Using Integrated Earth Observation-Informed Modeling to Support Sustainable Development Decision-Making

Jack Reid

Thesis Proposal Critique

Space Enabled Research Group, MIT Media Lab

January 20, 2022

space enabled

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Land Acknowledgement

MIT and this author acknowledge Indigenous Peoples as the traditional stewards of the land, and the enduring relationship that exists between them and their traditional territories. The land on which this work was performed and these words were written is the traditional unceded territory of the Wampanoag Nation, Massachusett, and Nipmuc peoples. We acknowledge the painful history of genocide and forced occupation of their territory, and we honor and respect the many diverse indigenous people connected to this land on which we gather from time immemorial.

https://diversity.mit.edu/resources/land-acknowledgement-statement

Outline

I. Introduction

II. Background & Definitions

III. Research Questions / Methodology

a. Critical Analysis & Framework Development

b. Decision Support Development & Evaluation for Case Studies

c. Extension & Scaling of Concept

This work centers on

exploring the efficacy and difficulties of ***collaboratively developing***

a ***systems-architecture-informed***,

multidisciplinary ***GIS*** ***decision support system***

for ***sustainable development*** applications

that makes significant use of ***remote observation data***.

collaboratively developing

PPGIS: Public Participation Geospatial Information System (GIS)

PGIS: Participatory GIS

Participatory design: An approach that actively involves the people who are being served through direct engagement with the stakeholders at every step.

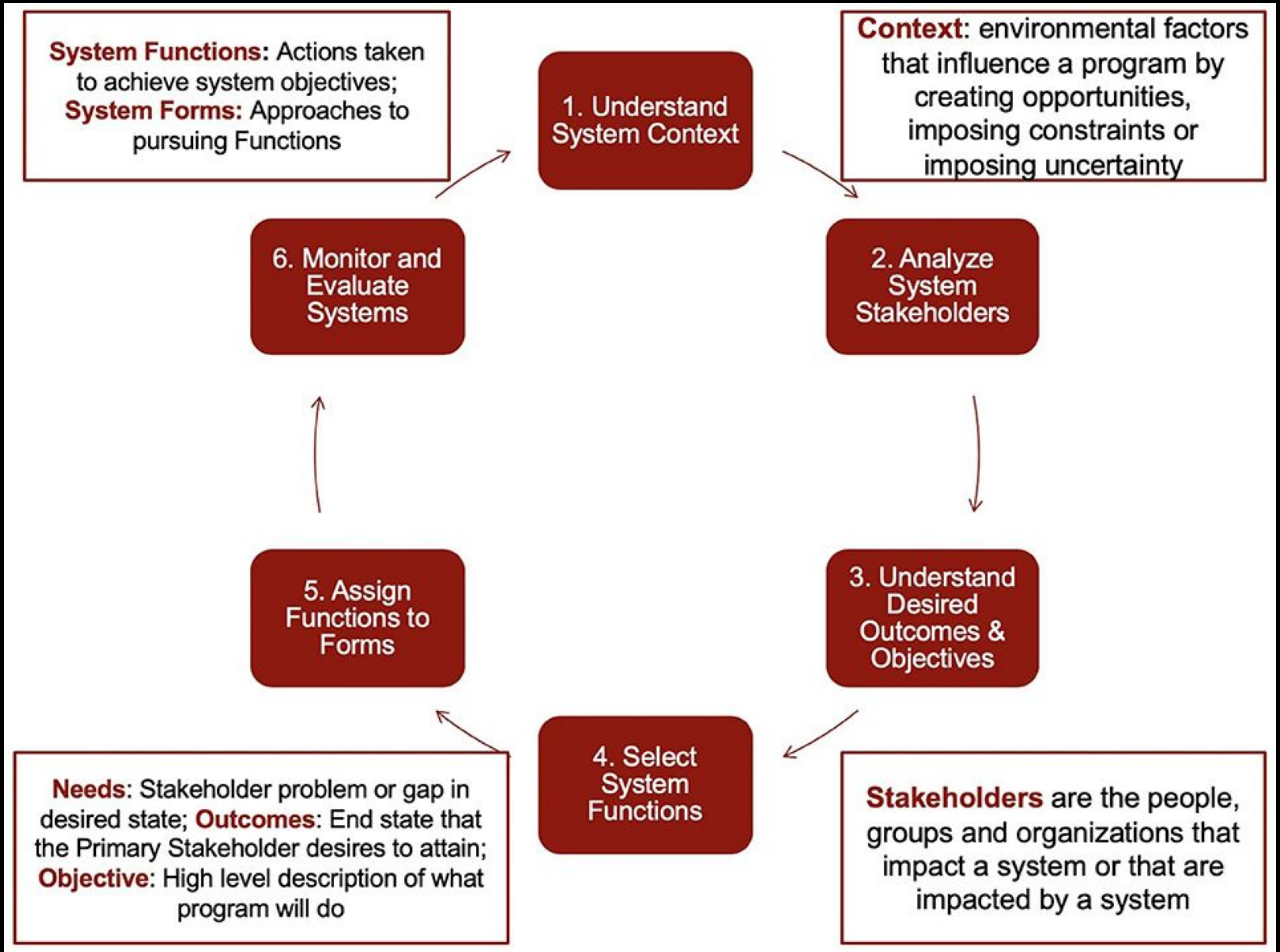
Co-design: “approaches communities not as (solely) consumers, test subjects, 'test beds,' or objects of study, and instead imagines them as co-designers and coauthors of shared knowledge, technologies, narratives, and social practices.” (Costanza-Chock & Henshaw-Plath, 2016)

System Architecture Framework: “A generic model that captures decision making and design for complex systems; particularly useful for describing human-designed, technology-enabled systems that provide public services such as access to infrastructure or education” (Ovienmhada et al., 2021)

systems-architecture-informed

Maier: the art and science of creating and building complex systems. That part of systems development most concerned with scoping, structuring, and certification.

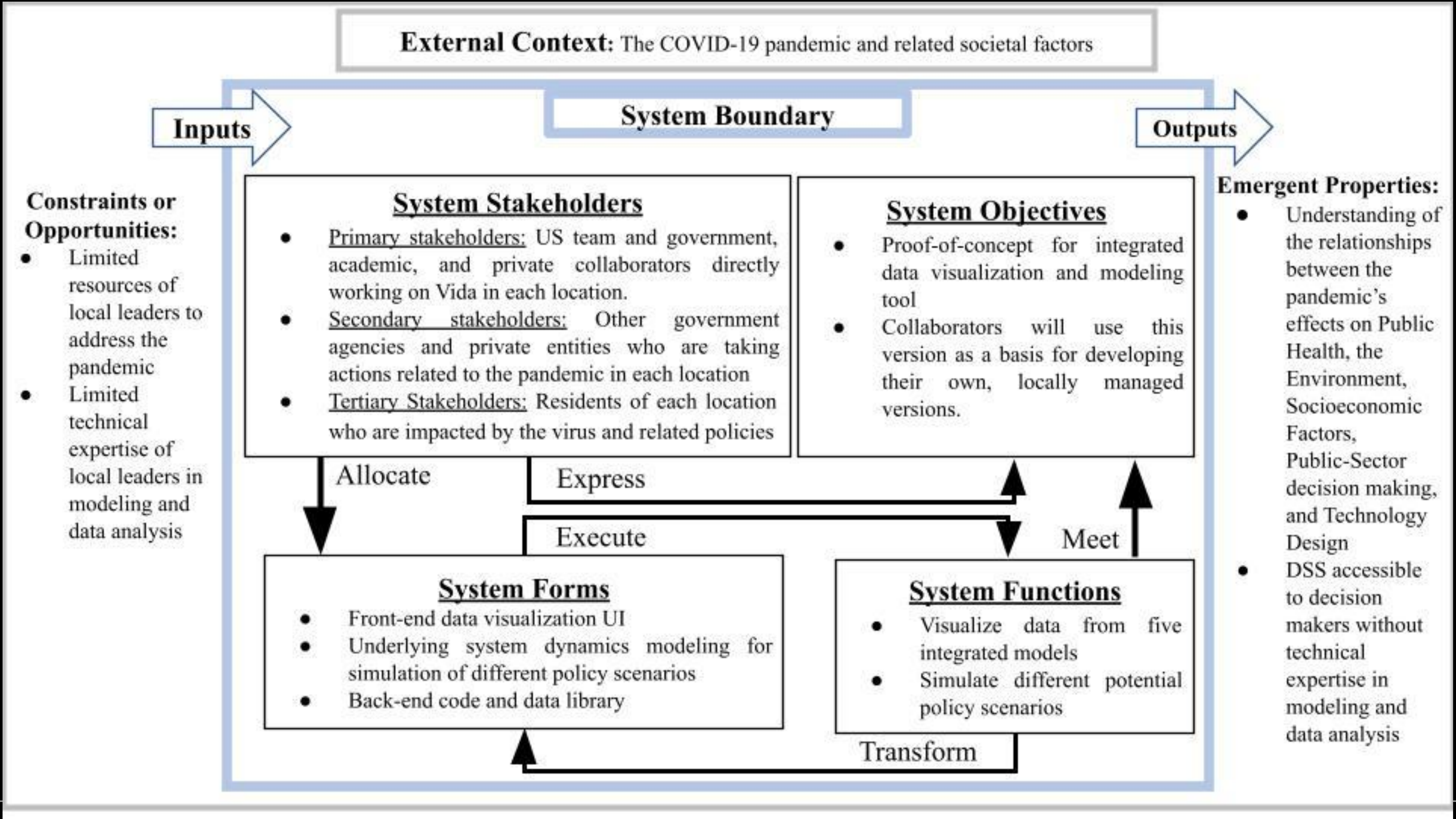
Crawley: the mapping of function to form such that the essential features of the system are represented. The intent of architecture is to reduce ambiguity, employ creativity, and manage complexity



