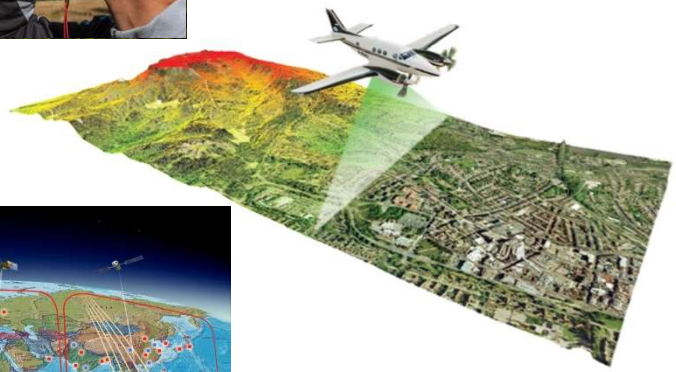
Monitoring Carbon Stocks and Emissions at GCF Jurisdictional Scales is Scientifically Robust

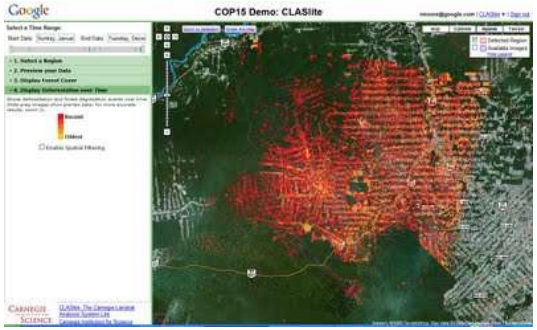
The latest scientific and technological approaches are a great fit for GCF jurisdictions in terms of delivery and uncertainty



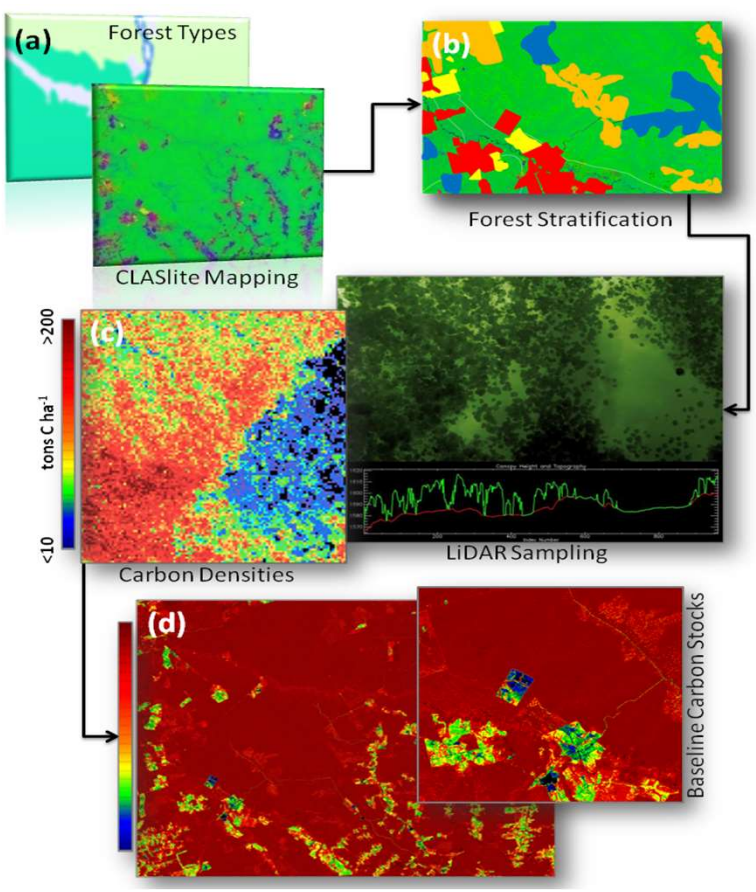
Carbon Monitoring Technology Programs within California's Institutional Network

- Methods for rapid forest plot inventory
- Methods to greatly extend the coverage of plot inventory networks using aircraft
- Methods for satellite based forest cover and carbon emissions monitoring
- New geospatial communications tools





How Modern Forest Carbon MRV Systems Work

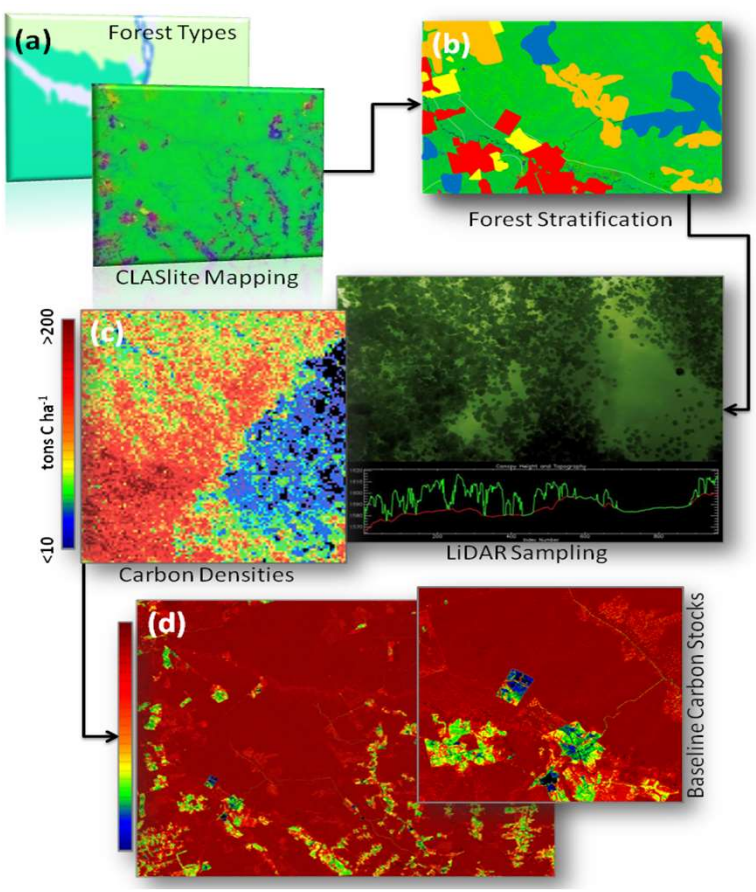


Satellite for strategic mapping of forest cover and type

Carbon stock sampling

Scaling; Monitoring carbon emissions and gains

How Modern Forest Carbon MRV Systems Work



Satellite for strategic mapping of forest cover and type

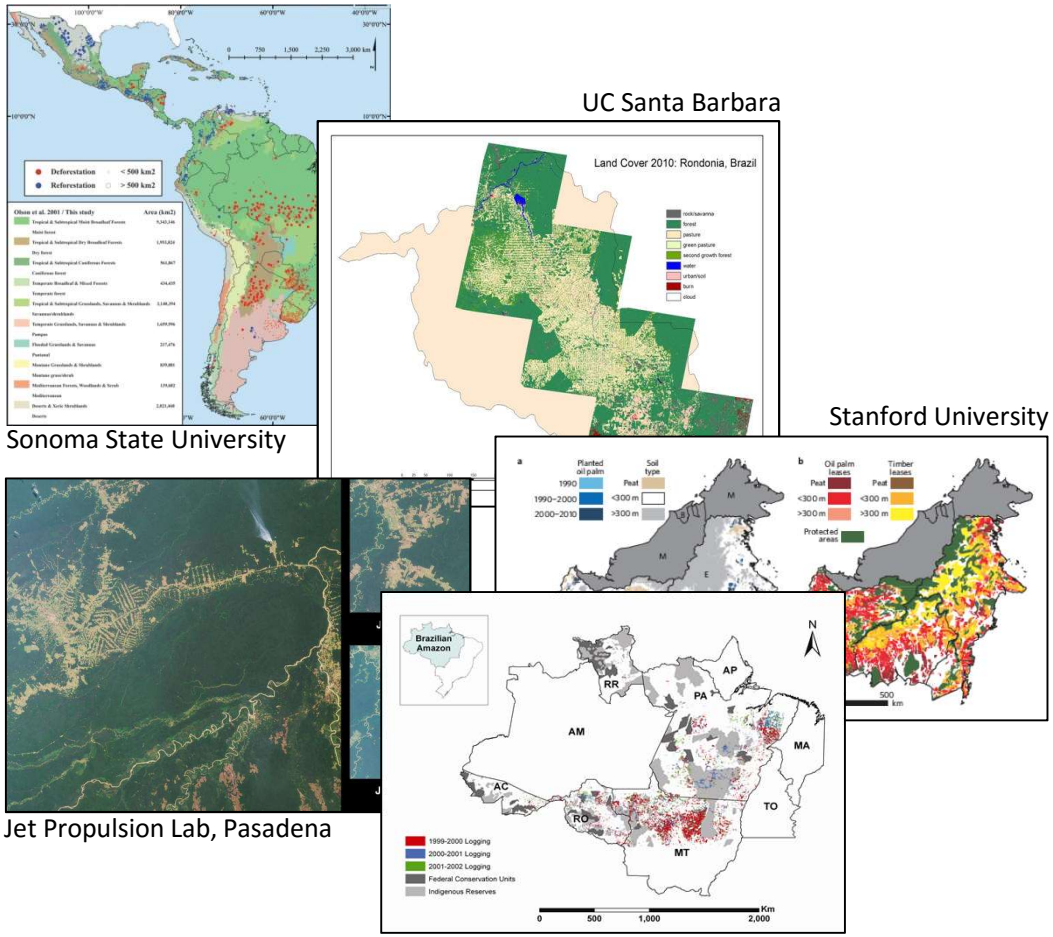
Carbon stock sampling

Scaling; Monitoring carbon emissions and gains

Forest Cover Monitoring

At jurisdictional scales, forest cover change - from *deforestation*, *degradation*, *and regrowth* – are straightforward to monitor with California-grown satellite monitoring technologies.

- Measurement resolutions: ≤ 0.1 ha
- Mapping and reporting: ≤ 1.0 ha



Sonoma State University

UC Santa Barbara

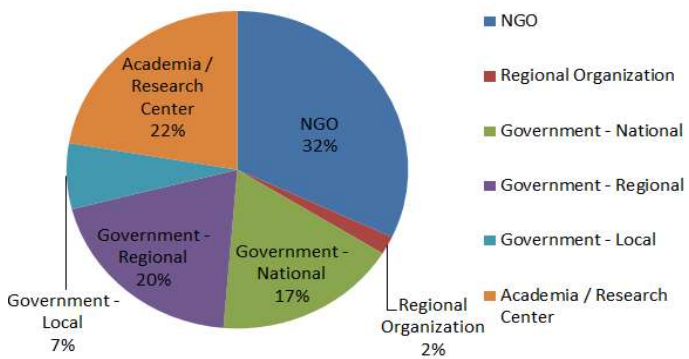
Stanford University

Jet Propulsion Lab, Pasadena

Carnegie Institution, Palo Alto

Carnegie Landsat Analysis System-lite (CLASlite)

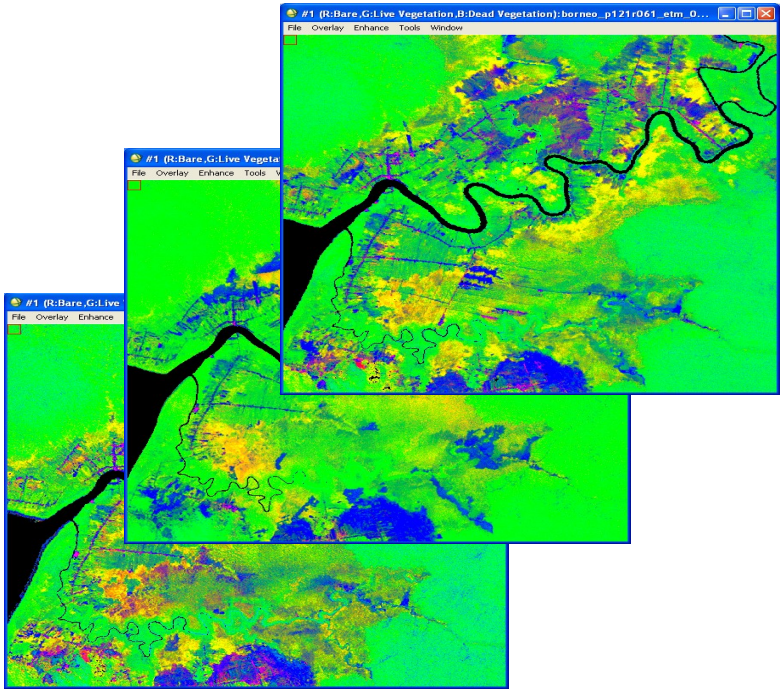
- System to automatically analyze imagery from 9 different satellites
- Provides detailed maps of forest cover, deforestation, and forest degradation
- Supports users from about 2229 organizations in 133 countries
- Stanford Online Course for training and disseminating CLASlite in English and Spanish



http://claslite.stanford.edu

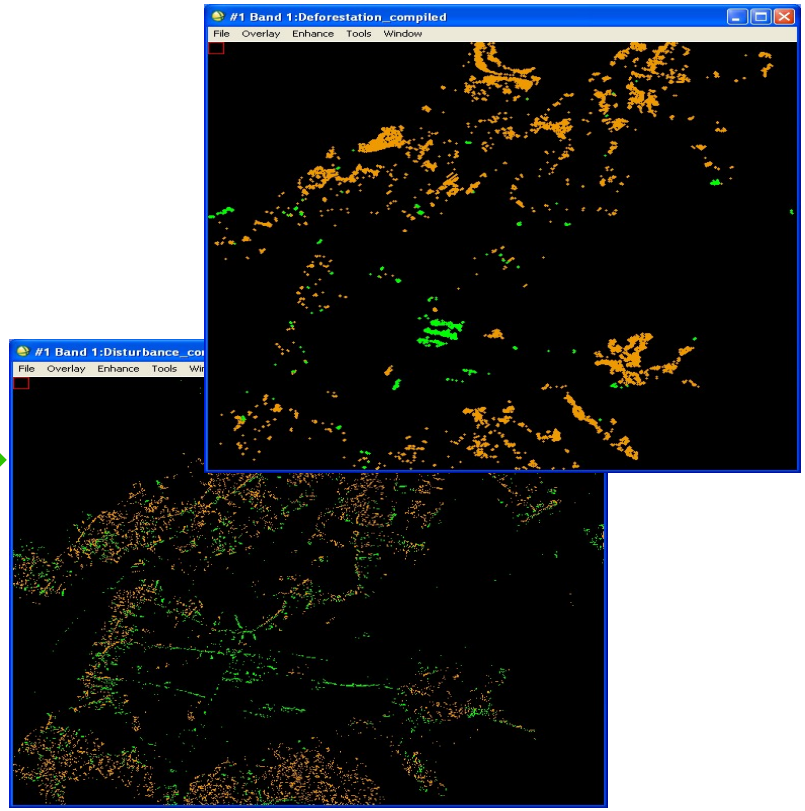
What is CLASlite?

