

# Satellite image processing in Google Earth Engine cloud platform

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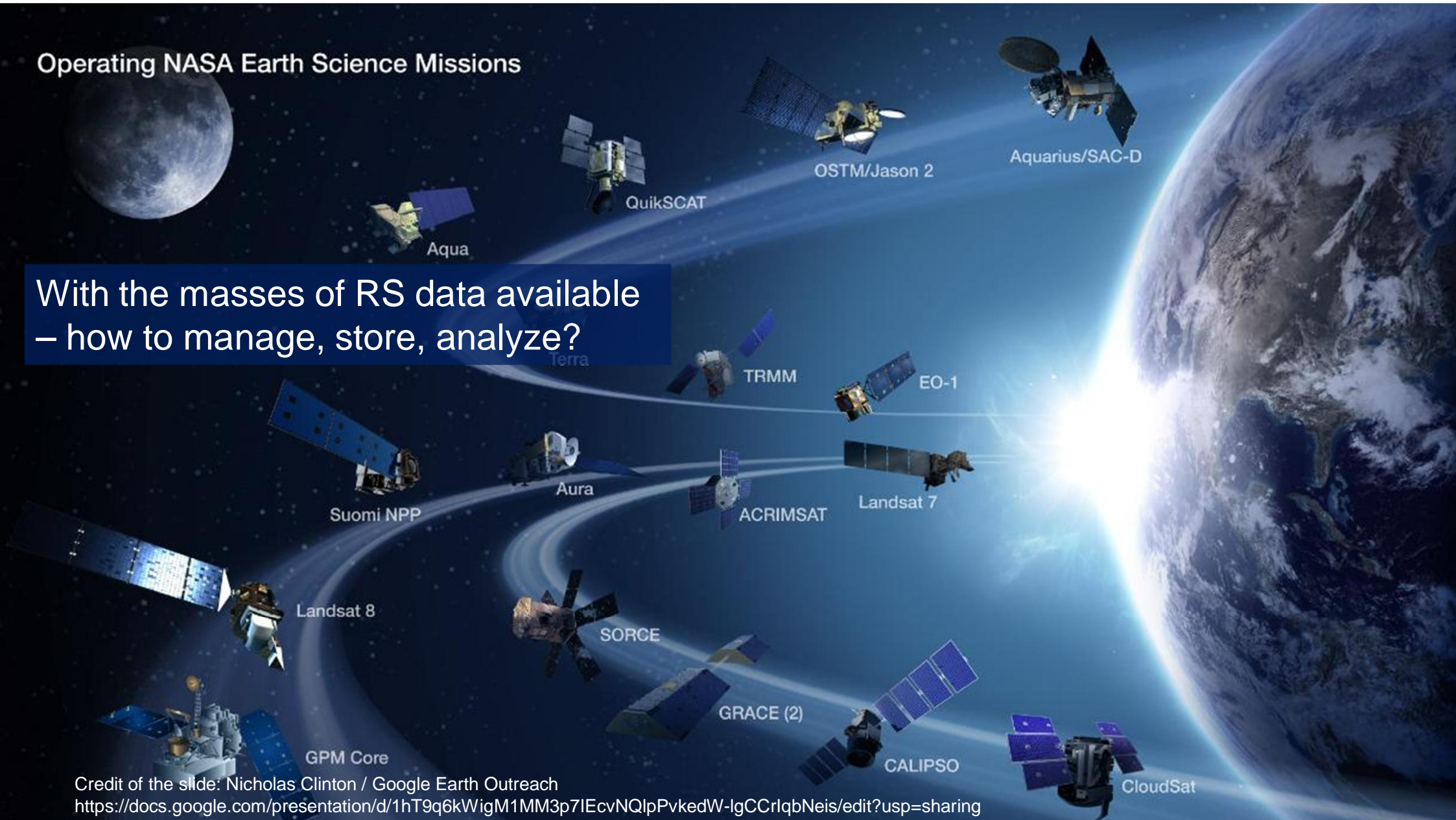
UNIVERSITY  
OF TURKU

# Topics of the presentation

- Introducing Google Earth Engine platform
- Case study of GEE / forest plantation mapping in Tanzania

## Operating NASA Earth Science Missions

With the masses of RS data available  
– how to manage, store, analyze?



Credit of the slide: Nicholas Clinton / Google Earth Outreach

<https://docs.google.com/presentation/d/1hT9q6kWiGMM3p7IEcvNQLpPvkedW-IgCCrIqbNeis/edit?usp=sharing>

# Goodchild et al. (2012):



## Next-generation Digital Earth

Michael F. Goodchild<sup>a,1</sup>, Huadong Guo<sup>b</sup>, Alessandro Annoni<sup>c</sup>, Ling Bian<sup>d</sup>, Kees de Bie<sup>e</sup>, Frederick Campbell<sup>f</sup>, Max Craglia<sup>g</sup>, Manfred Ehlers<sup>h</sup>, John van Genderen<sup>e</sup>, Davina Jackson<sup>h</sup>, Anthony J. Lewis<sup>i</sup>, Martino Pesaresi<sup>c</sup>, Gábor Remetey-Fülöpp<sup>j</sup>, Richard Simpson<sup>k</sup>, Andrew Skidmore<sup>l</sup>, Changlin Wang<sup>o</sup>, and Peter Woodgate<sup>l</sup>

<sup>a</sup>Department of Geography, University of California, Santa Barbara, CA 93106; <sup>b</sup>Center for Earth Observation and Digital Earth, Chinese Academy of Sciences, Beijing 100094, China; <sup>c</sup>Joint Research Centre of the European Commission, 21027 Ispra, Italy; <sup>d</sup>Department of Geography, University at Buffalo, State University of New York, Buffalo, NY 14261; <sup>e</sup>Faculty of Geo-Information Science and Earth Observation, University of Twente, 7500 AE, Enschede, The Netherlands; <sup>f</sup>Fred Campbell Consulting, Ottawa, ON, Canada K2H 5G8; <sup>g</sup>Institute for Geoinformatics and Remote Sensing, University of Osnabrück, 49076 Osnabrück, Germany; <sup>h</sup>D\_City Network, Newtown 2042, Australia; <sup>i</sup>Department of Geography and Anthropology, Louisiana State University, Baton Rouge, LA 70803; <sup>j</sup>Hungarian Association for Geo-Information, H-1122, Budapest, Hungary; <sup>k</sup>Nextspace, Auckland 1542, New Zealand; and <sup>l</sup>Cooperative Research Center for Spatial Information, Carlton South 3053, Australia

“The supply of geographic information from satellite-based and ground-based sensors has expanded rapidly, encouraging belief in a new, fourth, or “big data,” paradigm of science that emphasizes **international collaboration, data-intensive analysis, huge computing resources, and high-end visualization.**”