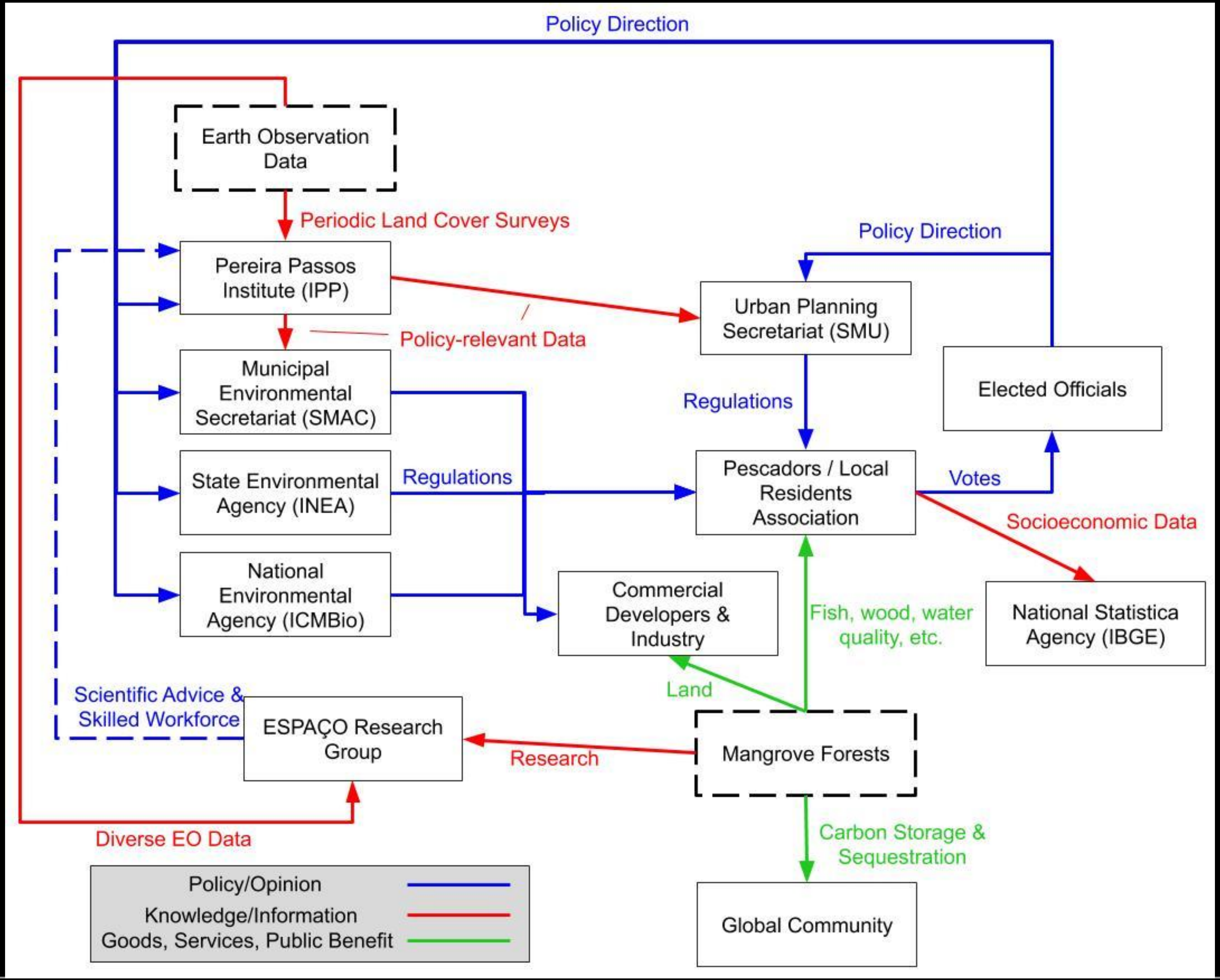
Credit: Danielle Wood

systems-architecture-informed

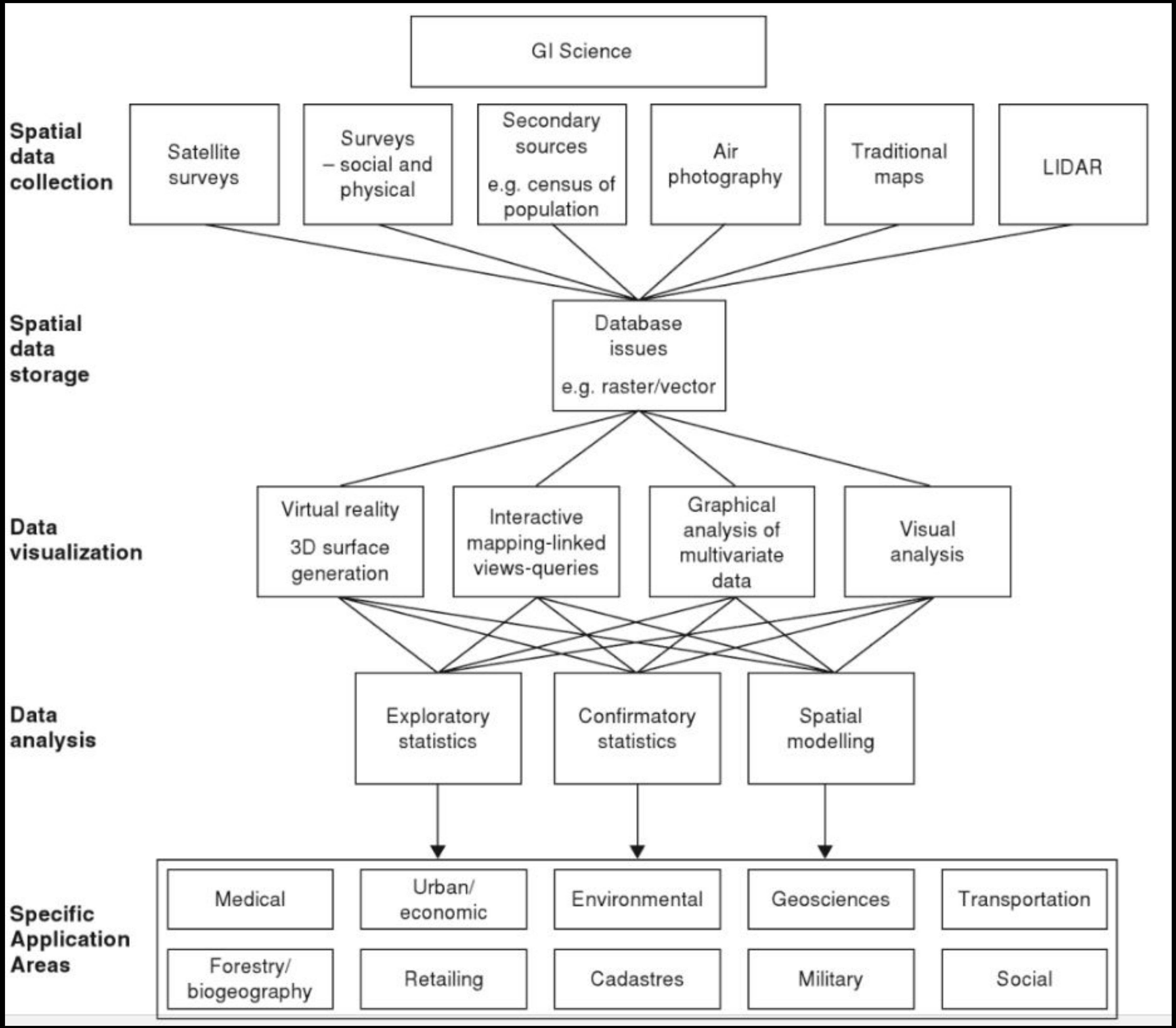
Credit: Danielle Wood

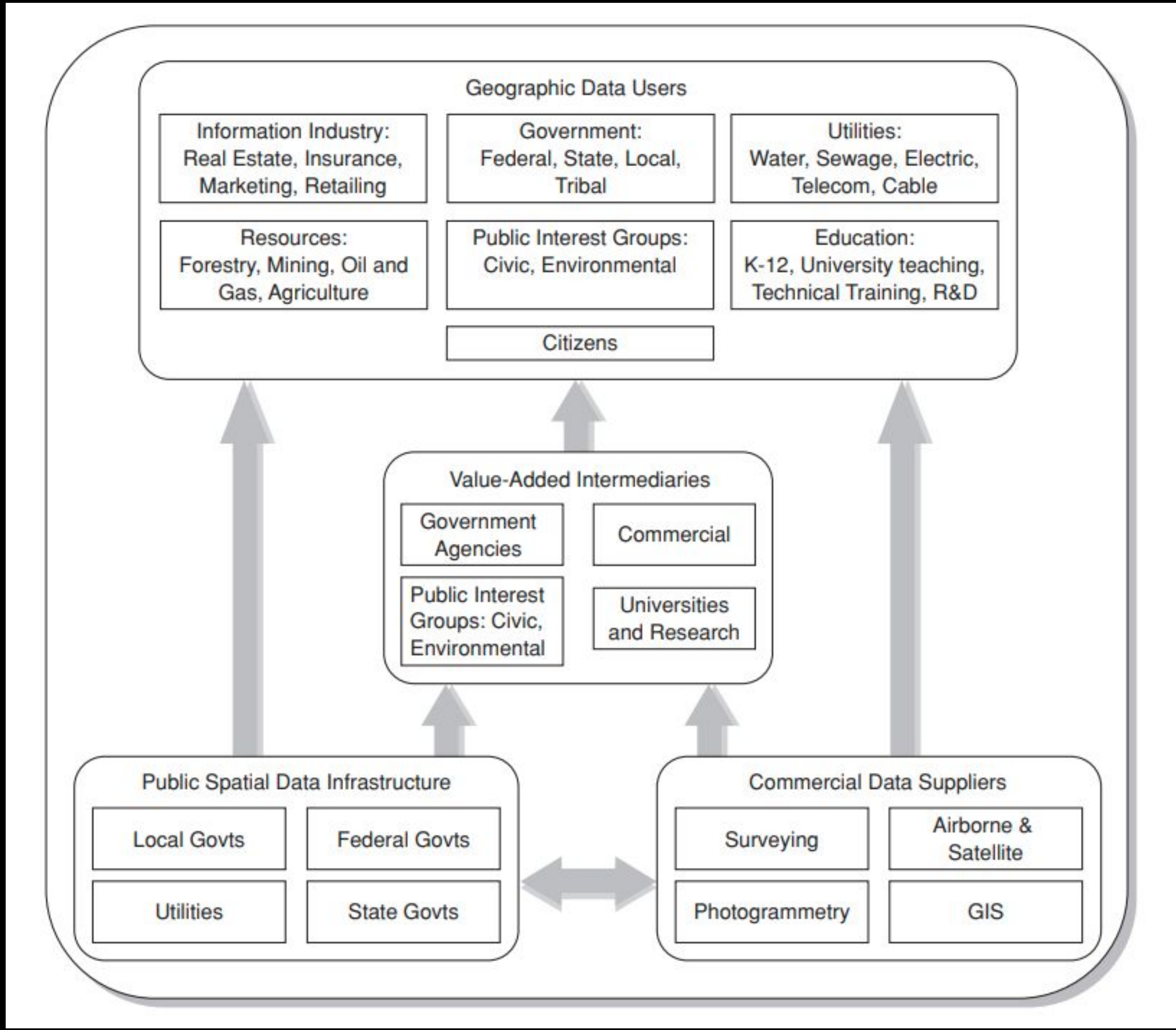


systems-architecture-informed



geospatial information system (GIS)



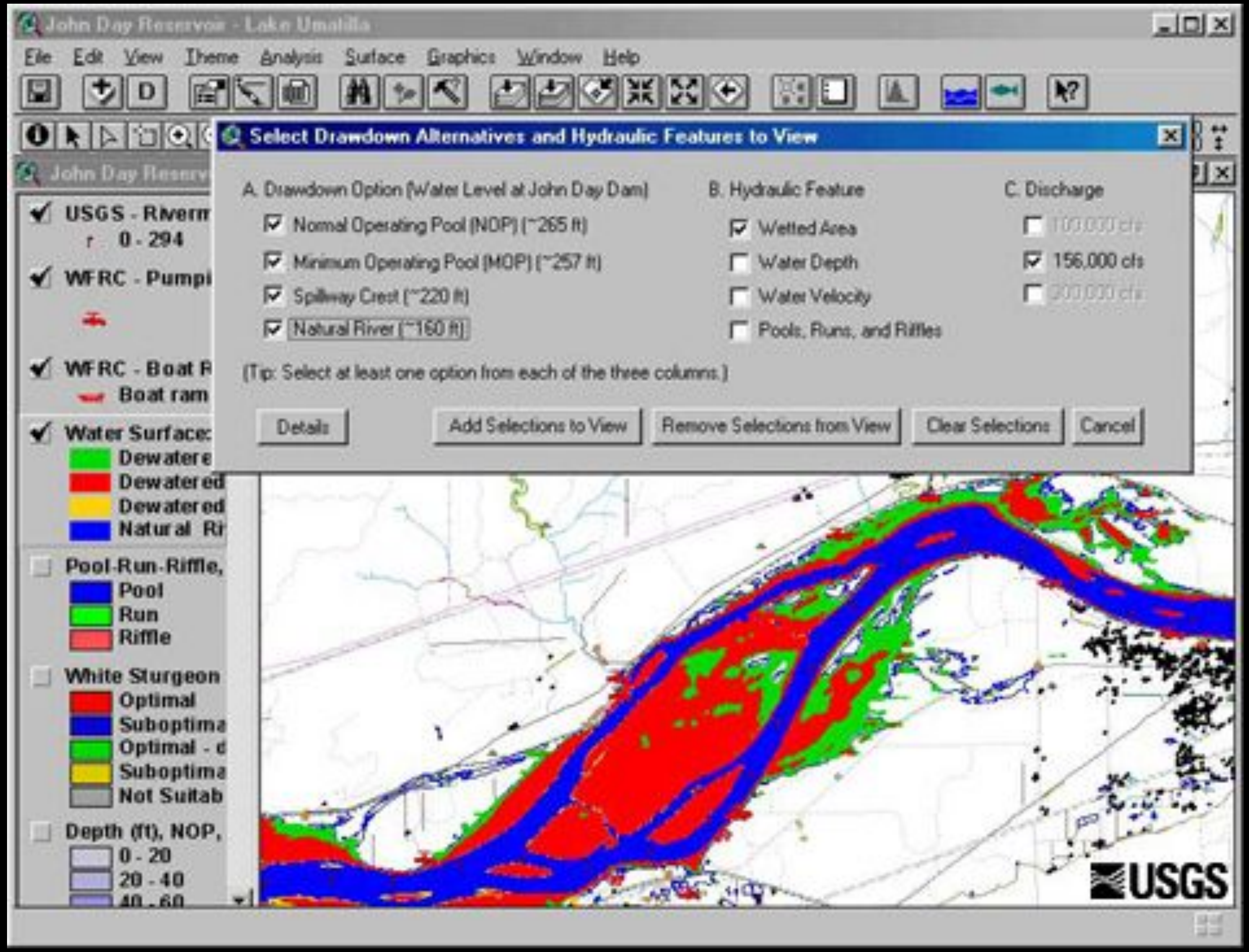


Fotheringham, A. Stewart, and John P. Wilson. “Geographic Information Science: An Introduction.” *The Handbook of Geographic Information Science*, John Wiley & Sons, Ltd, 2007, pp. 1–7.

Cowen, David J. “The Availability of Geographic Data: The Current Technical and Institutional Environment.” *The Handbook of Geographic Information* Science, John Wiley & Sons, Ltd, 2007, pp. 11–34.

decision support system (DSS)

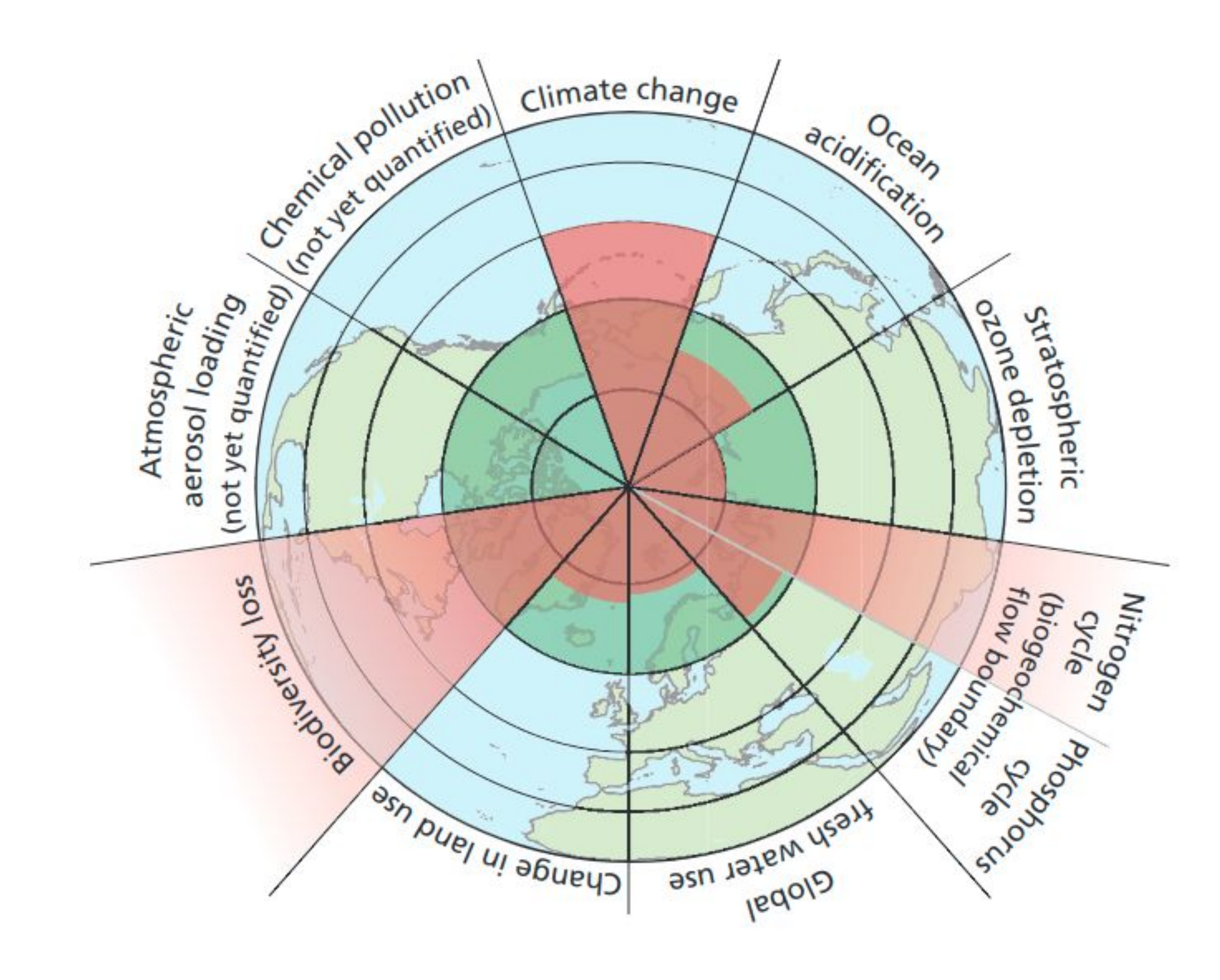
A technical system aimed at facilitating and improving decision-making. Functions can include visualization of data, analysis of past data, simulations of future outcomes, and comparisons of options.