Automated analysis of satellite imagery



Maps of Forest Change

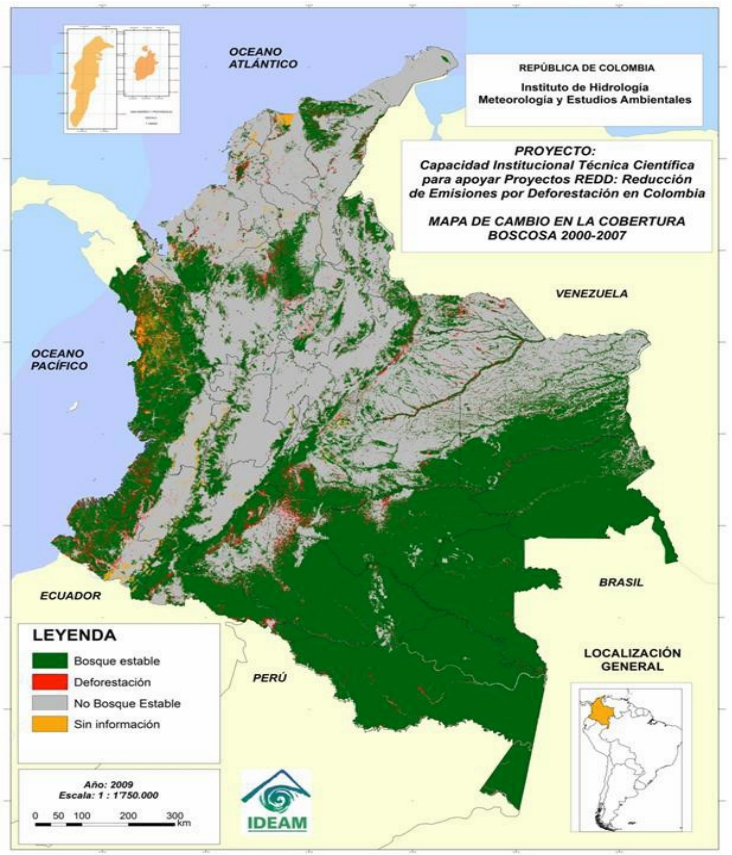
Deforestation over Time



Degradation over Time

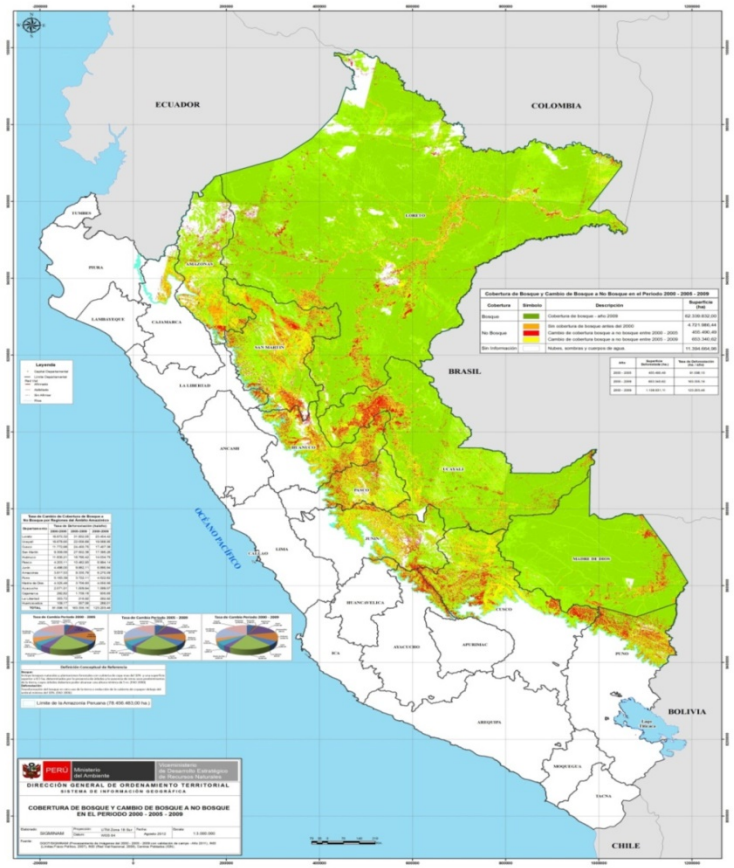
Colombian Government uses CLASlite

National forest cover change

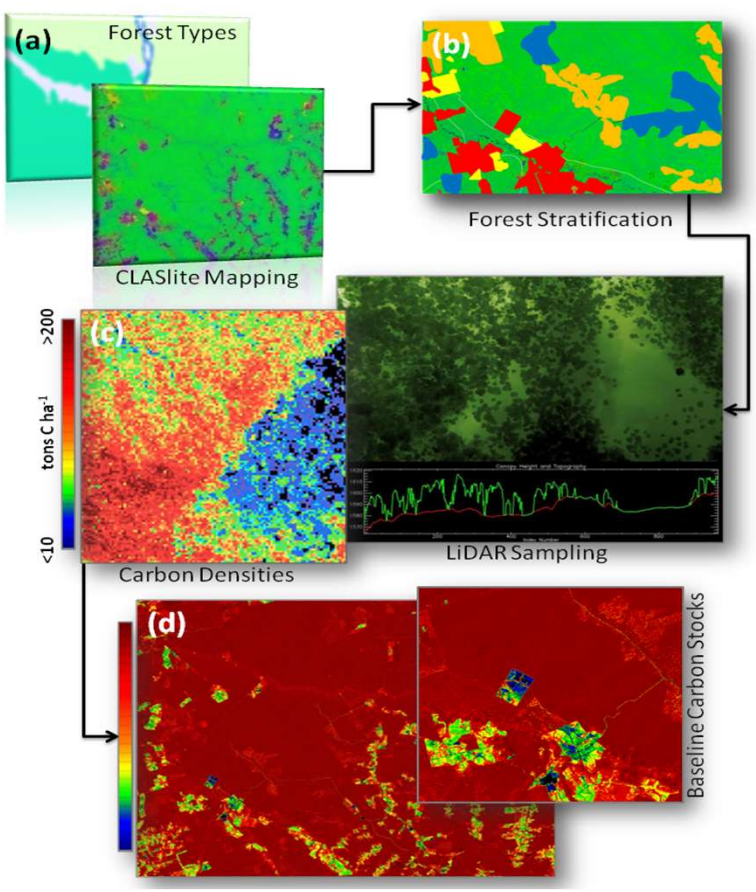


Peruvian Government uses CLASlite

Amazon forest cover change



How Modern Forest Carbon MRV Systems Work



Satellite for strategic mapping of forest cover and type

Carbon stock sampling

Scaling; Monitoring carbon emissions and gains

Jurisdictional Forest Inventory

- Field plot networks are essential for most carbon monitoring systems.
- Lots of innovation ongoing in standardizing plot-level measurements and calculations (allometrics)
- But plots ultimately cover a small proportion of the jurisdictional landscape.
- This has raised a lot of doubt regarding deployment, maintenance and long-term efficacy.

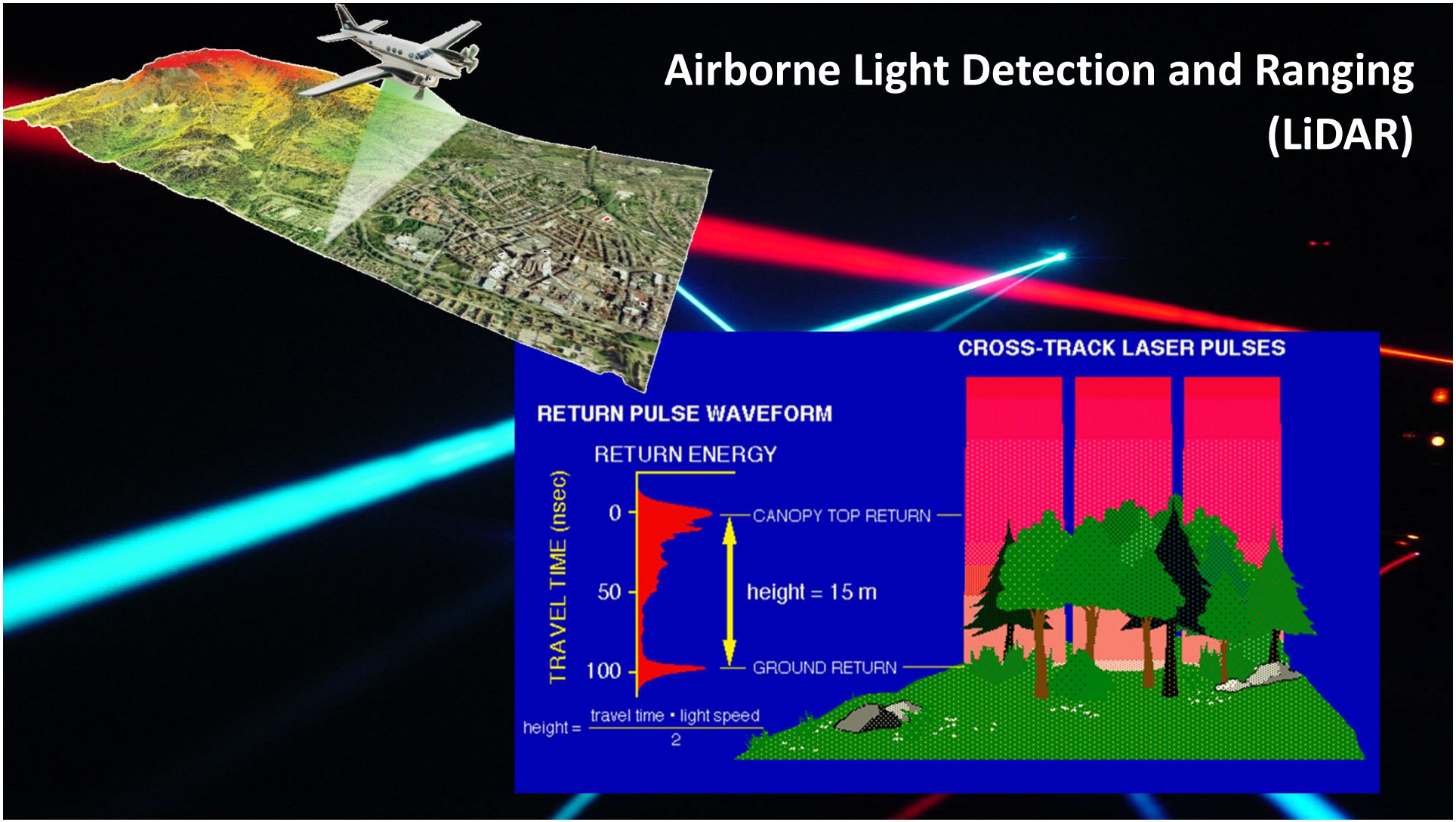
Surrogates for Field Inventory Plots?