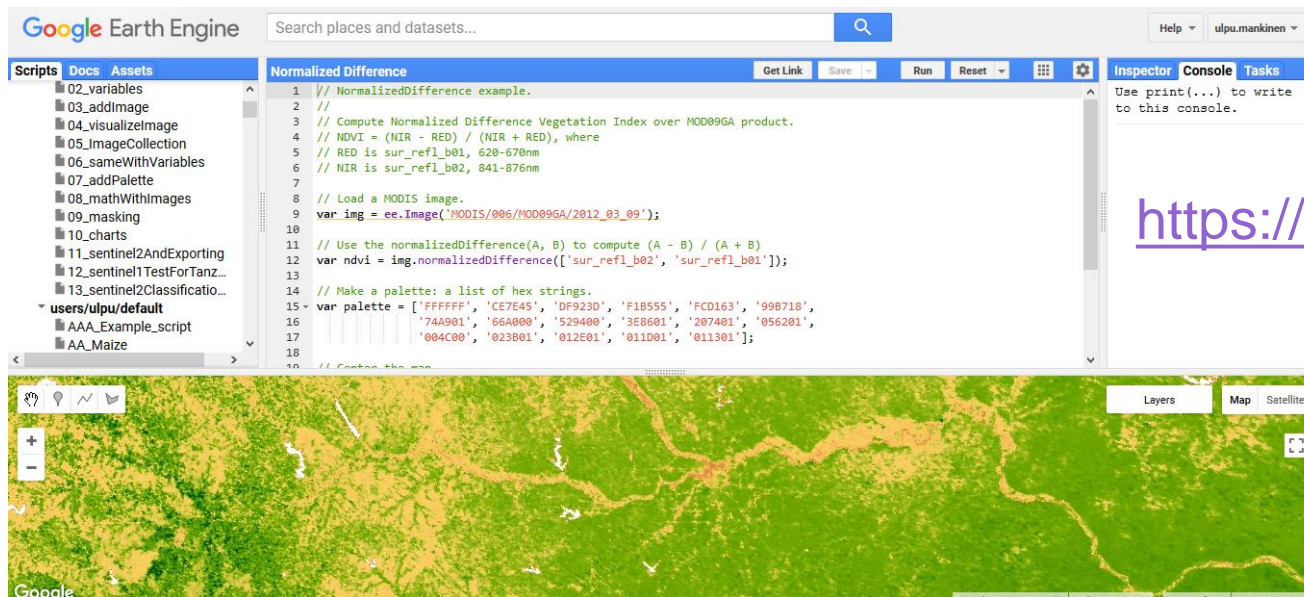
Credit of the slide: Nicholas Clinton / Google Earth Outreach

<https://docs.google.com/presentation/d/1hT9q6kWigM1MM3p7IEcvNQlpPvkedW-lgCCrlqbNeis/edit?usp=sharing>



# Google Earth Engine (GEE)

- A planetary-scale platform for Earth science that allows users to run geospatial analysis on data which is readily in Google's infrastructure



<https://earthengine.google.com/>

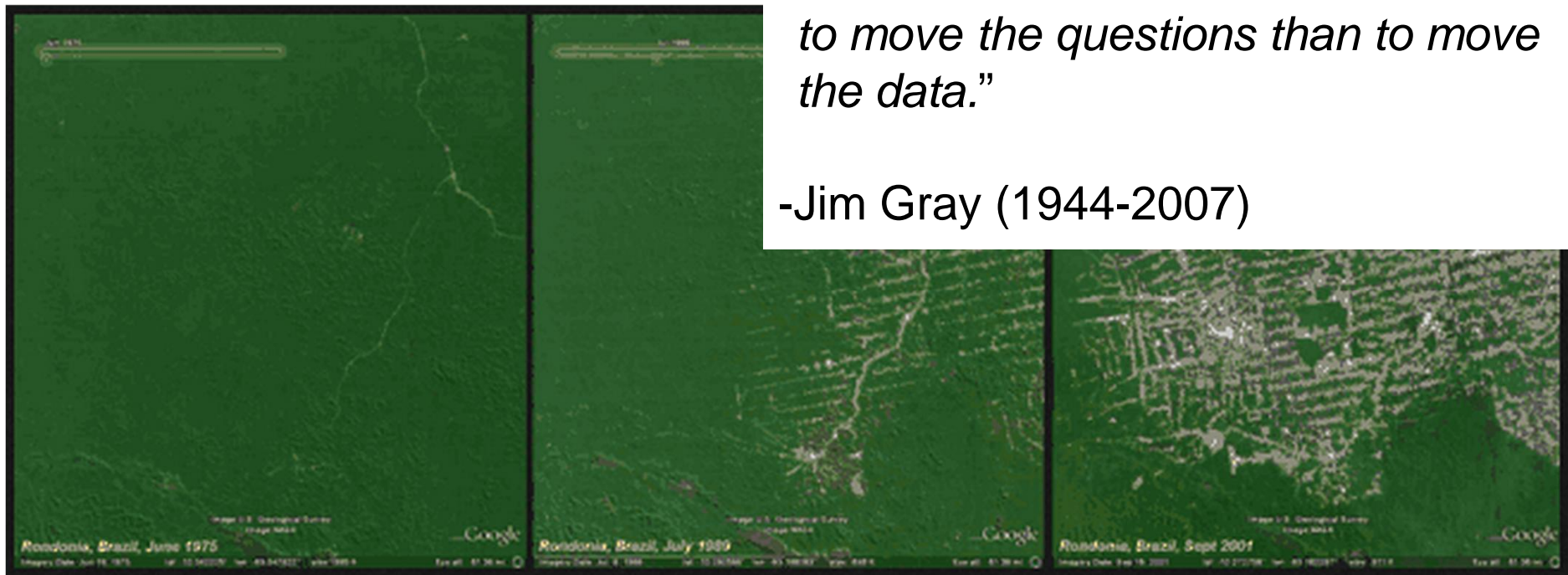


Google Earth Engine

# What started with Google Earth was taken further..

*“Often it turns out to be more efficient to move the questions than to move the data.”*

-Jim Gray (1944-2007)



Credit of the slide: Nicholas Clinton / Google Earth Outreach

<https://docs.google.com/presentation/d/1hT9q6kWigM1MM3p7IEcvNQlpPvkedW-lgCCrlqbNeis/edit?usp=sharing>



# Google Earth Engine: petabyte-scale archive of satellite and geospatial data + analysis possibilities

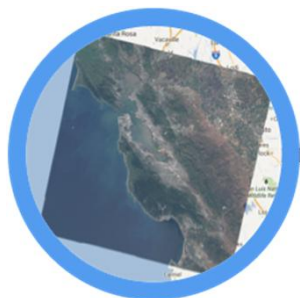
**Colocated Data + Computation + APIs**

Credit of the slide: Nicholas Clinton / Google Earth Outreach

<https://docs.google.com/presentation/d/11T9q6kWiM1MM3p7IEcvNQlpPvkedW-IgCCrIqbNeis/edit?usp=sharing>

# The Earth Engine Public Data Catalog

<https://developers.google.com/earth-engine/datasets/>



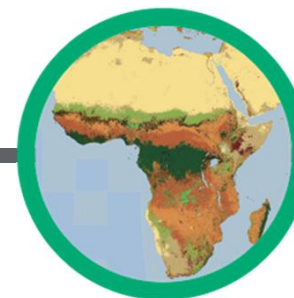
**Landsat and Sentinel**  
Raw, TOA, SR, ...



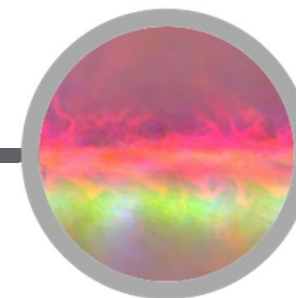
**MODIS**  
Daily, NBAR, LST, ...



**Terrain**  
SRTM, GTOPO, NED,  
...



**Land Cover**  
GlobCover, NLCD, ...



**Atmospheric**  
NOAA NCEP, OMI, ...

... and many more, updating daily!

> 200 public datasets

> 5 million images

> 4000 new images every day

> 5 petabytes of data



# Online IDE (JavaScript)

<https://code.earthengine.google.com/>

Google Earth Engine

Search places and datasets...

