Designing applications to foster the health of terrestrial and wetland ecosystems in the coastal zone of West Africa

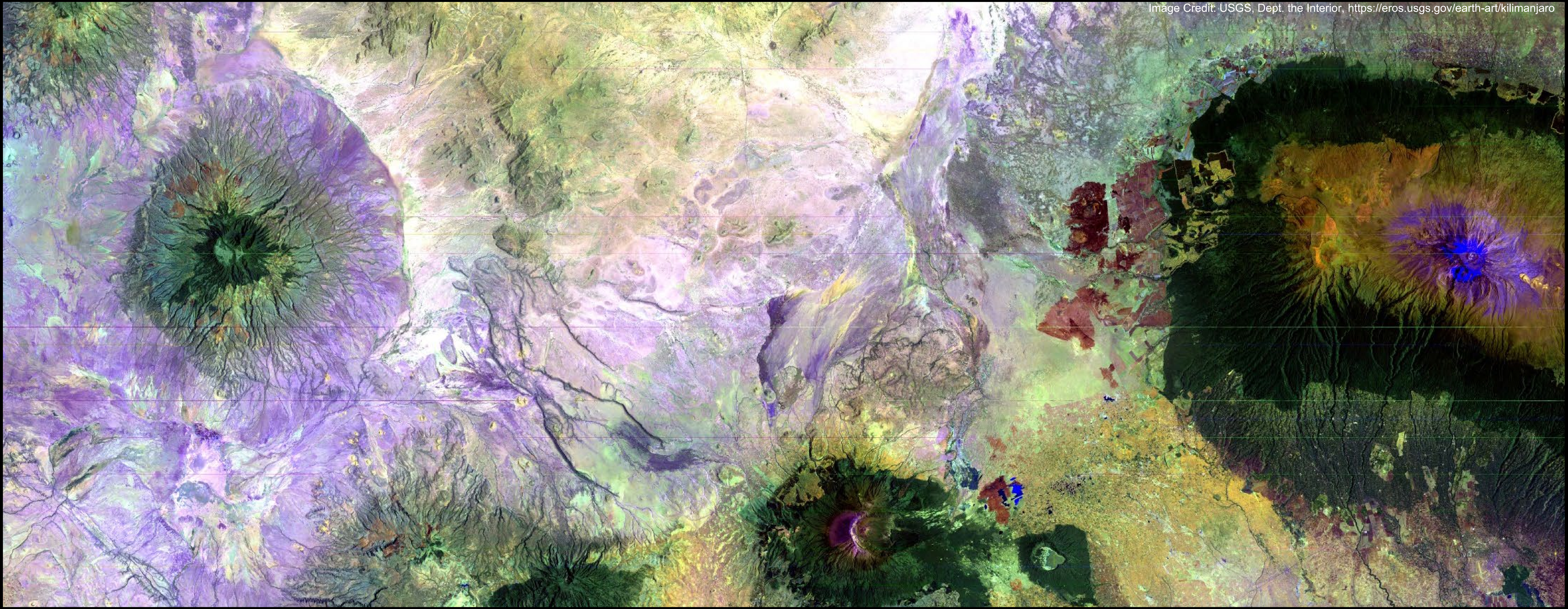


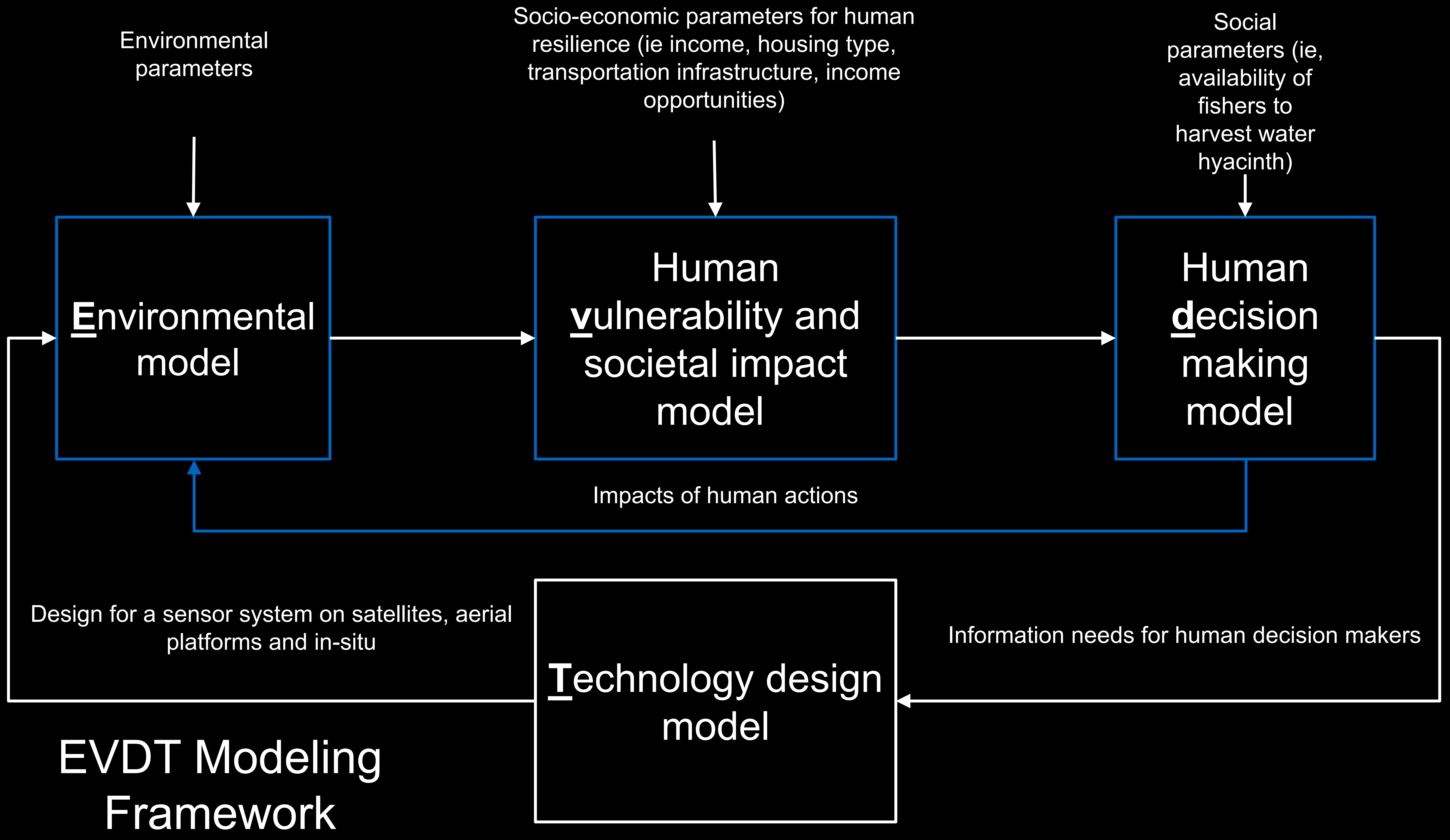
Image Credit: USGS, Dept. the Interior, https://eros.usgs.gov/earth-art/kilimanjaro

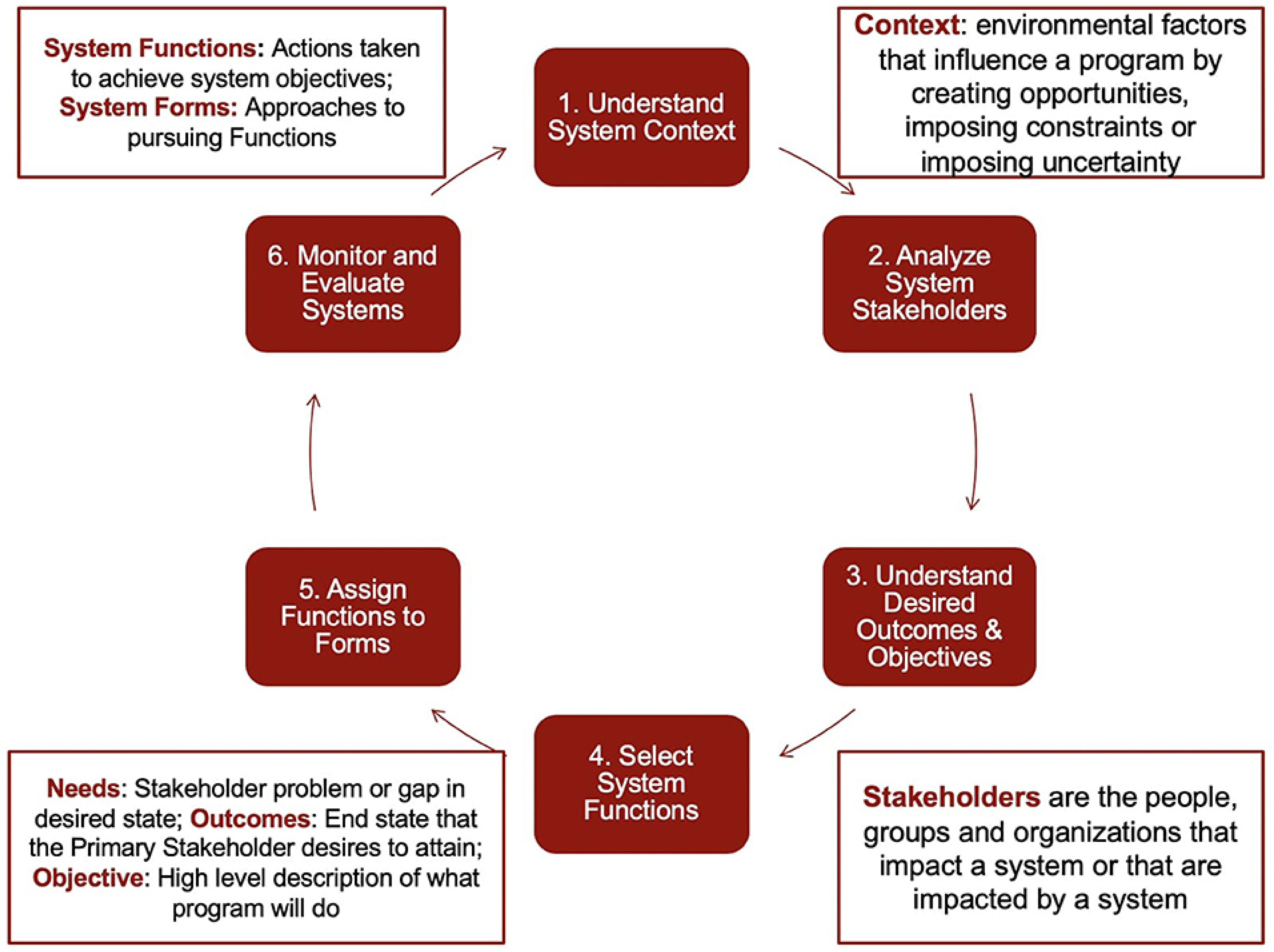
Danielle Wood (MIT), David Lagomasino (ECU), Ufuoma Ovienmhada (MIT), Abigail Barenblitt (NASA), Amanda Payton (ECU), Jack Reid (MIT), Seamus Lombardo (MIT), Eric Ashcroft (Blue Raster), Temilola Fatoyinbo-Agueh (NASA)


1 NO POVERTY
2 NO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 RENEWABLE ENERGY
8 GOOD JOBS AND ECONOMIC GROWTH
9 INNOVATION AND INFRASTRUCTURE
010
011
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS
For Sustainable Development

1. Earth Observation (EO) System Design and Implementation
2. EO System Operation, Data Retrieval, Calibration & Validation
3. EO Data Correction and Processing
4. Earth Science Modeling and Assimilation of Earth Observations
5. EO Data Discovery & Visualization: Providing interface to find and explore data
6. EO Data Transformation: Creating data interface based on user needs
7. Knowledge Integration: Combining physical, social, economic and other data
8. Decision Support: Providing recommendations for action

Raha Hakimdavar, Danielle Wood, John Eylander, Christa Peters-Lidard, Jane Smith, Brad Doorn, David Green, Corey Hummel, Thomas C Moore, "Transboundary Water: Improving Methodologies and Developing Integrated Tools to Support Water Security," NASA Goddard Space Flight Center, Technical Report, February 2018. NASA/TM–2018-219026


Environmental parameters
Socio-economic parameters for human resilience (ie income, housing type, transportation infrastructure, income opportunities)
Social parameters (ie, availability of fishers to harvest water hyacinth)
Environmental model
Human vulnerability and societal impact model
Human decision making model
Impacts of human actions
Design for a sensor system on satellites, aerial platforms and in-situ
Technology design model
Information needs for human decision makers
EVDT Modeling Framework


System Functions: Actions taken to achieve system objectives; System Forms: Approaches to pursuing Functions
1. Understand System Context
Context: environmental factors that influence a program by creating opportunities, imposing constraints or imposing uncertainty
6. Monitor and Evaluate Systems
2. Analyze System Stakeholders
5. Assign Functions to Forms
3. Understand Desired Outcomes & Objectives
4. Select System Functions
Needs: Stakeholder problem or gap in desired state; Outcomes: End state that the Primary Stakeholder desires to attain; Objective: High level description of what program will do
Stakeholders are the people, groups and organizations that impact a system or that are impacted by a system

Analysis of deforestation due to mining in Southwestern Ghana

US Co-Investigators: Space Enabled Research Group @ MIT Media Lab, NASA Goddard Space Flight Center, East Carolina University

West African Co-Investigators: Ghana Statistical Service, Ghana Space Science and Technology Institute

GHANA SPACE SCIENCE AND TECHNOLOGY CENTRE

GHANA STATISTICAL SERVICE

NASA

space enabled

Science of the Total Environment 781 (2021) 146644

ELSEVIER

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

The large footprint of small-scale artisanal gold mining in Ghana

Check for updates

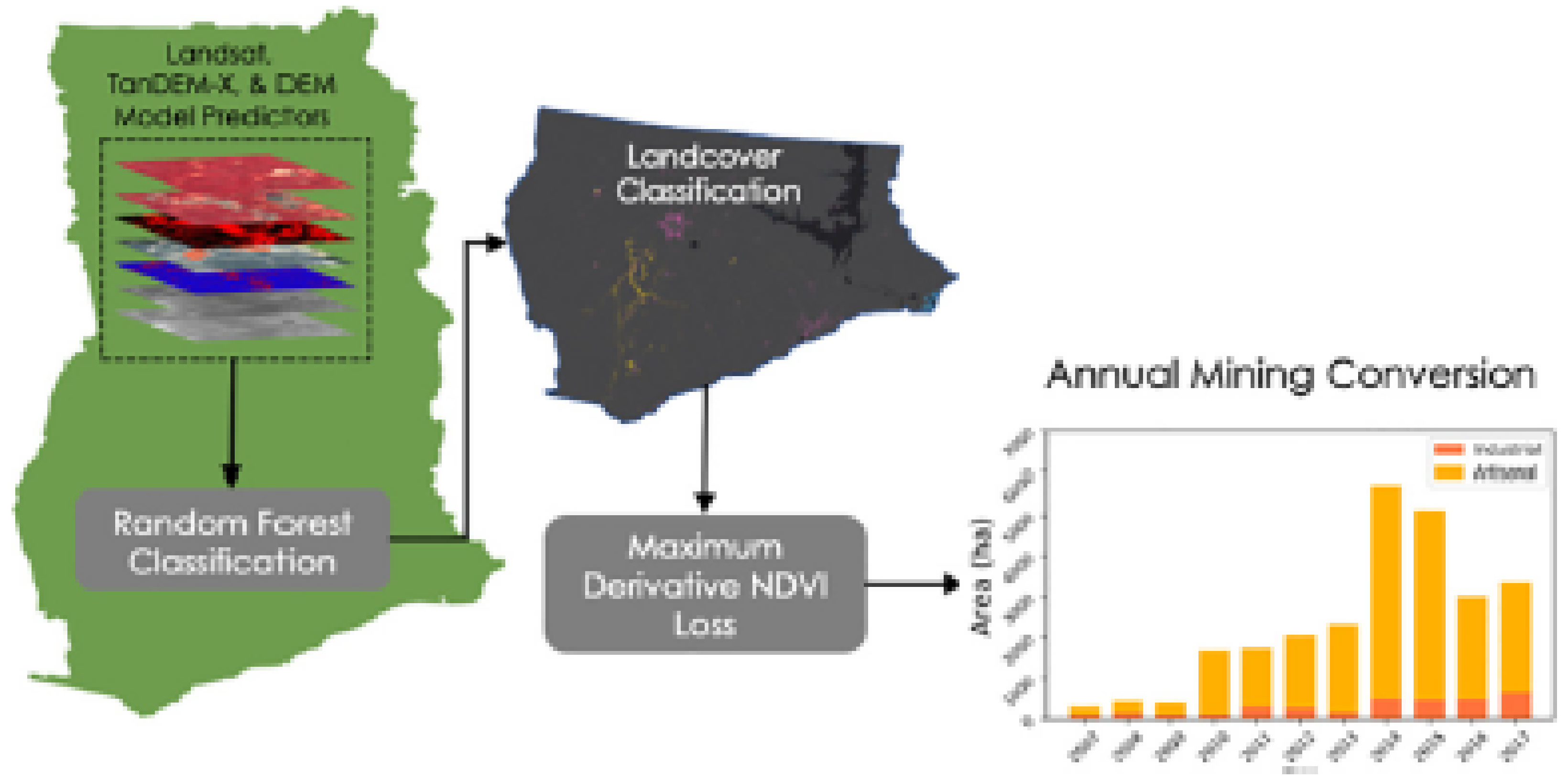
Abigail Barenblitt [a,c,*], Amanda Payton [b], David Lagomasino [b], Lola Fatoyinbo [c], Kofi Asare [d], Kenneth Aidoo [d], Hugo Pigott [e], Charles Kofi Som [e], Laurent Smeets [e], Omar Seidu [e], Danielle Wood [f]

[a] *Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, United States*
[b] *Department of Coastal Studies, East Carolina University, Wanchese, NC, United States*
[c] *Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, United States*
[d] *Ghana Space Science and Technology Institute, Accra, Ghana*
[e] *Ghana Statistical Service, Accra, Ghana*
[f] *Space Enabled Research Group, Massachusetts Institute of Technology, Cambridge, MA, United States*

HIGHLIGHTS

- Land conversion in due to artisanal gold mining = that of urban expansion.
- New mining extent (2005 and 2019) was dominated by artisanal mining (~89%).
- Over 700 ha of artisanal mining was detected in protected areas.
- This mining is degrading and destroying forested ecosystems.