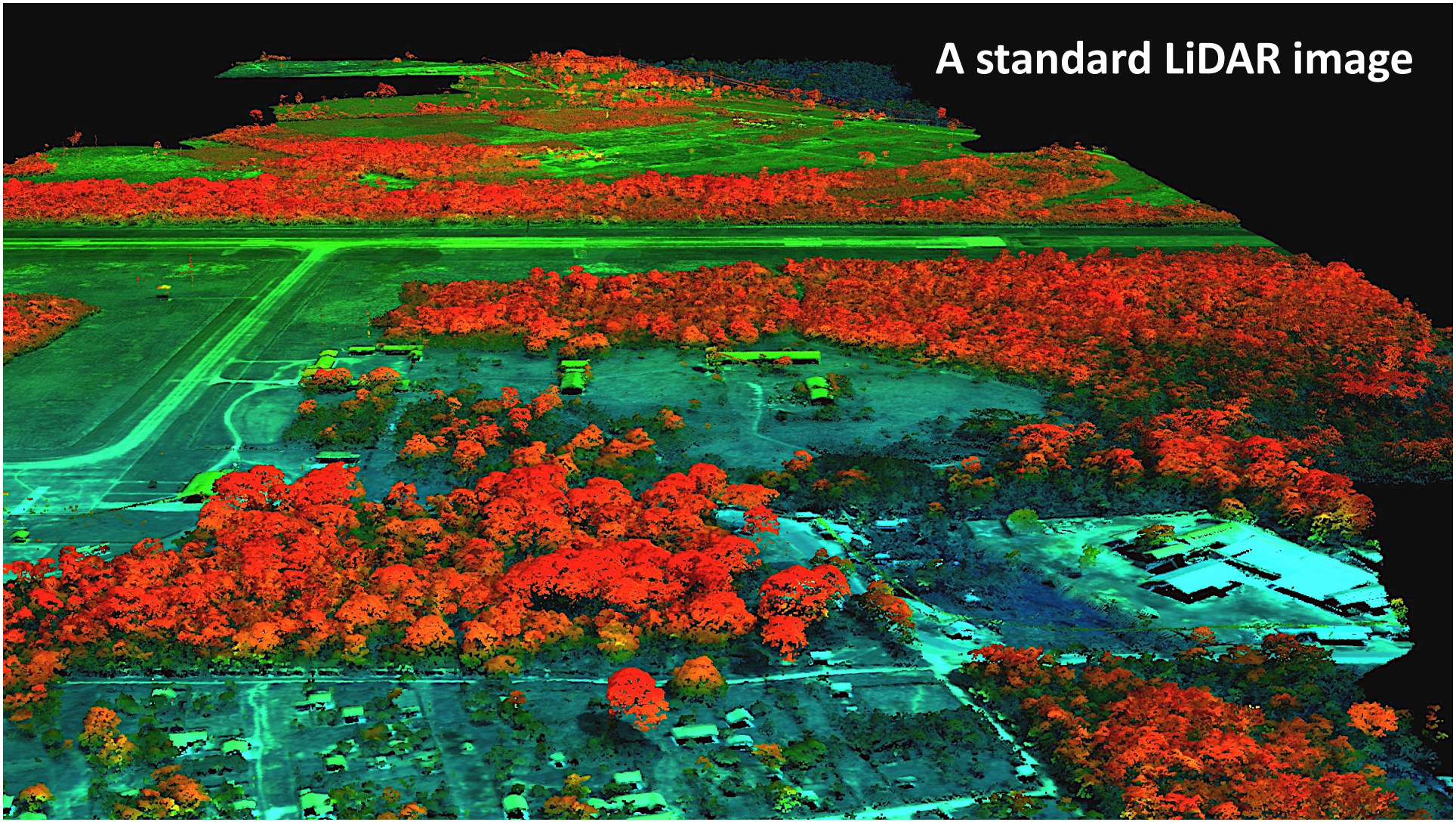
Requirements

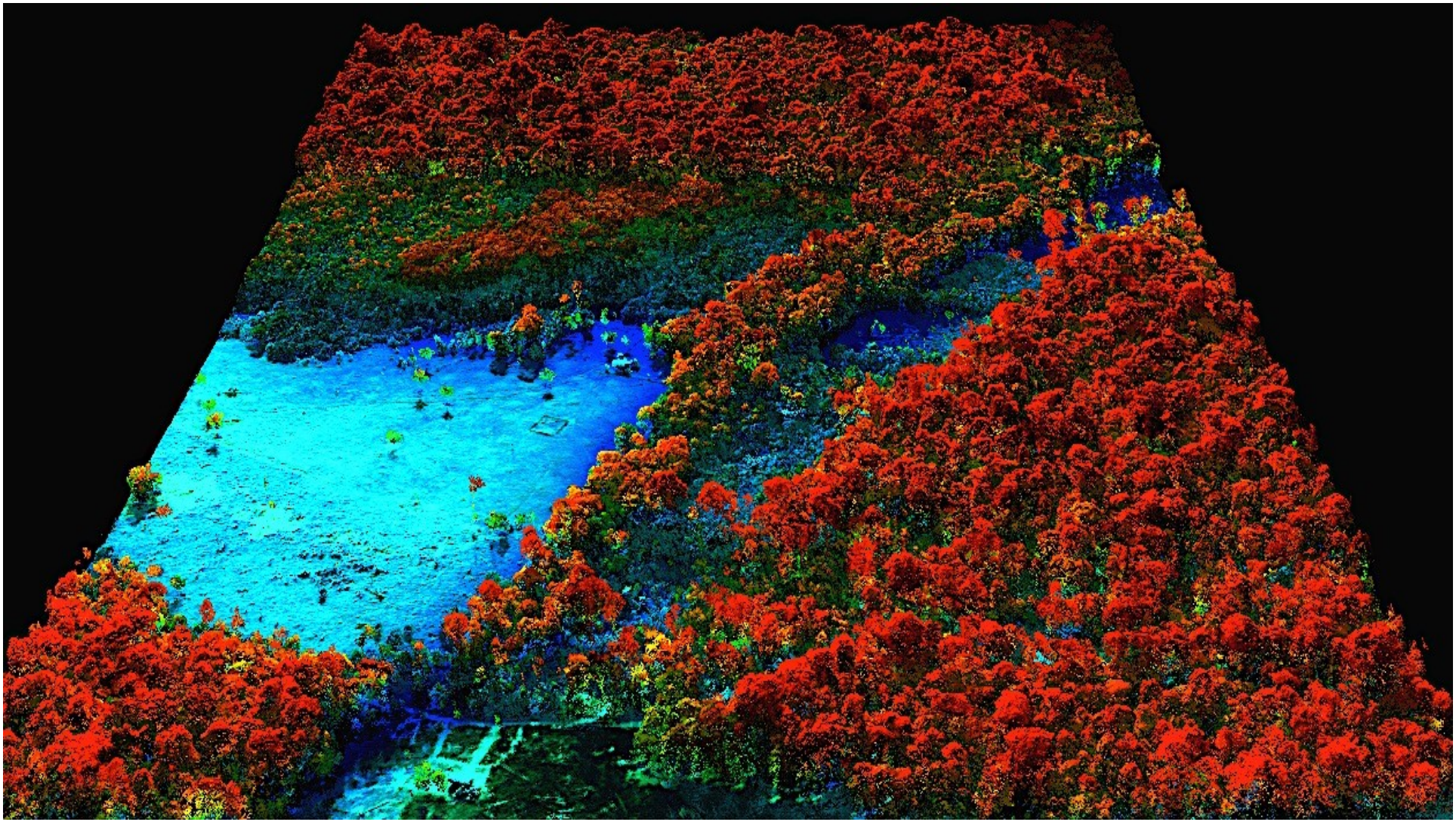
- Measures an allometric (biomass-structural) property of the vegetation
- Is not limited to any specific type of vegetation
- Can be calibrated against hand-measured field plots
- Can be used on thousands to millions of hectares per year
- Is affordable at jurisdictional levels

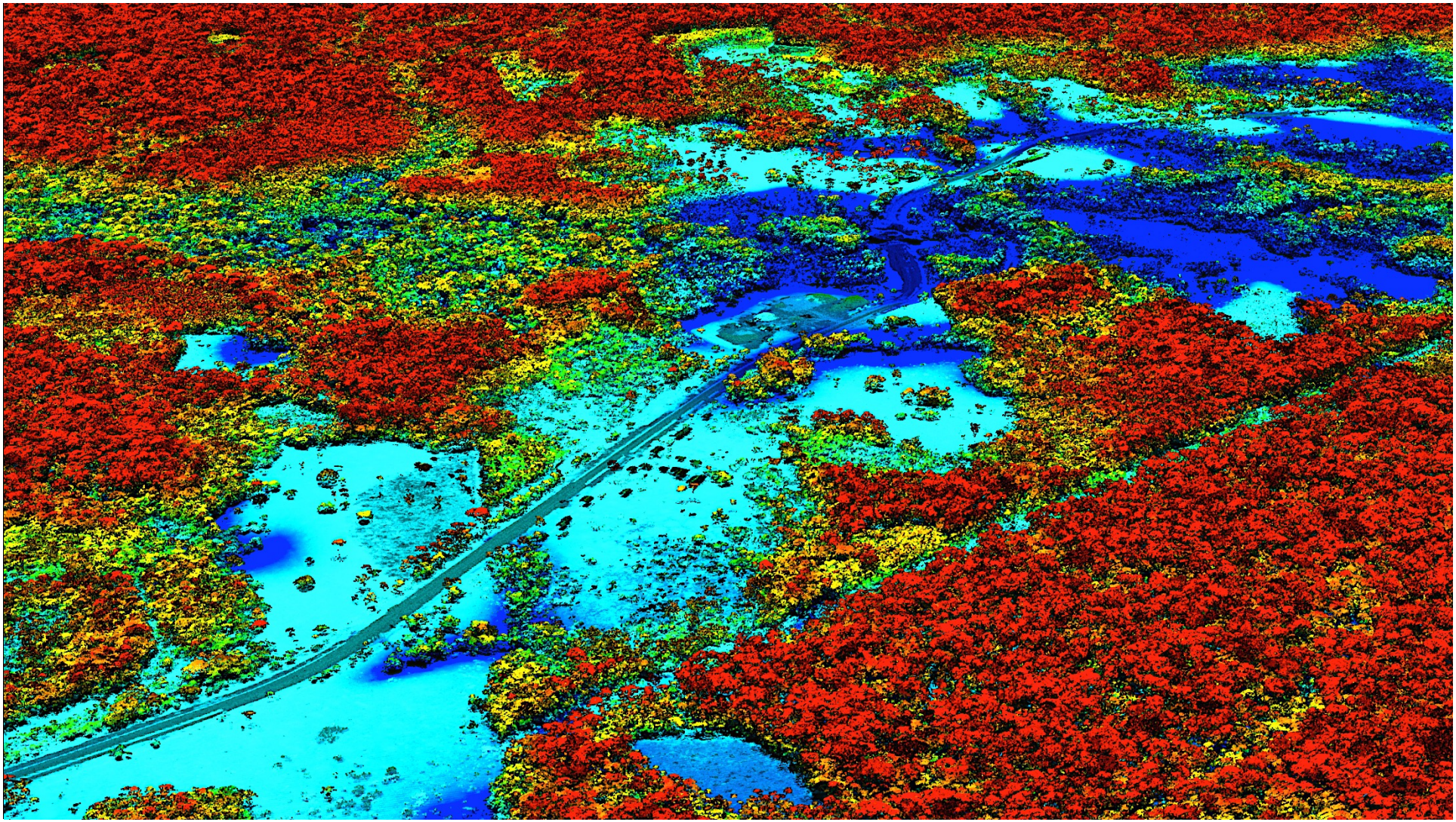
?

Airborne Light Detection and Ranging (LiDAR)

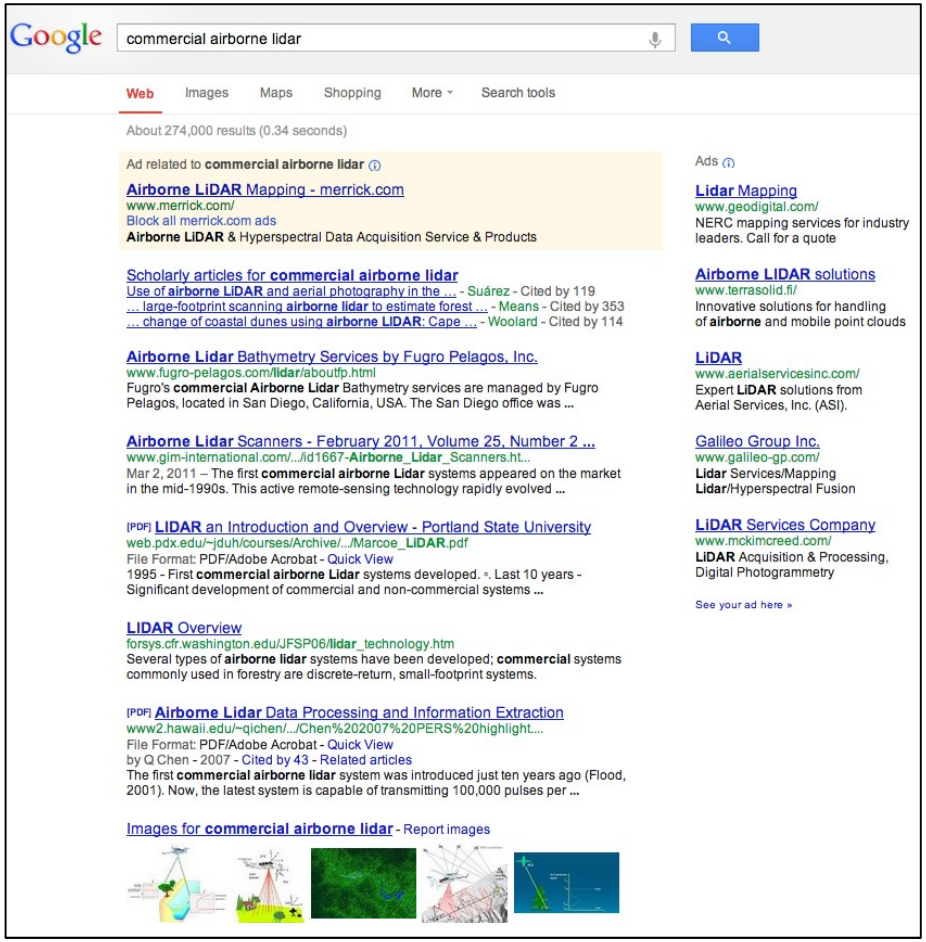



A standard LiDAR image



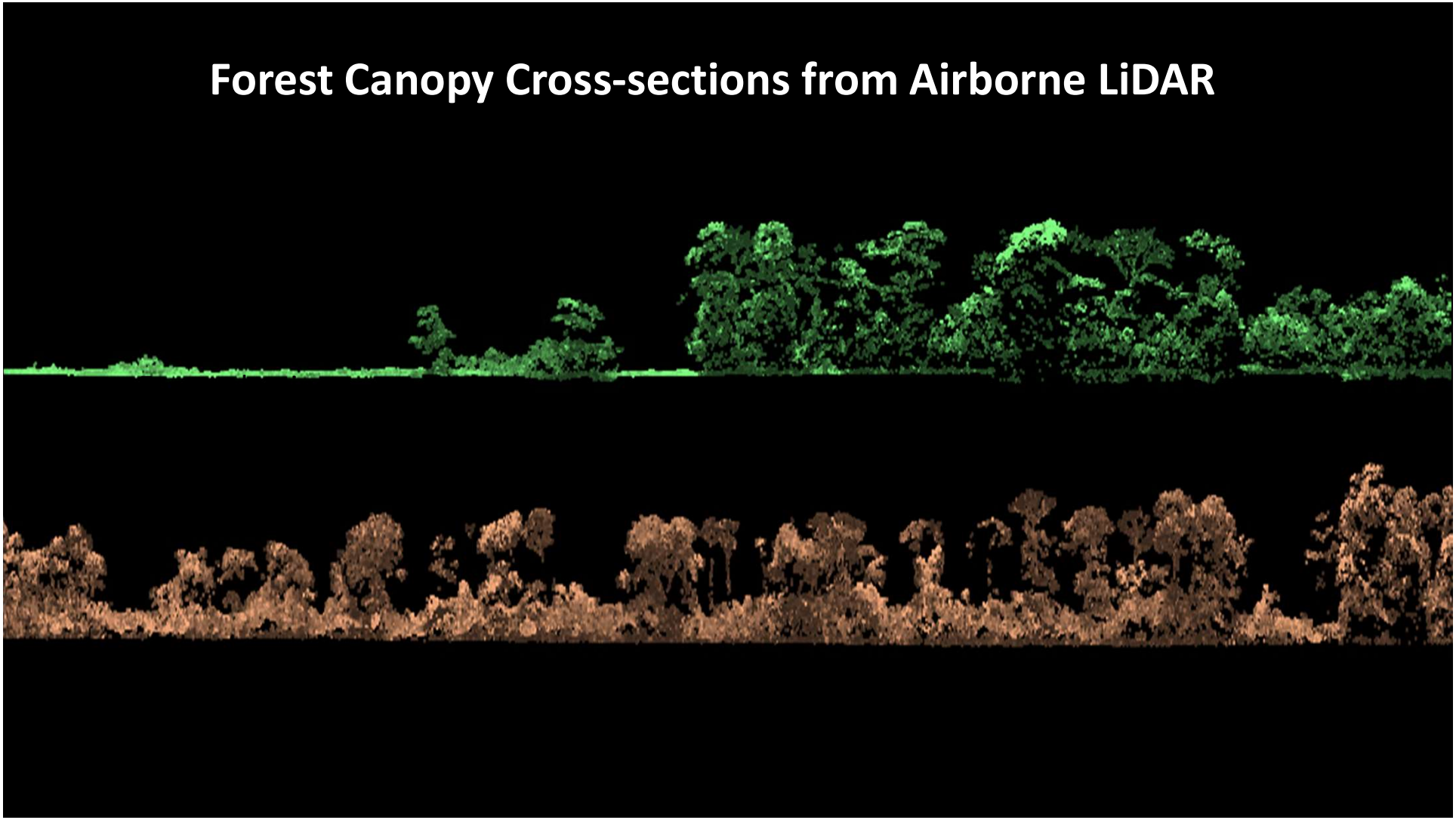


Airborne LiDAR has become very common, and this is useful to REDD+ MRV

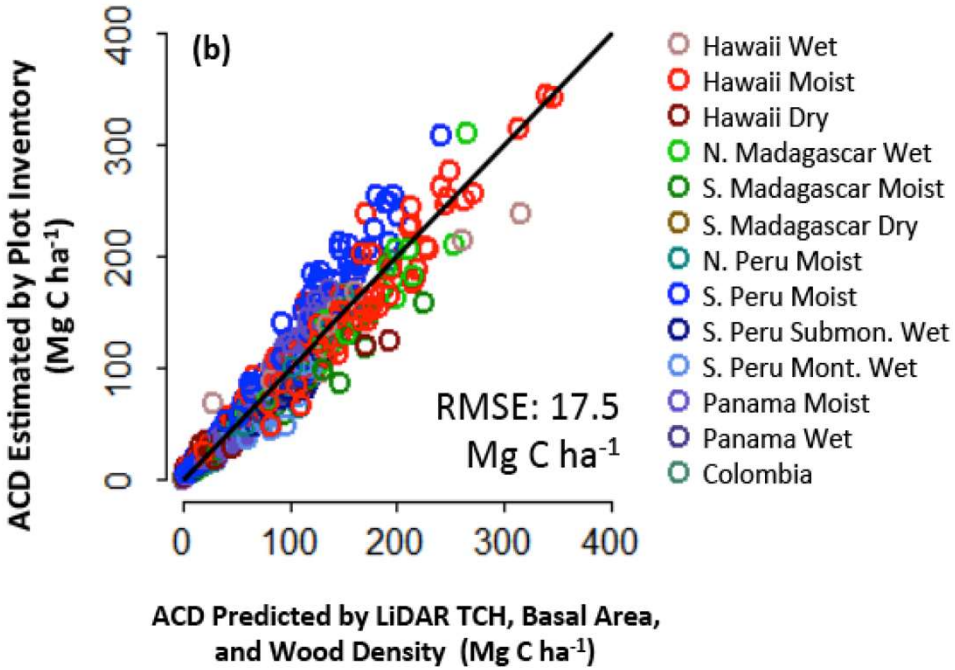


Carnegie is not a LiDAR provider.
We are a carbon science, applications, and training source.