Help ▾ davethau ▾

Scripts Docs Assets

- Modis Qa Bands
- Pixel Area
- Pixel Lon Lat
- Polynomial
- Zero Crossing
- Image Collection
  - Clipped Composite
  - Expression Map
  - Filtered Composite
  - Linear Fit
  - Modis Cloud Masking
  - Simple Cloud Score

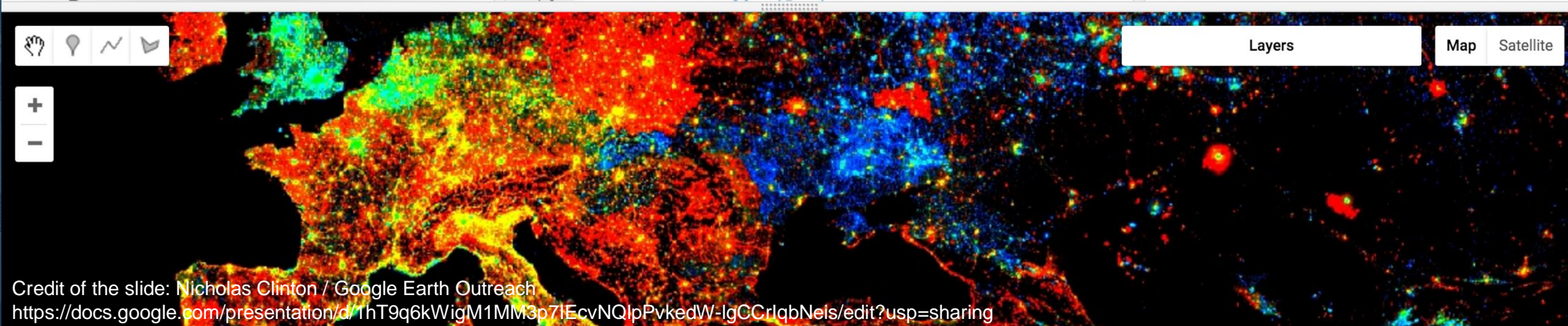
Linear Fit

Get Link Save Run Reset

```
1 // Compute the trend of nighttime lights from DMSP.
2
3 // Add a band containing image date as years since 1
4 function createTimeBand(img) {
5   var year = ee.Date(img.get('system:time_start')).c
6   return ee.Image(year).byte().addBands(img);
7 }
8
9 // Fit a linear trend to the nighttime lights collec
10 var collection = ee.ImageCollection('NOAA/DMSP-OLS/M
11   .select('stable_lights')
12   .map(createTimeBand);
13 var fit = collection.reduce(ee.Reducer.linearFit());
14
15 // Display a single image
```

Inspector Console Tasks

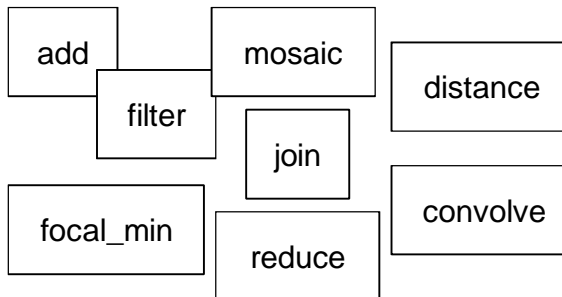
Use print(...) to write to this console.



Requests

Results

Geospatial  
Datasets



Algorithmic  
Primitives

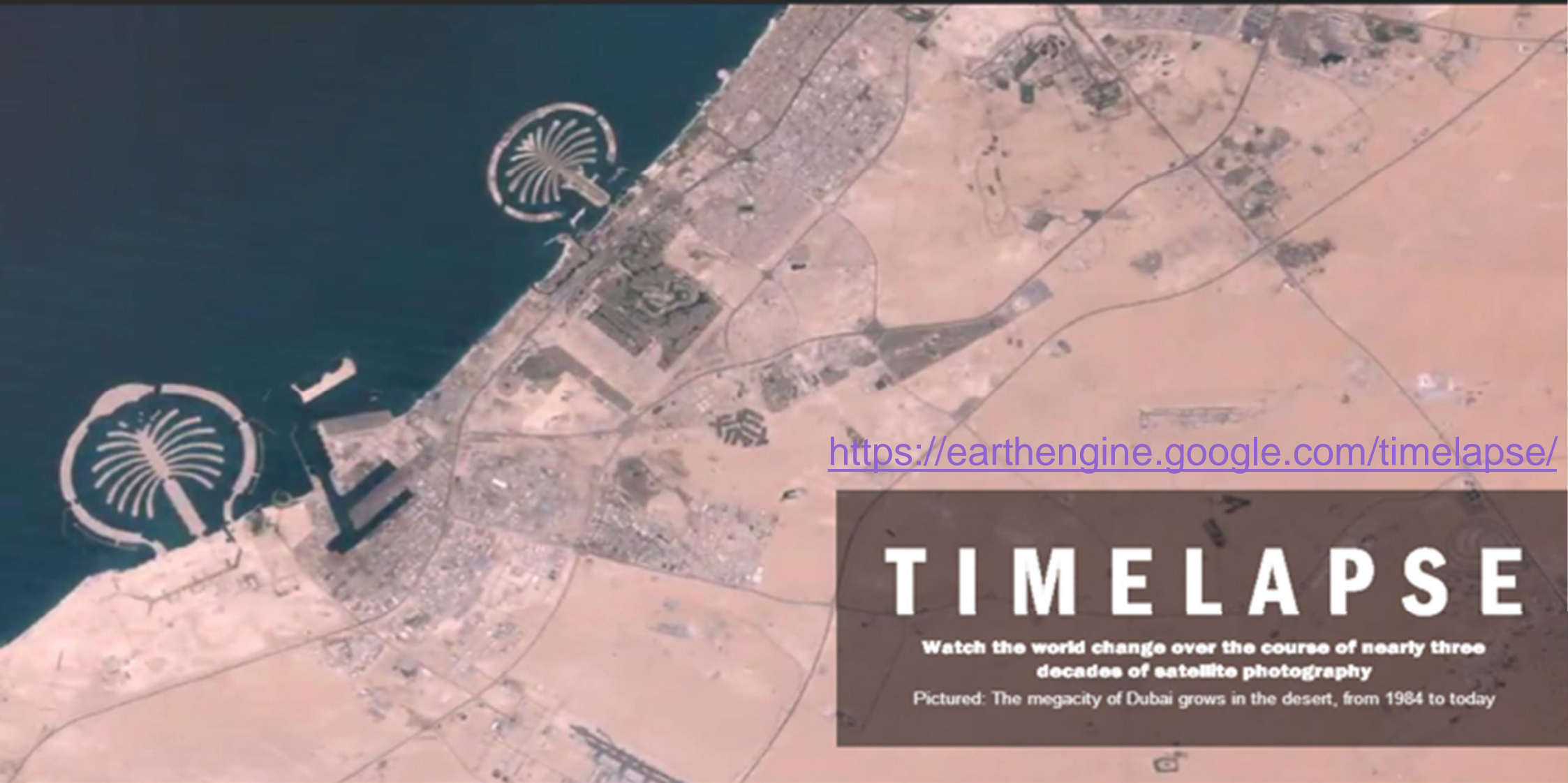


Storage and parallel computing

# After Earth Engine



Credit of the slide: Nicholas Clinton / Google Earth Outreach  
<https://docs.google.com/presentation/d/1hT9q6kWigM1MM3p7IEcvNQlpPvkedW-IgCCrlqbNeis/edit?usp=sharing>