GRAPHICAL ABSTRACT



Barenblitt et al 2021

The Ghana Space Science and Technology Institute is also a Co-Investigator on the project funded by NASA

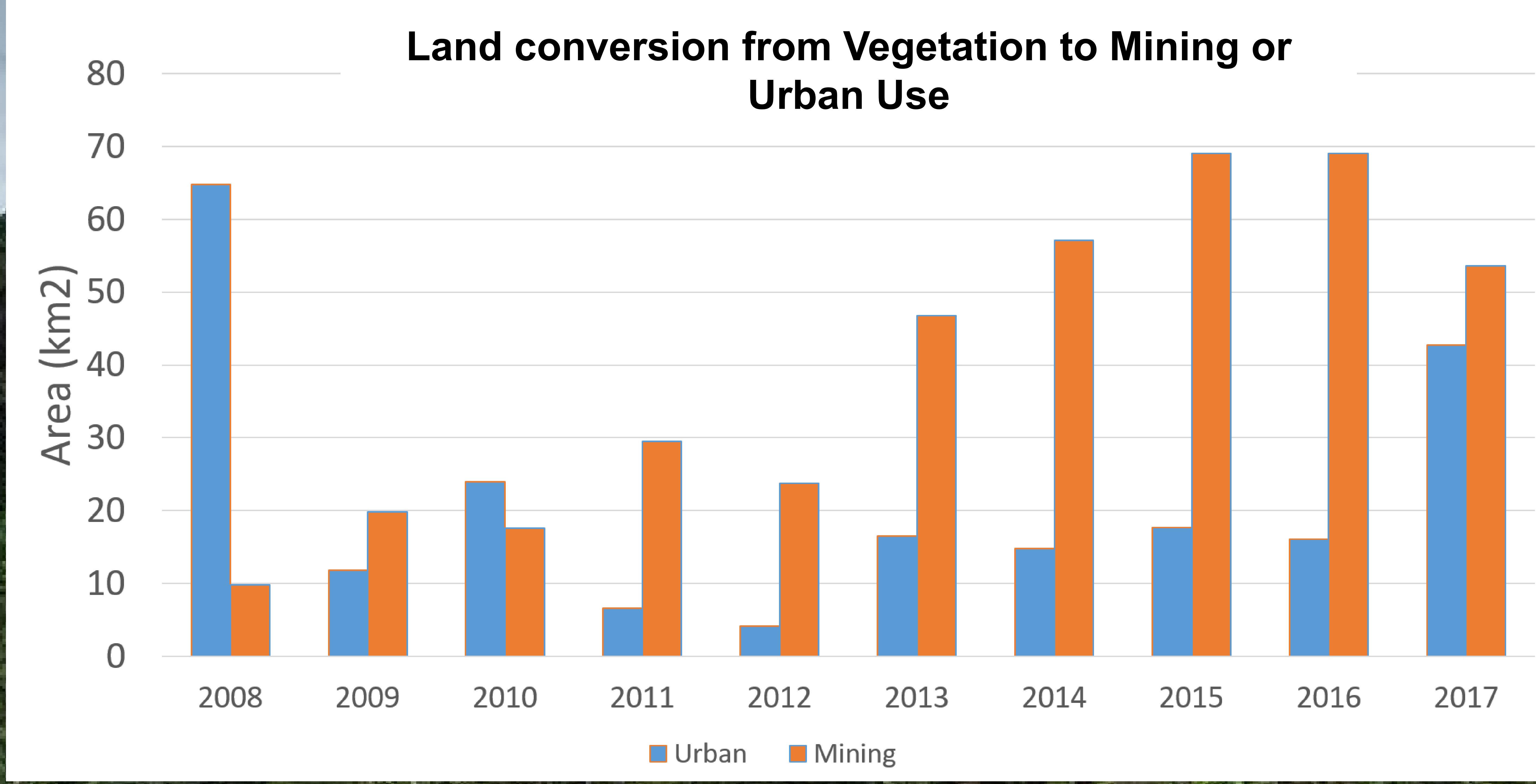
GHANA SPACE SCIENCE AND TECHNOLOGY CENTRE

Gold Mining in Ghana

+ Ghana is the 7th Largest producer of gold worldwide
+ Artisanal Mining has increased from 5% of gold production in 1990 to 30% in 2012
+ Artisanal mining causes deforestation and produces Mercury pollution in the environment

Study Area: Analysis of deforestation due to mining in Southwestern Ghana

Barenblitt et al 2021

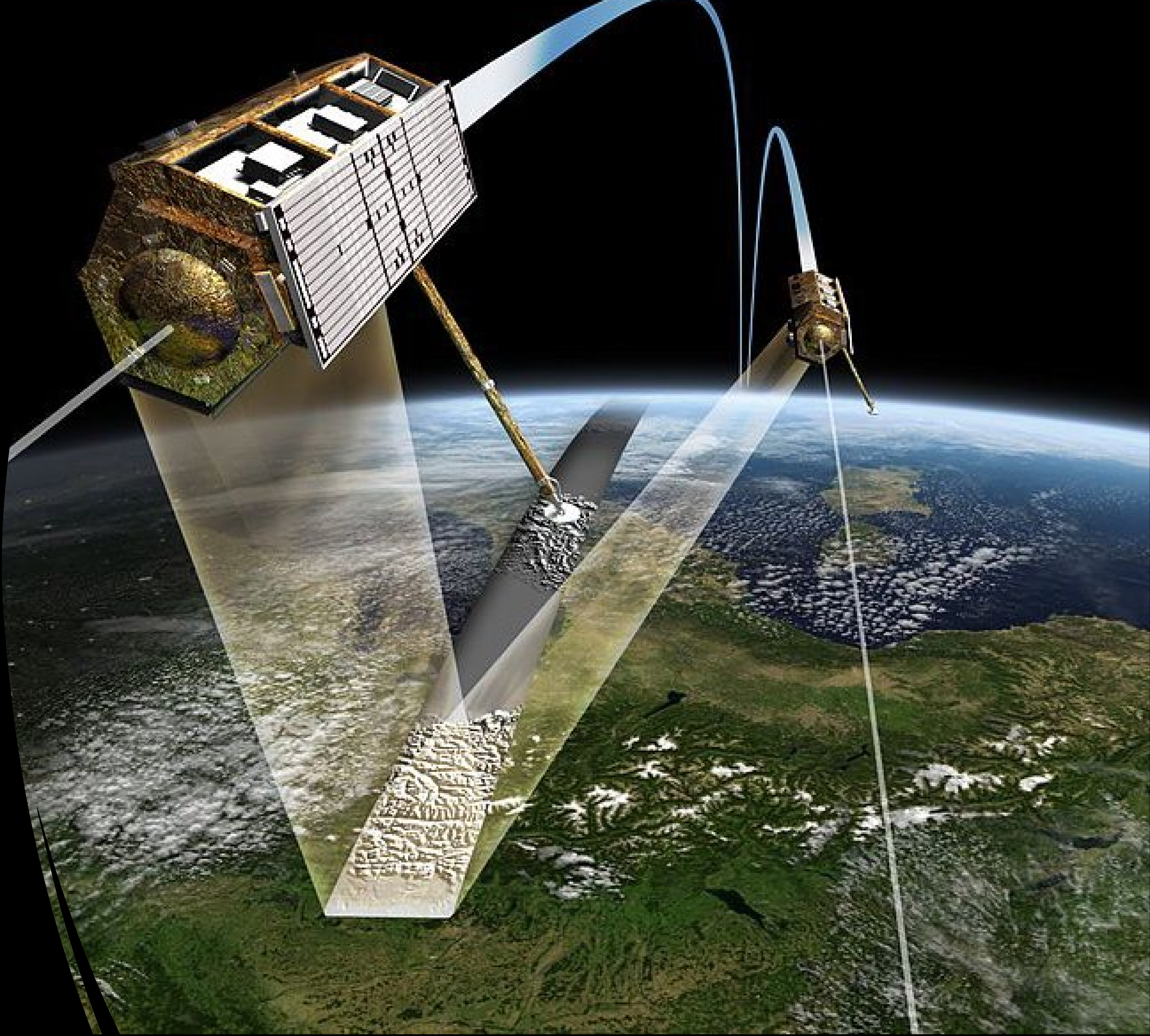


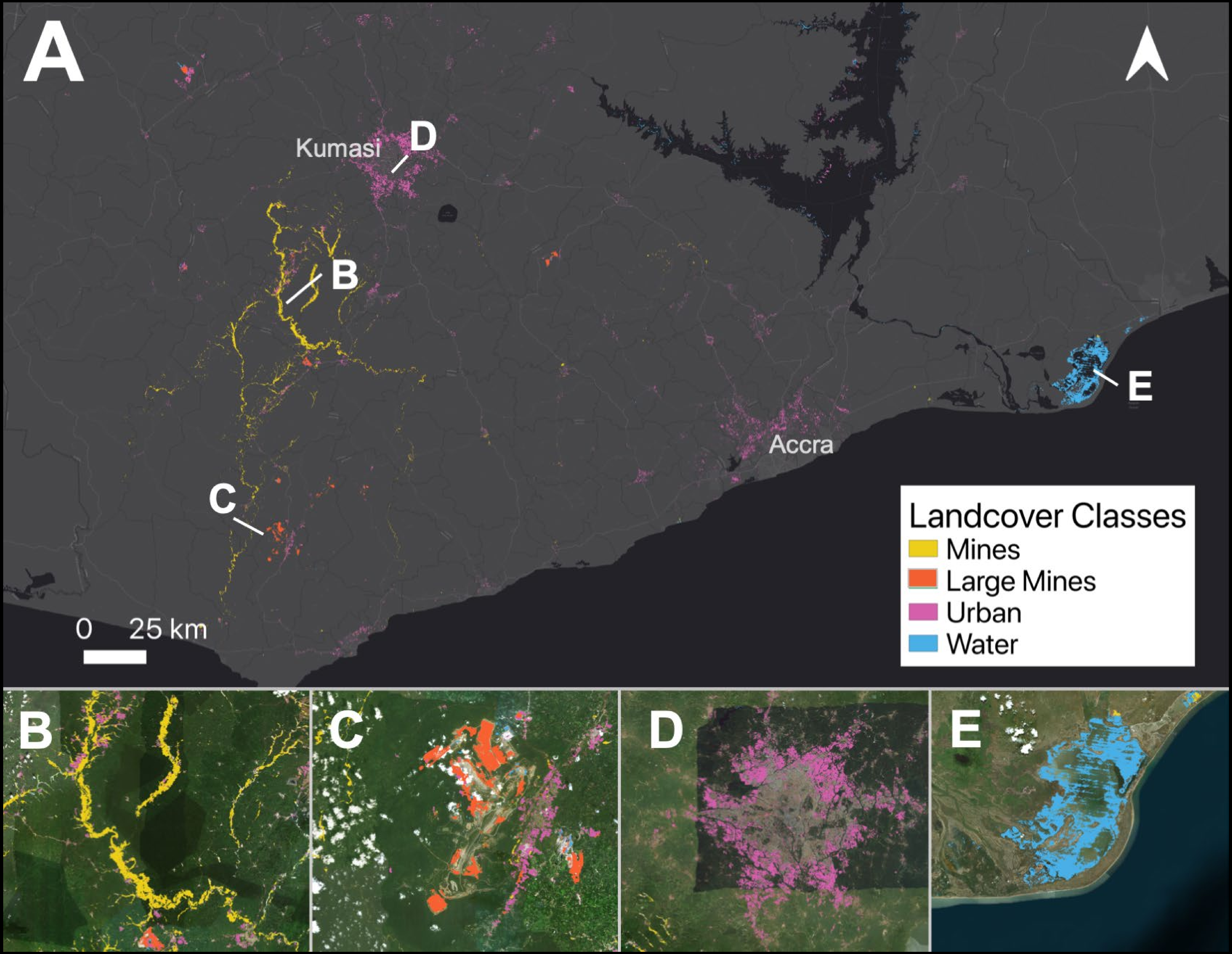
The analysis used Landsat 7 and 8 Imagery (Bands 4 to 7). The observational period was 2008-2017. Land was classified into four classes: Water, Urban, Mine and Vegetation

https://assets.bwbx.io/images/users/iqjWHBFdfxIU/iCk5guosUGns/v2/1000x-1.jpg

Categorizing Large Scale vs Small Scale Mines

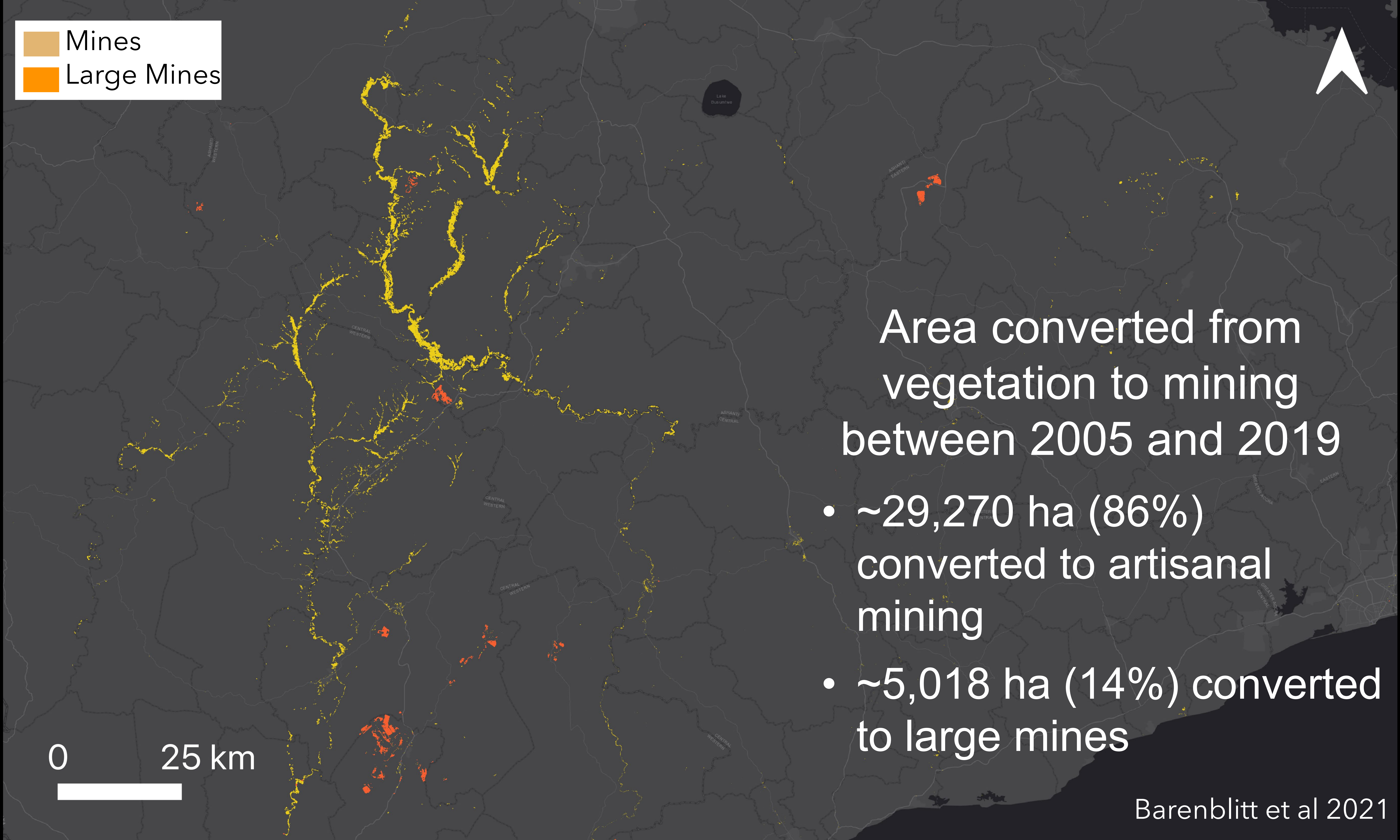
- Used TanDEM-X, Shuttle Radar Topography Mission (SRTM), and Landsat 8 NIR
- Random Forest Classification cleaned in QGIS
- 0.01 km^2 threshold