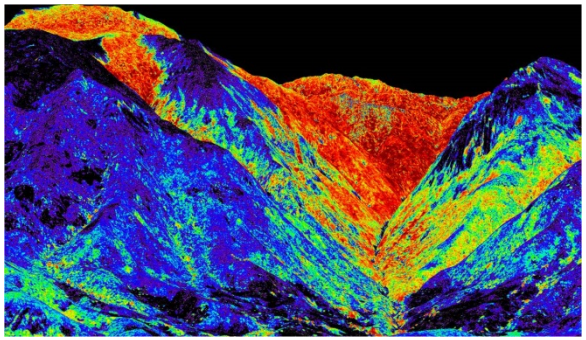
Forest Canopy Cross-sections from Airborne LiDAR



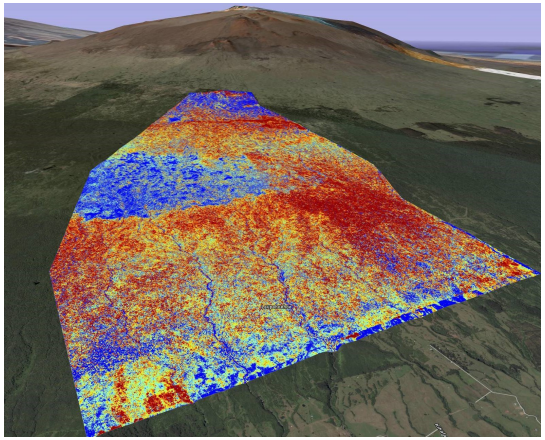
Plot-scale calibration of Airborne LiDAR



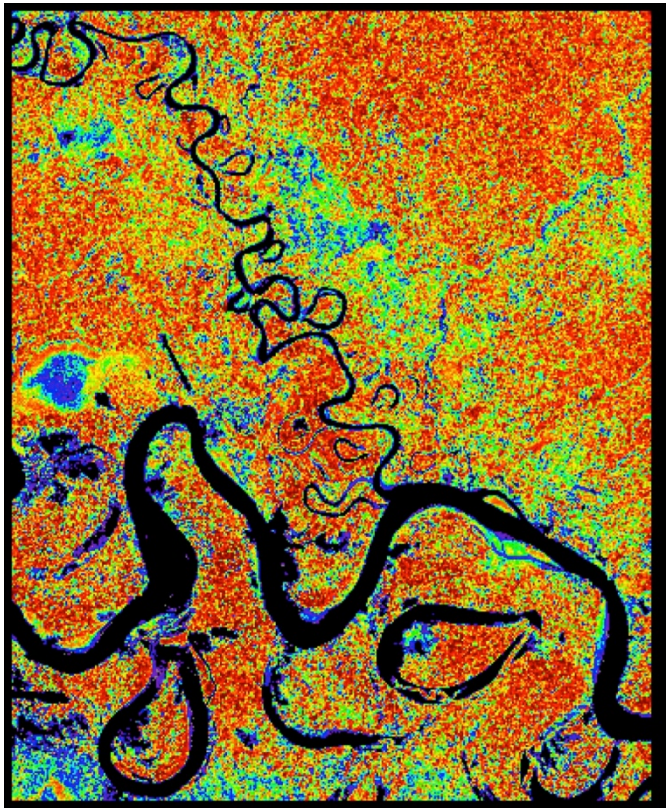
And an Explosion in LiDAR-based Forest Carbon Mapping



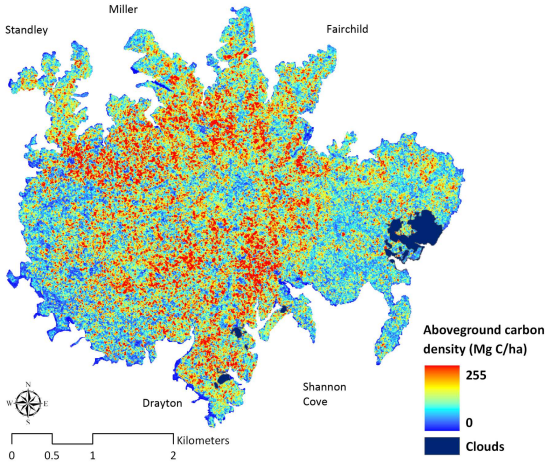
Madagascar



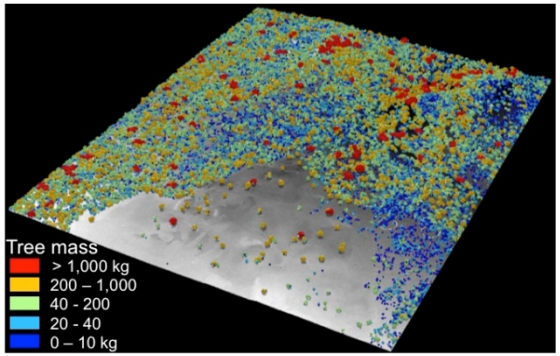
Pacific Islands



Western Amazon (Peru, Colombia, Ecuador)

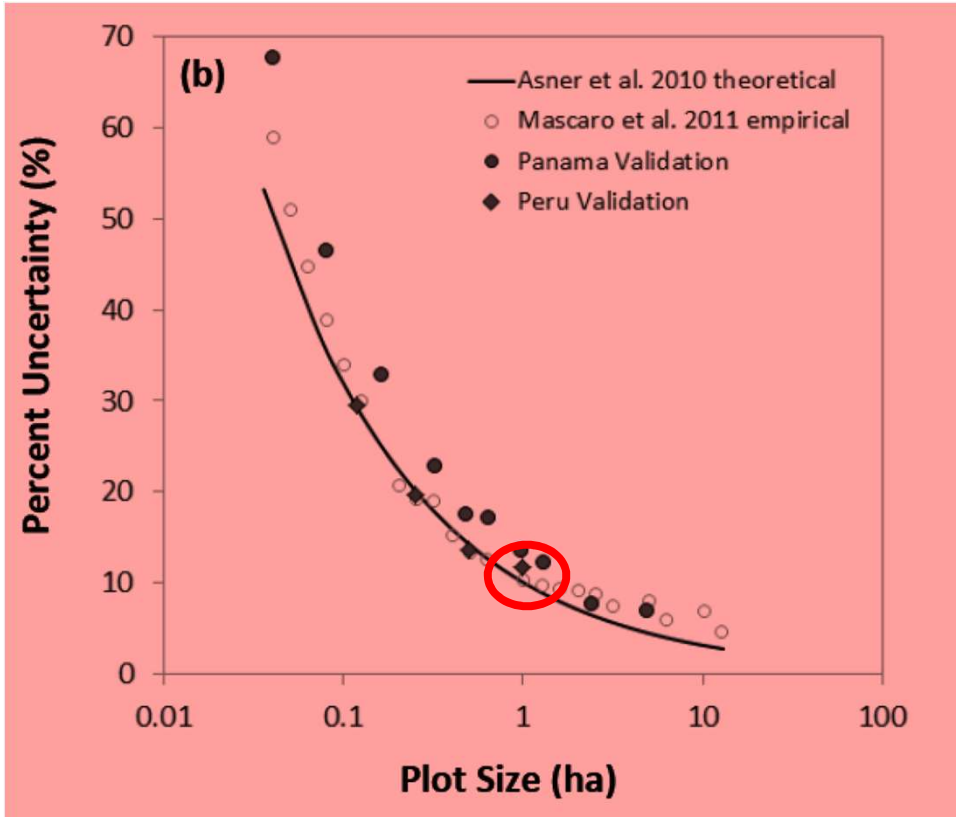


Barro Colorado Island, Panama

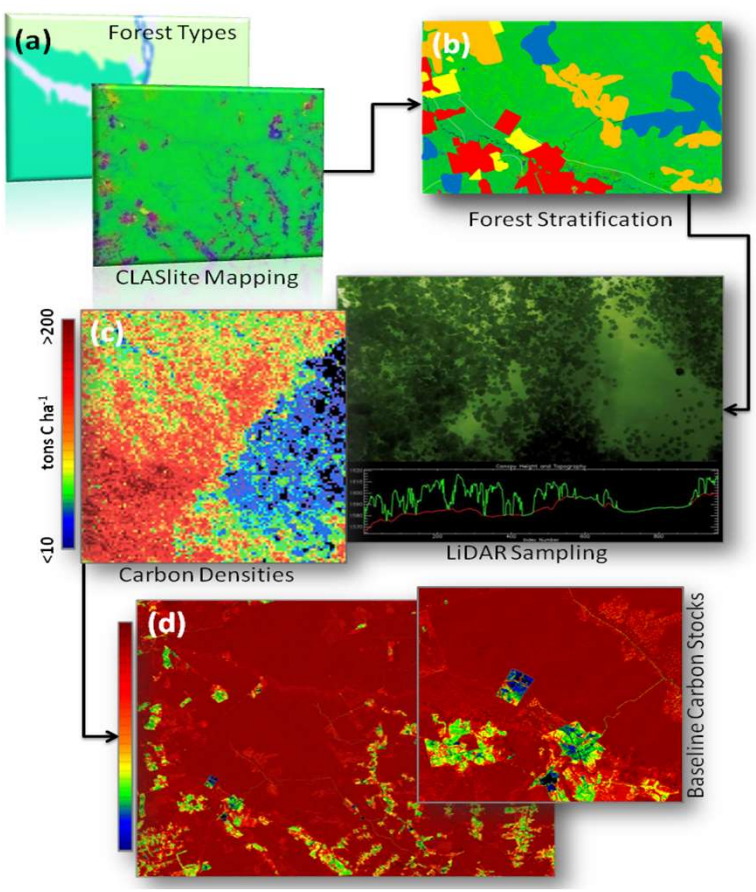


African Savannas

Uncertainty in LiDAR-based Carbon Estimation



How Modern Forest Carbon MRV Systems Work

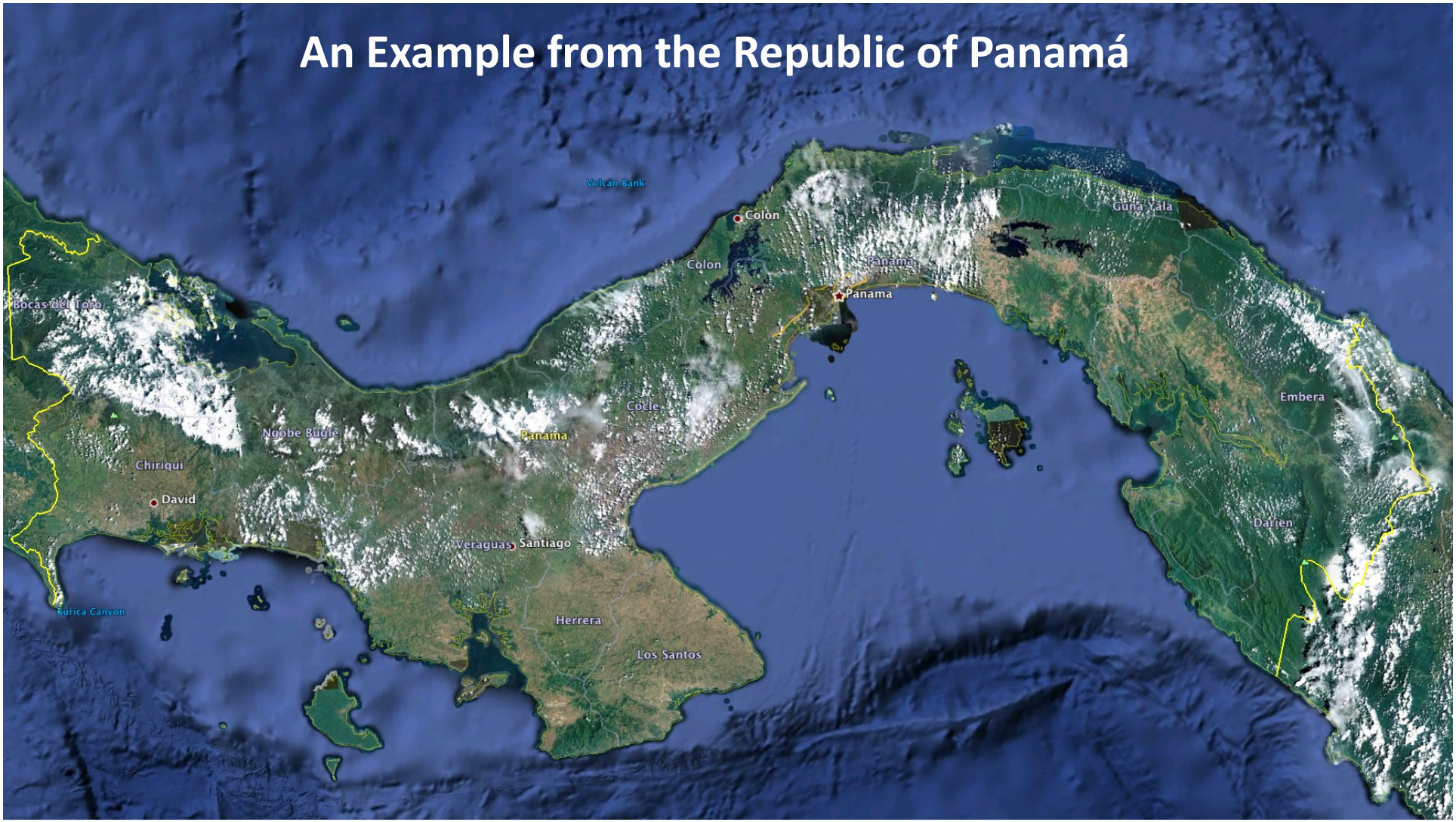


Satellite for strategic mapping of forest cover and type

Carbon stock sampling

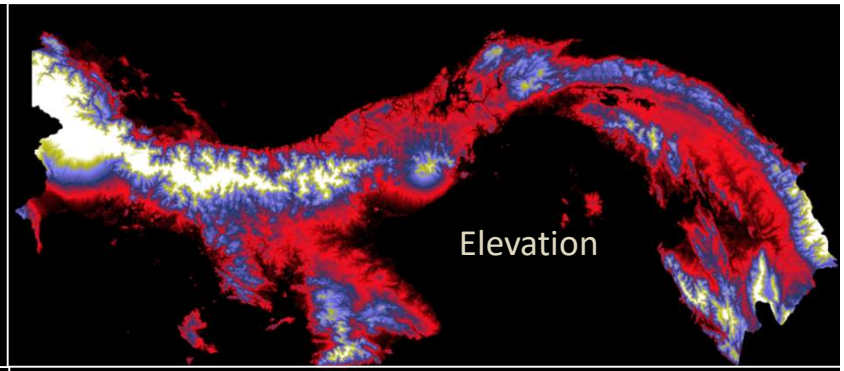
Scaling; Monitoring carbon emissions and gains