<https://earthengine.google.com/timelapse/>

# TIMELAPSE

Watch the world change over the course of nearly three decades of satellite photography

Pictured: The megacity of Dubai grows in the desert, from 1984 to today

**29 years**  
of satellite data

**2,068,467**  
landsat scenes analyzed

**909**  
terabytes of data

More than **2M** hours of computation over **66,000** computers

Elapsed time: **~1.5** days to build the mosaics

**TIMELAPSE**

the course of nearly three decades of satellite photography

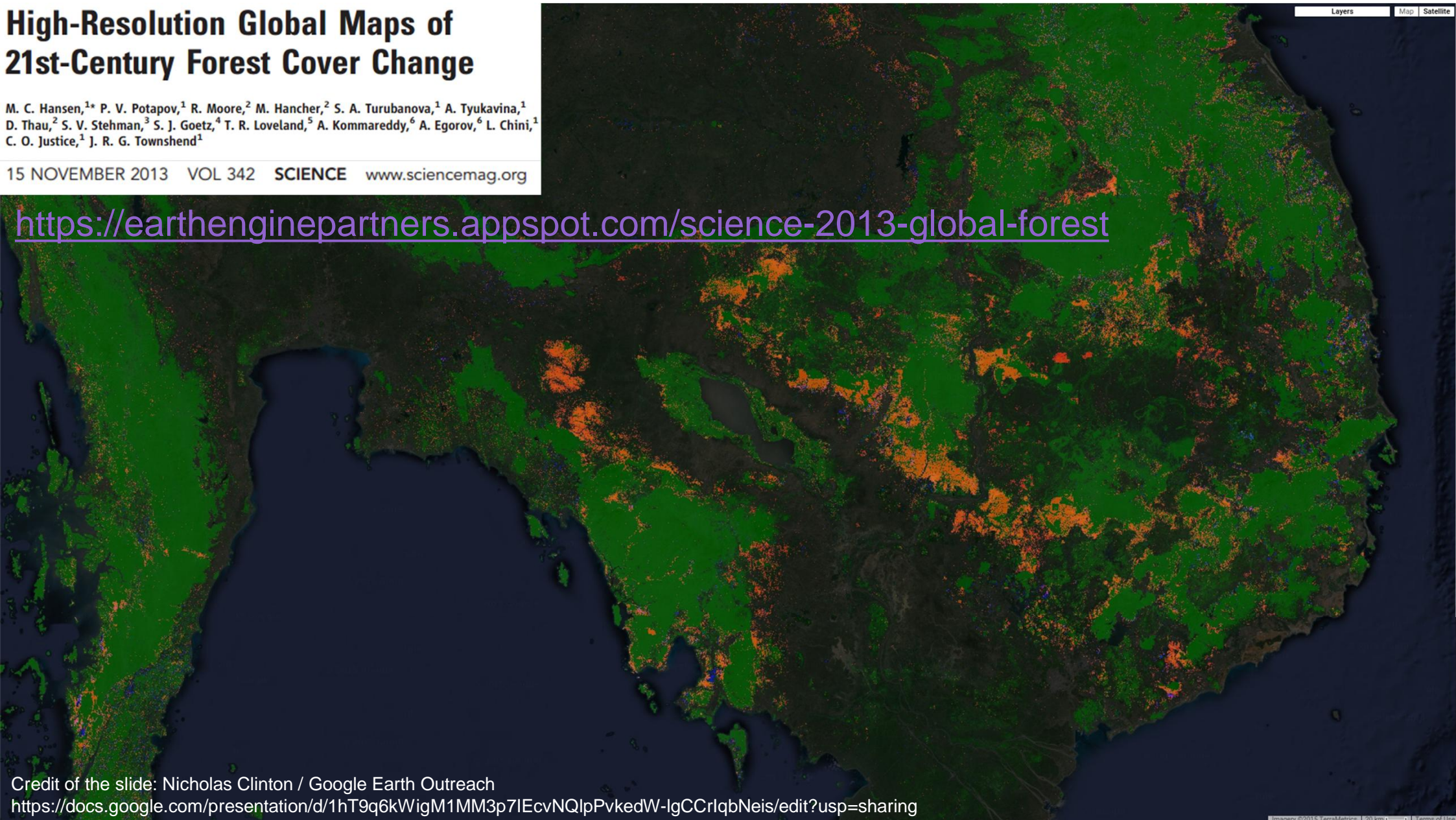
Pictured: The megacity of Dubai grows in the desert, from 1984 to today

# High-Resolution Global Maps of 21st-Century Forest Cover Change

M. C. Hansen,<sup>1\*</sup> P. V. Potapov,<sup>1</sup> R. Moore,<sup>2</sup> M. Hancher,<sup>2</sup> S. A. Turubanova,<sup>1</sup> A. Tyukavina,<sup>1</sup> D. Thau,<sup>2</sup> S. V. Stehman,<sup>3</sup> S. J. Goetz,<sup>4</sup> T. R. Loveland,<sup>5</sup> A. Kommareddy,<sup>6</sup> A. Egorov,<sup>6</sup> L. Chini,<sup>1</sup> C. O. Justice,<sup>1</sup> J. R. G. Townshend<sup>1</sup>

15 NOVEMBER 2013 VOL 342 SCIENCE www.sciencemag.org

<https://earthenginepartners.appspot.com/science-2013-global-forest>



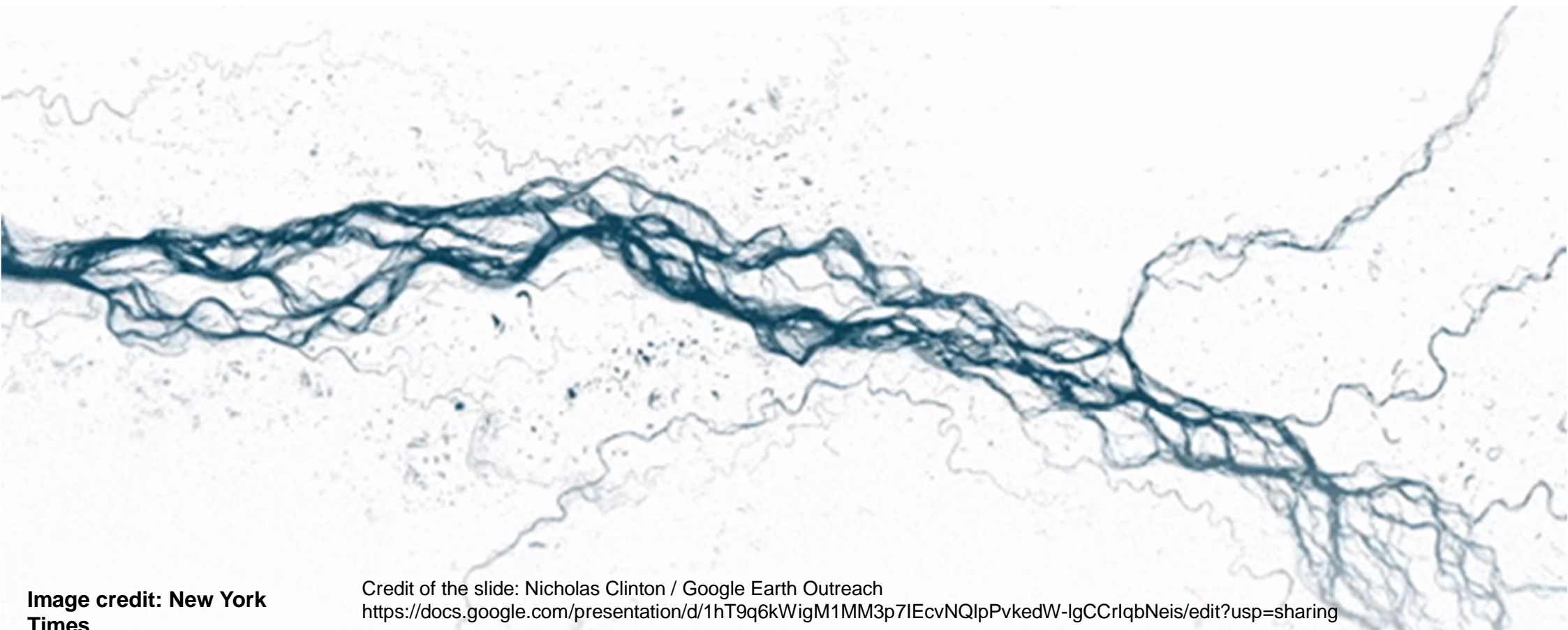
Credit of the slide: Nicholas Clinton / Google Earth Outreach