Examples of land cover classes categorized through Random Forest Model


A
B
C
D
Kumasi
Accra
Loss of vegetation in Southwest Ghana
0 2 km
0 2 km
0 2 km
0 25 km
Year of Loss
2007
2017



Area converted from vegetation to mining between 2005 and 2019

- ~29,270 ha (86%) converted to artisanal mining
- ~5,018 ha (14%) converted to large mines

Barenblitt et al 2021

https://assets.bwbx.io/images/users/iqjWHBFdfx

IU/iCk5guosUGns/v2/1000x-1.jpg

Key Findings

- Land conversion due to mining was almost equivalent to urban expansion
- New mining extent was dominated (~89%) by artisanal mining
- 700 ha of mining in Protected Areas
- Mining is destroying forest ecosystems and has potential human health risks due to co-location with rivers and mercury used
- Accuracy assessment was done using Google Earth Pro and Collect Earth showing 84% overall accuracy and 90% accuracy for the primary land use types

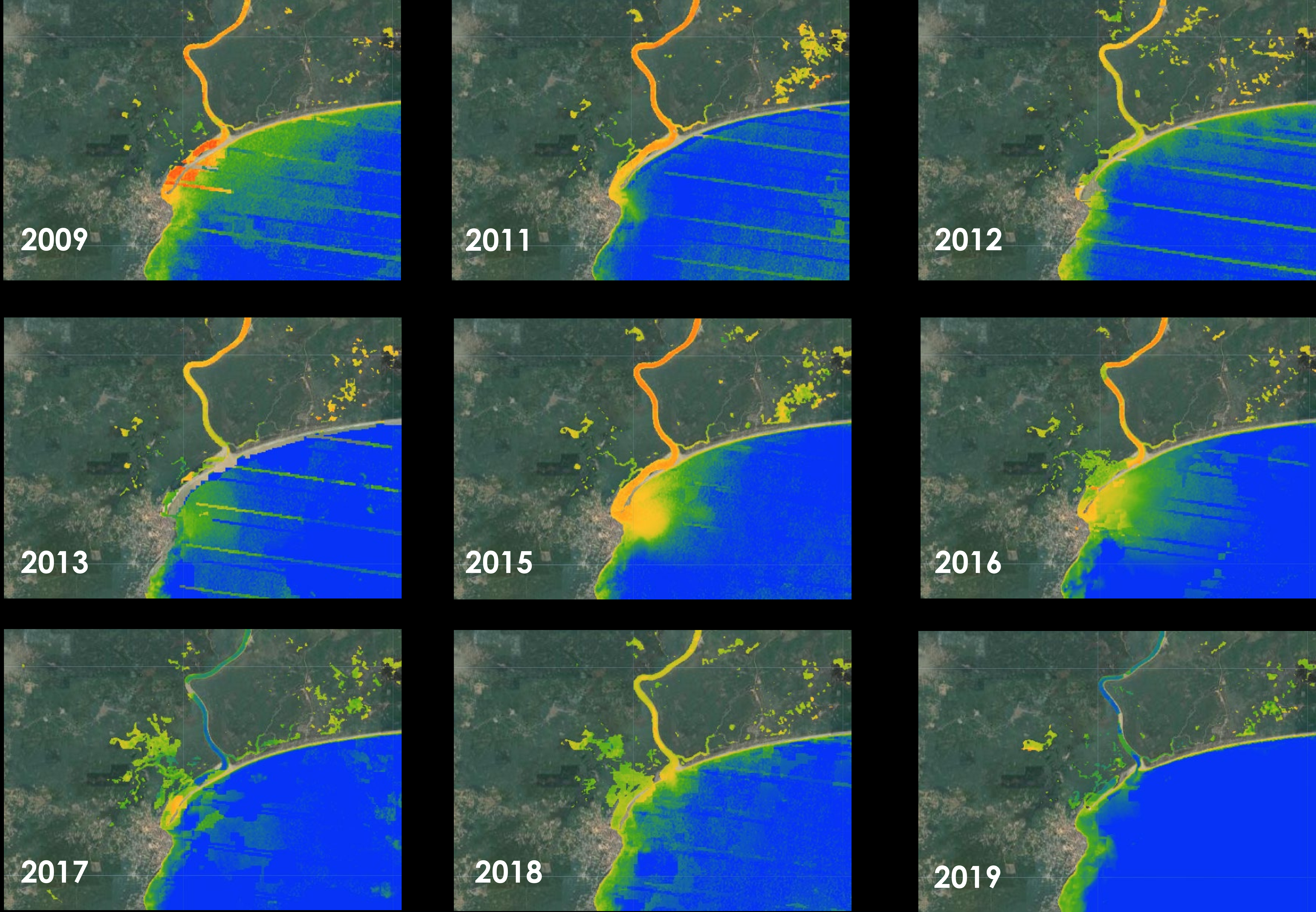
- Barenblitt, A., Payton, A., Lagomasino, D., Fatoyinbo, L., Asare, K., Aidoo, K., Pigott, H., Som, C. K., Smeets, L., Seidu, O., & Wood, D. (2021). The large footprint of small-scale artisanal gold mining in Ghana. *Science of The Total Environment*, *781*, 146644.
- https://doi.org/10.1016/j.scitotenv.2021.146644


mangrovescience.earthengine.app/view/miningresults
Earth Engine Apps
Experimental
Search places
Layers
Map
Satellite
Select layers to display.
2007
2017
Mining Conversion Year
2016
Annual Mining Conversion
Total Mining Area
Artisanal
Industrial
World Database Protected Areas
Visit Example Locations
Select
Graphs of Results
Total Mining Area by Year
Industrial
Artisanal
6,000
4,000
2,000
0
Area in Hectares
2,010

- Mining activity is heavily associated with Pra and Ankobra River Basins, but not yet with Volta
- Analysis finds correlation between Suspended Particulate Matter and Red Band from Landsat
- Hypothesis:
    - Upstream degradation due to mining is increasing sedimentation at the coast

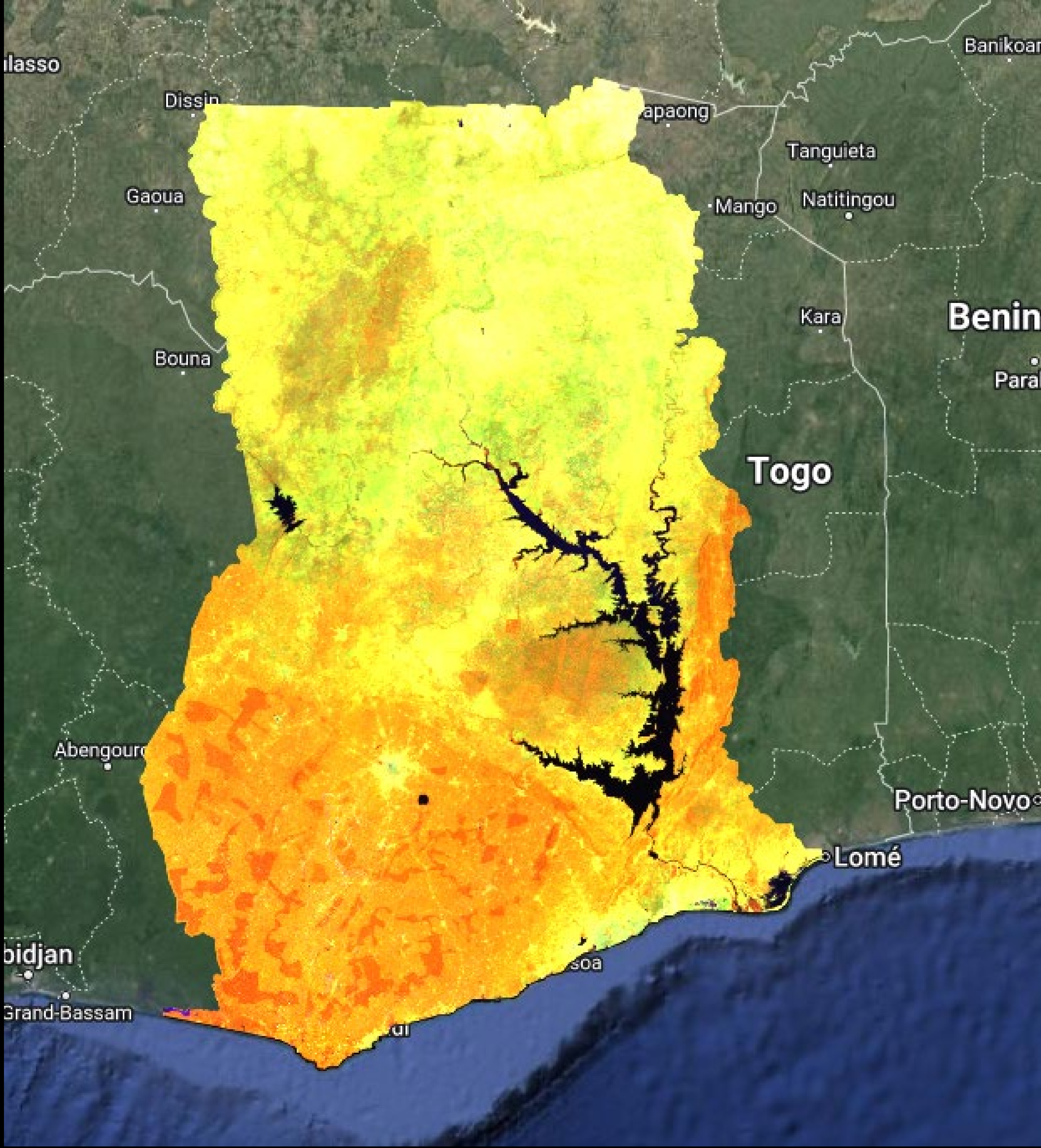

2002-2005
Ankobra River
Pra River
Volta River
2019-2020
Red Band Change
Asanta
Axim
Big Ada
Agbletokwei
Ada Foah

Pra River



Ghana Landcover Classification

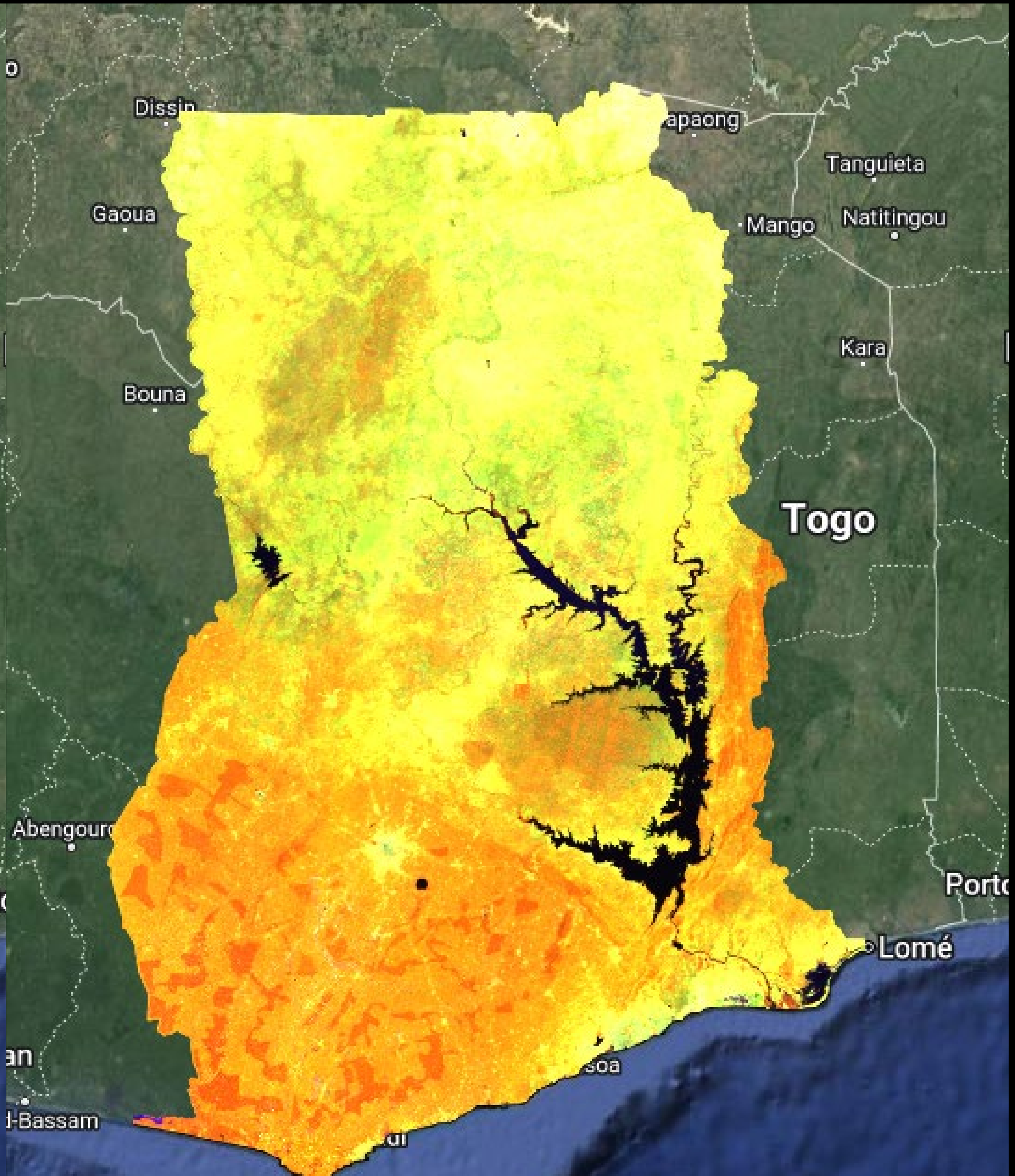
+ Following the gold mining analysis, collaborators expressed interest in a country-wide landcover classification
+ Landcover maps for different years will inform us how forests and other ecosystems are changing over time
+ We constructed a new Random Forest Classification for the whole country