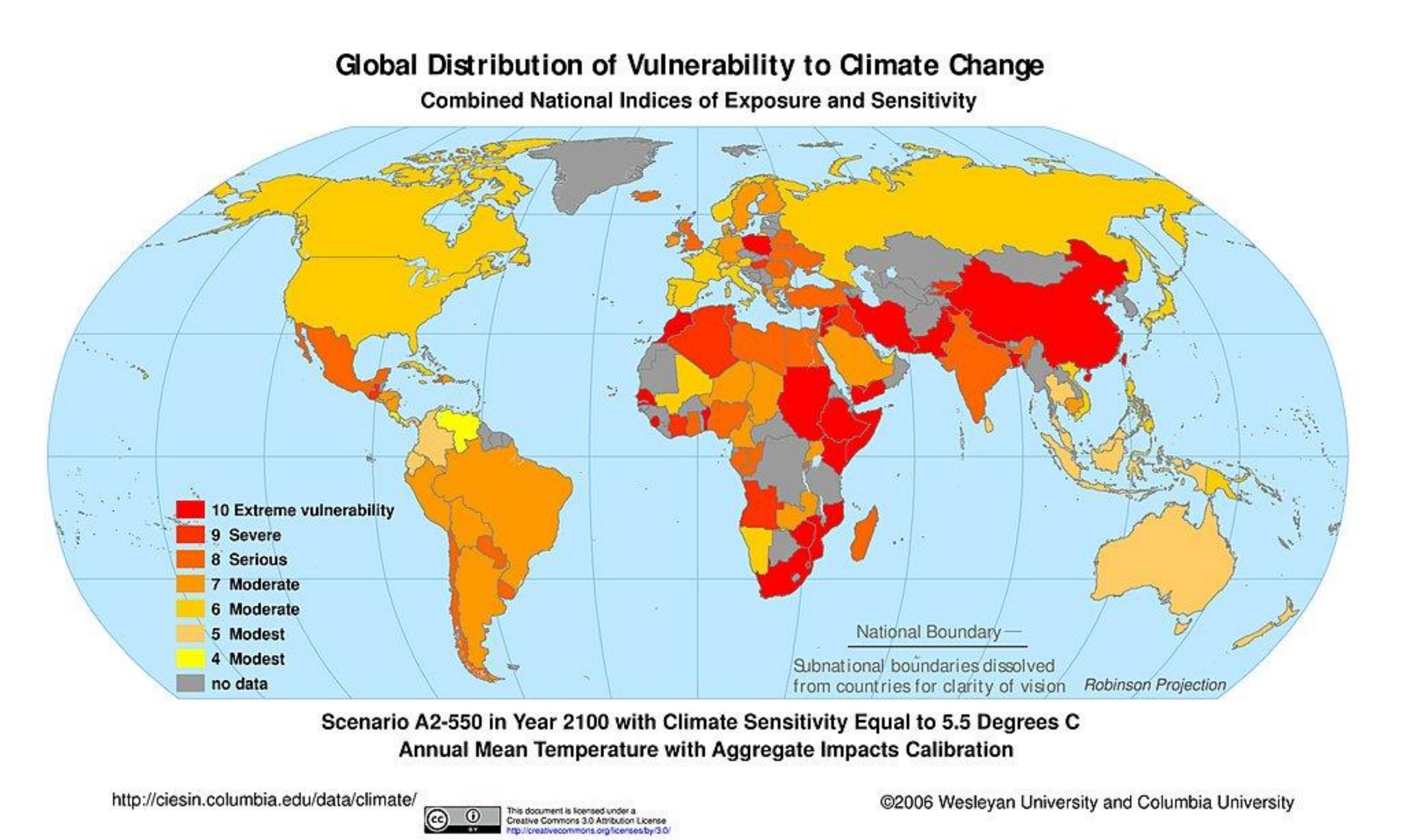
Michael J. Parsley, U.S. Geological Survey

Yan Zhang 'Ryan', City Science, MIT Media Lab

sustainable development

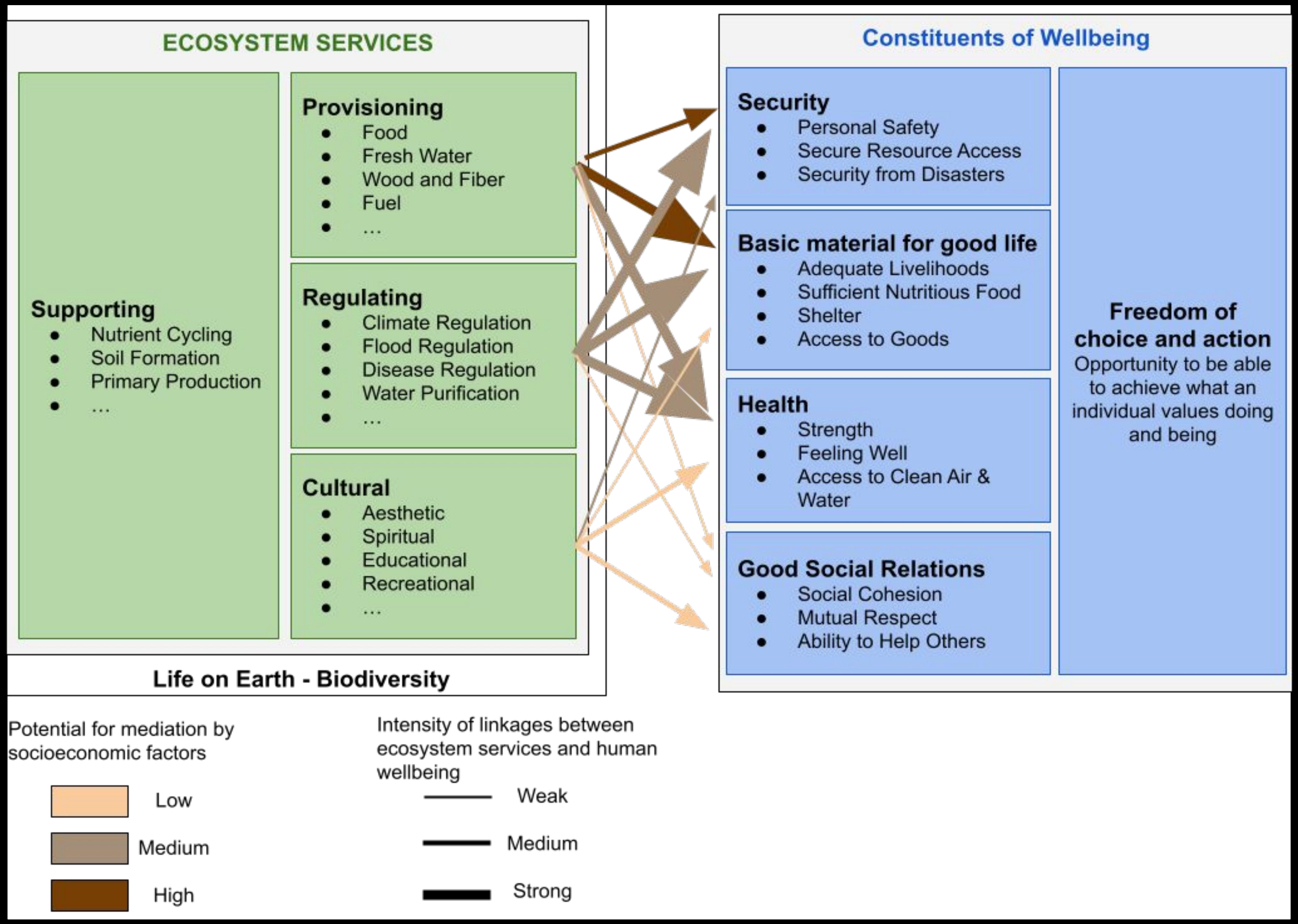


Rockström, Johan, et al. "A Safe Operating Space for Humanity." Nature, vol. 461, no. 7263, Sept. 2009, pp. 472–75



Yohe, Gary W., et al. "Global Distributions of Vulnerability to Climate Change." Integrated Assessment, vol. 6, no. 3, 3, July 2006

sustainable development



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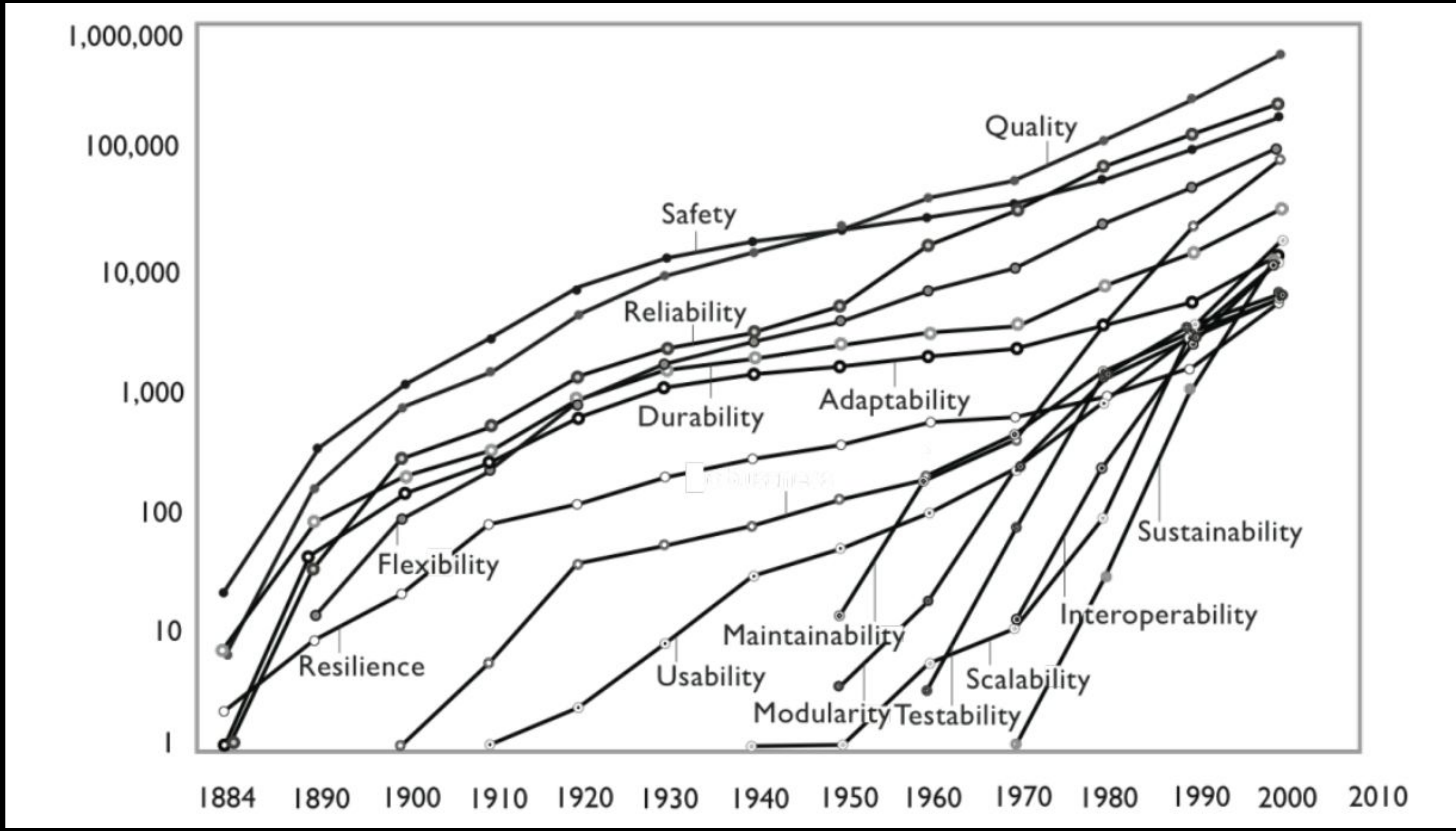
Reid, W. V., et al. *Ecosystems and Human Well-Being - Synthesis: A Report of the Millennium Ecosystem Assessment*. Island Press, 2005.

sustainable development



de Weck, Olivier L., et al. Investigating Relationships and Semantic Sets amongst System Lifecycle Properties (Ilities). Working Paper, Massachusetts Institute of Technology. Engineering Systems Division, Mar. 2012. dspace.mit.edu, https://dspace.mit.edu/handle/1721.1/102927.

sustainable development

socio-environmental-technical systems (SETS)

Socio-Environmental Systems (SES): modeling involves developing and/or applying models to investigate complex problems arising from interactions among human (i.e. social, economic) and natural (i.e. biophysical, ecological, environmental) systems. (Elsawah et al. 2020)