<https://docs.google.com/presentation/d/1hT9q6kWigM1MM3p7IEcvNQlpPvkedW-lgCCrlqbNeis/edit?usp=sharing>

# High-resolution mapping of global surface water and its long-term changes

Jean-François Pekel<sup>1</sup>, Andrew Cottam<sup>1</sup>, Noel Gorelick<sup>2</sup> & Alan S. Belward<sup>1</sup>

doi:10.1038/nature20584



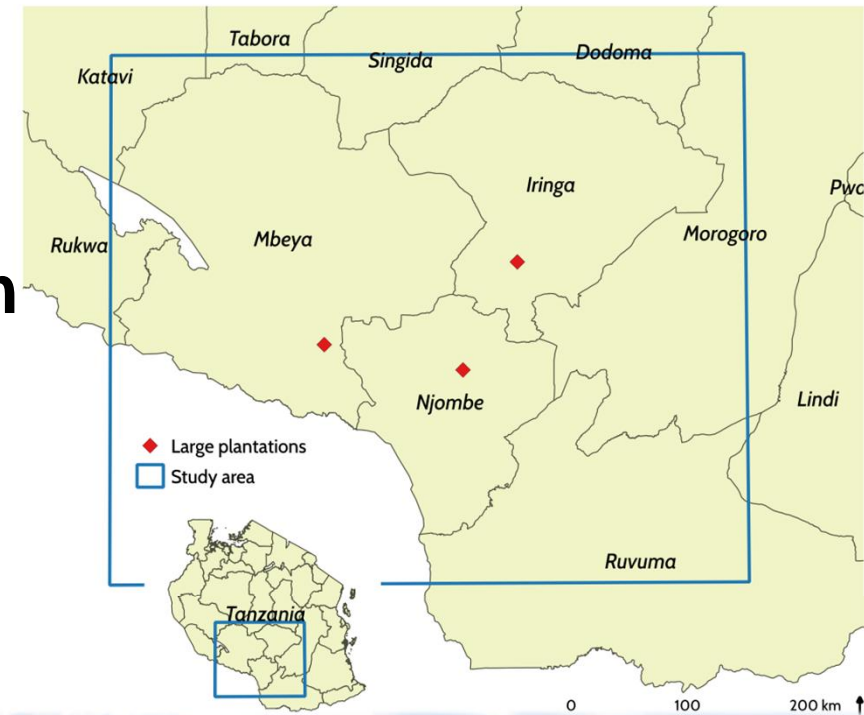
**Image credit: New York Times**

Credit of the slide: Nicholas Clinton / Google Earth Outreach  
<https://docs.google.com/presentation/d/1hT9q6kWiG1MM3p7IEcvNQlpPvkedW-IgCCrIqbNeis/edit?usp=sharing>

**FAO/University of Turku case study with GEE:**

## **Mapping forest plantations in Southern Tanzania using Google Earth Engine**

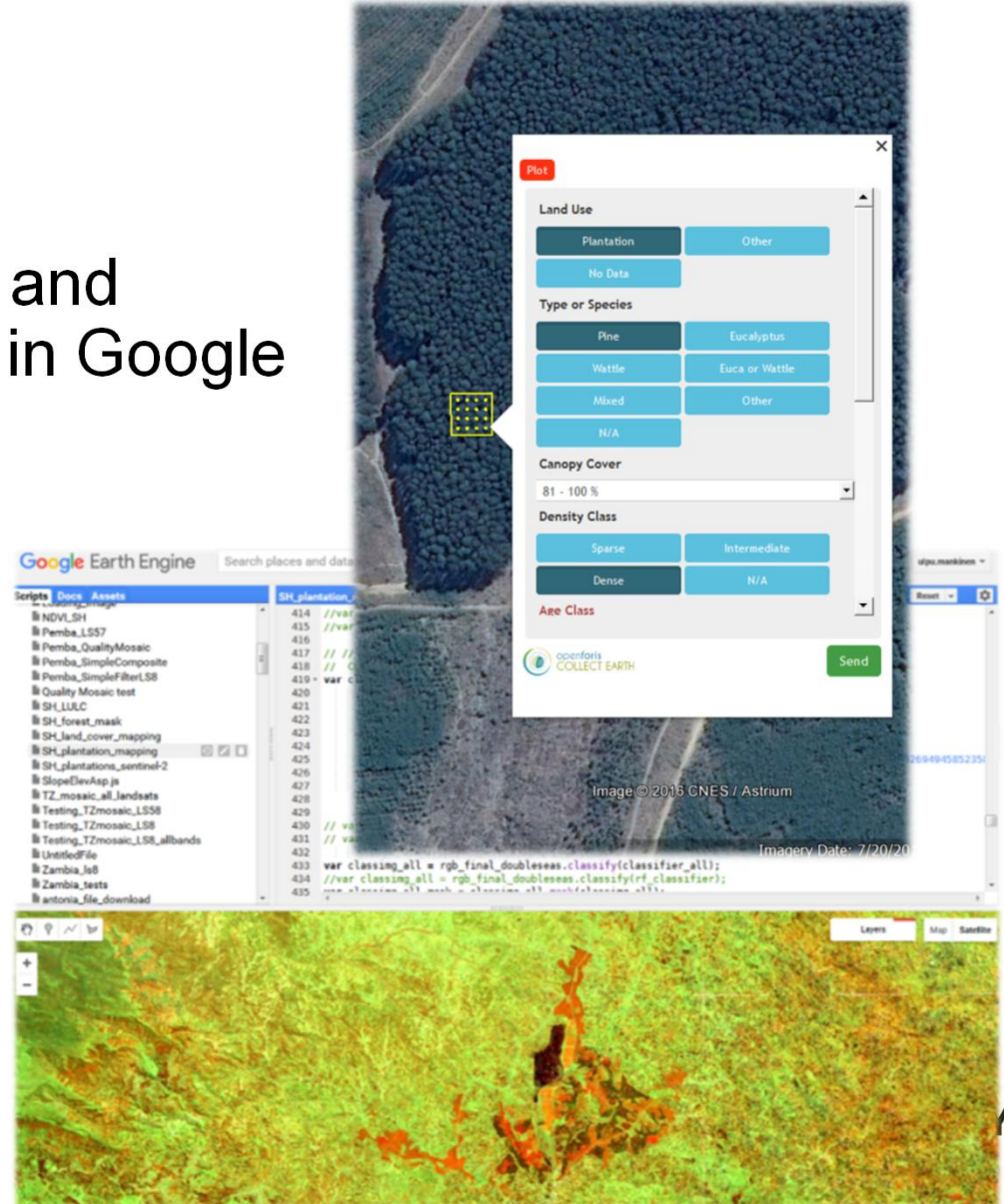
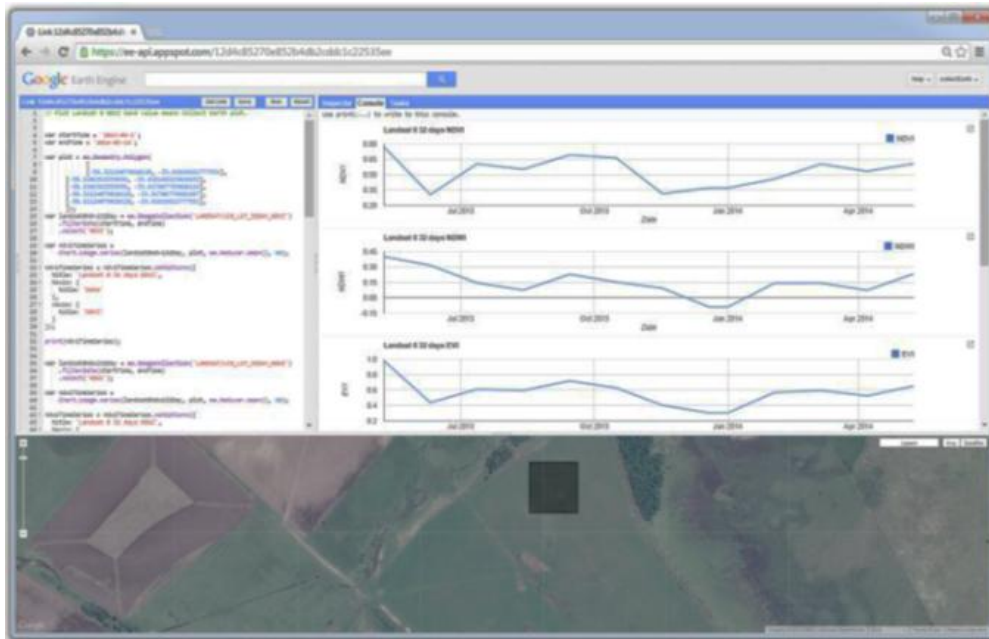
- Most important wood production area in Tanzania; extremely cloudy
- Study area approx. 200,000km<sup>2</sup>
- Existing forest plantation baseline has not been known outside the large industrial-scale plantations
  - Potential of the smallholder owned plantations?