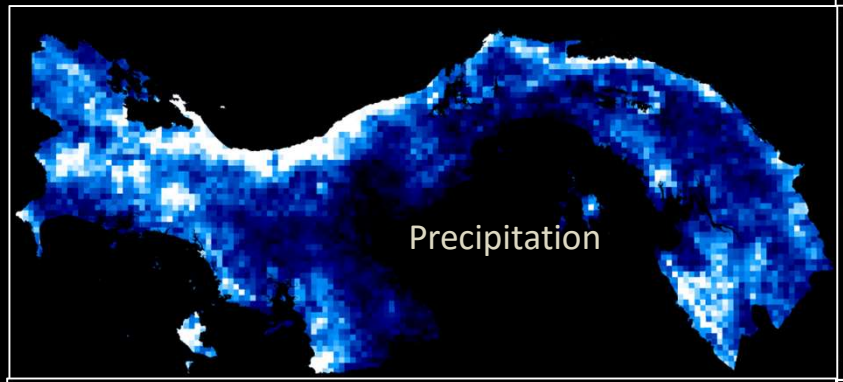
An Example from the Republic of Panamá

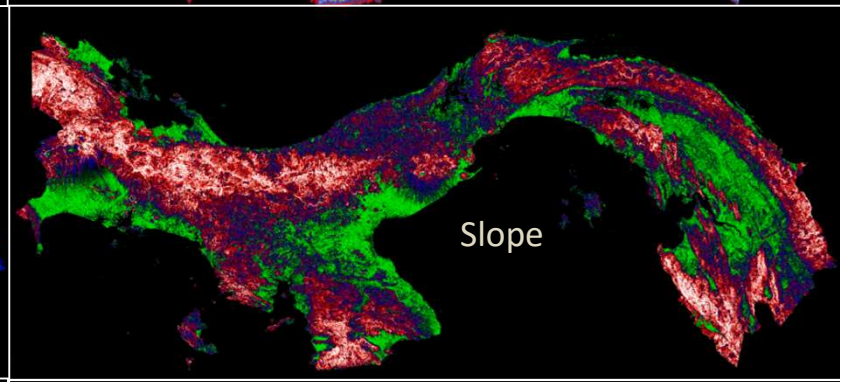


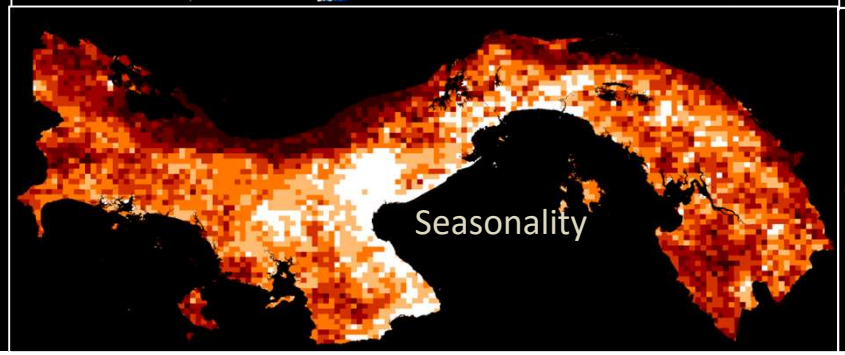
Jurisdictional Stratification

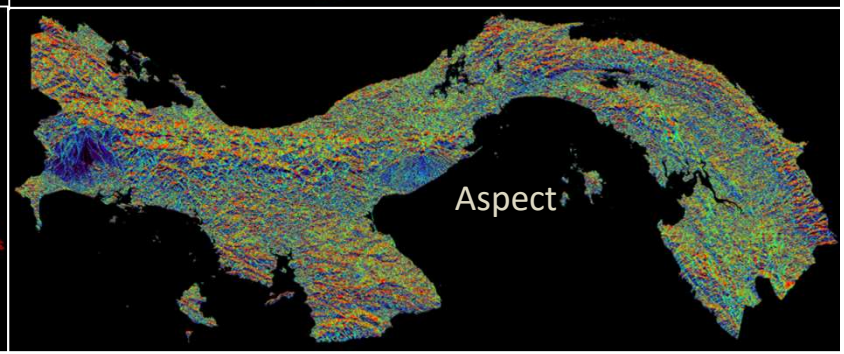
- Freely available NASA data
- Easy to use and ready for analysis