Class	Description
Waterbodies	All areas of open water, water present >50% of the year
Mangroves and Forested Wetlands	Areas where trees account for >50% of the vegetative cover and the soil or substrate is saturated with or covered with water >50% of the year
Non-Forested Wetlands	Areas where trees account for <50% of the vegetative cover and the soil or substrate is saturated with or covered with water >50% of the year
Woody Crop	Areas with >50% domesticated woody vegetation. Includes cocoa, palm, shea and other tree crops
Agriculture	Areas dominated by all other domesticated vegetation. Usually followed by harvest and bare soil and/or grassland/mixed vegetation period.
Grasslands/ Shrubland	Areas dominated with herbaceous and low woody cover with <10% tree canopy
Forest – Dense/Closed	Areas where natural tree canopy covers >75%
Forest – Open	Areas where natural tree canopy covers 50-75%
Mixed Vegetation	Vegetated areas where neither herbaceous, shrubs, or trees dominate
Artificial Surfaces	Buildings and other man-made structures cover >50% of the surface
Mining	All areas of mining activity, mining covers >50% of the surface
Barren Land	Areas characterized by bare rock and/or exposed soil with <10% vegetation present

Cloud-Free Landsat/SAR Composite

True Color Composite

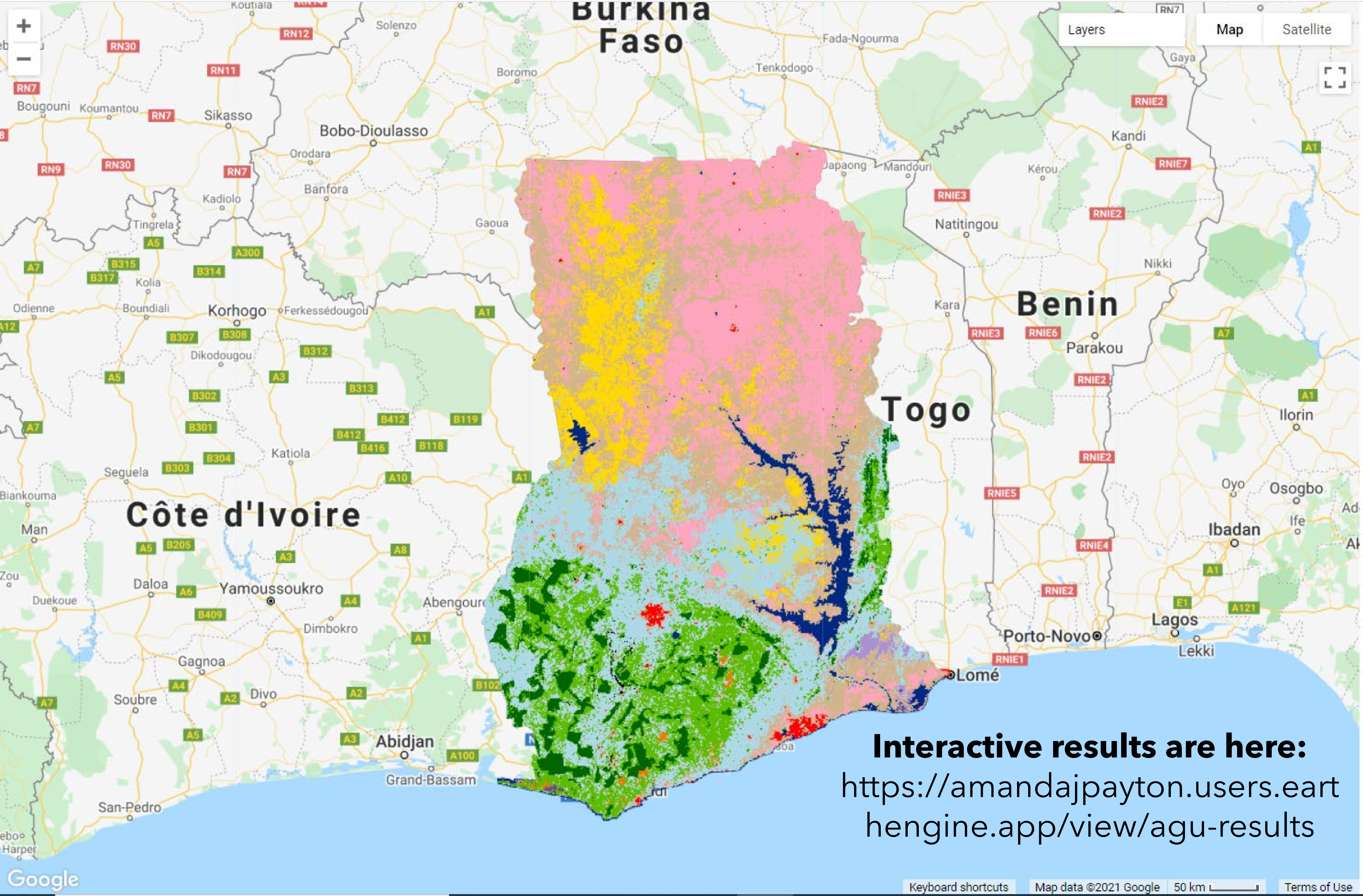


False Color Composite (SWIR, R, NIR)

A combination of spectral and SAR bands and indices are available for landcover classifications

Earth Engine Apps

Search places



Ghana Climate and Landcover Results

The results shown represent recent landcover changes in Ghana and longer-term trends in temperature and precipitation in Southern Ghana. Landcover classifications are shown for 2015 and 2020. These layers are preliminary results and are subject to change.The temperature and precipitation changes are represented by annual and seasonal trends. The temperature analyses used FLDAS data from 1982 to 2019 and is presented at a 95% confidence level. The precipitation analyses used CHIRPS data from 1981 to 2019 and is presented at a 95% confidence level, with the exception of the annual analysis in Ghana which is presented at 80% confidence.

Choose Layers

2015 Classification

Layer Legend

- Water
- Wetlands
- Mining
- Artificial Surfaces
- Closed Forest
- Open Forest
- Woody Crops
- Agriculture
- Grassland
- Mixed Vegetation
- Bare

Interactive results are here:

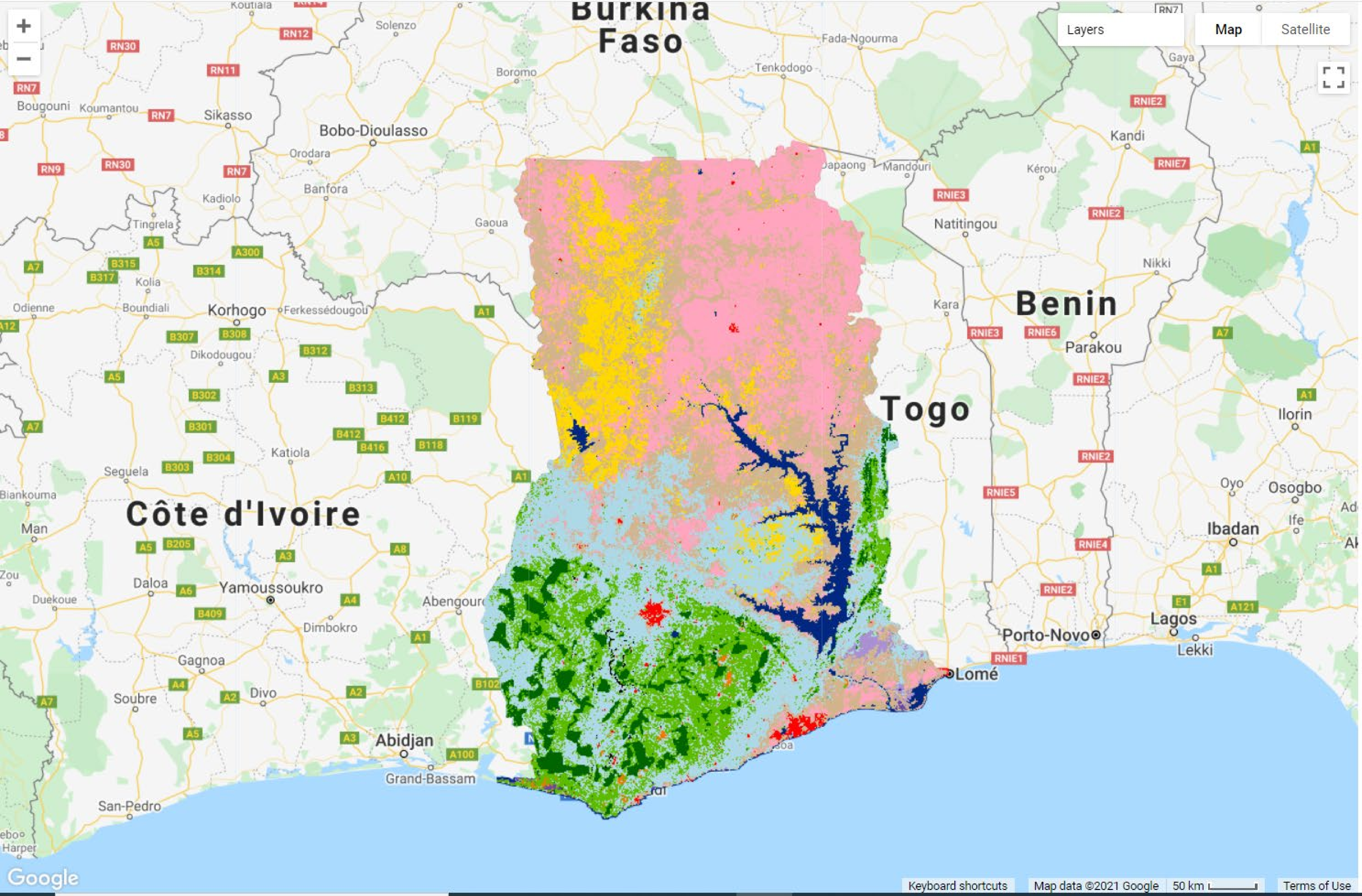
https://amandajpayton.users.earthengine.app/view/agu-results

Type here to search

11:29 PM
12/8/2021

Earth Engine Apps

Search places



Ghana Climate and Landcover Results

The results shown represent recent landcover changes in Ghana and longer-term trends in temperature and precipitation in Southern Ghana. Landcover classifications are shown for 2015 and 2020. These layers are preliminary results and are subject to change.The temperature and precipitation changes are represented by annual and seasonal trends. The temperature analyses used FLDAS data from 1982 to 2019 and is presented at a 95% confidence level. The precipitation analyses used CHIRPS data from 1981 to 2019 and is presented at a 95% confidence level, with the exception of the annual analysis in Ghana which is presented at 80% confidence.

Choose Layers

2020 Classification

Layer Legend

- **Water**
- **Wetlands**
- **Mining**
- **Artificial Surfaces**
- **Closed Forest**
- **Open Forest**
- **Woody Crops**
- **Agriculture**
- **Grassland**
- **Mixed Vegetation**
- **Bare**

Designing a Decision Support Tool to support Integrated Water Resource Management and Biodiversity in Lake Nokoue, Benin

US Co-Investigators: Space Enabled Research Group @ MIT Media Lab, NASA Goddard Space Flight Center, Blue Raster, East Carolina University

Benin Co-Investigators: Green Keeper Africa

Additional Scientific Input: National Institute of Water & CENATEL, Benin

frontiers in Climate

ORIGINAL RESEARCH
published: 09 September 2021
doi: 10.3389/fclim.2021.717418

Check for updates

Inclusive Design of Earth Observation Decision Support Systems for Environmental Governance: A Case Study of Lake Nokoué

Ufuoma Ovienmhada[1*], *Fohla Mouftaou*[2] *and Danielle Wood*[1]

[1] *MIT Media Lab, Space Enabled Research Group, Massachusetts Institute of Technology, Cambridge, MA, United States,*
[2] *Green Keeper Africa, Cotonou, Benin*

Earth Observation (EO) data can enhance understanding of human-environmental systems for the creation of climate data services, or Decision Support Systems (DSS), to improve monitoring, prediction and mitigation of climate harm. However, EO data is not always incorporated into the workflow for decision-makers for a multitude of reasons including awareness, accessibility and collaboration models. The purpose of this study is to demonstrate a collaborative model that addresses historical power imbalances between communities. This paper highlights a case study of a climate harm mitigation DSS collaboration between the Space Enabled Research Group at the MIT Media Lab and Green Keeper Africa (GKA), an enterprise located in Benin. GKA addresses the management of an invasive plant species that threatens ecosystem health and economic activities on Lake Nokoué. They do this through a social entrepreneurship business model that aims to advance both economic empowerment and environmental health. In demonstrating a Space Enabled-GKA collaboration model that advances GKA's business aims, this study first considers several popular service and technology design methods and offer critiques of each method in terms of their ability to address inclusivity in complex systems. These critiques lead to the selection of the Systems Architecture Framework (SAF) as the technology design method for the case study. In the remainder of the paper, the SAF is applied to the case study to demonstrate how the framework coproduces knowledge that would inform a DSS with Earth Observation data. The paper offers several practical considerations and values related to epistemology, data collection, prioritization and methodology for performing inclusive design of climate data services.

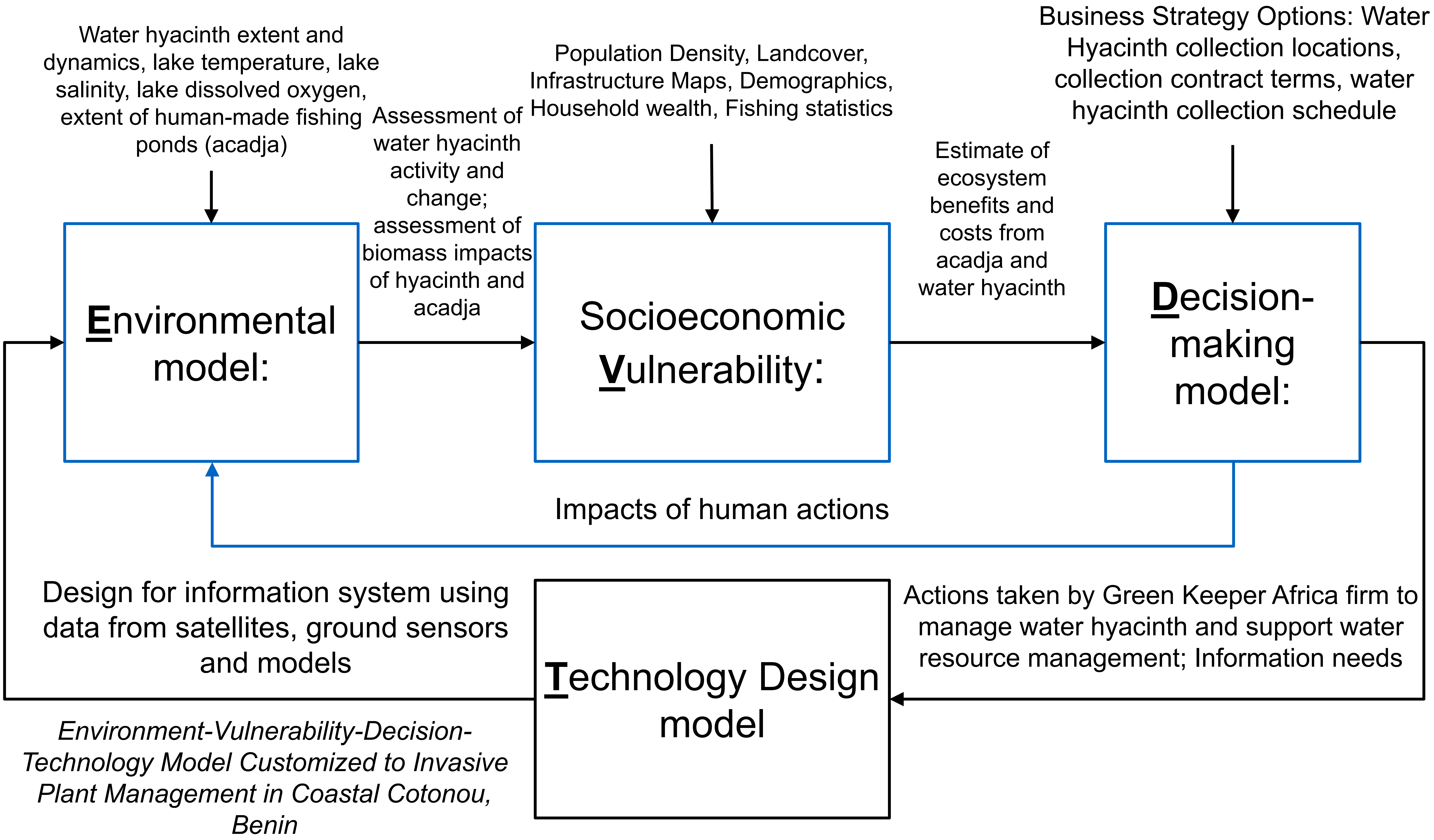
Keywords: earth observation, water hyacinth, climate data services, decision support systems, design

Edited by:
Emily C. Adams,
University of Alabama in Huntsville,
United States

Reviewed by:
Xinxuan Zhang,
George Mason University,
United States
Tasnuva Rouf,
University of California, Berkeley,
United States

****Correspondence:***
Ufuoma Ovienmhada
ufuoma@mit.edu

Specialty section:
This article was submitted to
Climate Services,
a section of the journal
Frontiers in Climate


Water hyacinth extent and dynamics, lake temperature, lake salinity, lake dissolved oxygen, extent of human-made fishing ponds (acadja)
Assessment of water hyacinth activity and change; assessment of biomass impacts of hyacinth and acadja
Population Density, Landcover, Infrastructure Maps, Demographics, Household wealth, Fishing statistics
Estimate of ecosystem benefits and costs from acadja and water hyacinth
Business Strategy Options: Water Hyacinth collection locations, collection contract terms, water hyacinth collection schedule
Environmental model:
Socioeconomic Vulnerability:
Decision-making model:
Impacts of human actions
Design for information system using data from satellites, ground sensors and models
Technology Design model
Actions taken by Green Keeper Africa firm to manage water hyacinth and support water resource management; Information needs
Environment-Vulnerability-Decision-Technology Model Customized to Invasive Plant Management in Coastal Cotonou, Benin

Ecotechnology firm Green Keeper Africa is a co-Investigator focused on invasive species management in Benin (SDG 15.8). Photo from August 2019 visit.