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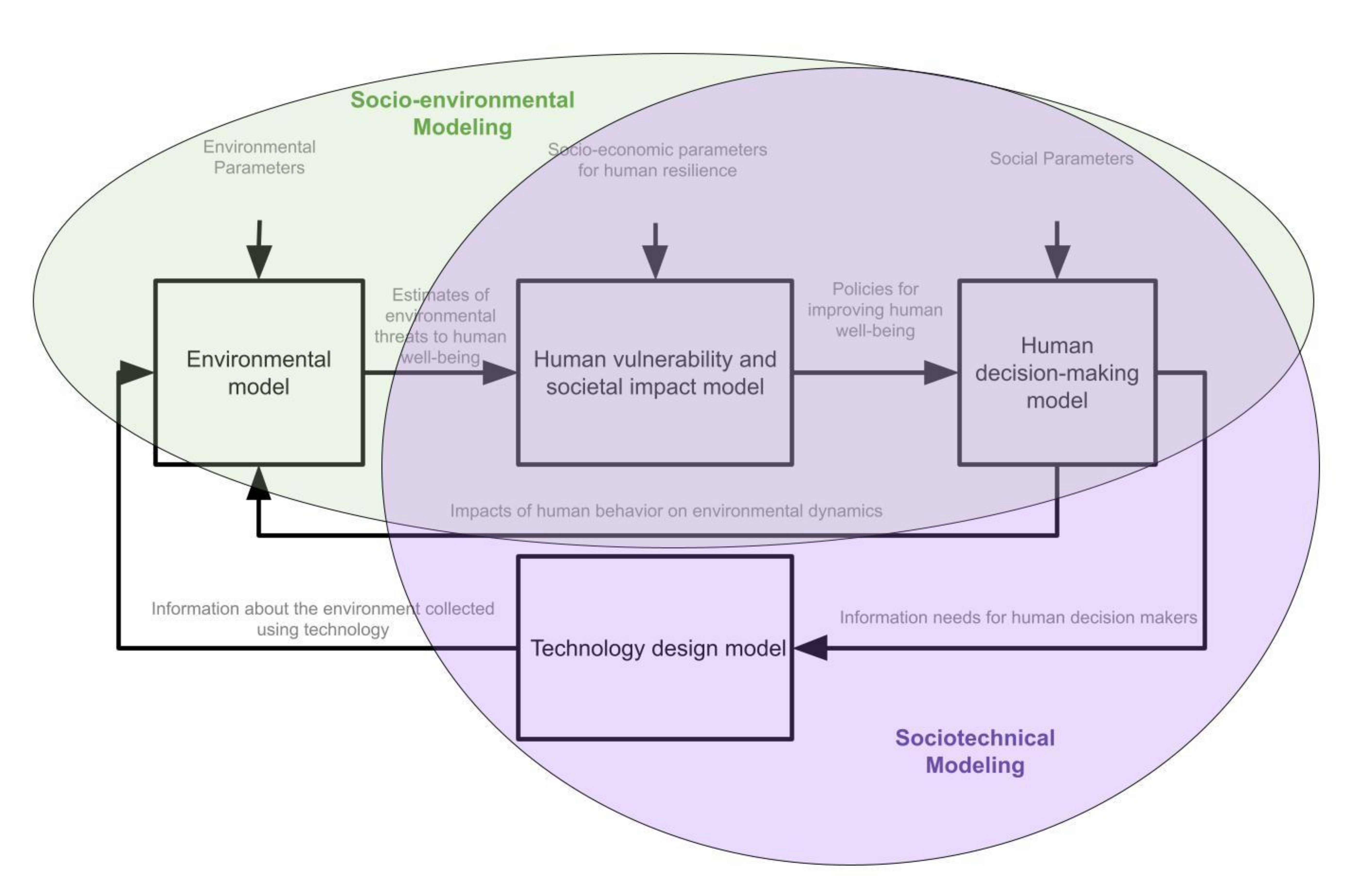
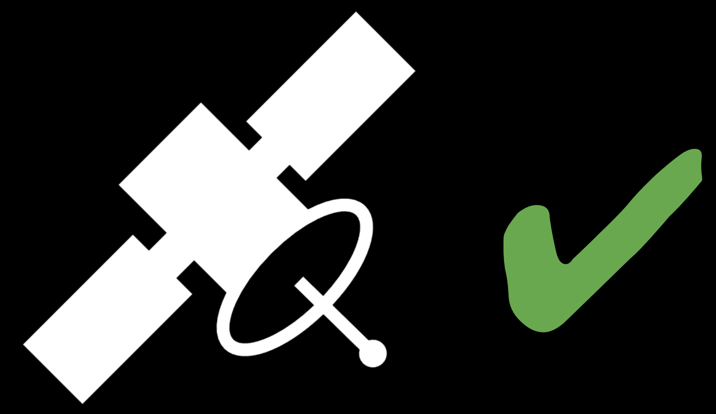
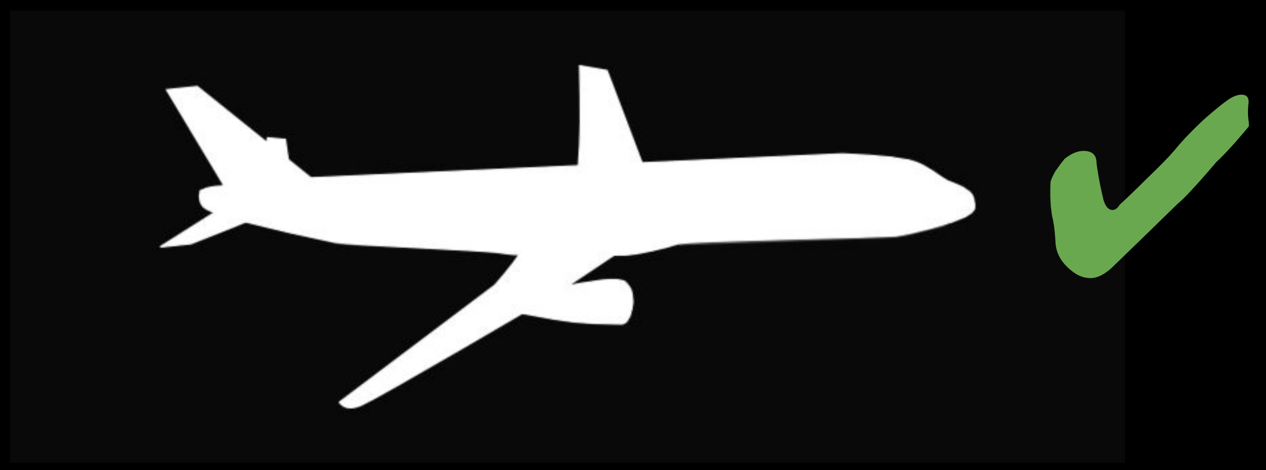
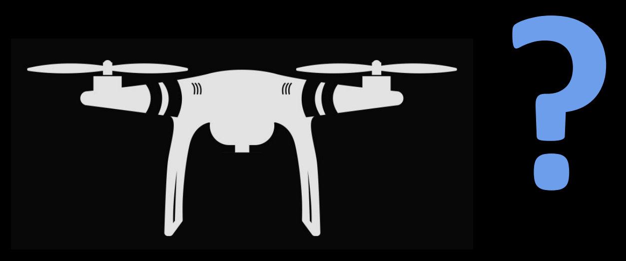
Sociotechnical Systems (STS): Technical works involving significant social participation, interests, and concerns. (Maier, *The Art of Systems Architecting*)



remote observation data

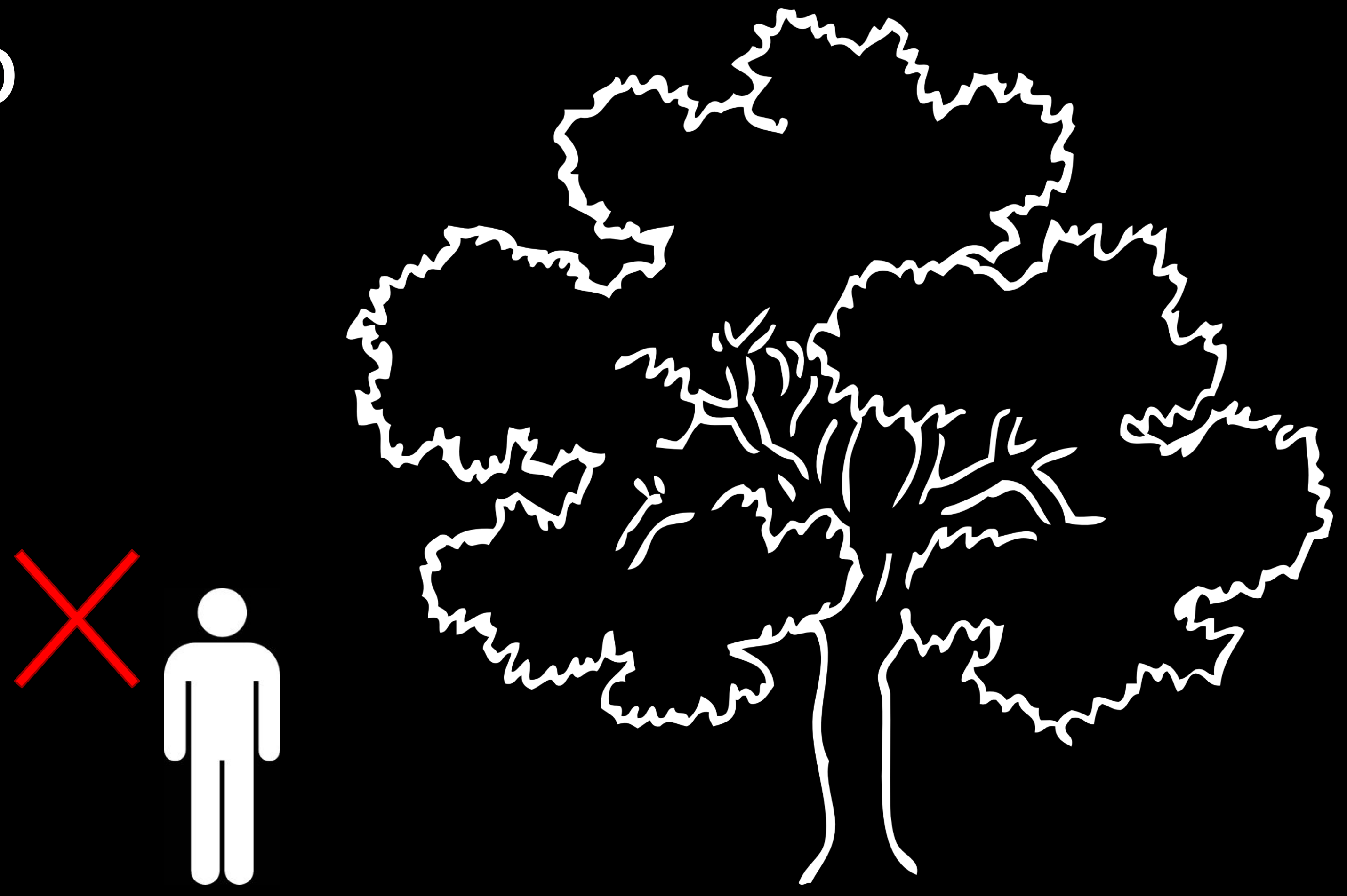






Any form of data collection that takes place at some remote distance from the subject matter. While there is no specific distance determining whether a collector is 'remote,' in practice this tends to mean some distance of more than a quarter of a kilometer.