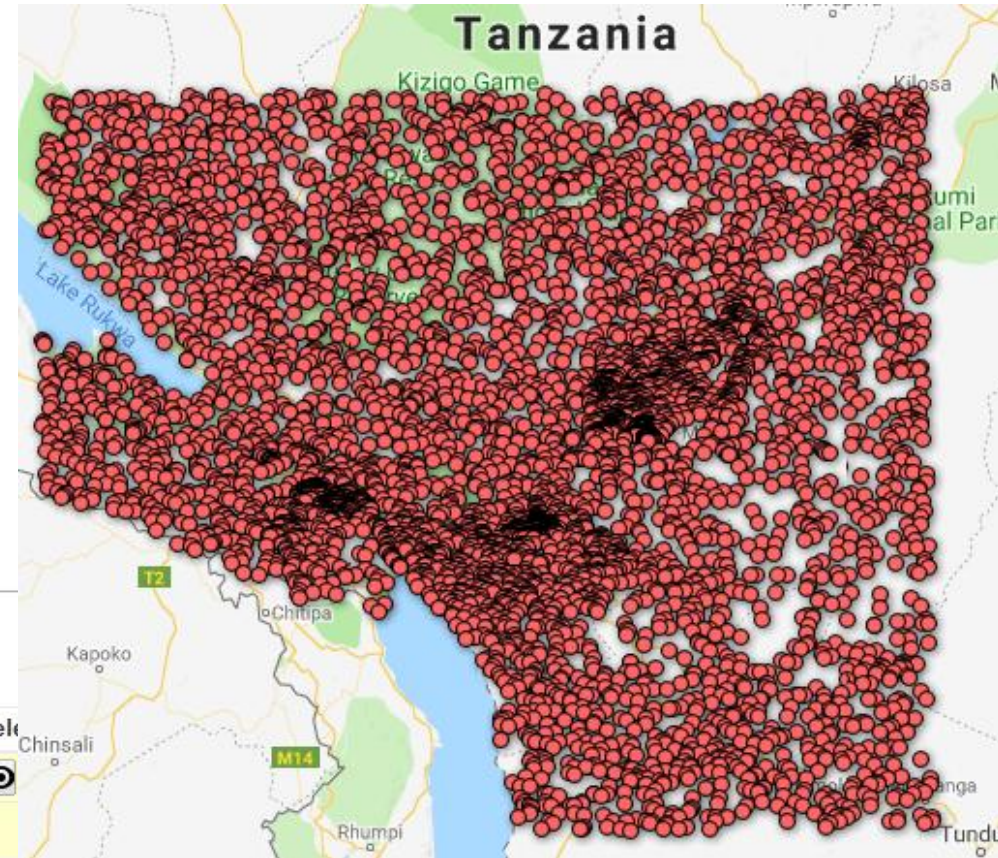
# Mapping methodology

- Reference data collection from high and medium resolution satellite imagery in Google Earth, Bing Maps and Earth Engine
  - Participation of 20 Tanzanian experts



# Mapping methodology

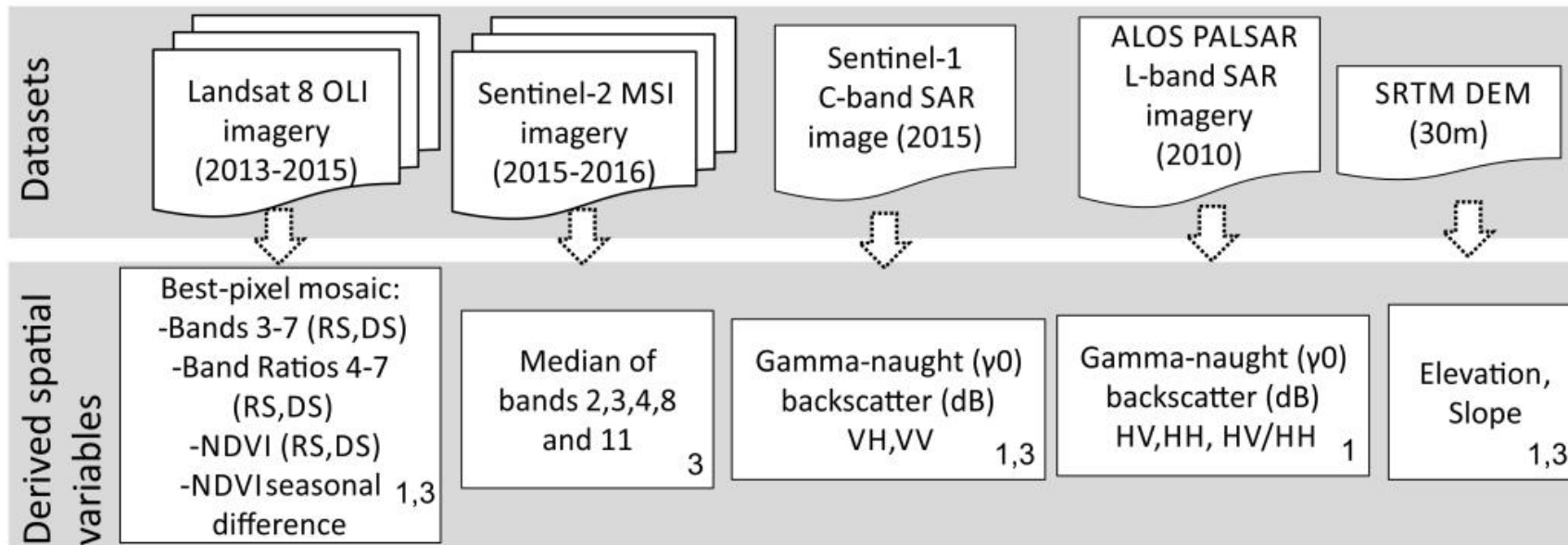
- Reference data taken into GEE as a fusion table
  - Possibility to upload shp added since