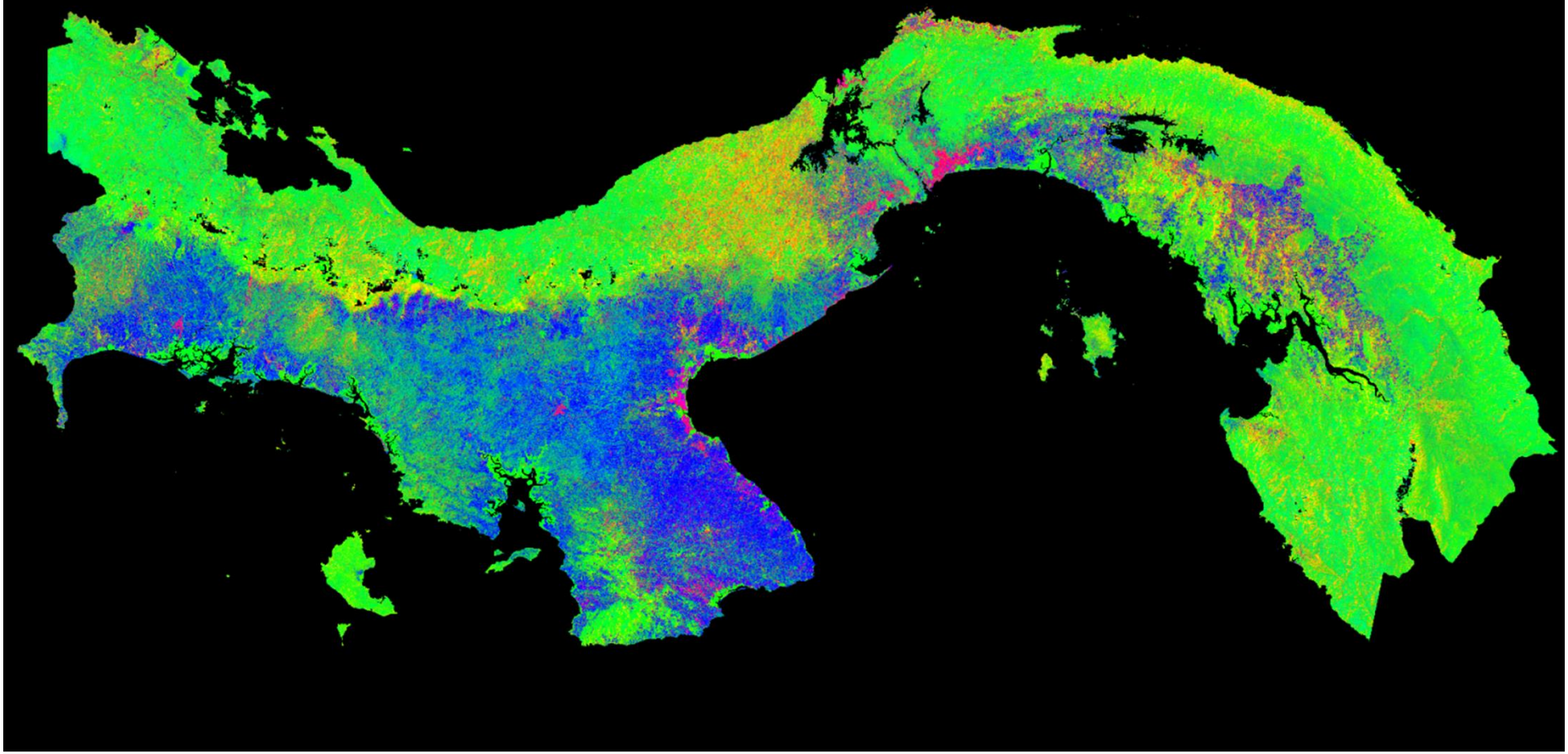




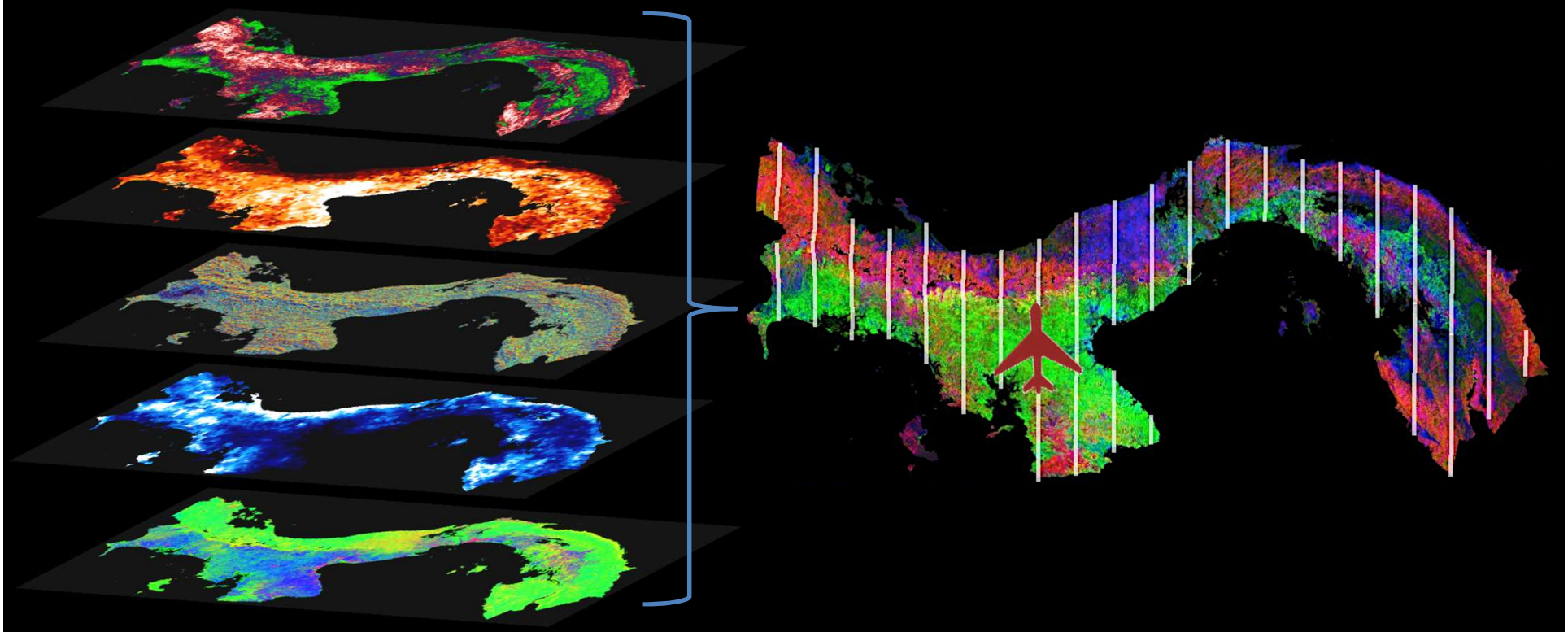


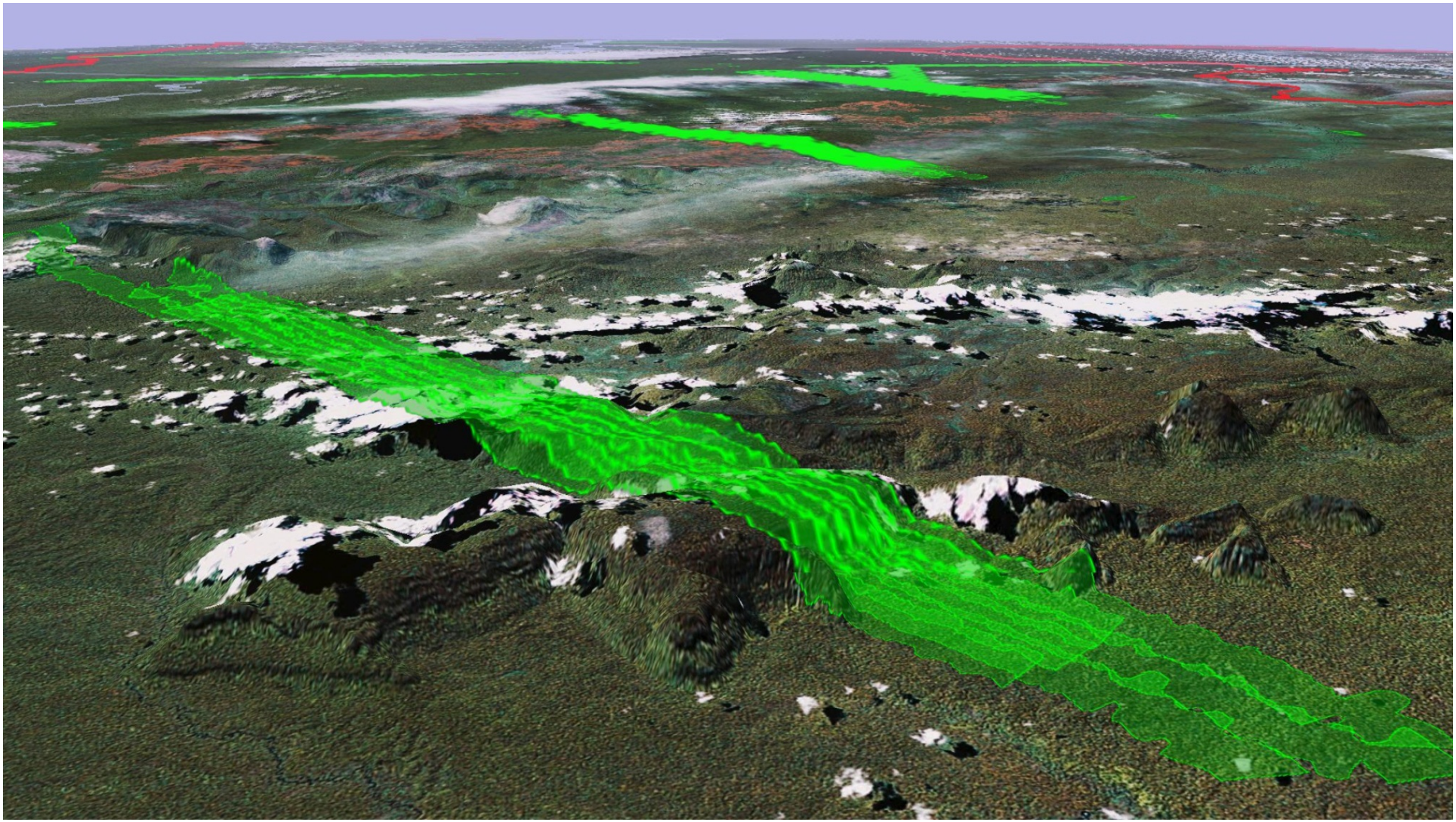


Jurisdictional Stratification with CLASlite

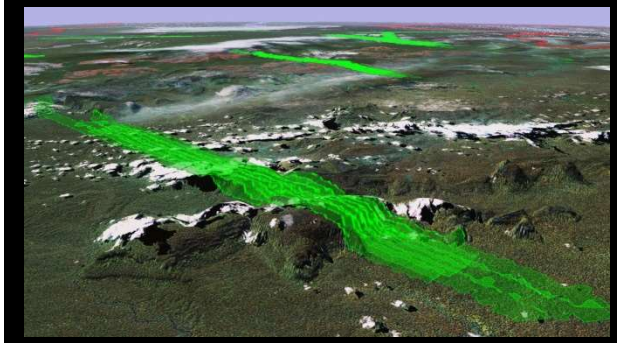


National Stratification Directs Airborne LiDAR Sampling

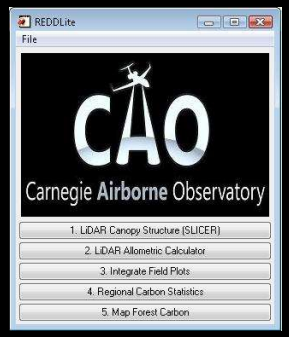


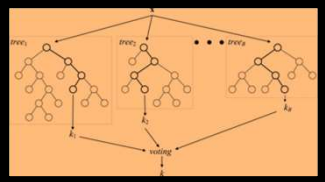


Scaling Up the LiDAR Data to the Jurisdiction using Well-established Models

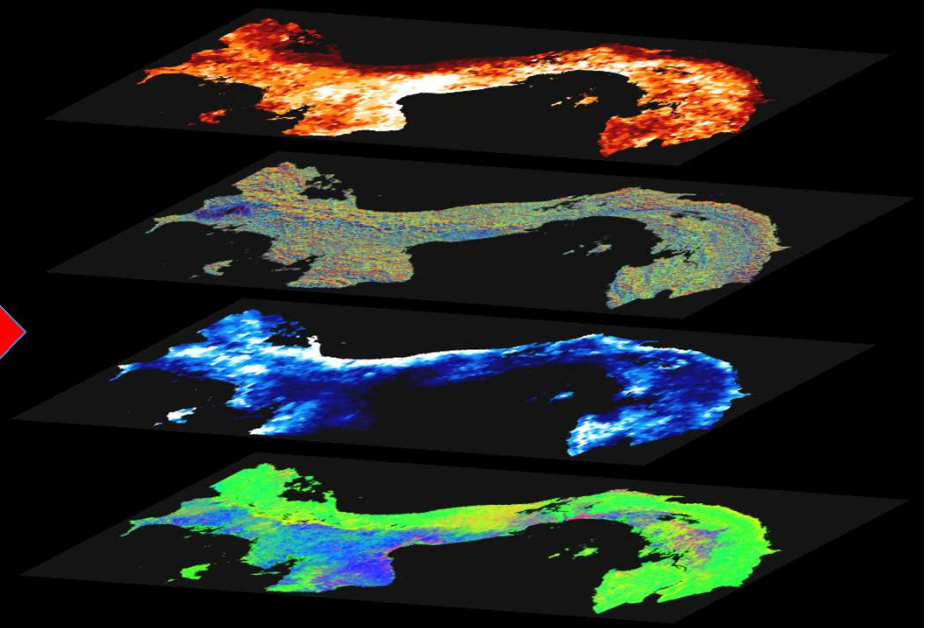


LiDAR Mapping Software

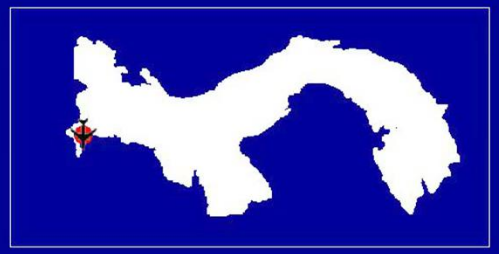




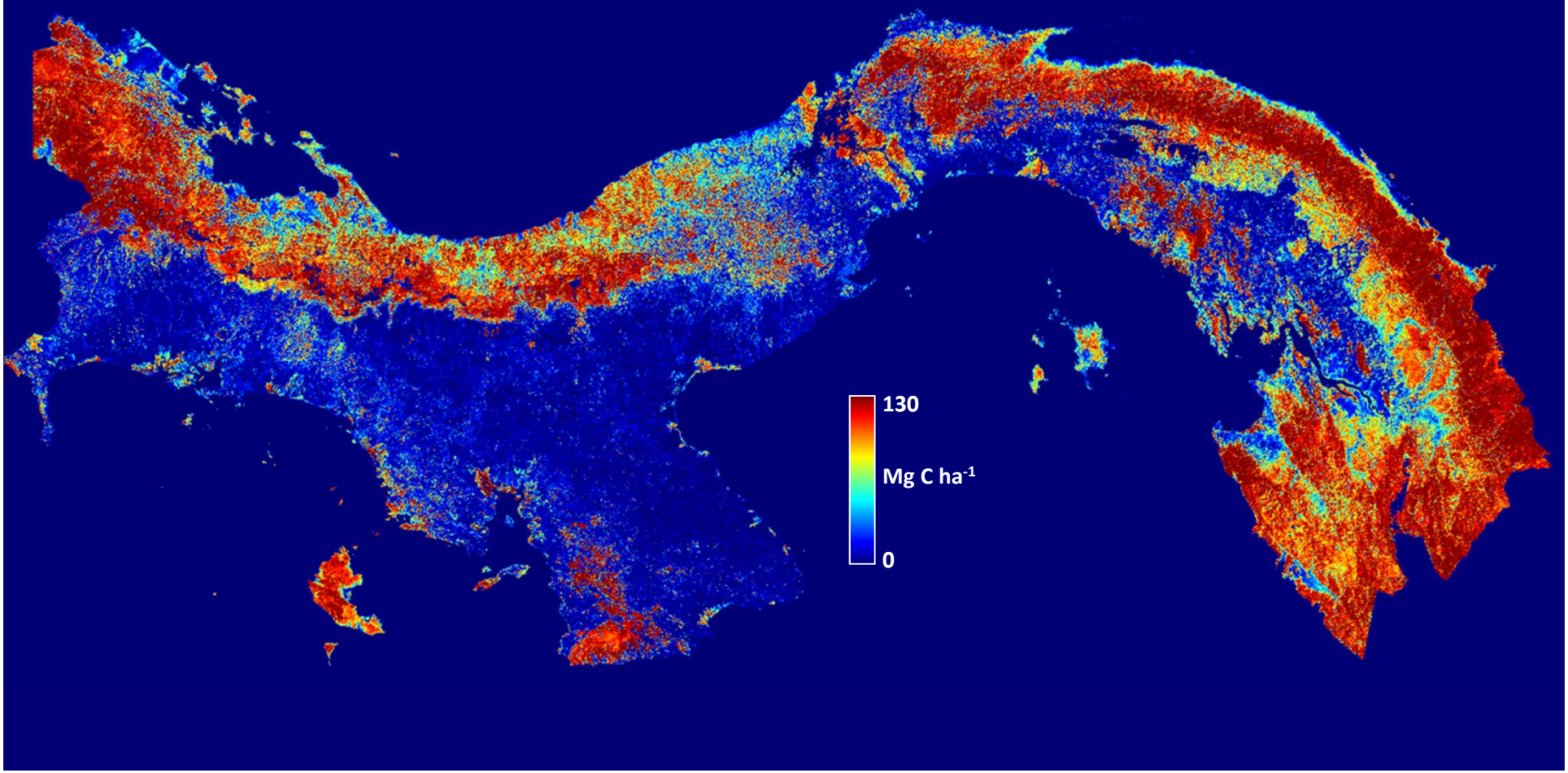
Geospatial Models



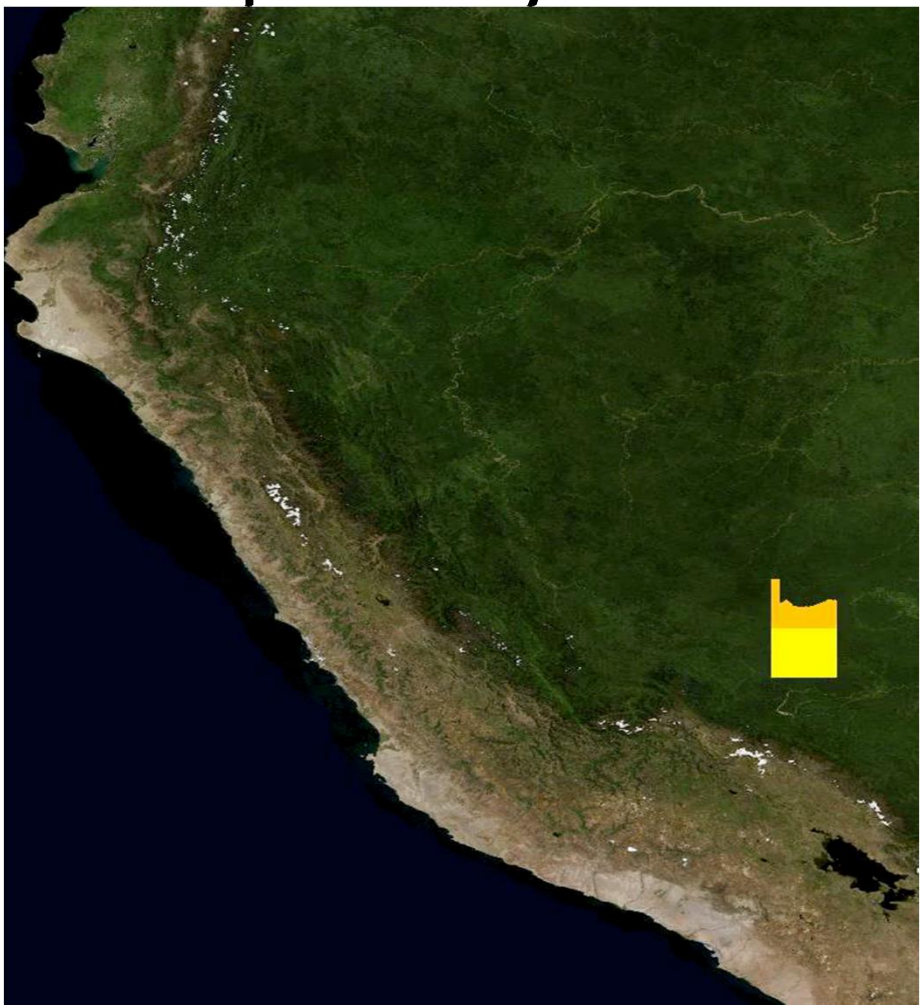
Jurisdictional Environmental Data



National 1-ha Resolution Carbon Basemap of Panamá



Deploy Aircraft & Sample Country Until Statistical Needs Met

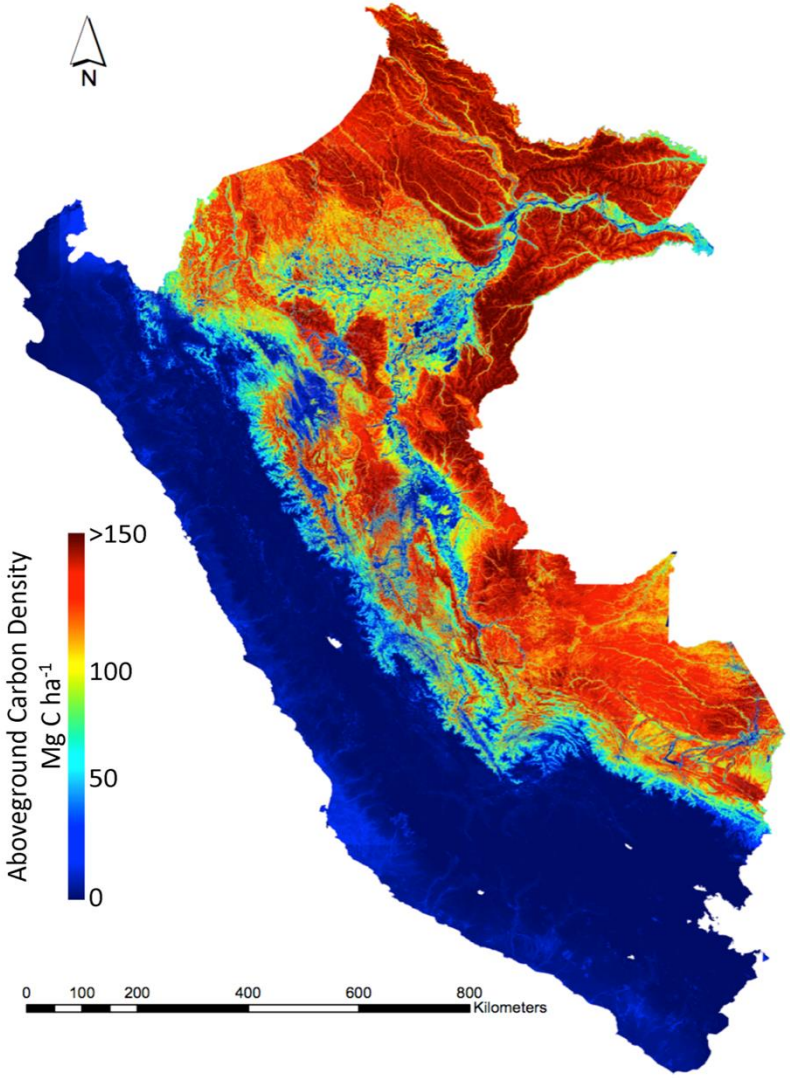


> 10.0%
5.0-10.0%
2.0-5.0%
1.0-2.0%
0.5-1.0%

5,000 hectares

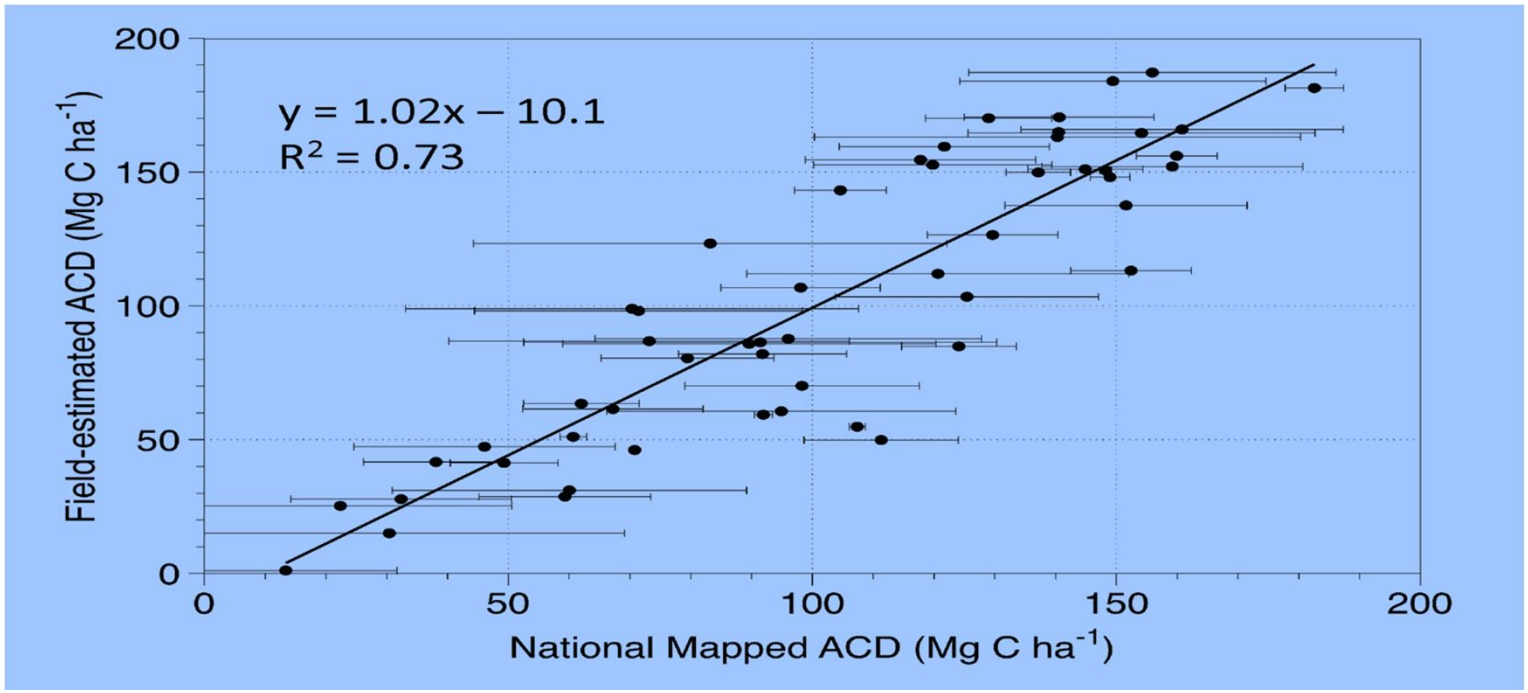
The High-resolution Carbon Geography of Perú