Earth Observation (EO): Remote observation directed at the Earth



remote observation data

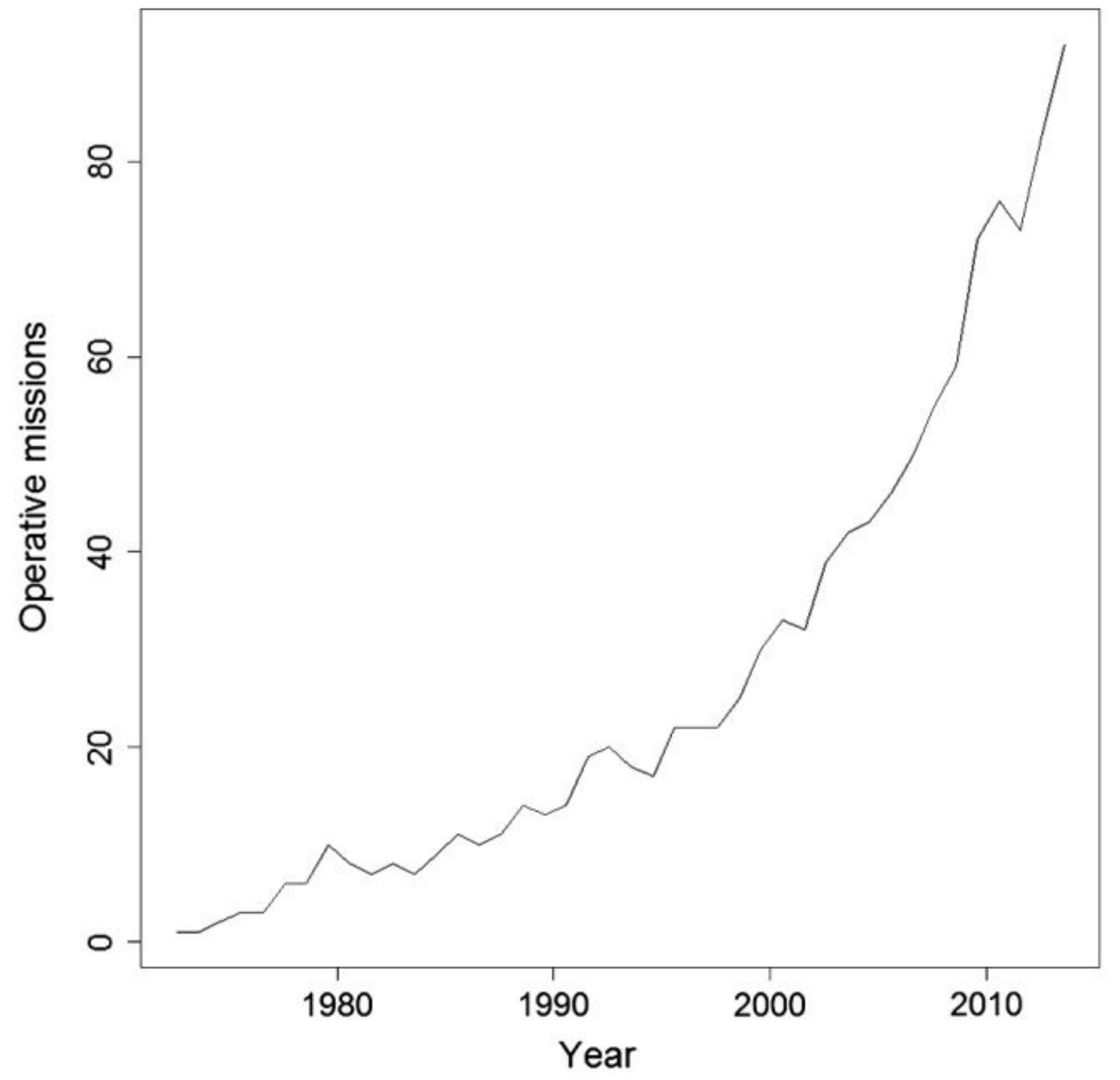
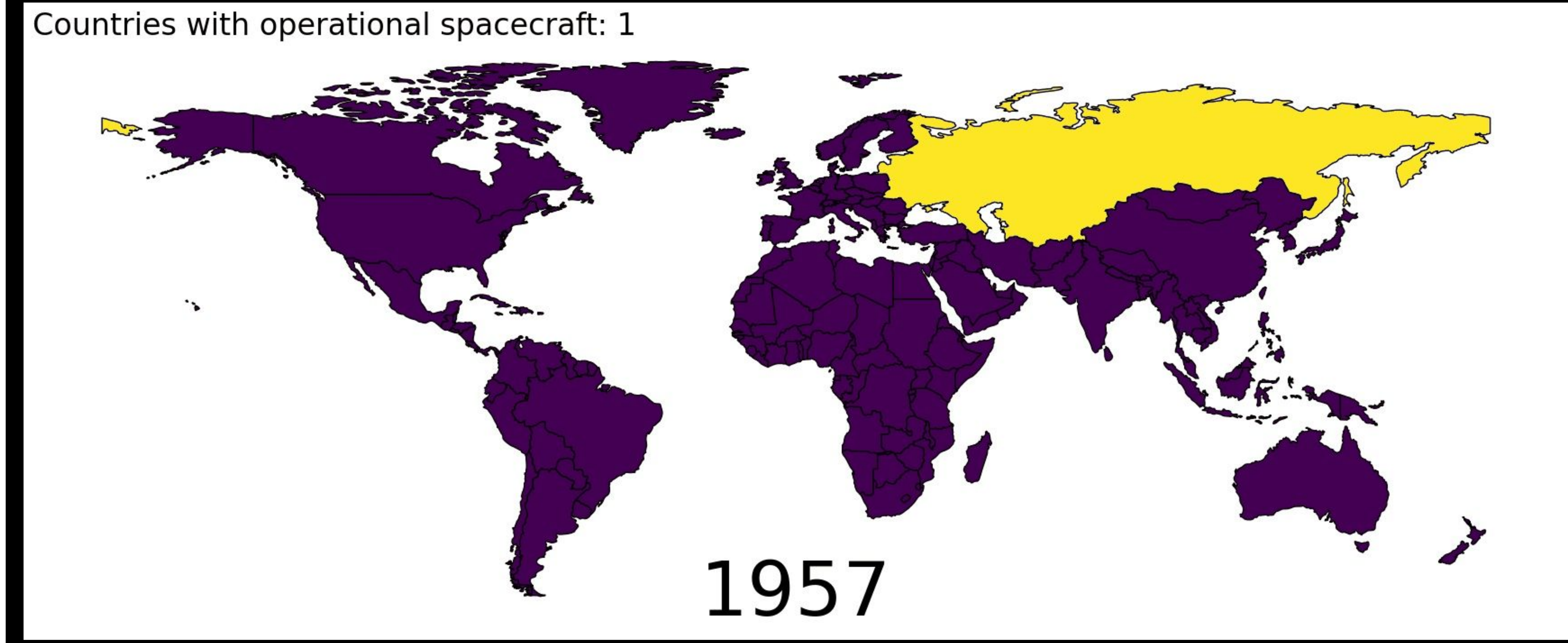
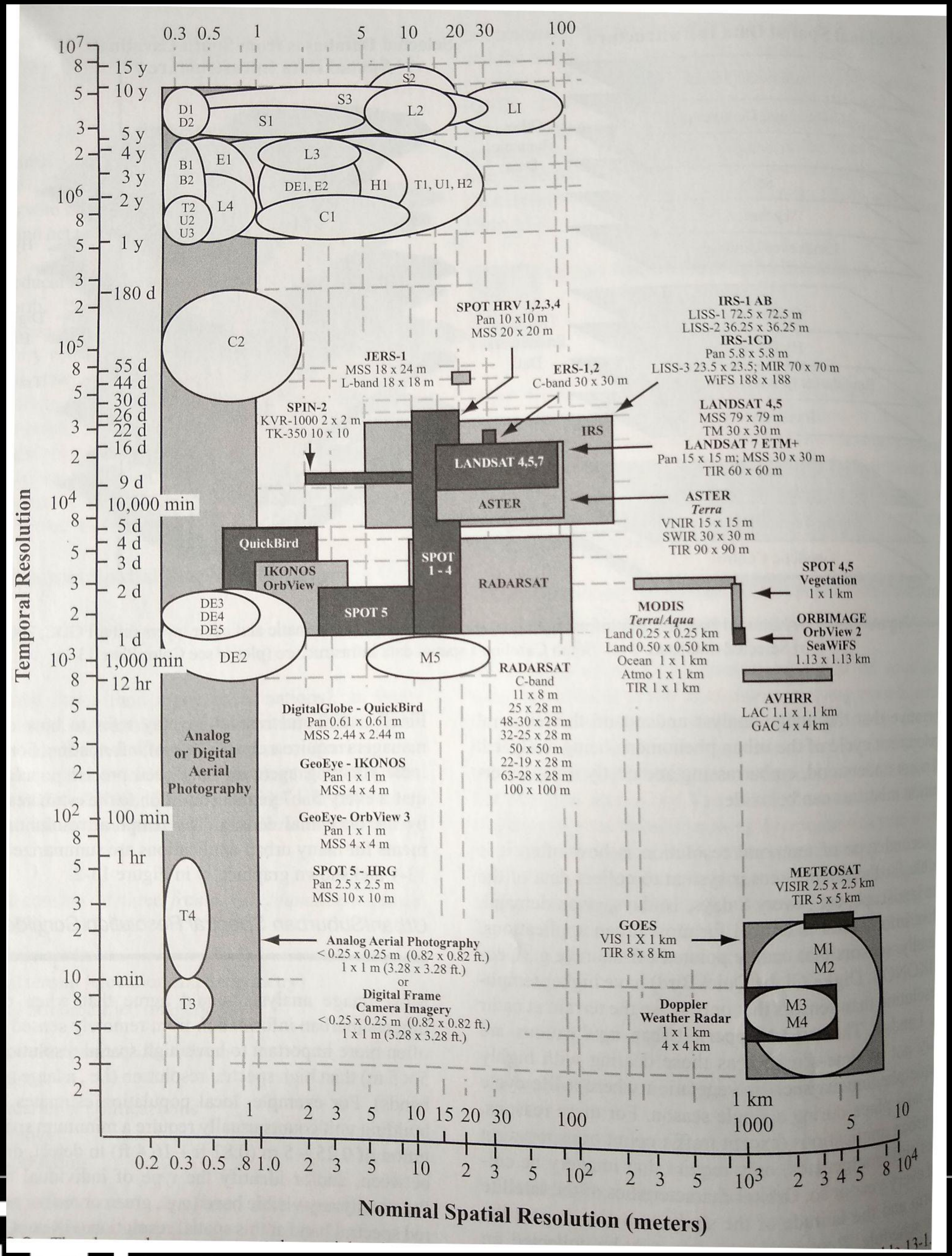


Fig. 2. The number of near-polar orbiting, land imaging civilian satellites operational as of 1st August 1972 to 2013.



←Belward, Alan S., and Jon O. Skøien. "Who Launched What, When and Why; Trends in Global Land-Cover Observation Capacity from Civilian Earth Observation Satellites." ISPRS Journal of Photogrammetry and Remote Sensing, vol. 103, Elsevier, May 2015, pp. 115–28, https://doi.org/10.1016/j.isprsjprs.2014.03.009.

remote observation data



- Improved resolutions (spatial, spectral, radiometric, temporal)
- More refined indices
- New Data Types
  - SAR
  - LIDAR
  - Gravitational Field Anomalies
- Supervised & Unsupervised Classification
- Cloud-based access and computation

Jensen, John. *Remote Sensing of the Environment: An Earth Resource Perspective.* 2nd edition. Upper Saddle River, NJ: Pearson, 2006.

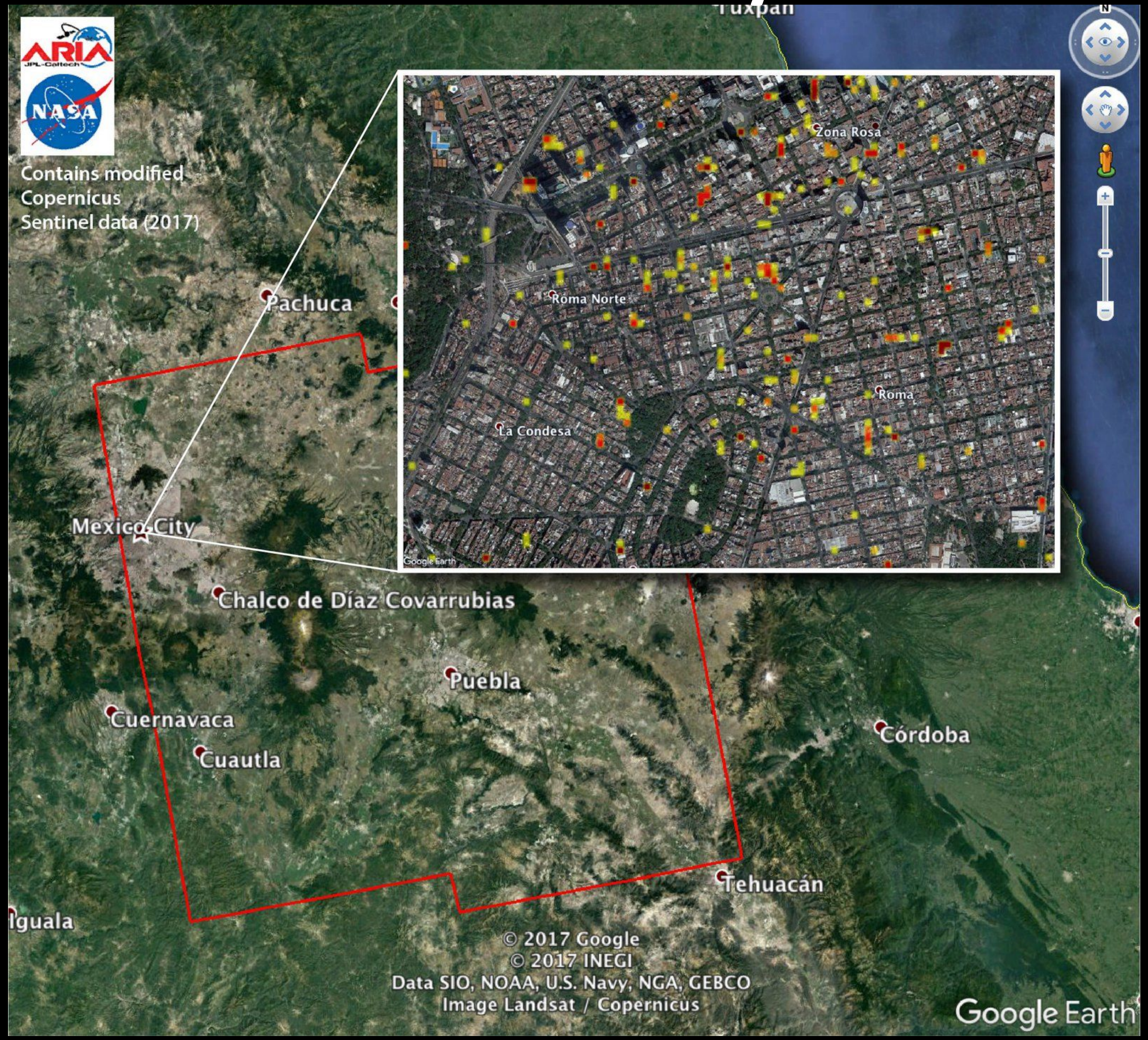
remote observation data

C: Remote Sensing Application Trends - Disaster Response

Puerto Rico

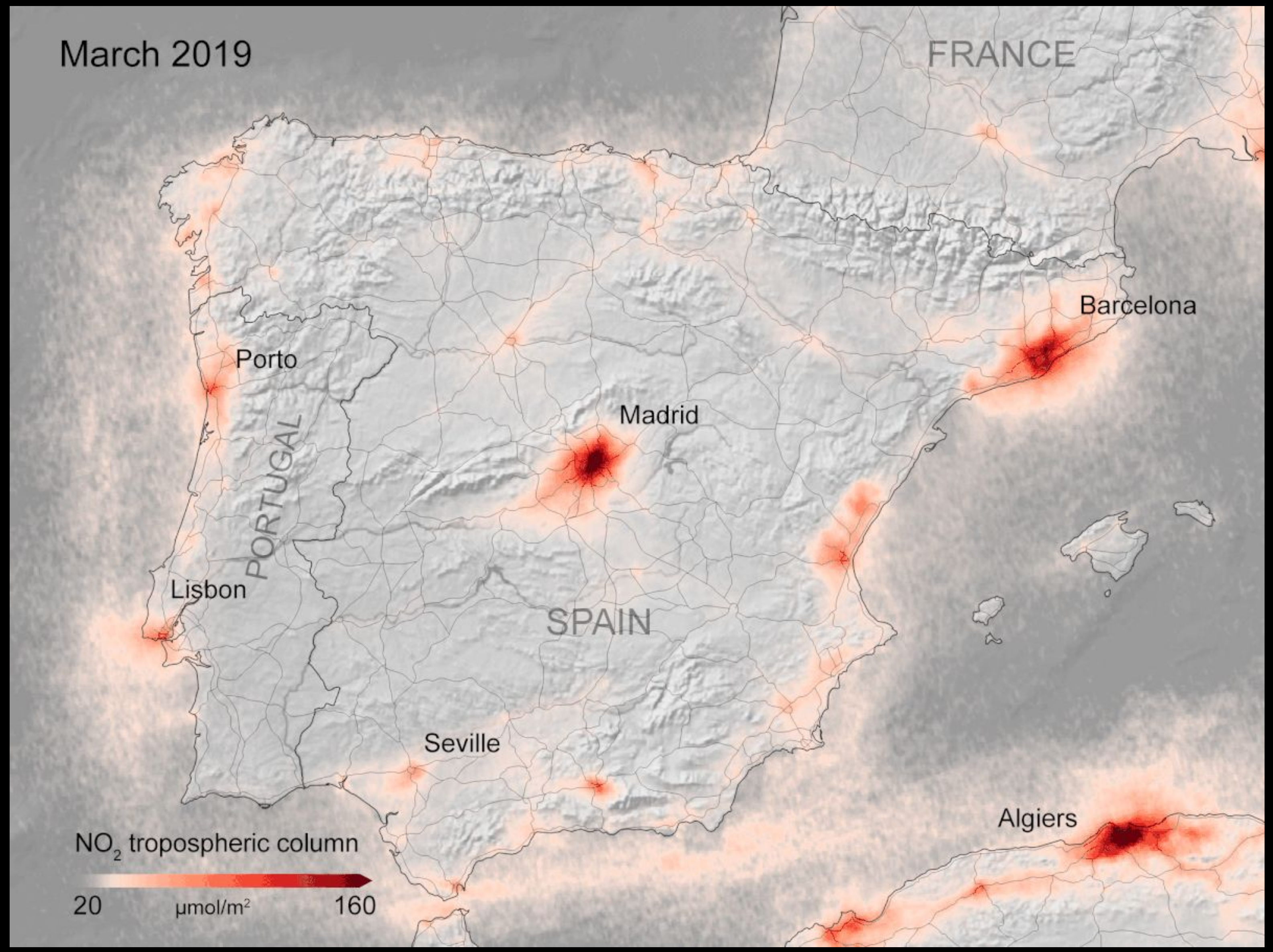
Hurricane Maria makes landfall on Sep 20, 2017.
NASA supplies damage maps on Sep 22, 2017