File Edit Tools Help												
Rows 1 Cards 1 Map of geometry												
Filter No filters applied												
1-100 of 6866												
id	location_x	location_y	land_use	land_use_type	accuracy	location_srs						
1	35.7485079192657	-8.08642824189543	plantation	wattle	true	EPSG:4326						
2	36.2826381896034	-9.14462112083547	other	bushland	true	EPSG:4326	713	0.13104...	0.300...	open_bushland	not_available	
3	33.725180007788	-9.02761856543711	other	forest	true	EPSG:4326	2467	0.06657...	4.374...	montane_forest	not_available	81_100
5	34.7795635011952	-10.2942392523658	other	bushland	true	EPSG:4326	877	0.05567...	2.330...	dense_bushland	dry_bushland	
7	35.3939629665148	-8.60096738668217	other	grassland	true	EPSG:4326	1777	0.02297...	2.633...	not_available	not_available	
8	36.3264461231359	-7.11149764656447	other	bushland	true	EPSG:4326	1072	0.28044...	3.696...	open_bushland	dry_bushland	
11	34.6541258778505	-7.7414067529533	other	woodland	true	EPSG:4326	965	0.02201...	1.277...	closed_woodland	deciduous_woo...	

# Mapping methodology

- Collected data used as training data in classification of satellite imagery (natural forest / planted forest / other land cover)
  - Different classifiers and input combinations tested with validation data



Google Earth Engine

Search places and datasets...

Help ulpu.mankinen

Scripts Docs Assets

- SH\_plantation\_mapping
- SH\_plantation\_mapping\_...
- SH\_plantation\_mapping\_...
- SH\_plantation\_variables\_...
- SH\_plantations...
- SH\_plantations\_sentinel-2
- SH\_plantations\_with\_AA
- SH\_treecover\_Jan17
- Segmentation\_GFG
- Segmentation\_example
- Sentinel-2 mosaic for SH
- Sentinel-2 seasonal mosa...
- Sentinel2 SH ESA
- Sentinel2 image selection
- Sentinel2 ESA cloudmask

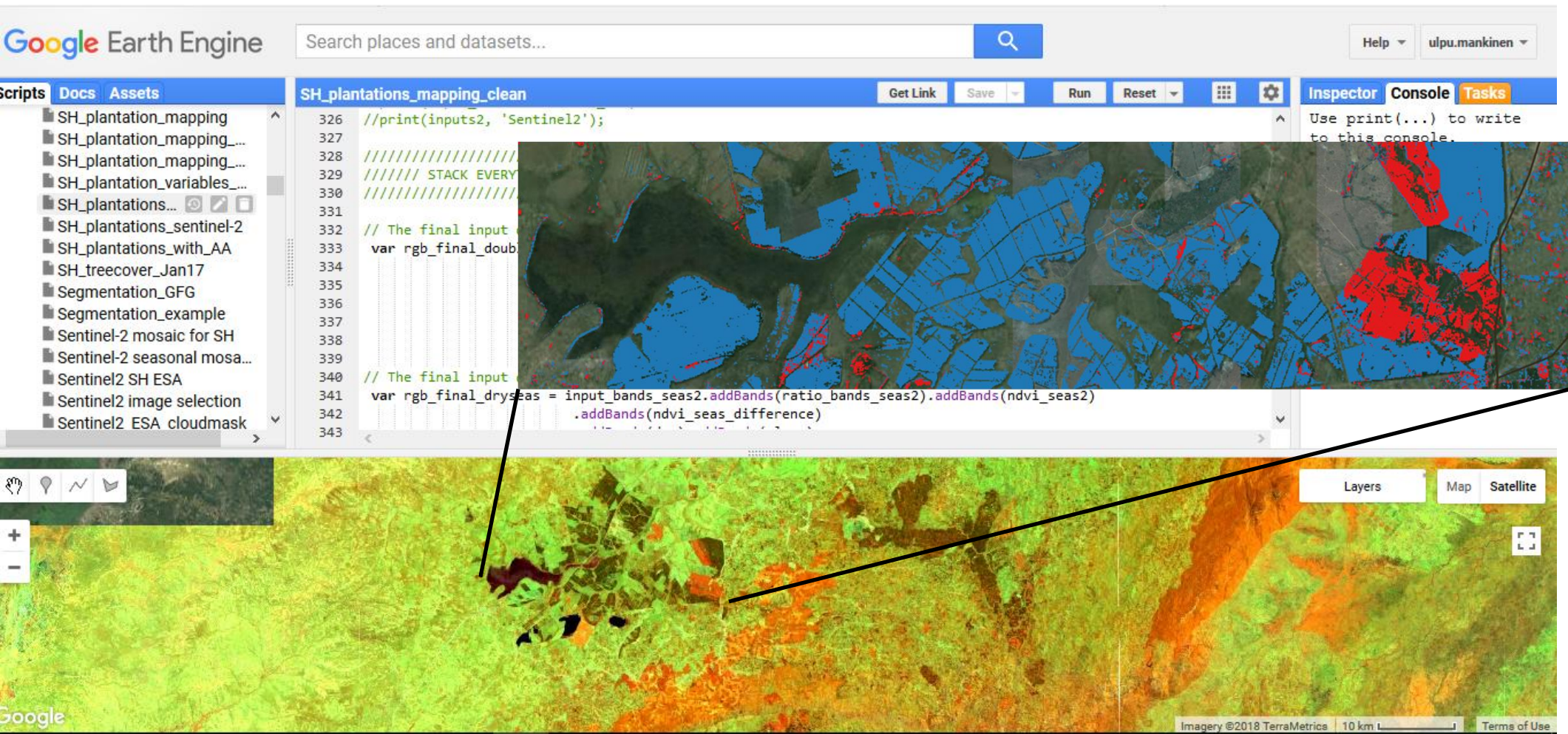
SH\_plantations\_mapping\_clean

Get Link Save Run Reset

```
326 //print(inputs2, 'Sentinel1');
327
328 //////////////////////////////////
329 ////////// STACK EVERY
330 //////////////////////////////////
331
332 // The final input
333 var rgb_final_doub
334
335
336
337
338
339
340 // The final input
341 var rgb_final_dryseas = input_bands_seas2.addBands(ratio_bands_seas2).addBands(ndvi_seas2)
342                               .addBands(ndvi_seas_difference)
343
```

Inspector Console Tasks

Use print(...) to write to this console.