128,546,068 hectares
(321 million acres)
at 1-hectare resolution with uncertainty reported for every hectare throughout the country

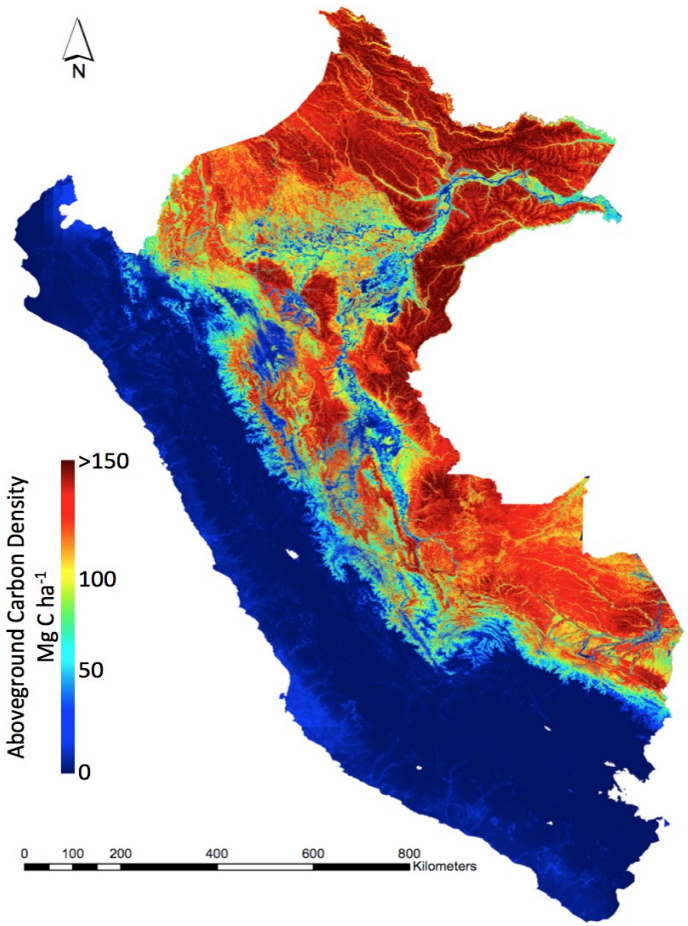


Field Verification

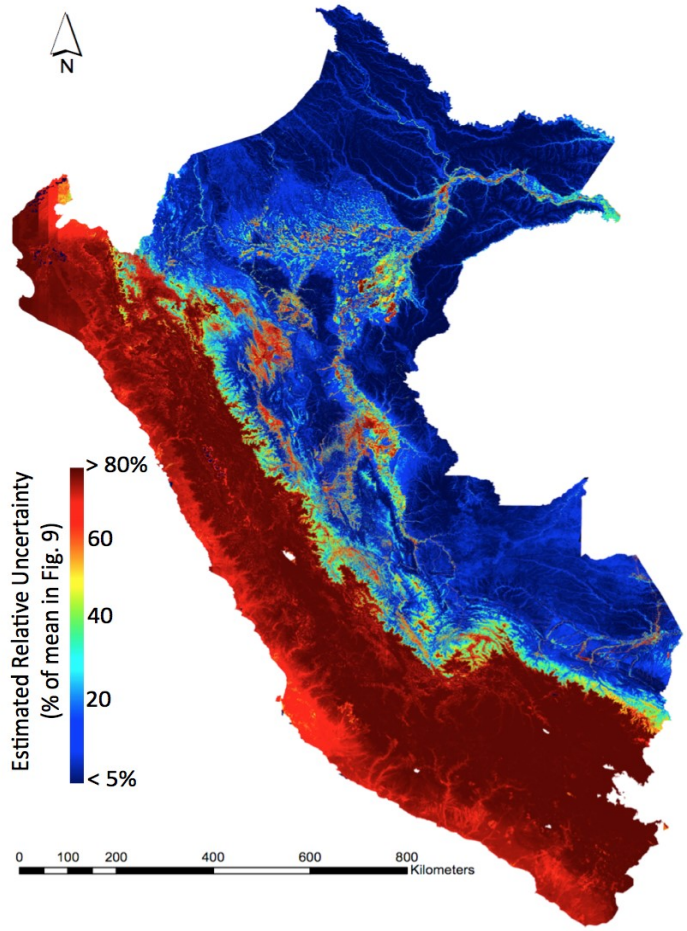
Years of work



One day of flight

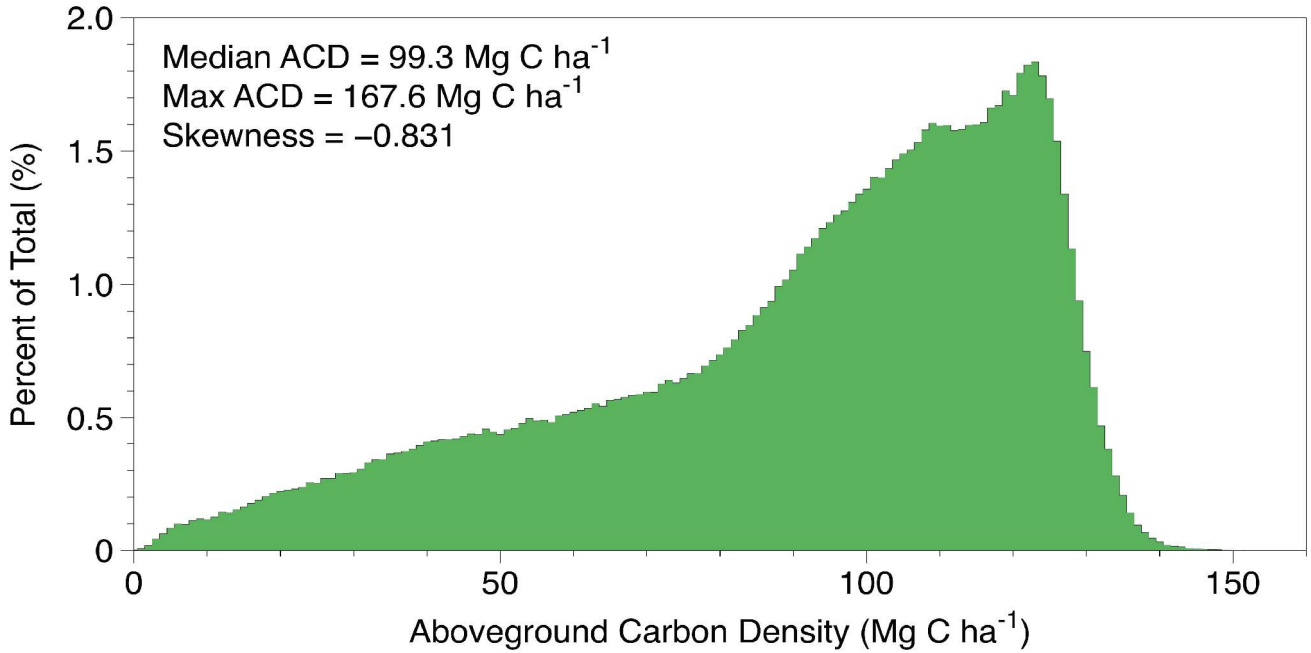


Carbon Stocks in Every Hectare of Perú



Uncertainty in Every Hectare of Perú

Distribution of Carbon Stocks throughout Peru's forests

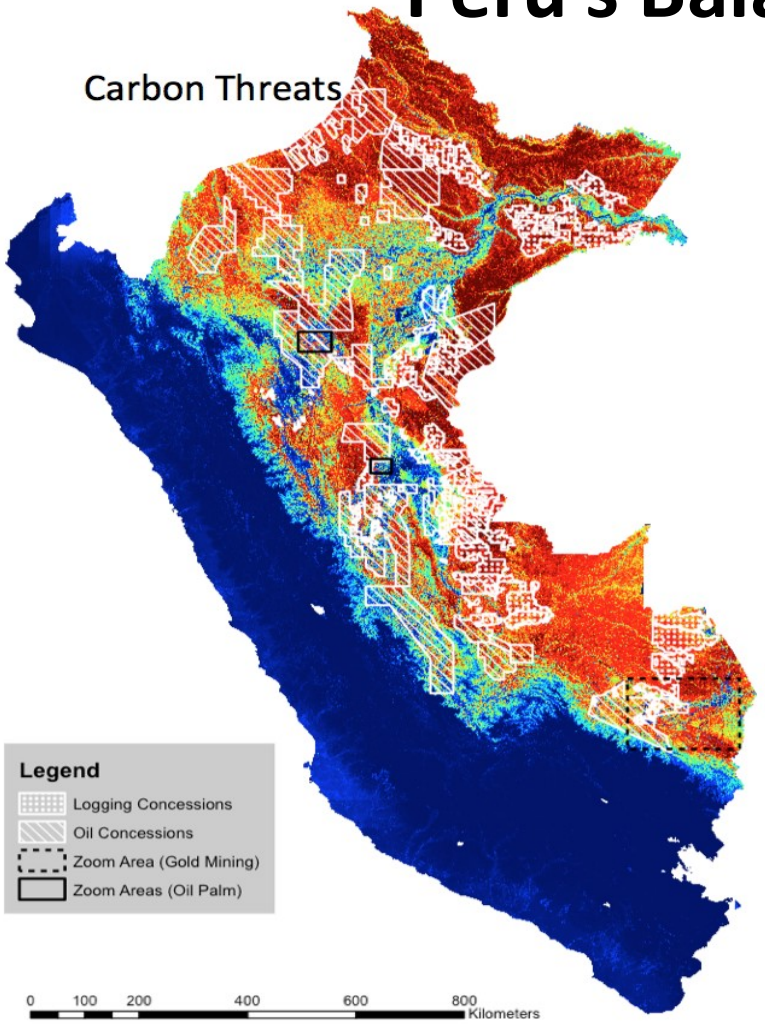


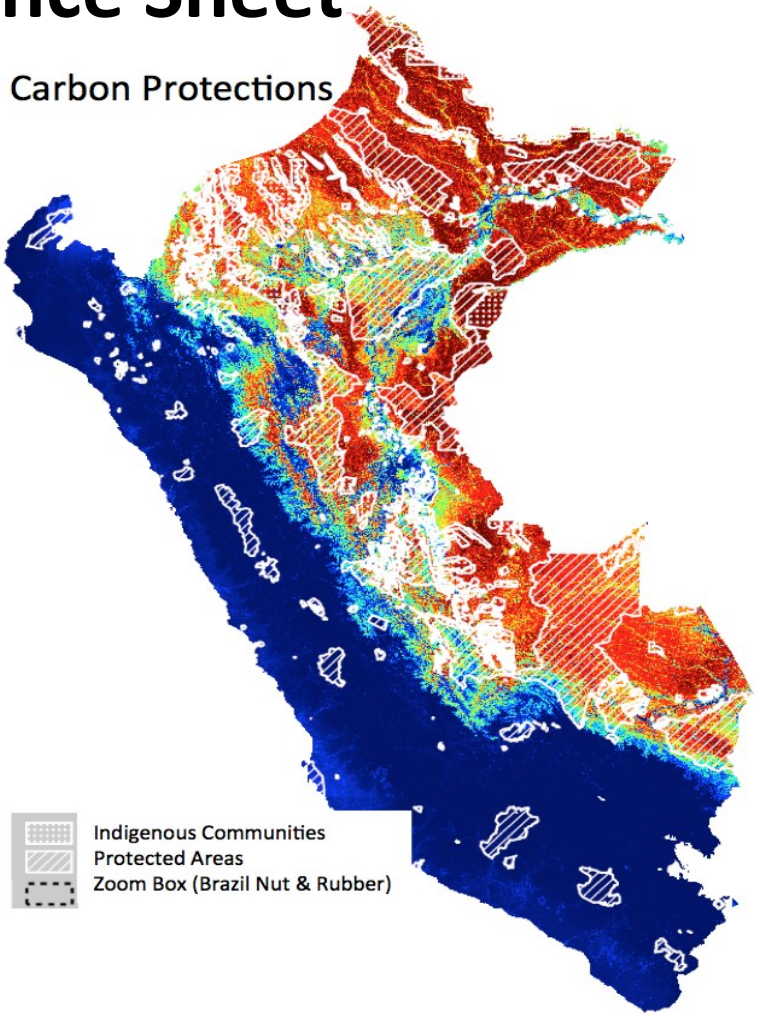
Carbon Stocks by Jurisdiction

Table 1. Mean and variance of aboveground carbon density, and total aboveground carbon stock, for each Peruvian Region. The proportion of carbon stocks in each region relative to the total for Peru is also given. SD = standard deviation. Tg = Teragram = one million metric tons.

Region	Area (ha)	Mean Carbon Density (Mg C ha^{-1})	SD of Carbon Density (Mg C ha^{-1})	Total Carbon Stock (Tg C)	Proportion of Perú (%)
Amazonas	3,930,390	61.9	38.7	242.9	3.51
Ancash	3,595,941	2.3	2.6	8.1	0.12
Apurimac	2,111,640	1.0	2.1	2.2	0.03
Arequipa	6,325,762	2.2	2.6	14.2	0.21
Ayacucho	4,349,951	4.7	13.8	20.4	0.29
Cajamarca	3,304,619	9.2	17.0	30.5	0.44
Callao	14,167	6.4	2.8	0.1	0.01
Cusco	7,207,883	32.2	38.8	231.7	3.35
Huancavelica	2,206,335	1.8	4.2	3.9	0.06
Huánuco	3,720,347	35.2	37.5	130.6	1.89
Ica	2,108,125	7.7	4.2	16.1	0.23
Junín	4,399,697	33.4	37.5	146.4	2.11
La Libertad	2,529,588	4.0	8.2	10.0	0.14
Lambayeque	1,434,306	3.01	2.6	4.4	0.06
Lima	3,499,260	3.3	3.0	11.6	0.17
Loreto	37,511,259	98.8	29.4	3685.1	53.24
Madre de Dios	8,504,866	96.4	23.0	819.2	11.83
Moquegua	1,580,513	2.7	3.2	4.3	0.06
Pasco	2,411,598	51.2	42.5	123.3	1.78
Piura	3,605,927	3.3	4.6	11.7	0.17
Puno	6,796,462	15.6	32.3	106.0	1.53
San Martin	5,096,436	59.8	37.8	303.8	4.39
Tacna	1,608,229	2.9	2.6	4.7	0.07
Tumbes	469,182	10.3	7.0	4.3	0.06
Ucayali	10,533,060	93.7	31.1	986.8	14.26