Mexico City

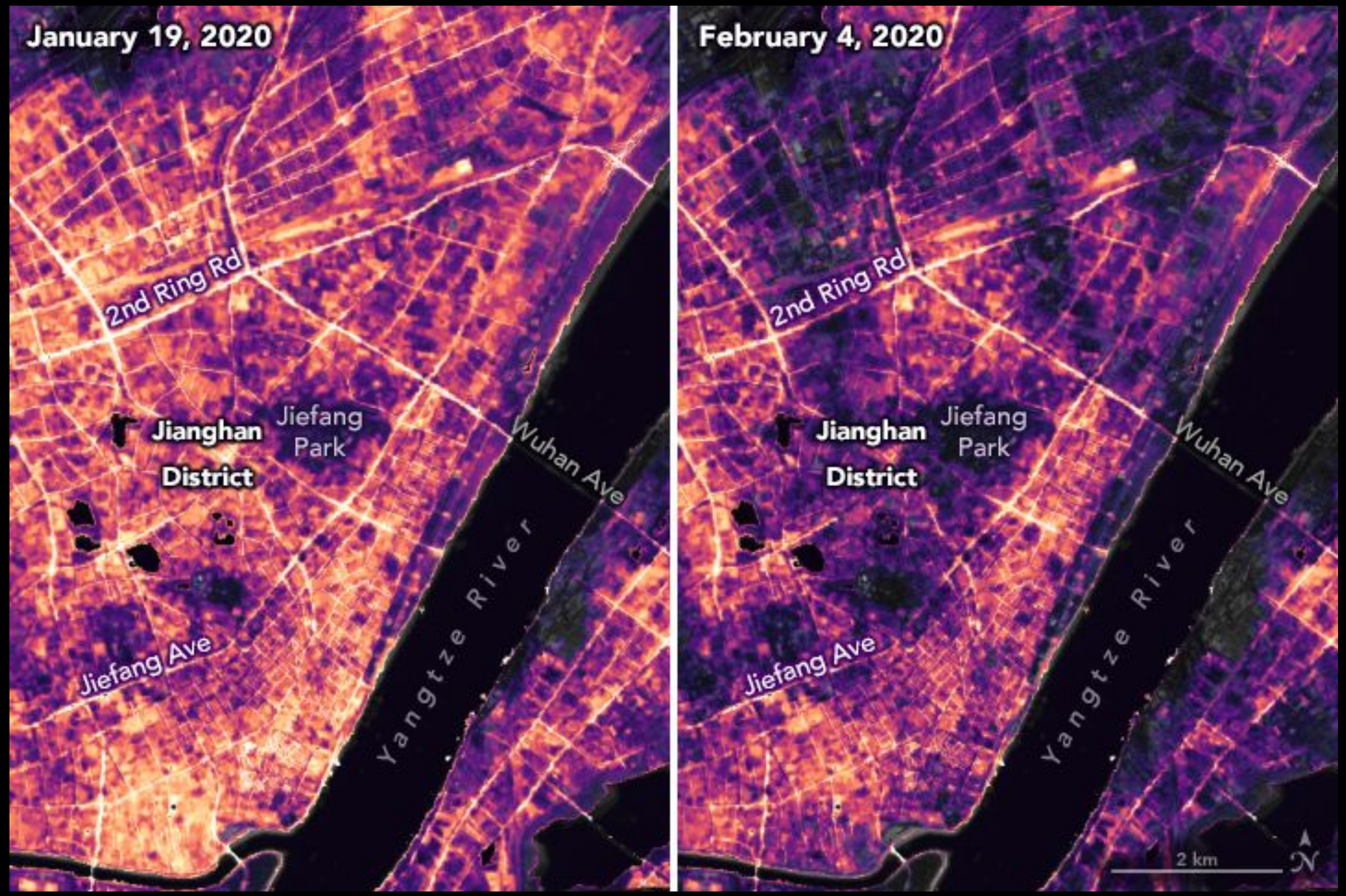


Earthquake occurs on Sep 19, 2017
NASA supplies damage maps on Sep 20, 2017

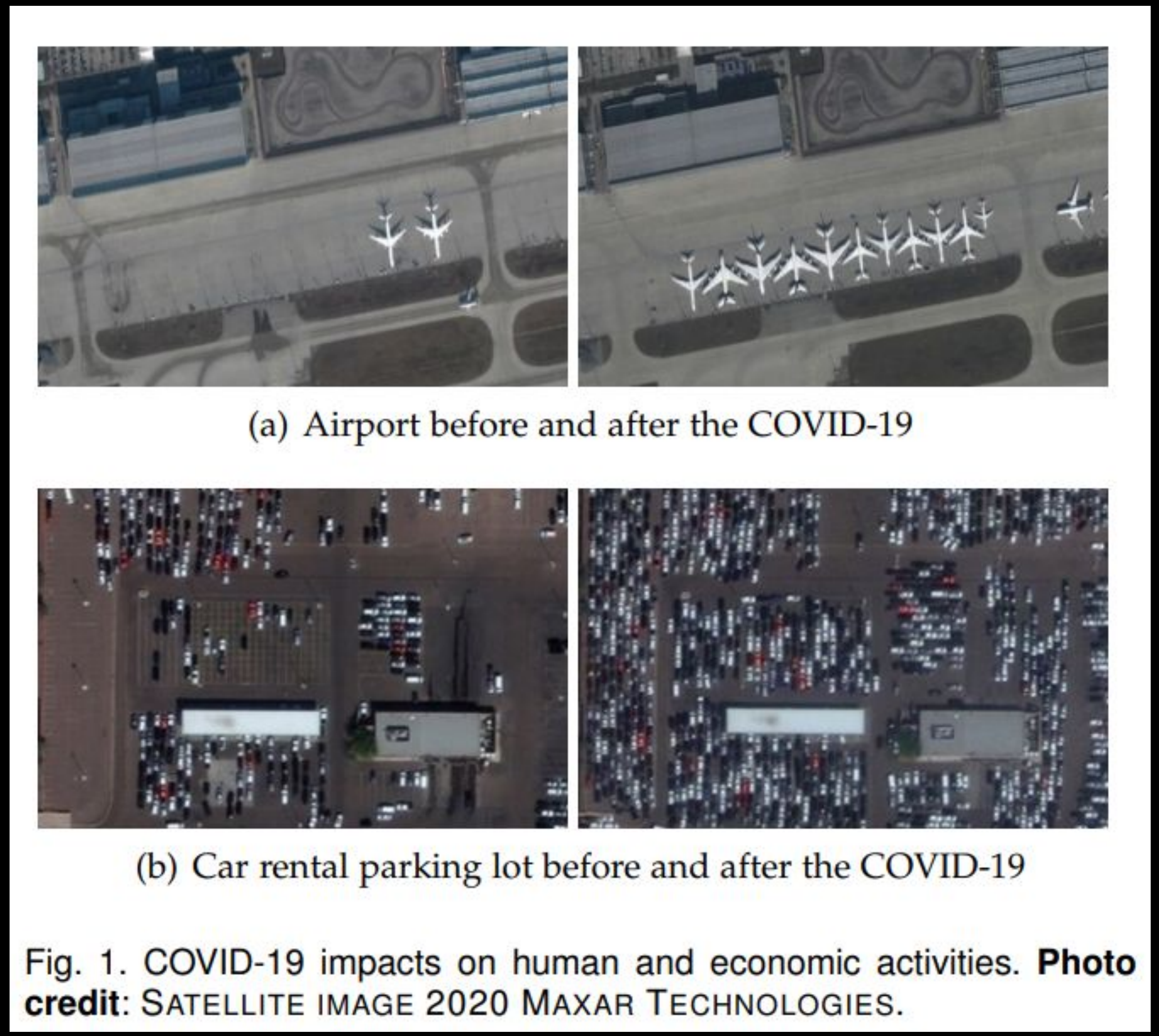
C: Remote Sensing Application Trends - COVID-19



Emissions



Nightlights



Traffic

Research Questions

1. What aspects of systems architecture (and systems engineering in general) are relevant and useful for approaching issues of sustainability in complex SETS? In particular, how can they be adapted using techniques from collaborative planning theory and other critical approaches to enable avoid the technocratic excesses of the past?

2. How can collaborative development of DSSs using the EVDT Modeling Framework in particular be relevant and useful to sustainability in such complex SETS?

3. How can EVDT be established as a continually development framework, a community of practice, and a growing code repository?

Research Questions

1. What aspects of systems architecture (and systems engineering in general) are relevant and useful for approaching issues of sustainability in complex SETS? In particular, how can they be adapted using techniques from collaborative planning theory and other critical approaches to enable avoid the technocratic excesses of the past?

Critical Theory / Hypothesis Generation

2. How can collaborative development of DSSs using the EVDT Modeling Framework in particular be relevant and useful to sustainability in such complex SETS?

Prototype Demonstrate Evaluate

3. How can EVDT be established as a continually development framework, a community of practice, and a growing code repository?

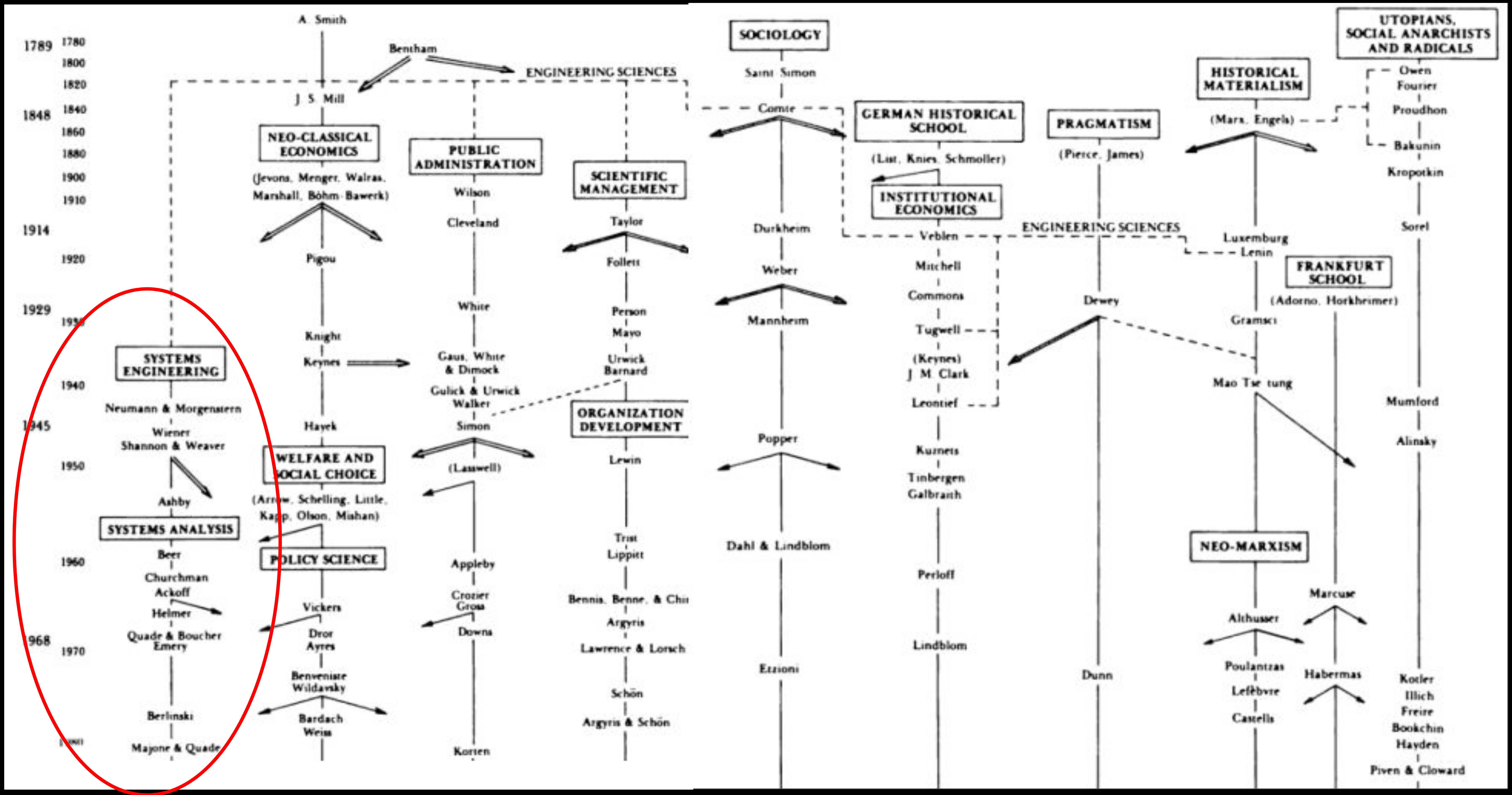
Extend & Scale

Research Question 1

1. **What aspects of systems architecture (and systems engineering in general) are relevant and useful for approaching issues of sustainability in complex SETS? In particular, how can they be adapted using techniques from collaborative planning theory and other critical approaches to enable avoid the technocratic excesses of the past?**
   a. A critical analysis of systems engineering, GIS, and the other technical fields relied upon in this work
   b. A proposed framework for applying systems engineering for sustainable development in an anticolonialist manner