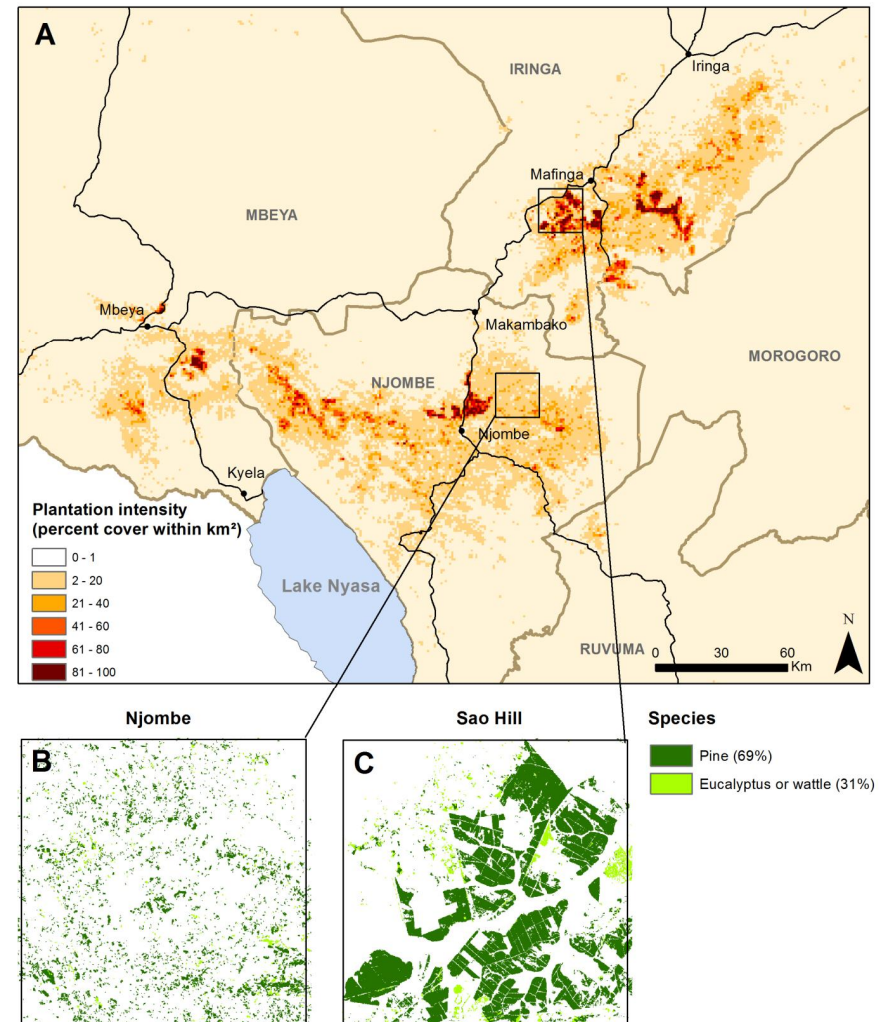


<https://github.com/utu-tanzania/sh-plantations>

# Some results

- Combining optical and radar satellite data and Random Forest classifier provided the best result
  - Data sets used: Landsat-8, Sentinel-1, Sentinel-2 and SRTM elevation & slope
- Overall accuracy  $85 \pm 2\%$

	Forest plantation	Forest	Other	Total	Map area (ha)	Estimated area (ha)	User's accuracy	Producer's accuracy
Forest plantation	0.0075	0.0006	0.0008	0.0089	180011	$239842 \pm 87023$	$0.84 \pm 0.07$	$0.96 \pm 0.04$
Forest	0.0044	0.3399	0.1100	0.4542	9200524	$7132229 \pm 425063$	$0.75 \pm 0.04$	$0.95 \pm 0.02$
Other	0	0.0116	0.5252	0.5369	10874033	$12882496 \pm 420410$	$0.98 \pm 0.01$	$0.76 \pm 0.04$
Total	0.0118	0.3521	0.6360	1	20254568			
Overall Accuracy	$0.85 \pm 0.02$							



Source: Koskinen et al., in review at the ISPRS Journal of Photogrammetry and Remote Sensing

# On the experience of using GEE..

- Extremely powerful for large area satellite image processing
  - Access to a huge amount of data; currently one of the most significant **free** satellite image repositories in the world
- Computing in the cloud gives freedom
  - Creation of cloud-free composites for very cloudy regions, multi-temporal and multi-sensor analysis etc.
  - Repeatability and testing without limitations (almost!)
- Constantly updating (data and ready algorithms)
- JavaScript IDE
  - Control over the code; you know what happens behind the hood (ideally)
  - Not all algorithms/functionalities/processed data sets available; limitations for a beginner in coding
  - For example scrutinizing the results was difficult; leads to data transfer between different software
- Highly recommended especially if your study area is outside Finland

# Google is responding to the geospatial big data paradigm

Google Earth Outreach

Google's mission:

"To organize the world's information and make it universally accessible and useful."



Google Earth Outreach empowers you to create positive change for people and the planet with Geo tools.

*"Often it turns out to be more efficient to move the questions than to move the data."*

-Jim Gray (1944-2007)

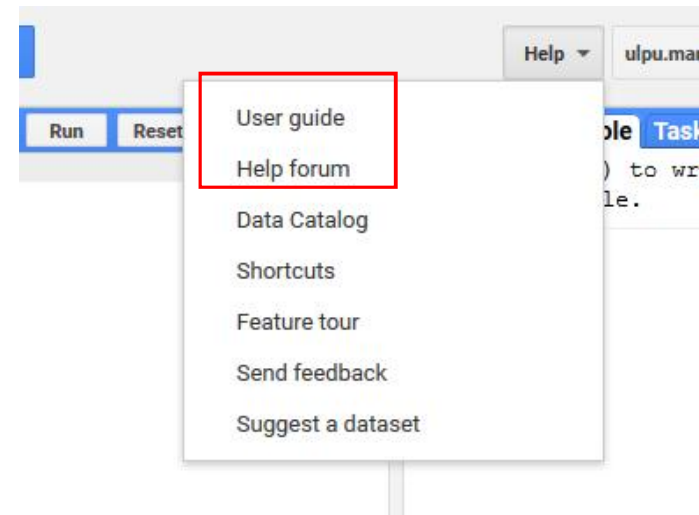
<https://earthengine.google.com/>

# To become a user

- [earthengine.google.com/signup](https://earthengine.google.com/signup)
  - The sign up means you request a **trusted tester access** to all the features of the API
  - Google account is needed, because then you can export data and outputs straight in to your Google Drive
- User guide and Help forum extremely useful, start with tutorials
- Basic GEE training at CSC later this year or next, stay tuned!



Google Earth Engine





# Contacts & links

- UTU Tanzania Team
  - Tanzania.utu.fi
  - Facebook: UTU Tanzania Team, @ututanzania
- Google Earth Engine
  - <https://earthengine.google.com>
  - <https://code.earthengine.google.com/>
- Forest plantation mapping results from the Southern Highlands, Tanzania
  - Participatory mapping of forest plantations with Open Foris and Google Earth Engine (Koskinen, J, Leinonen, U, Vollrath, A, Ortmann, A, Pekkarinen, A, & Käyhkö N, in review at the ISPRS Journal of Photogrammetry and Remote Sensing)
  - Data will become available at the time of publication at <https://doi.pangaea.de/10.1594/PANGAEA.894892>



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**Thanks for your attention!**

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