Sô RIVER
SO-AVA
Ouémé
ABOMEY CALAVI
NOKOUE LAKE
PORTO NOVO
LAGOON
PORTO-NOVO
SEME
COTONOU
ATLANTIC OCEAN
0
3
6
12 Km
440000
460000
720000
700000
N
S
E
W
Legend
Main town
Local government
Stream
Water body

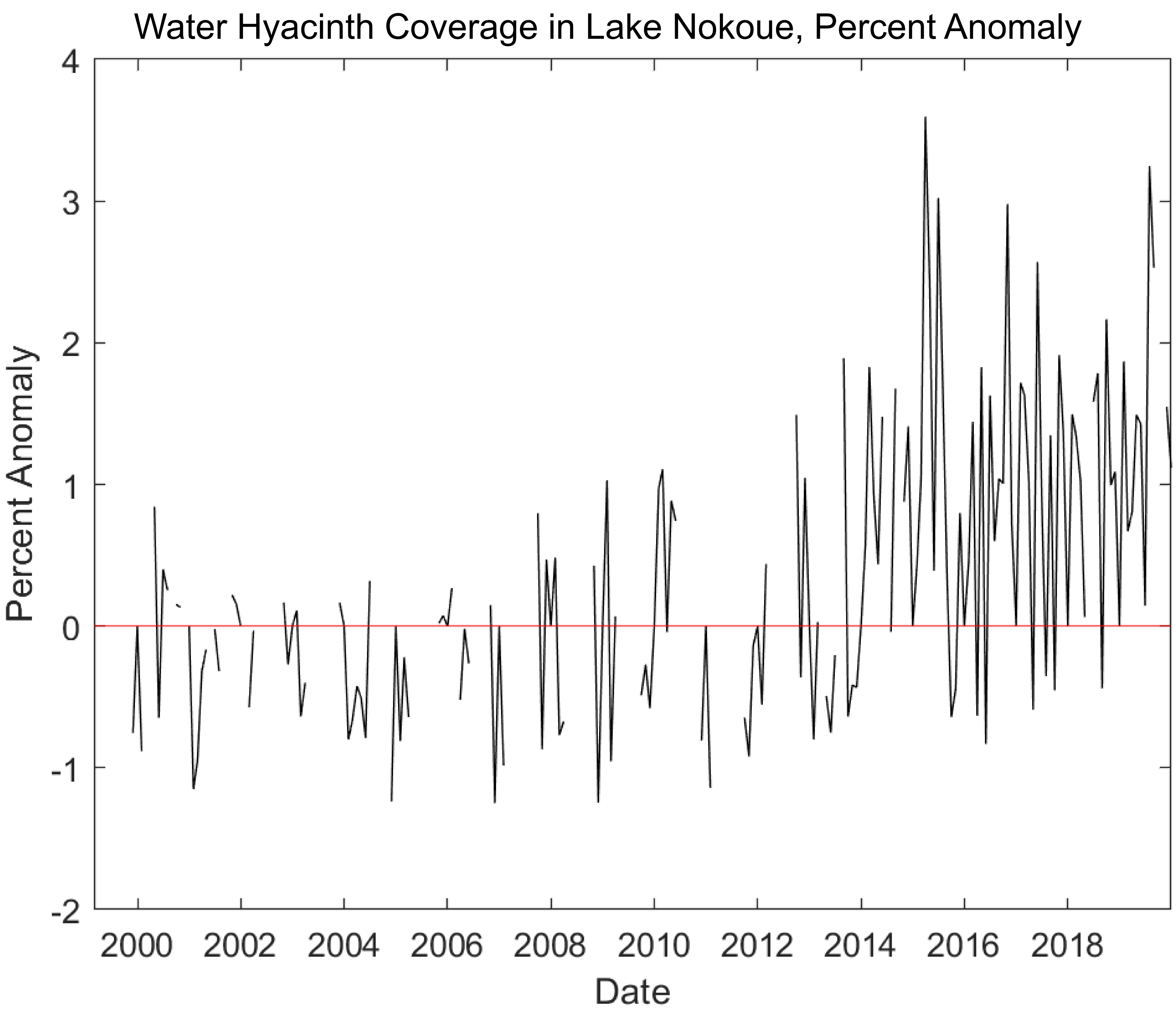
Lake Nokoue


GIVENCHY
PARIS
Columbia


Lake Djètouè at Lokossa

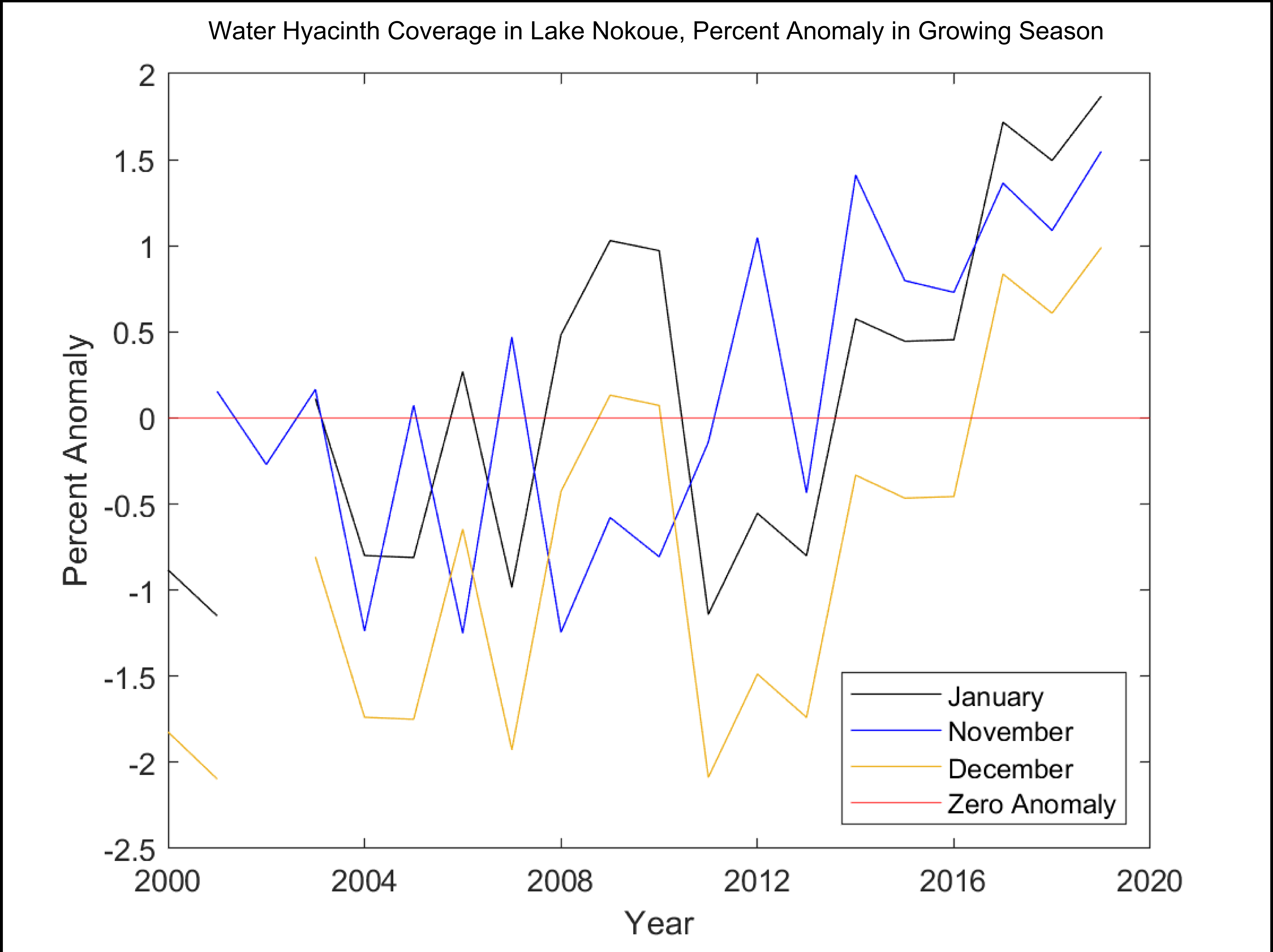
Water hyacinthe on the channel at Grand Popo