1a, critical analysis: Development Schools of Thought

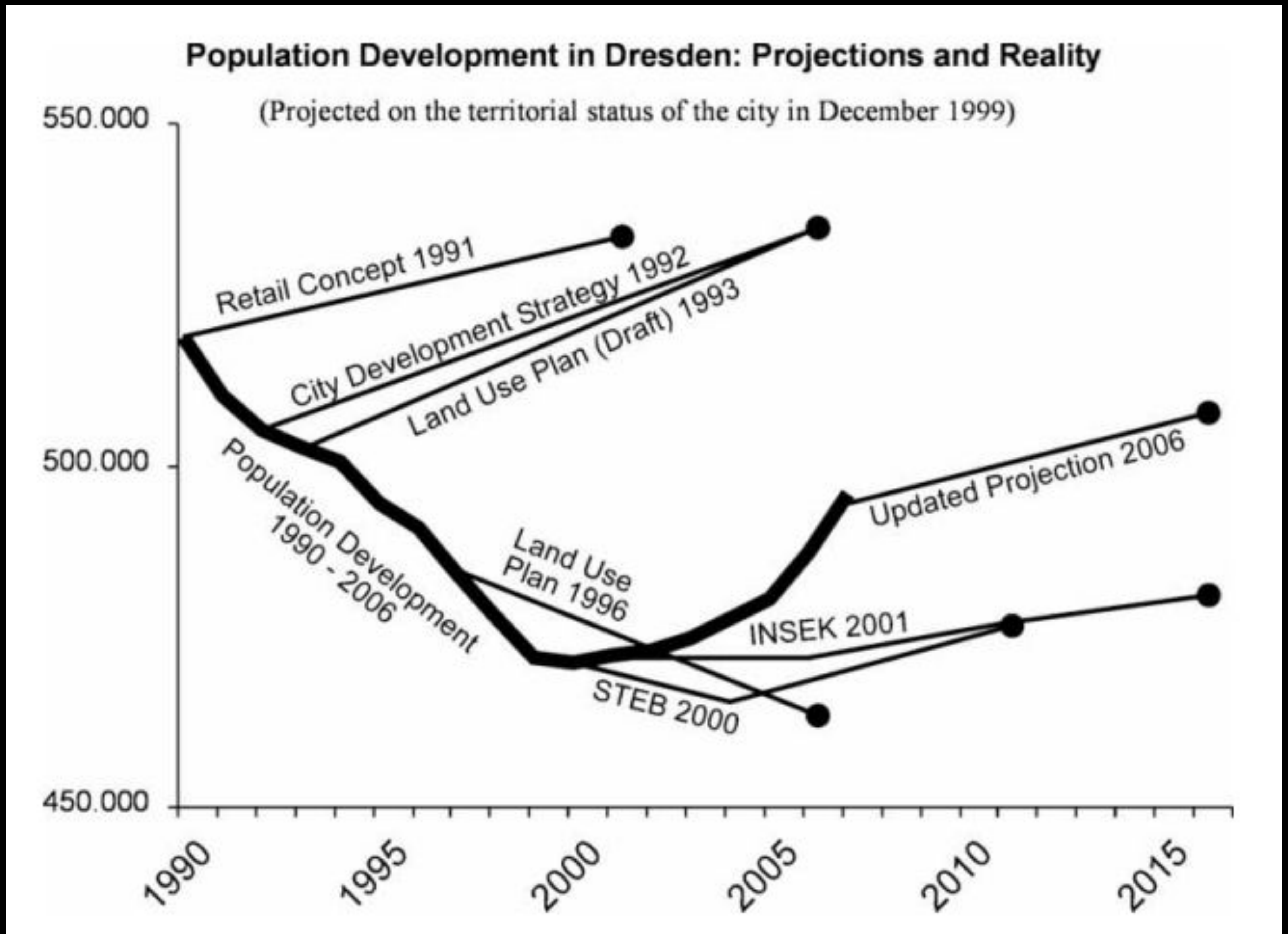
Conservative/Technical | **Social Reformist** | **Utopian/Anarchistic**



Friedmann, Johnn. “Two Centuries of Planning: An Overview.” *Explorations in Planning Theory*, edited by Seymour Mandelbaum et al., Routledge, 2017, pp. 10–29.

1a, critical analysis: The Technocratic Problem

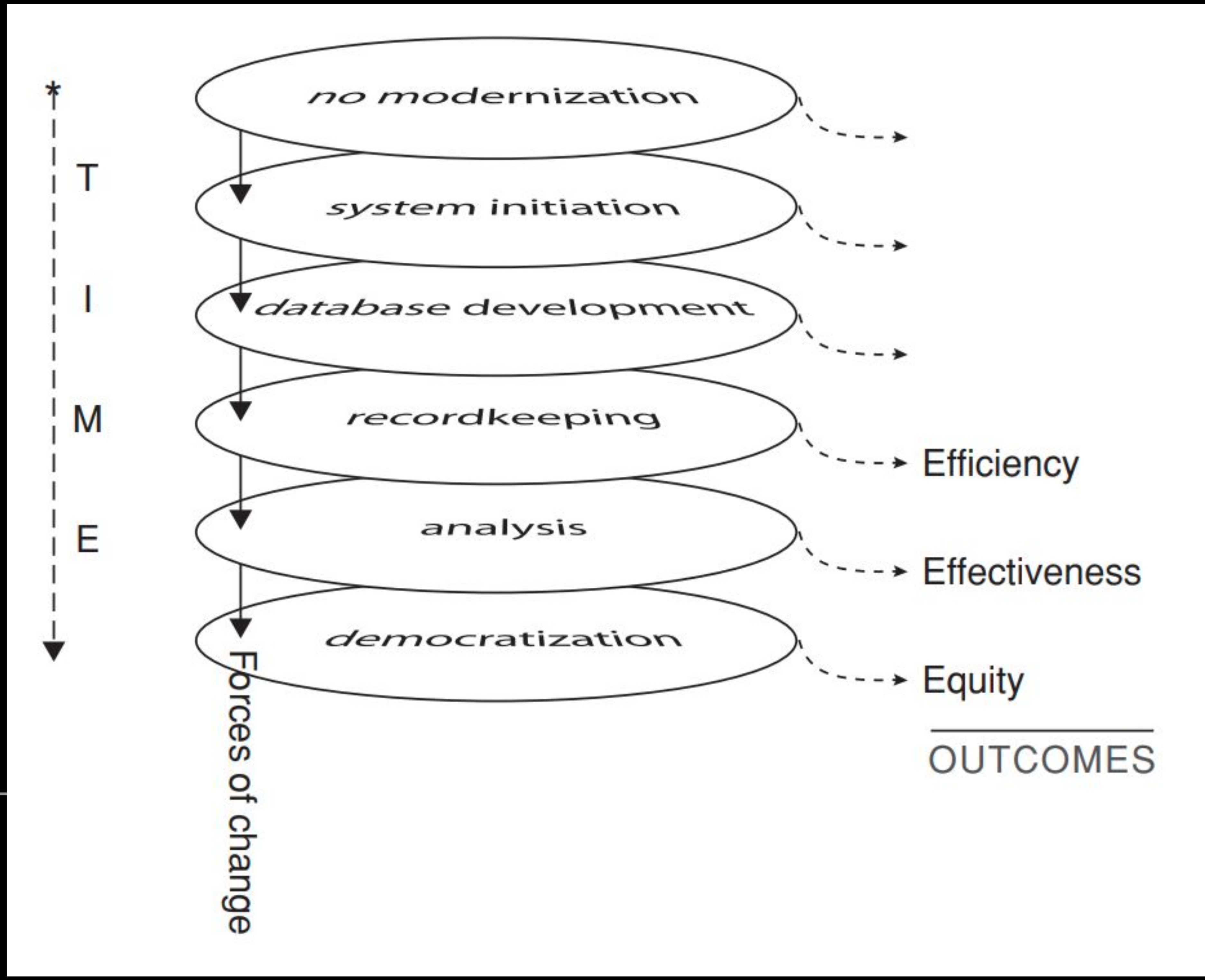
- Uphold existing systems of power and oppression (Friedmann, Eubanks, Robinson)
- Inevitably expand top-down control & surveillance (Scott)
- Fundamentally did not work (Jacobs, Light, Easterly, Lee Jr., etc)
  - Insufficient data for models
  - Lack of detailed causal understanding
  - Blank state / universality assumptions
  - Implementation tends to alienate
  - Overprioritization of easy to quantify metrics



Wiechmann, Dr Thorsten. “Errors Expected — Aligning Urban Strategy with Demographic Uncertainty in Shrinking Cities.” International Planning Studies, vol. 13, no. 4, Nov. 2008, pp. 431–46.

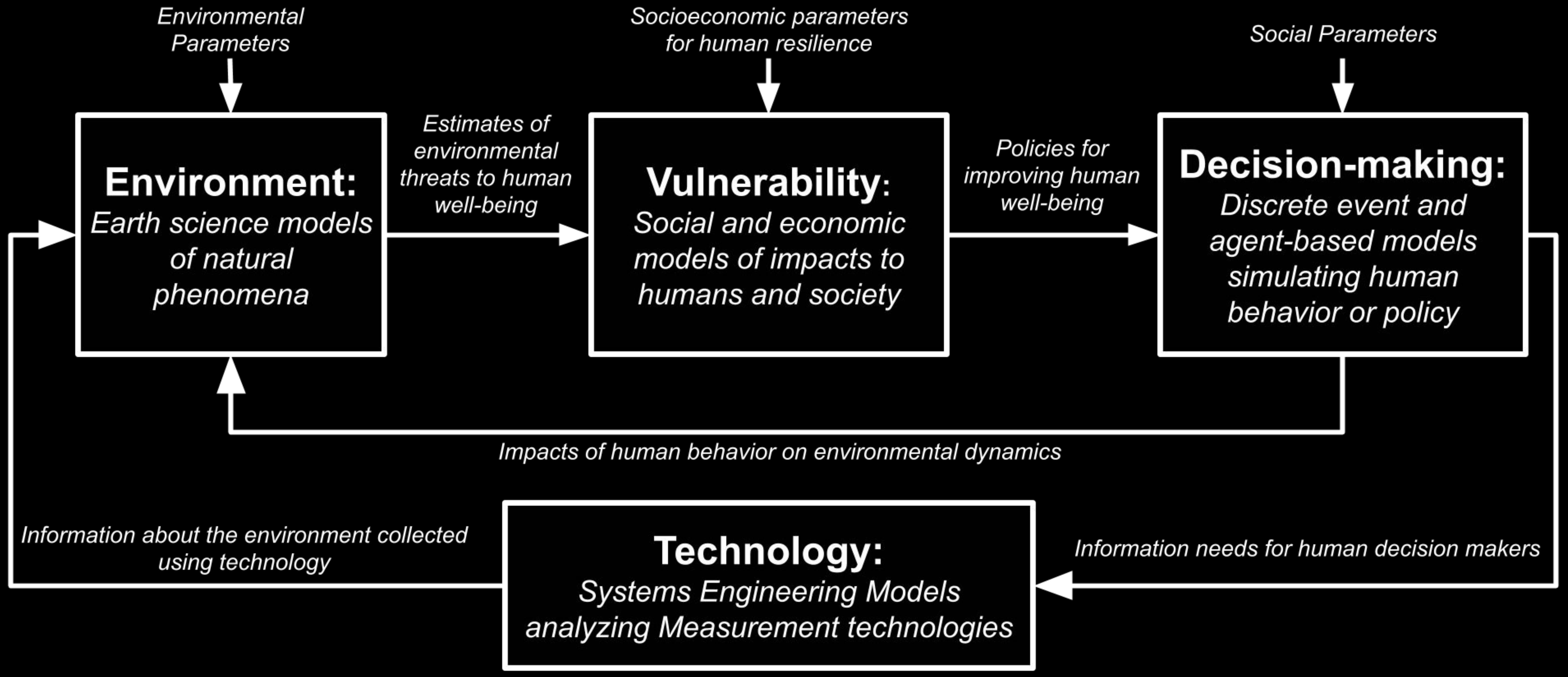
1a, critical analysis: Reform?

- Increased humility and a widened definition of value (in some circles)
  - Less emphasis on singular, monolithic solutions, more interest in complexity
    - In engineering (de Neufville) and in economics (Sachs)
- New models of planning, mapping, & systems engineering
  - Participatory Frameworks (PPGIS, Arnstein's Ladder, Stakeholder Analysis)
  - Critical Perspectives (Critical Cartography, Multistakeholder Decision-Making)
- Increased need
- More data, better models
  - GIS
  - Remote Sensing
  - Machine Learning
  - Telecommunications



Tulloch, David L. "Theoretical Model of Multipurpose Land Information Systems Development." Transactions in GIS, vol. 3, no. 3, 1999, pp. 259–83.