Peru's Balance Sheet

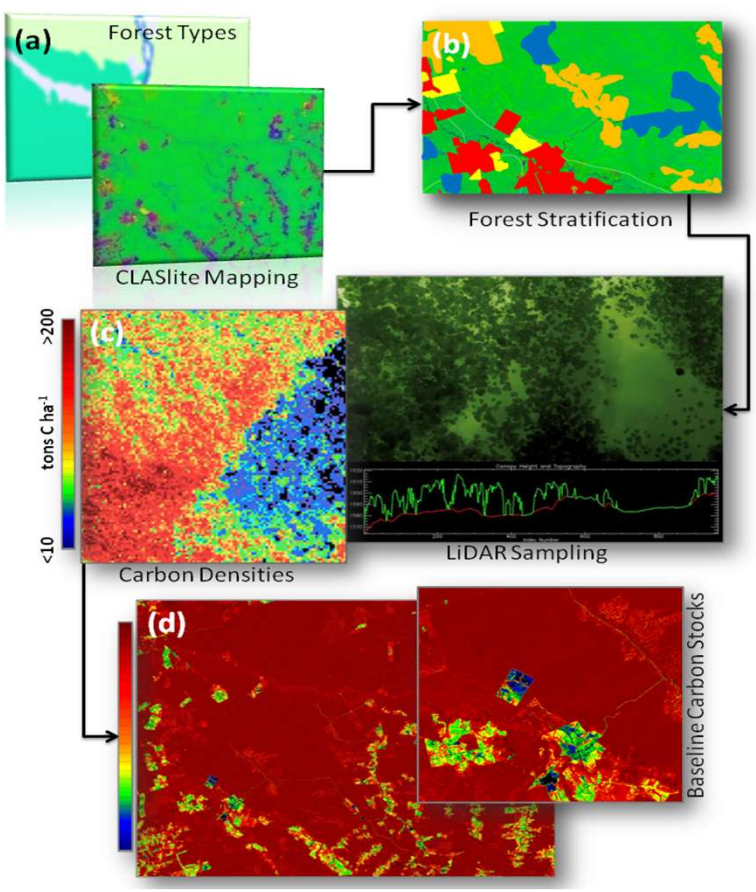




Peru's Balance Sheet

Type	Mean ACD (Mg C ha^{-1})	S.D. ACD (Mg C ha^{-1})	Area (ha)	Total AG Carbon Stock (Pg)
Threats				
Selective Logging[1]	104.9	22.1	6,417,552	0.68
Oil Concessions (< 500 m a.s.l.)[2]	93.1	32.3	13,226,773	1.24
Oil Concessions (500-2000 m)[2]	76.4	30.8	2,959,029	0.24
Oil Concessions (> 2000 m)[2]	42.9	20.3	76,231	0.04
Infrastructure, Animal and Crop Farming	5.0	5.8	1,400,000[5]	0.14[6]
Total Threats			**22,679,585**	**2.34**
Emerging Threats				
Artisanal Gold Mining[3]	34.5	29.6	37,831	0.01
Oil Palm Plantations[4]	15.4	10.9	9,684	0.001
Protections[1]				
Government Protected Areas	83.6	40.9	21,728,378	1.82
Non-government Protected Areas	100.9	14.8	1,743,277	0.17
Indigenous Communities	93.1	27.2	9,051,407	0.84
Brazil Nut Concessions	110.3	16.8	869,312	0.10
Rubber Concessions	90.6	19.1	16,158	0.01
Total Protections			**33,408,532**	**2.94**
Opportunities				
Lowland Amazonia (< 500 m a.s.l.)	86.3	39.4	22,639,377	1.95
Sub-Montane Vegetation (500-2000 m)	39.2	36.9	7,680,728	0.30
High Andean Vegetation (> 2000 m)	7.4	4.8	19,353,554	0.14
Total Opportunities			**49,673,659**	**2.39**

How Modern Forest Carbon MRV Systems Work



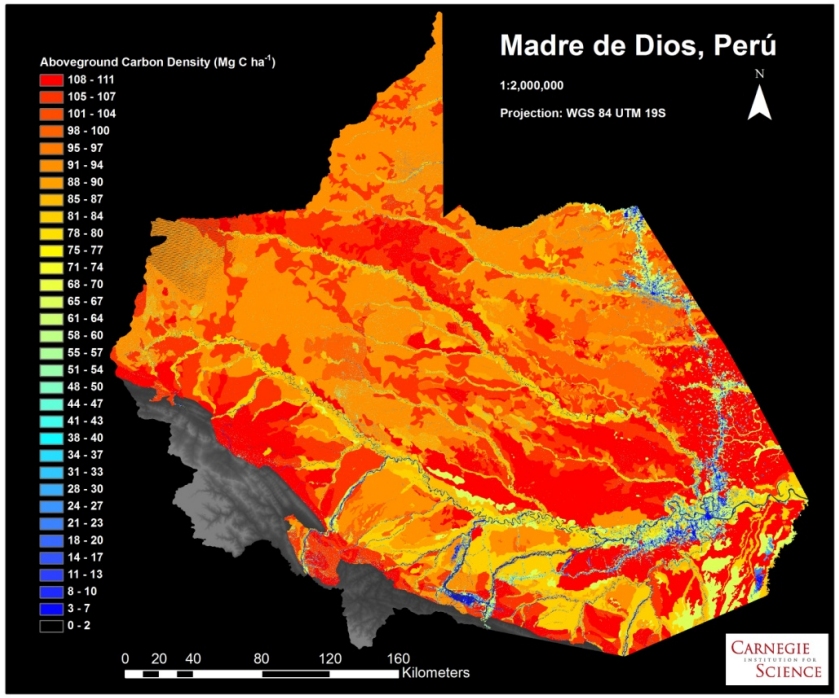
Satellite for strategic monitoring

Carbon stock sampling

Scaling; monitoring emissions and gains

An Example from a GCF Jurisdiction: Madre de Dios, Perú

Carbon Emissions



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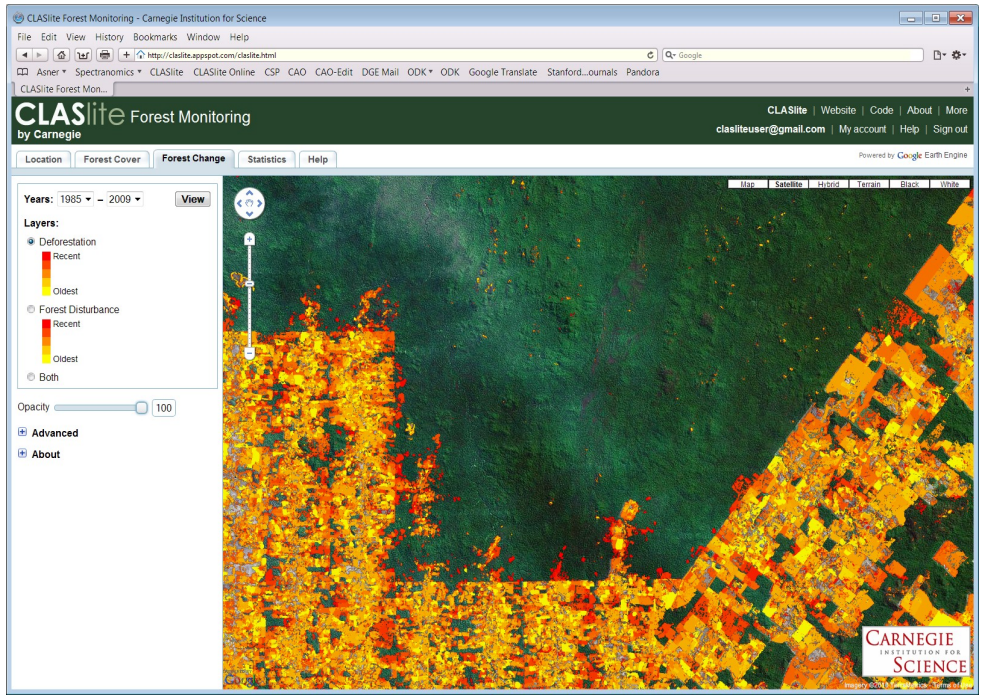
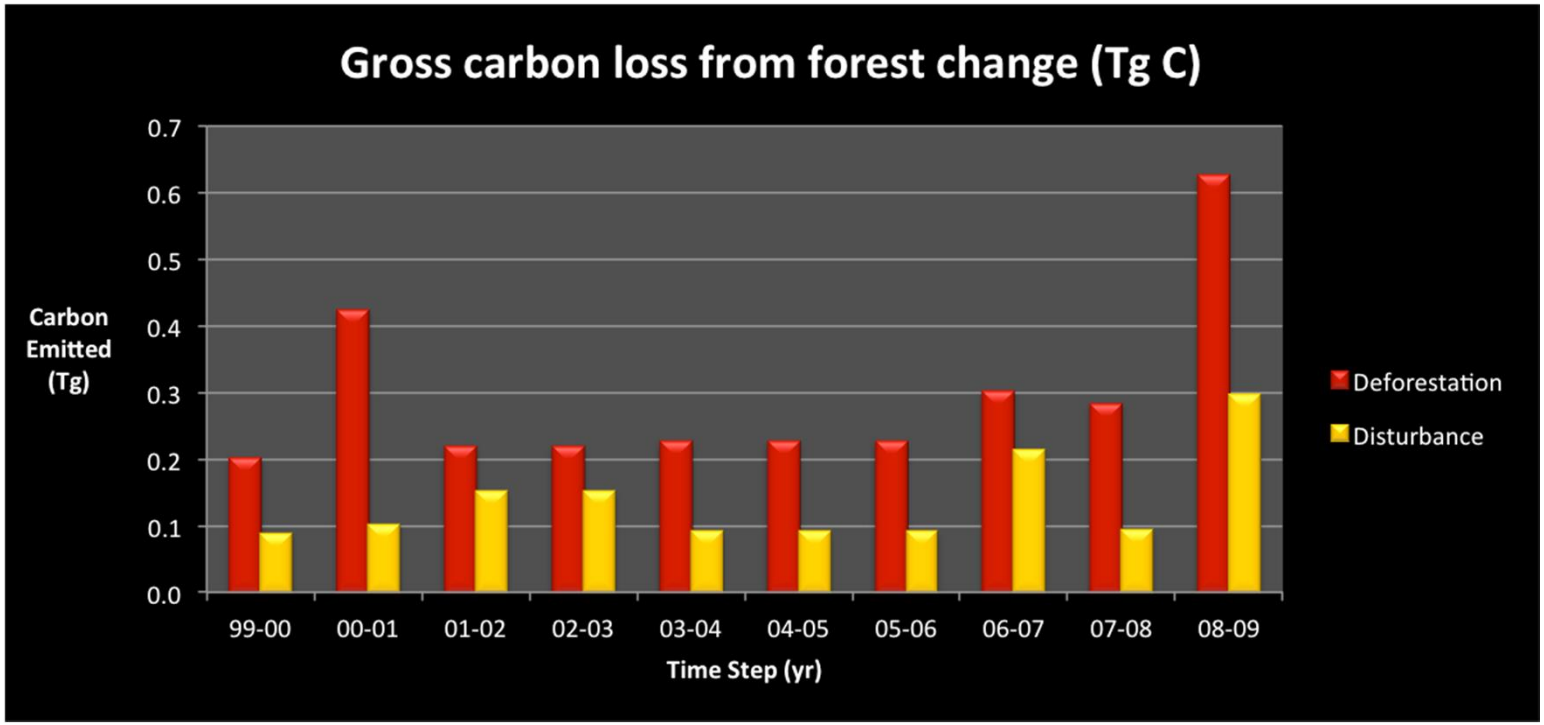
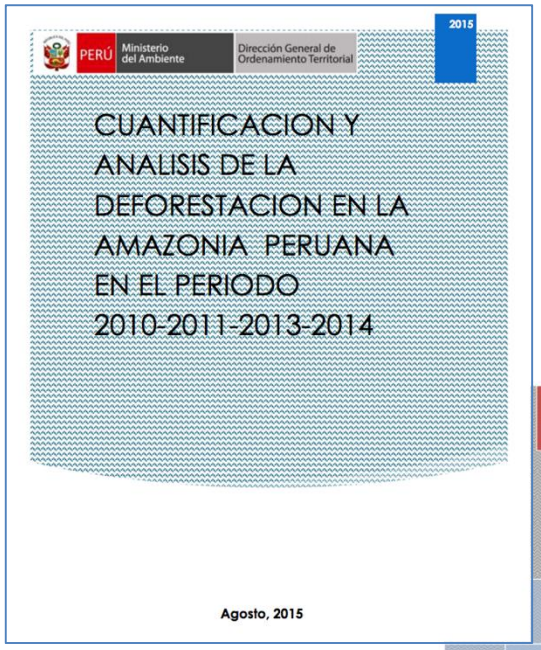


Carbon basemap adjusted by Continuous satellite monitoring

Carbon Emissions in Madre de Dios, Perú



1 Tg = 1 million metric tons



PERÚ Ministerio del Ambiente | Dirección General de Ordenamiento Territorial

2015

CUANTIFICACION Y ANALISIS DE LA DEFORESTACION EN LA AMAZONIA PERUANA EN EL PERIODO 2010-2011-2013-2014

Agosto, 2015

Cuantificación y Análisis de la Deforestación en la Amazonía Peruana en el Periodo 2010-2014

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Asesoramiento Técnico-Científico
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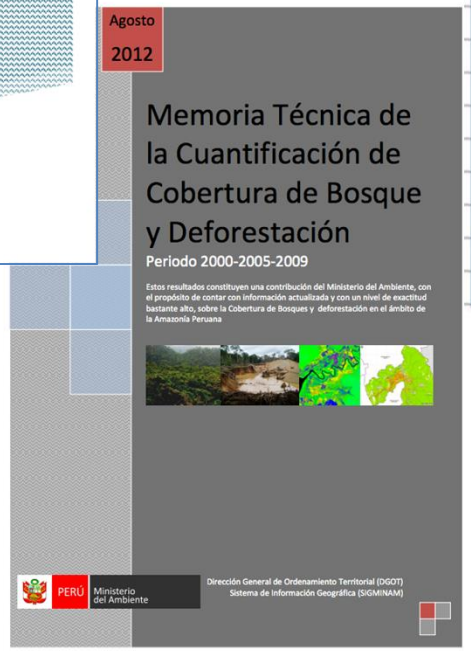
Gregory P. Asner, Investigador Principal



Agosto 2012

Memoria Técnica de la Cuantificación de Cobertura de Bosque y Deforestación

Periodo 2000-2005-2009

Estos resultados constituyen una contribución del Ministerio del Ambiente, con el propósito de contar con información actualizada y con un nivel de exactitud bastante alto, sobre la Cobertura de Bosques y deforestación en el ámbito de la Amazonía Peruana

PERÚ Ministerio del Ambiente

Dirección General de Ordenamiento Territorial (DGOT)
Sistema de Información Geográfica (SIGMINAM)

Figura 8 . Mapa de deforestación del periodo 2010-2014

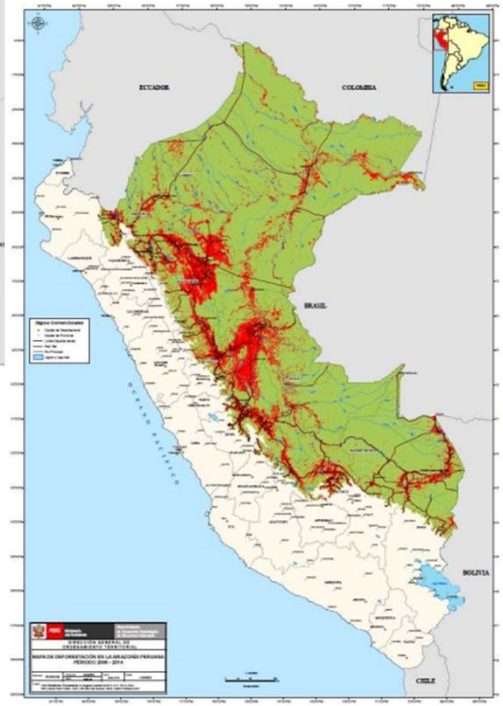


Figura 9 . Mapa de deforestación del periodo 2000-2014

Avatar Alliance Foundation
John D. and Catherine T. MacArthur Foundation
David and Lucile Packard Foundation
Mary Anne Nyburg Baker and G. Leonard Baker Jr.
William Hearst III