GIVENCHY
PARIS



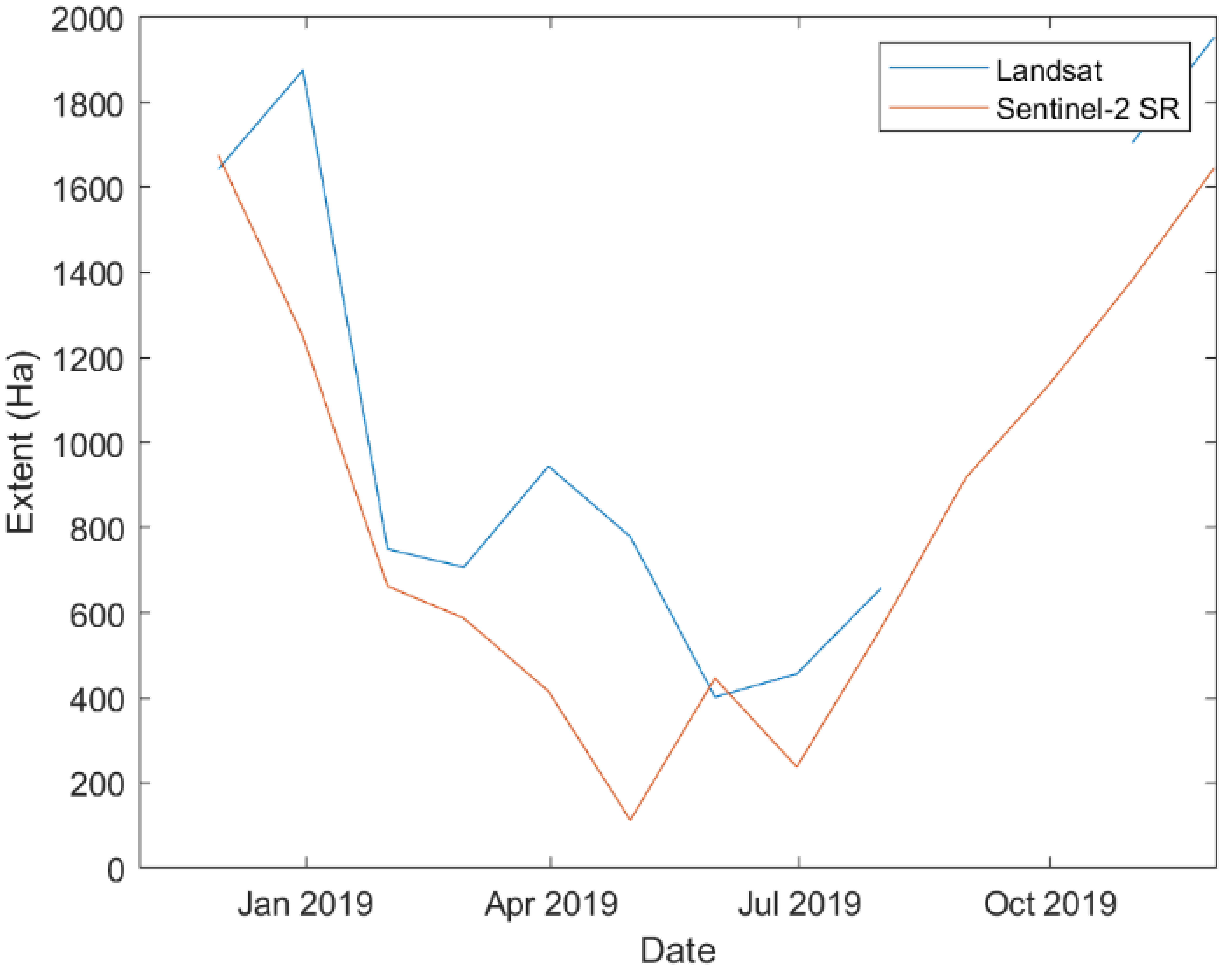
Ovienmhada

2020

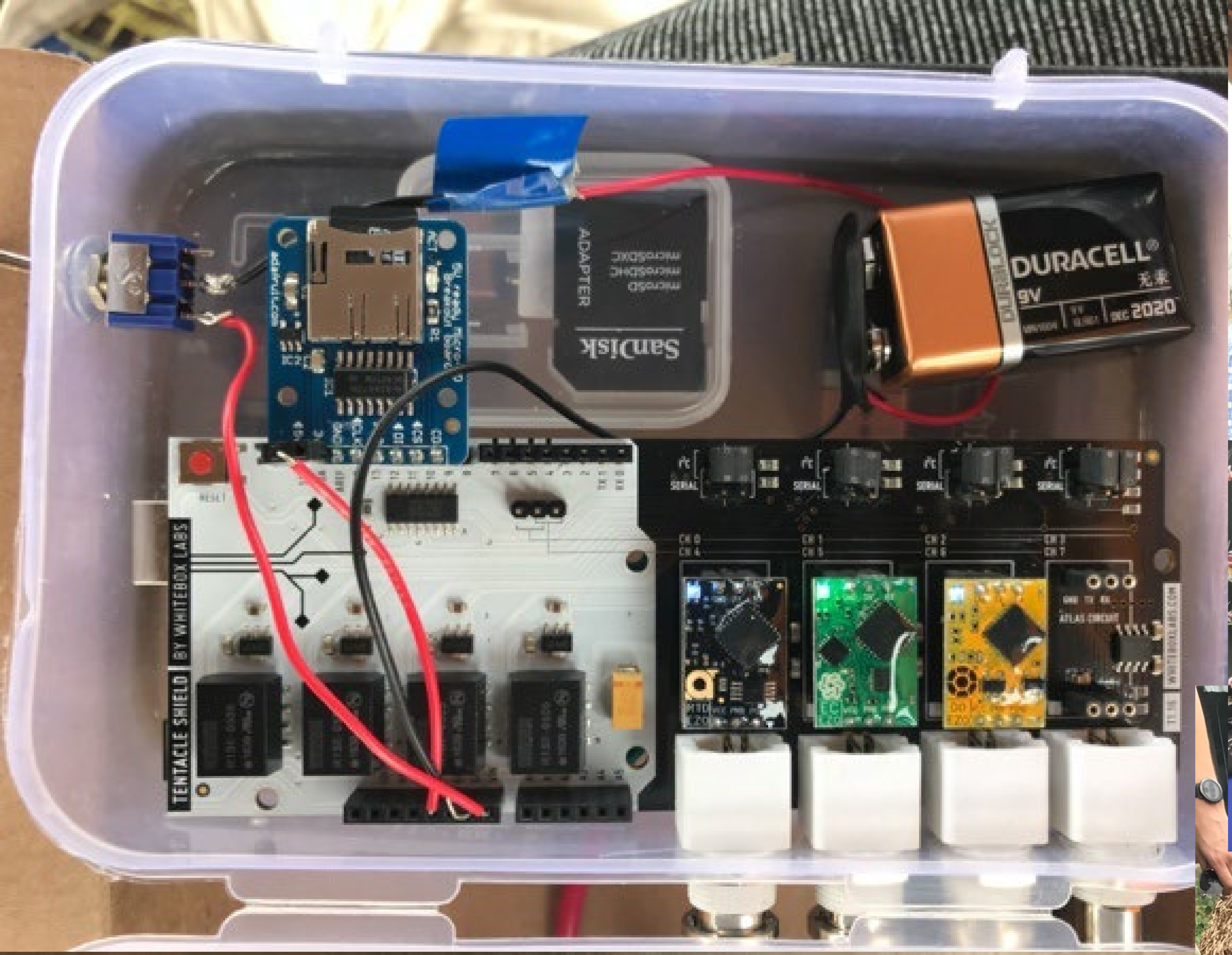


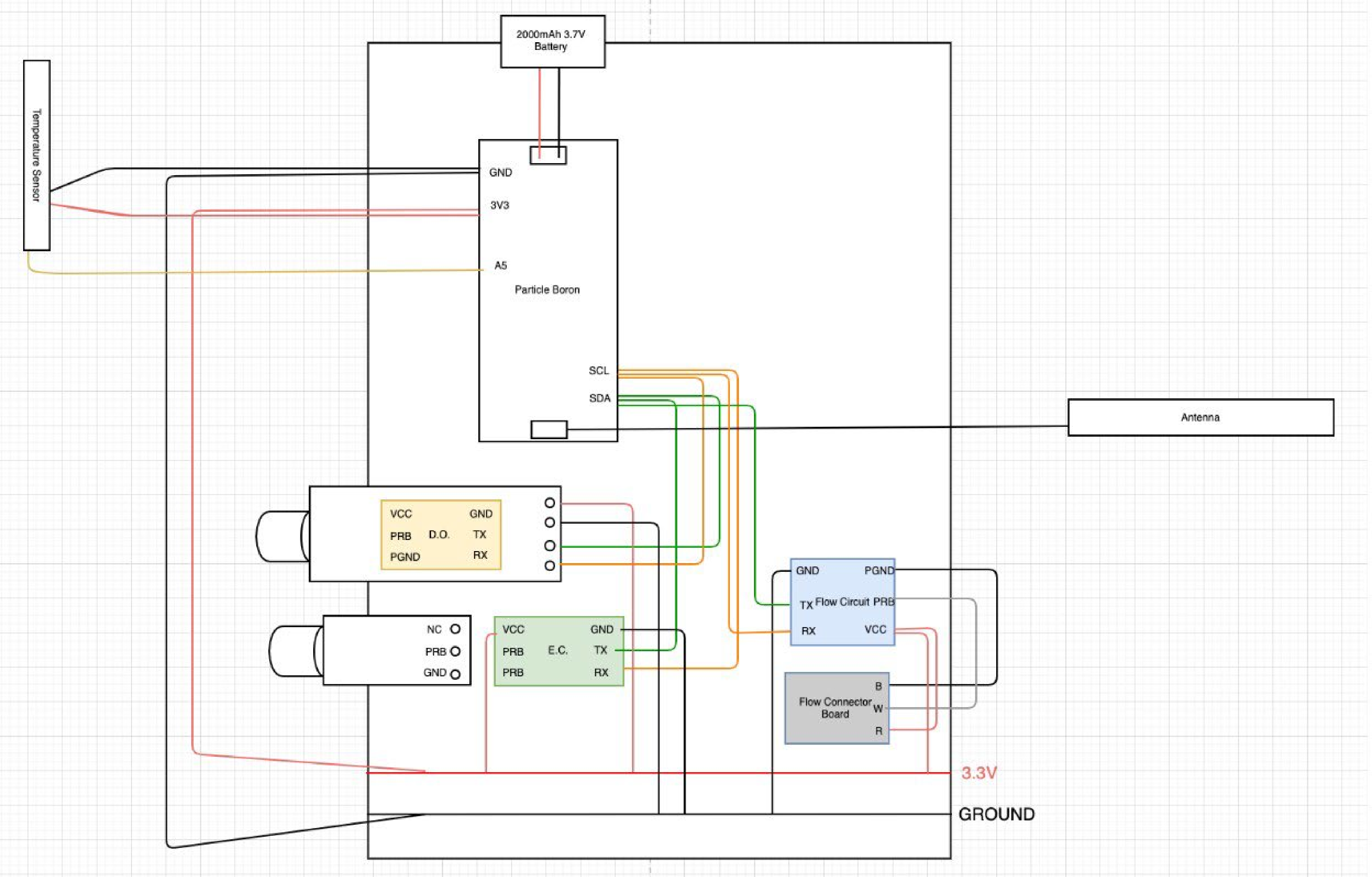
Water Hyacinth Coverage in Lake Nokoue, Percent Anomaly in Growing Season
Percent Anomaly
Year
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
2000
2004
2008
2012
2016
2020
January
November
December
Zero Anomaly

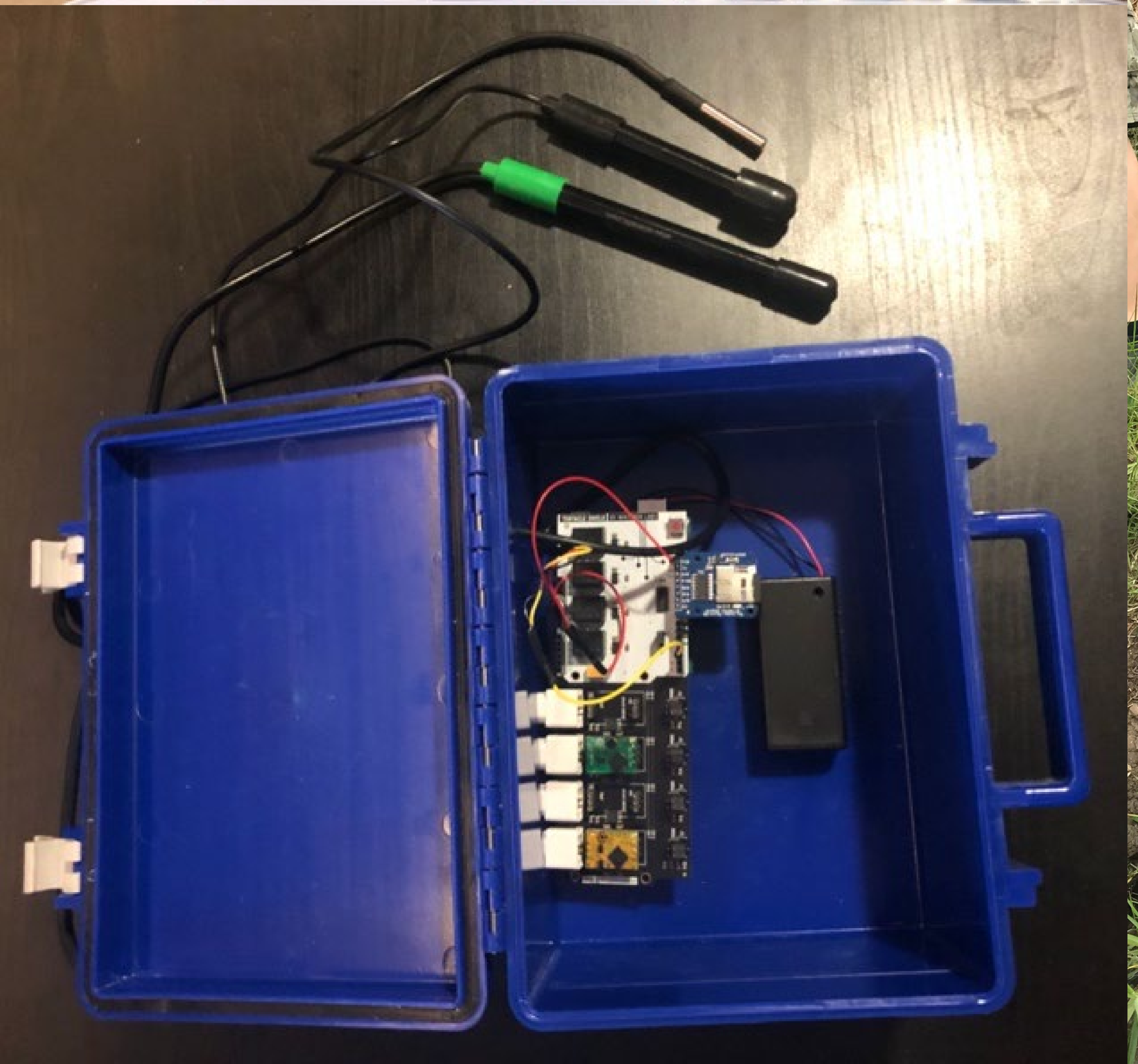
Reference Datasets	Resolution (meters)	Dates Images Obtained
Sentinel-2	10	Dec 2018 – Dec 2019
Djihouessi	10	November 2016 – November 2017
PlanetScope	3 m	Jan 2019
DJI Phantom 4 Pro	.03 m	Aug 2019
IPhone photos	Varied	Aug 2019, April 2019



Ovienmhada 2020




2000mAh 3.7V Battery
Temperature Sensor
GND
3V3
A5
Particle Boron
SCL
SDA
Antenna
VCC
GND
PRB
D.O.
TX
PGND
RX
NC
PRB
GND
VCC
GND
PRB
E.C.
TX
PRB
RX
GND
PGND
TX
Flow Circuit
PRB
RX
VCC
Flow Connector Board
B
W
R
3.3V
GROUND

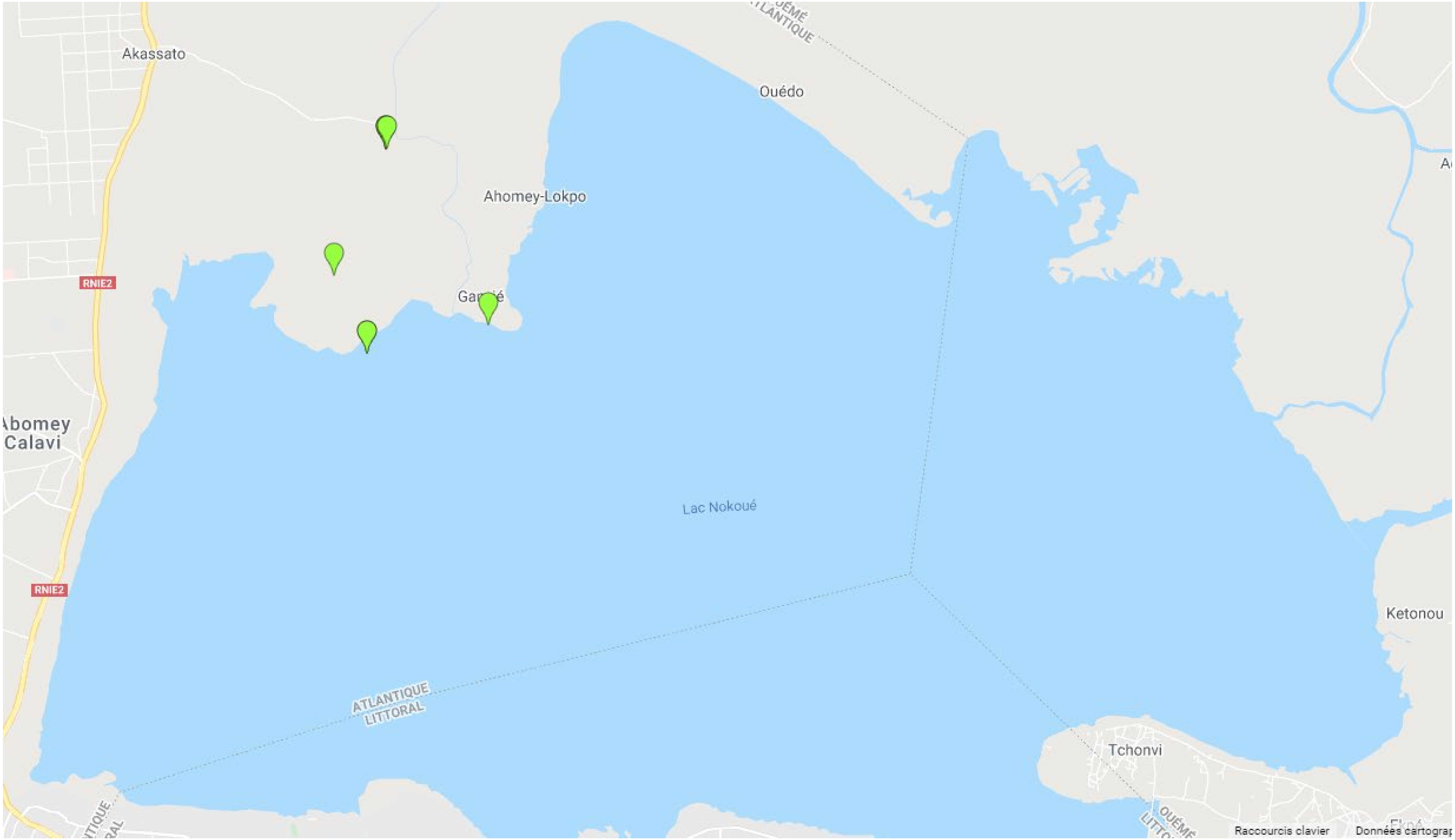


12-31-2021

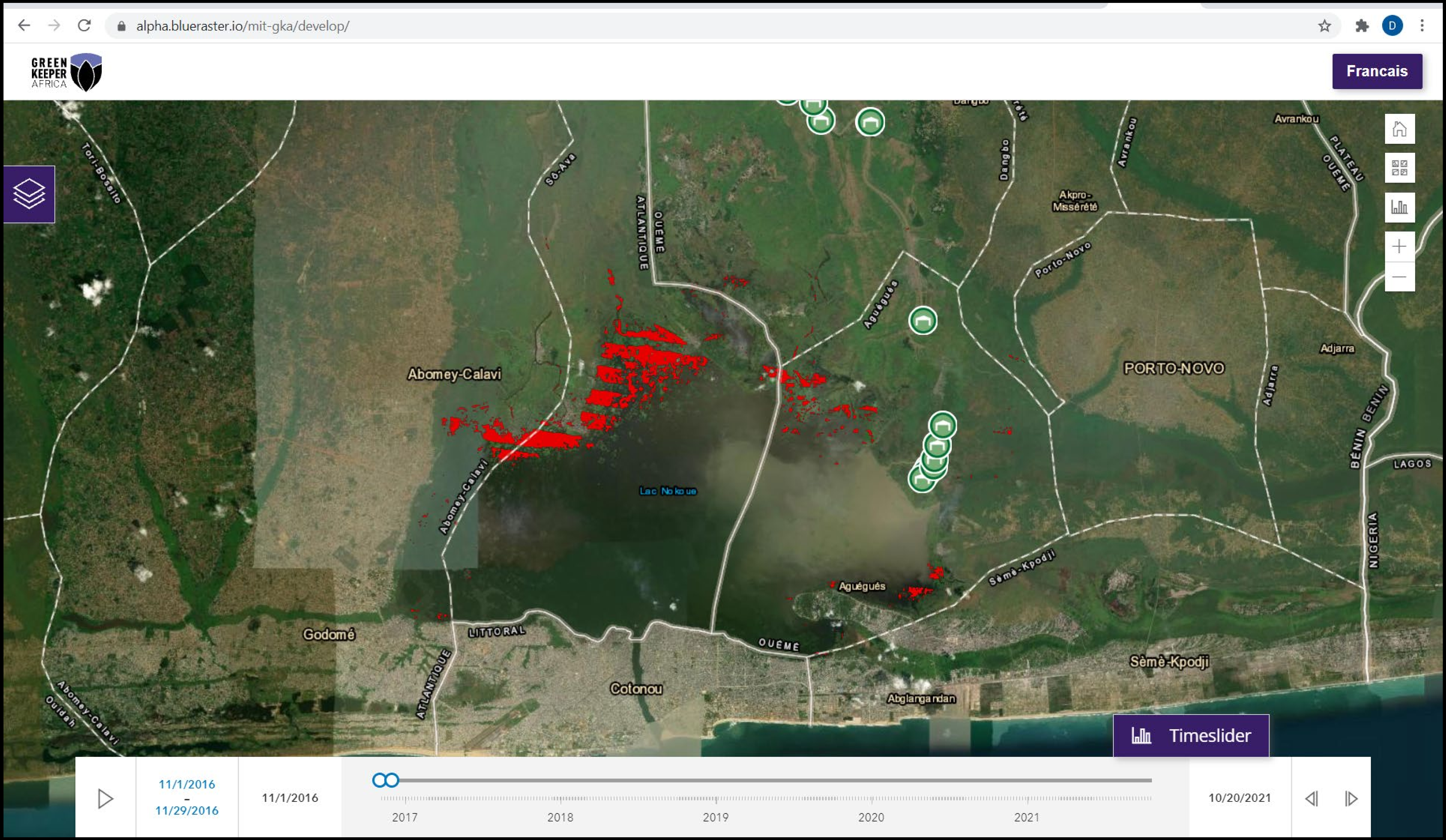

Layers
Map
Satellite
Akassato
Ouédo
Ahomey-Lo
Aguégués
Aholouyeme
Ketonou
Google

01-03-2021


Layers
Map
Satellite
Akassato
Ouédo
Ahomey-Lo
Aguégués
RNIE2
omey
alavi
Ketonou
Aholouy
Google
Keyboard shortcuts
Map data ©2022
1 km
Terms of Use


Akassato
Ouédo
Ahomey-Lokpo
RNIE2
Abomey
Calavi
Lac Nokoué
RNIE2
Ketonou
ATLANTIQUE
LITTORAL
Tchonvi
Raccourcis clavier

	Location		WH_Status	Salinity	Oxygene	Temperature	Time	Observation Method
1	6.49124	2.39822	Green	Low	6.6	29.875	6:03:36	In-Situ Measurement
2	6.49135	2.39833	Green	Low	5.82	30.1875	6:14:04	In-Situ Measurement
3	6.49137	2.398332	Green	Low	8.98	30.25	6:28:05	In-Situ Measurement
4	6.491376	2.398439	Green	Medium	8.51	30.375	7:00:13	In-Situ Measurement
5	6.46579	2.413176	Brown	High	None	None	8:36	Water Sample Collected
6	6.461699	2.395535	Brown	High	17.1	32.5	9:09:29	In-Situ Measurement
7	6.461733	2.395476	Green	Low	None	None	9:17	Water sample collected
8	6.472954	2.390784	Green	Low	10.89	32.4375	9:37:28	In-Situ Measurement


alpha.blueraster.io/mit-gka/develop/
GREEN KEEPER AFRICA
Francais
Abomey-Calavi
Lac Nokoue
PORTO-NOVO
Akpro-Missérété
Avrankou
Adjarra
Aguégués
Godomé
Cotonou
Sèmè-Kpodji
Abglangandan
LITTORAL
OUÉMÉ
ATLANTIQUE
PLATEAU
LAGOS
NIGERIA
BÉNIN
Timeslider
11/1/2016
–
11/29/2016
11/1/2016
2017
2018
2019
2020
2021
10/20/2021

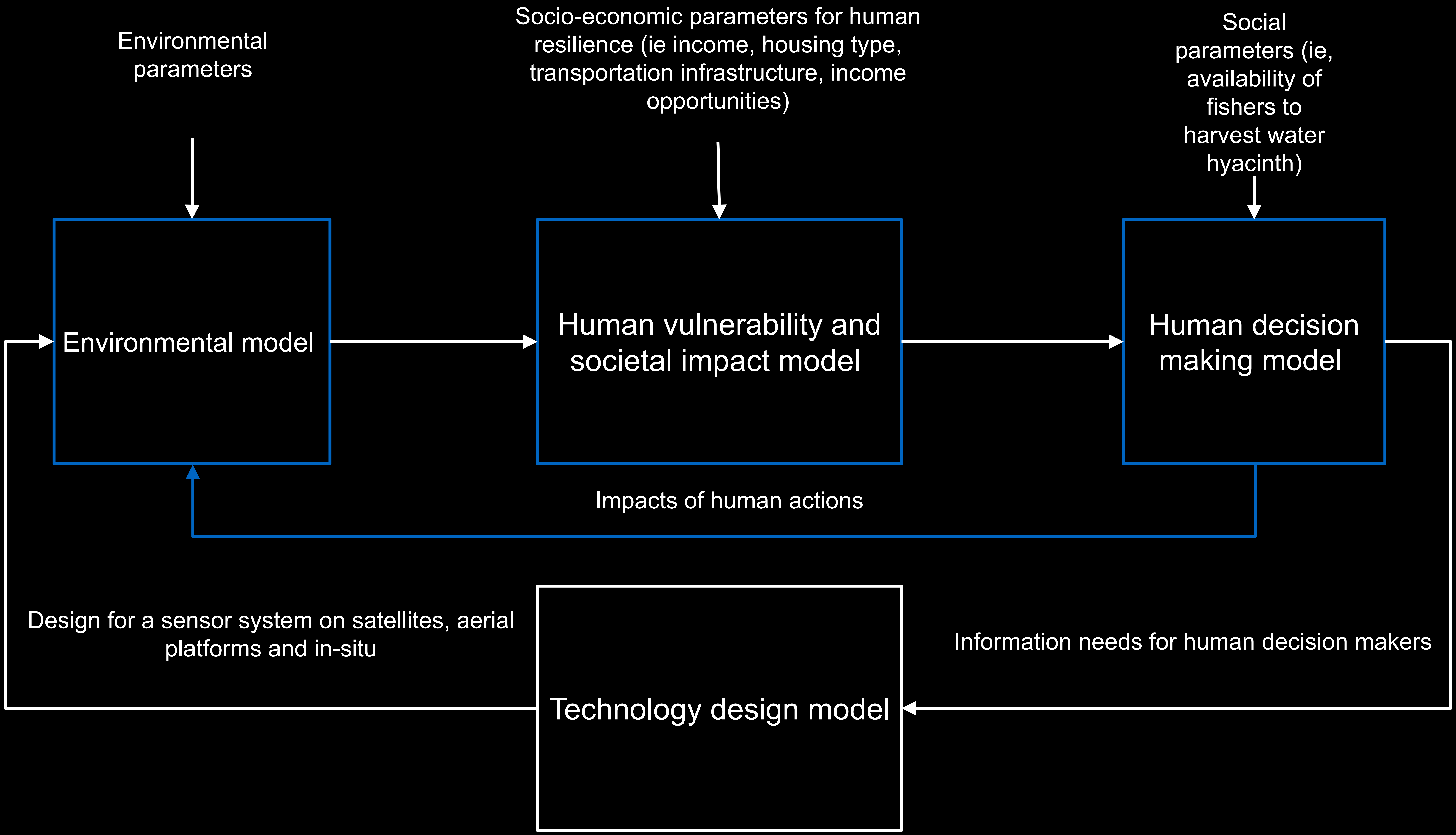
Project facilitated software training opportunities for Green Keeper Africa employees

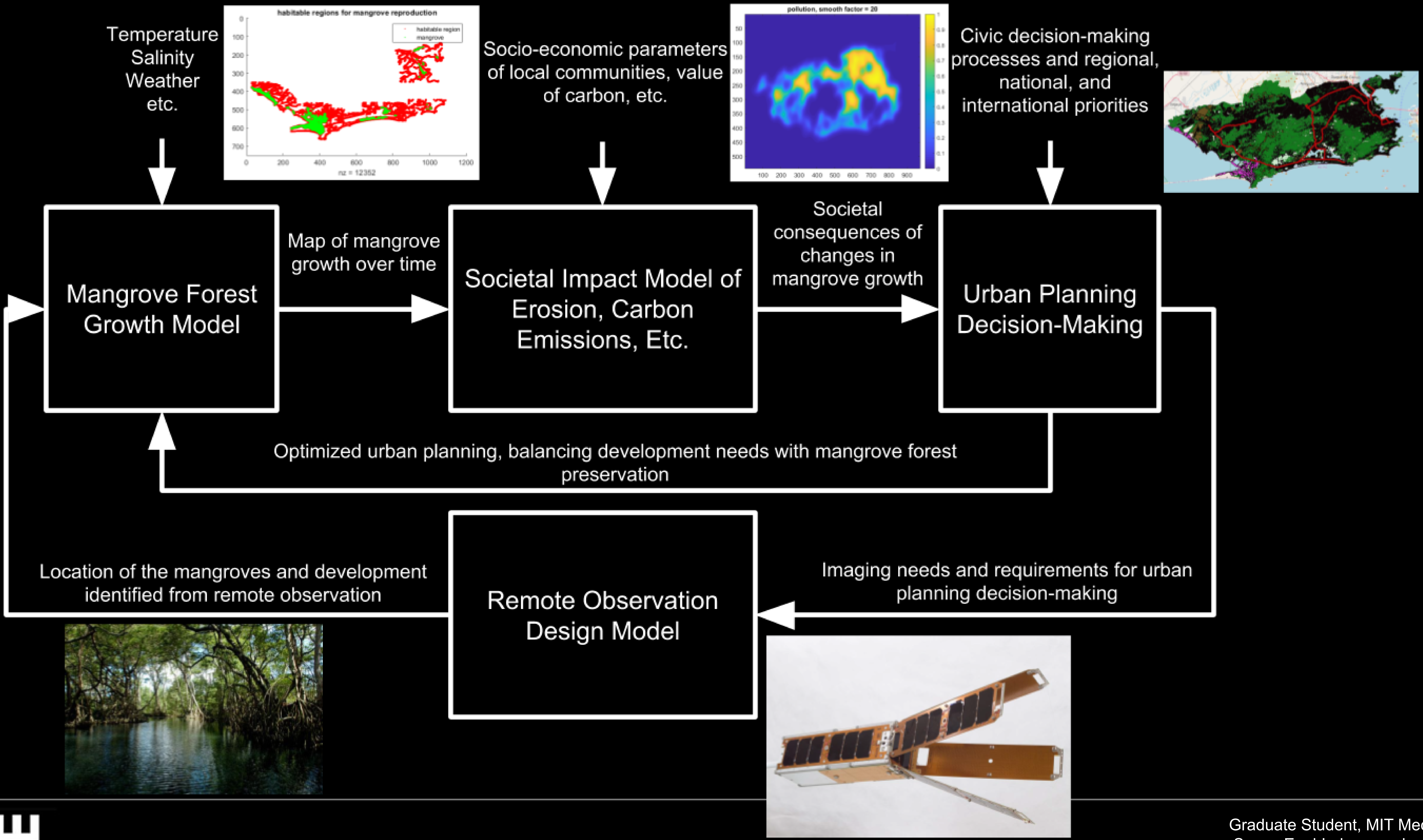
Technical exchange with national remote sensing and mapping office in Benin & National Institute of Water


REPUBLIQUE DU BENIN
UNIVERSITE D'ABOMEY - CALAVI
Institut National de l'Eau (INE)
Rez-de-chaussée: Laboratoire d'Hydrologie Appliquée (LHA)
1er Etage: Formation doctorale Wascal
2ème Etage: Salles de cours
neo

GOOGLE EARTH ENGINE TRAINING DELIVERED IN ENGLISH AND FRENCH IN BENIN

- Présentation de Google Earth Engine
- Comment GEE fonctionne
- Glossaire des termes
- Utilisation de l'interface de programmation d'application
- Utilisation de l'éditeur de code
  - Importation de fichiers de formes et de couches raster en tant qu'actifs dans GEE
  - Importation de jeux de données auxiliaires dans GEE


Environmental parameters
Socio-economic parameters for human resilience (ie income, housing type, transportation infrastructure, income opportunities)
Social parameters (ie, availability of fishers to harvest water hyacinth)
Environmental model
Human vulnerability and societal impact model
Human decision making model
Impacts of human actions
Design for a sensor system on satellites, aerial platforms and in-situ
Technology design model
Information needs for human decision makers

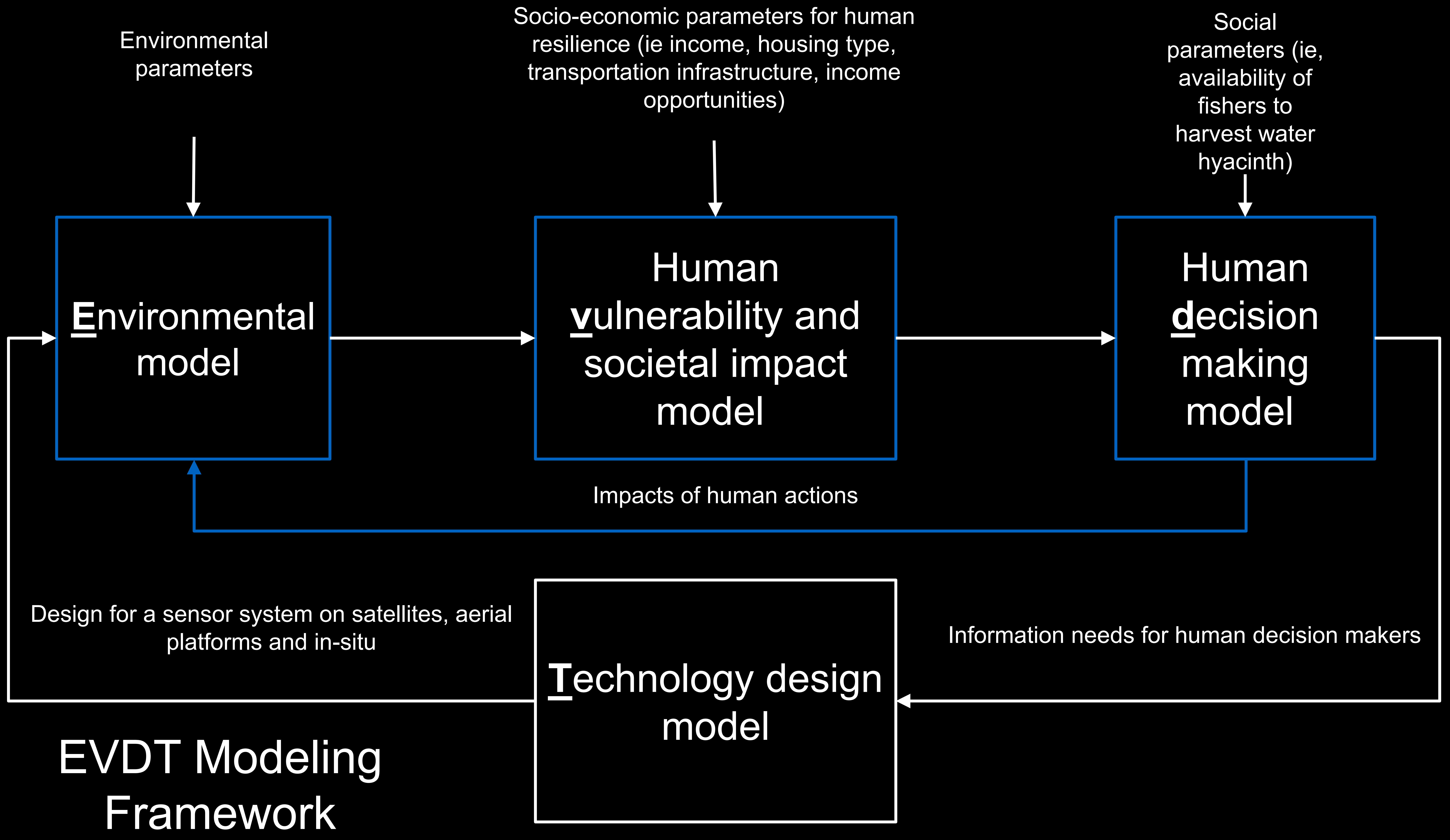


Graduate Student, MIT Media Lab
Space Enabled research group

Ilha de Maderia (NW) | Guaratiba (SW)

= Significant Mangrove Loss


Combining Social, Environmental and Design Models to Support the Sustainable Development Goals
Unidade de Análise
Cor da zona
Imagem do Mapa
Overlays
Zoom
Setembro 2018
Dados Reais
SEPETIBA
GUARATIBA
PEDRA DE GUARATIBA
VARGEM GRANDE
Prainha
GRUMARI
BARRA DE GUARATIBA
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Taxa de Emprego Agrícola
Exibição de Dados
Extensão dos Manguezais: 208080 ha
Área de Crescimento Recente: 2200 ha
Área de Perda Recente: 7270 ha
Área de Manguezais em Risco: 8560 ha
Mudança nos Manguezais: -5070 ha
Informações da Unidade
Dem
Div
Eco
ID
Geogr
Bairro: Guaratiba
Restaurar Original
Calcular
Mostrar Futuro Simulado
3:49 / 5:03

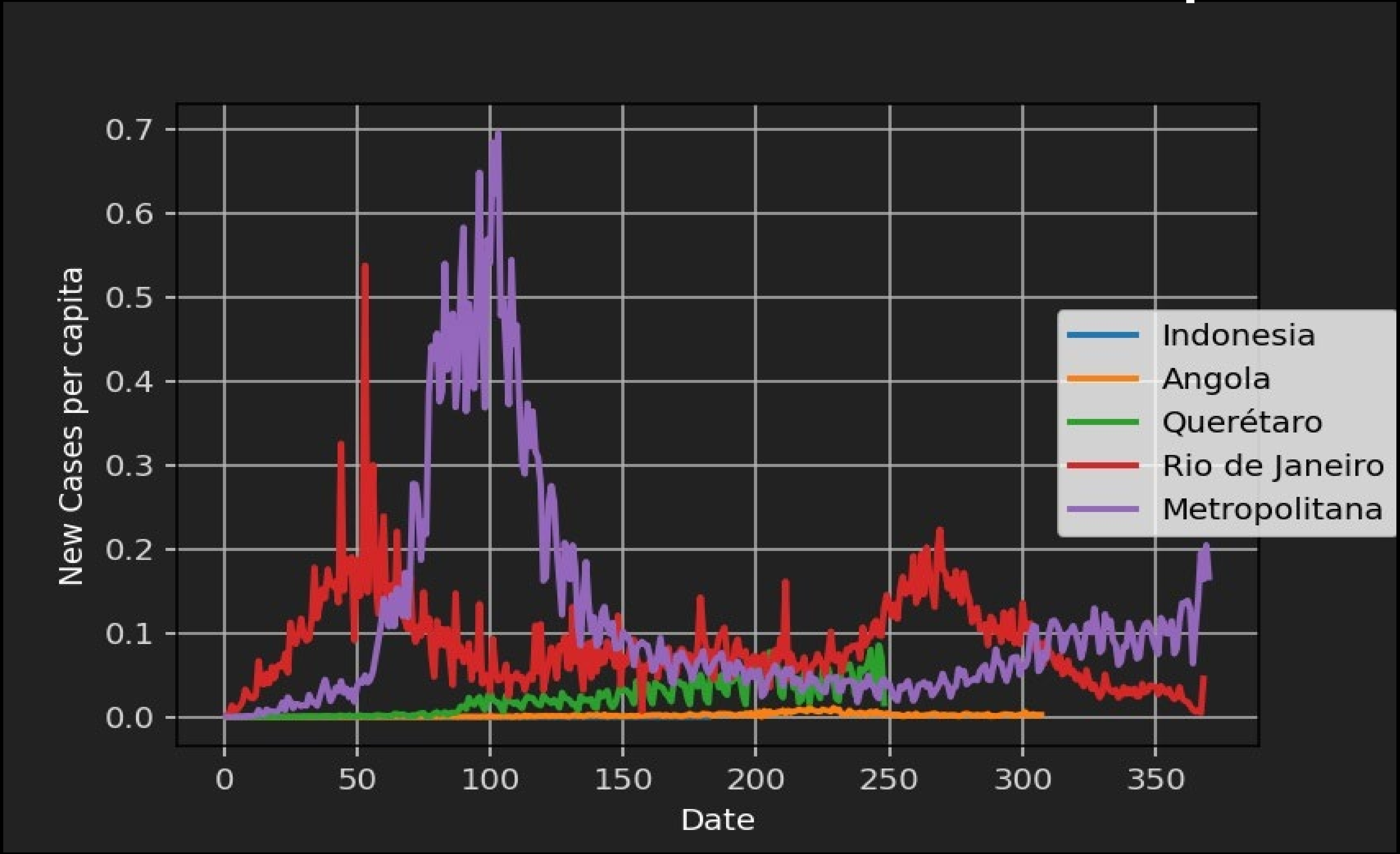

Environmental parameters
Socio-economic parameters for human resilience (ie income, housing type, transportation infrastructure, income opportunities)
Social parameters (ie, availability of fishers to harvest water hyacinth)
Environmental model
Human vulnerability and societal impact model
Human decision making model
Impacts of human actions
Design for a sensor system on satellites, aerial platforms and in-situ
Technology design model
Information needs for human decision makers
EVDT Modeling Framework


Vida Decision Support System
Reported COVID-19 & non-COVID Public Health Indicators
(Test Results, Exposures, Infections, Recoveries, Deaths, etc)
Environmental parameters
(Water quality, air quality, urban heat effects, land use, traffic, night lights, etc)
Socio-economic parameters
(Housing, employment, security, food access, emotional health, etc)
Policy Constraints & Opportunities
(Funding, Coordination across jurisdictions, etc)
Estimates of COVID cases
Environmental Dynamics
Estimates of impacts to vulnerable groups
Public Health Model: System Dynamics
Environmental Model: Satellite Data Analysis
Socio-economic Model: Qualitative Interviews and Quantitative Surveys
Public Sector Decision Making Model: Agent-Based Simulation
Policy Actions related to Public Health, Social Distancing, Essential Businesses, Social Safety Nets
Technology Design Model: System Engineering Technology Selection
Capabilities for improved technologies to improve estimate & explain COVID-19 cases
Information needs for Policy Making (COVID testing technology, Public Health Data Management systems)

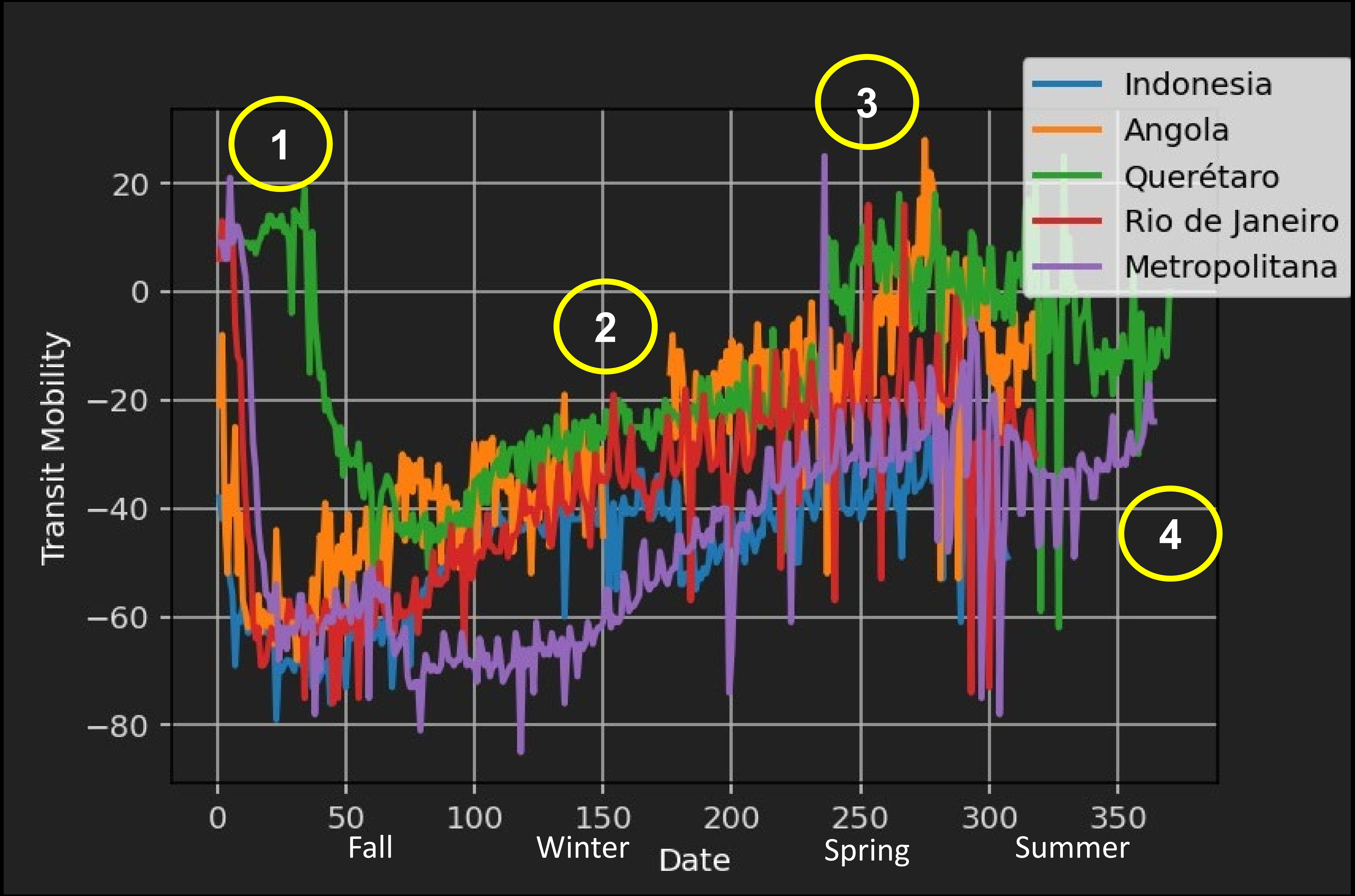
Vida Decision Support System International Network


Visualización de dinámica de sistemas
Idiomas Ubicaciones Salida
MP10
Grafico 1:
Población total infectada medida
Historia
personas
Dias
Grafico 2:
Población hospitalizada
Historia
personas
Dias
PM10
Dia:
115
Política de cierre:
Sin cierres
Política de distanciamiento:
Sin distanciamiento
Solicite nuevos ventiladores:
0
La próxima semana
Ejecutar de forma autónoma
Reiniciar la simulación
Reglas
Registro
Reglas 1: Cierres iniciales
Reglas 2: Cierres adicionales
Reglas 3: Cierre completo
Reglas 4: Reabrir algunos negocios
Reglas 5: Relax Distancia social obligatoria
Reglas 6: Solicite más ventiladores
Reglas 7: Pague más por los ventiladores para acelerar la ent

How did new COVID Case numbers compare?



How did transit mobility change across the Vida countries?



A team led by Prof Wood at MIT has been awarded a grant from NASA for $550,000 to collaborate with GGPEN to work on applying satellite data for drought management for Angola

space enabled
MIT Media Lab

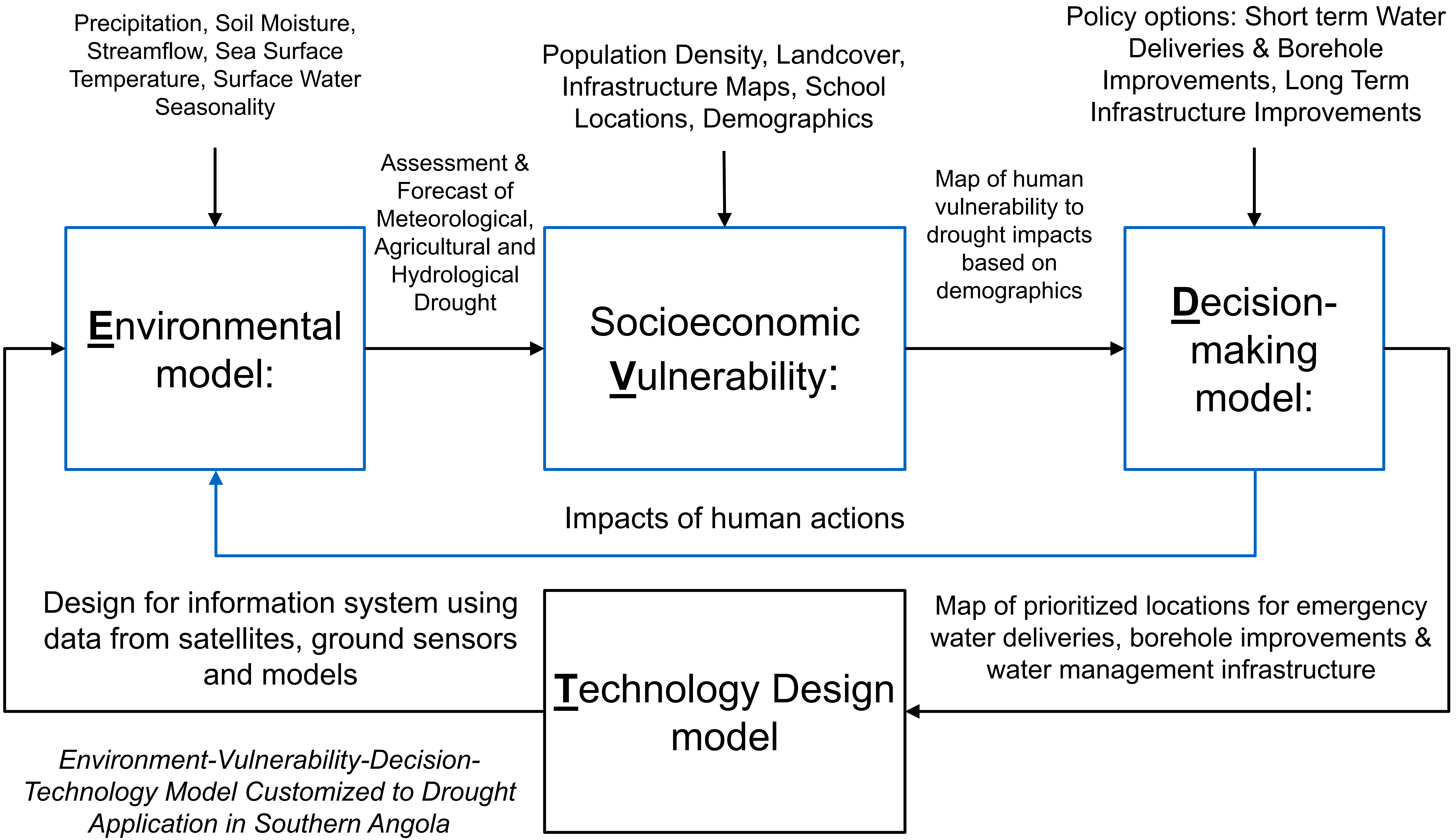
BLUE RASTER

GGPEN

RESOURCES
FOR THE FUTURE

Supporting Drought Management in Angola using Integrated Modeling of the Environment, Vulnerability, Decision Making and Technology (EVDT)

US Researchers: PI: Professor Danielle Wood (MIT); Co-Investigators Prof Dara Entekhabi (MIT); Other Professional: Dr. Katlyn Turner
US Data Analytics Firm: Eric Ashcroft, Blue Raster
US Socioeconomic Consultant: Dr. Mike Toman & Dr. Yusuke Kuwayama, Resources for the Future
Unfunded Collaborators from Angola: Dr. Zolana Joao, Director General of the Management Office of the National Space Program


Precipitation, Soil Moisture, Streamflow, Sea Surface Temperature, Surface Water Seasonality
Population Density, Landcover, Infrastructure Maps, School Locations, Demographics
Policy options: Short term Water Deliveries & Borehole Improvements, Long Term Infrastructure Improvements
Environmental model:
Assessment & Forecast of Meteorological, Agricultural and Hydrological Drought
Socioeconomic Vulnerability:
Map of human vulnerability to drought impacts based on demographics
Decision-making model:
Impacts of human actions
Design for information system using data from satellites, ground sensors and models
Technology Design model
Map of prioritized locations for emergency water deliveries, borehole improvements & water management infrastructure
Environment-Vulnerability-Decision-Technology Model Customized to Drought Application in Southern Angola

Angola Drought Decision Support System