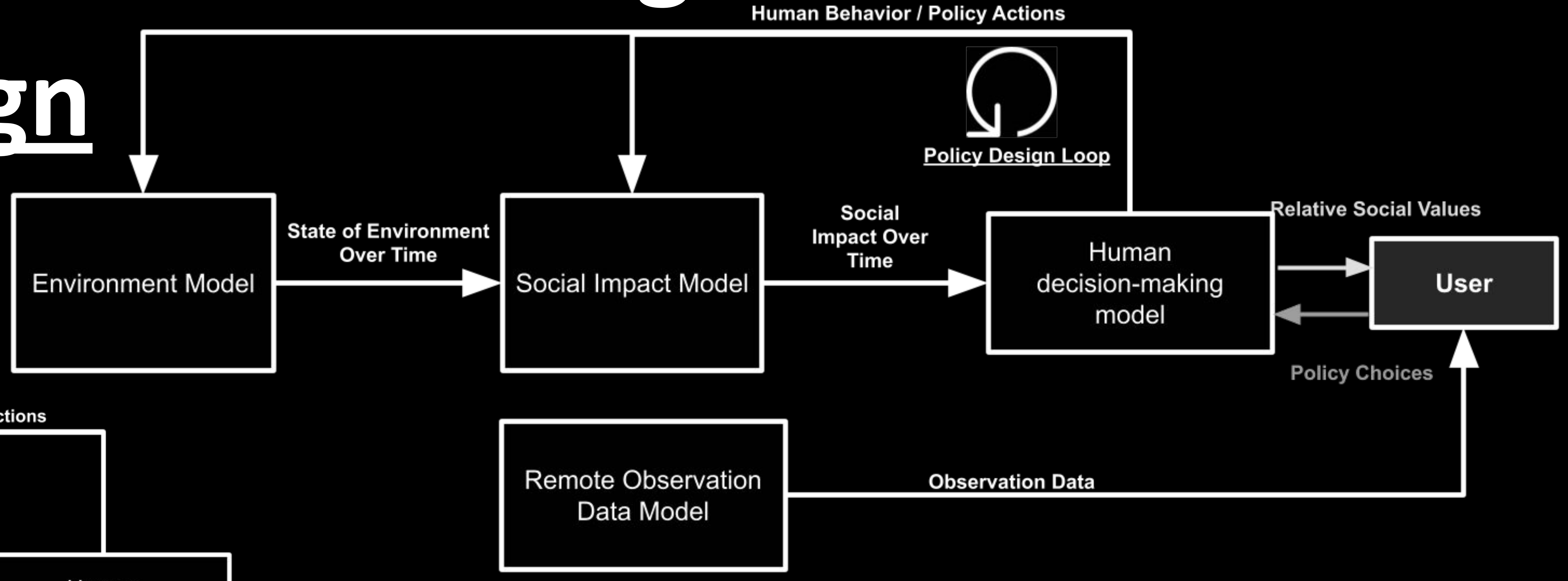
1b, proposed framework: EVDT

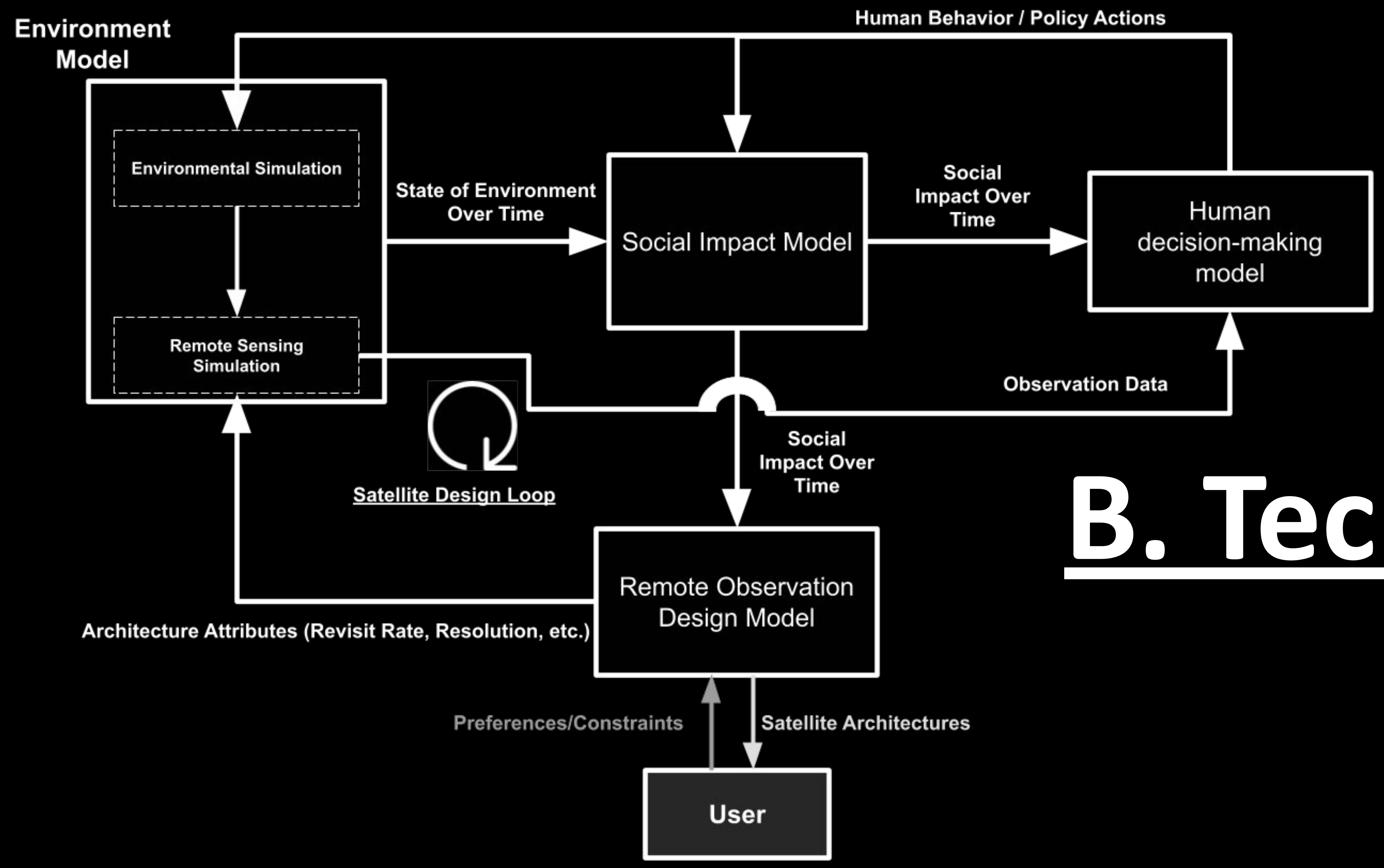


- What is happening in **the natural environment**?
- How will **humans be impacted** by what is happening in the natural environment?
- What **decisions are humans making** in response to environmental factors and why?
- What **technology system** can be designed to provide high quality information that supports human decision making?

1b, proposed framework: EVDT Arrangements

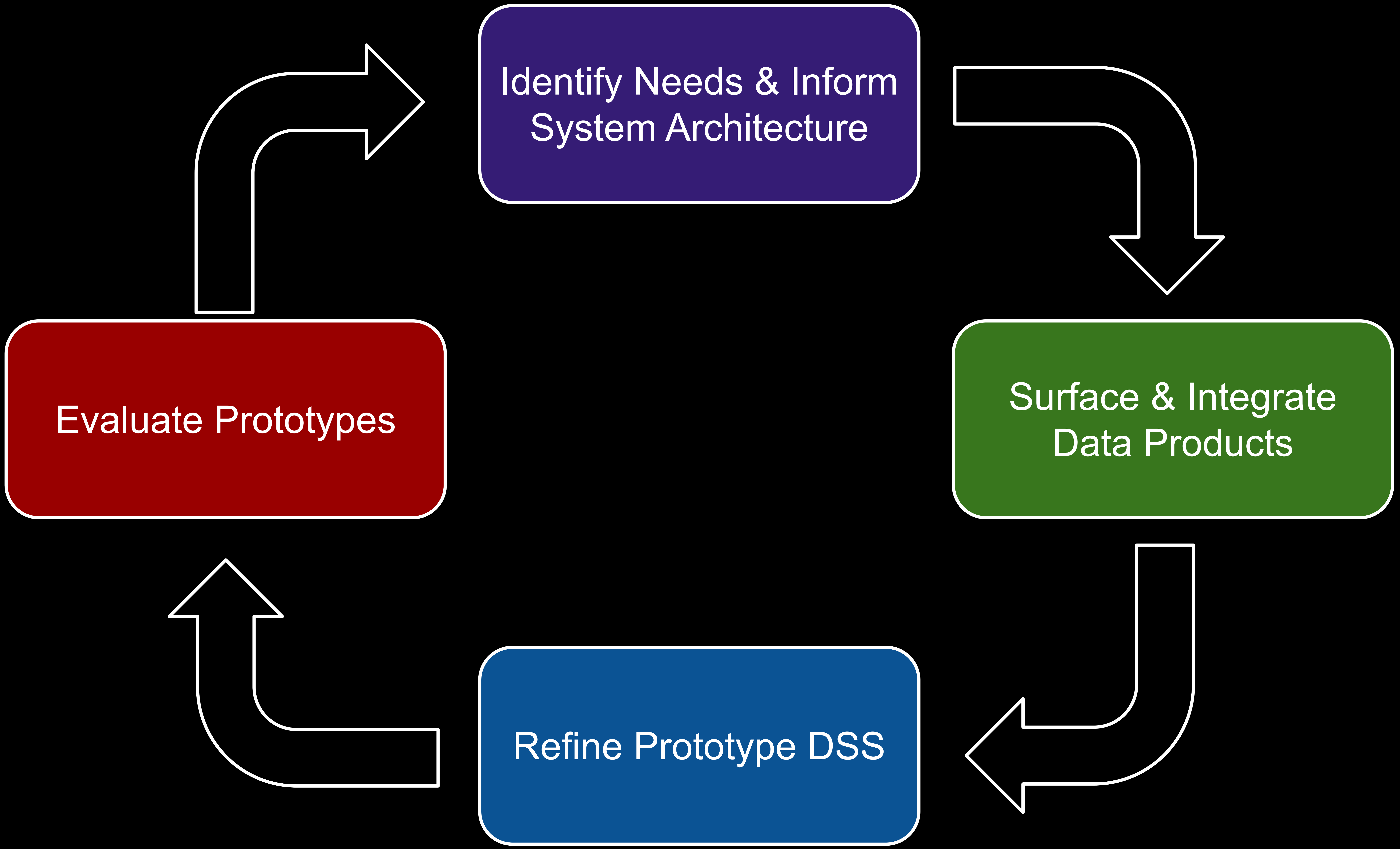
A. Policy Design



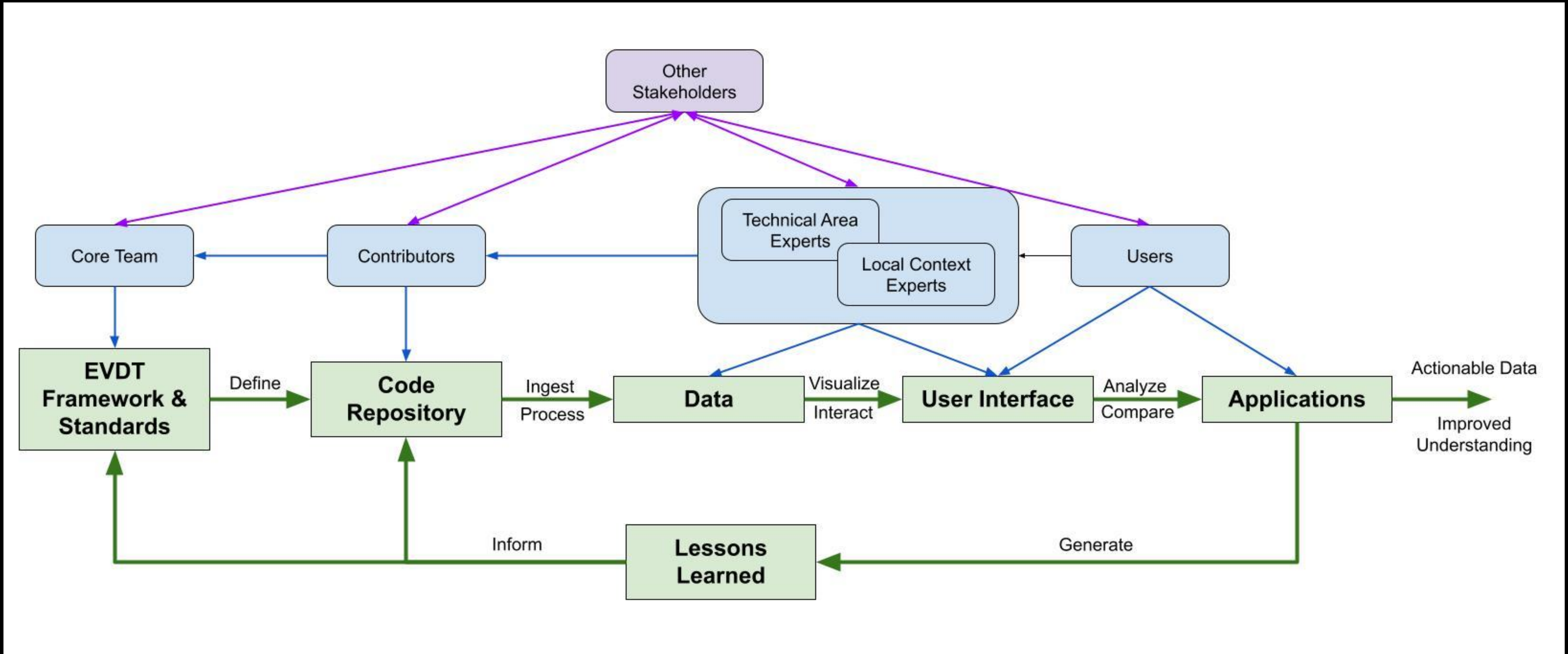


B. Technology Design

1b, proposed framework: Stakeholder Involvement



1b, proposed framework: Potential Development Pipeline



Research Question 2

2. **How can collaborative development of DSSs using the EVDT Modeling Framework in particular be relevant and useful to sustainability in such complex SETS?**
    a. System architecture analyses of each of the case studies
    b. Development of an EVDT-based DSS for each of the case studies
    c. An interview-based assessment of the development process and usefulness of each DSS

Case Study 1 (CS1): Rio de Janeiro Mangroves and Fishing Communities
Case Study 2 (CS2): The Vida COVID-19 Response Project

Case Study 1 (CS1): Rio de Janeiro Mangroves and Fishing Communities

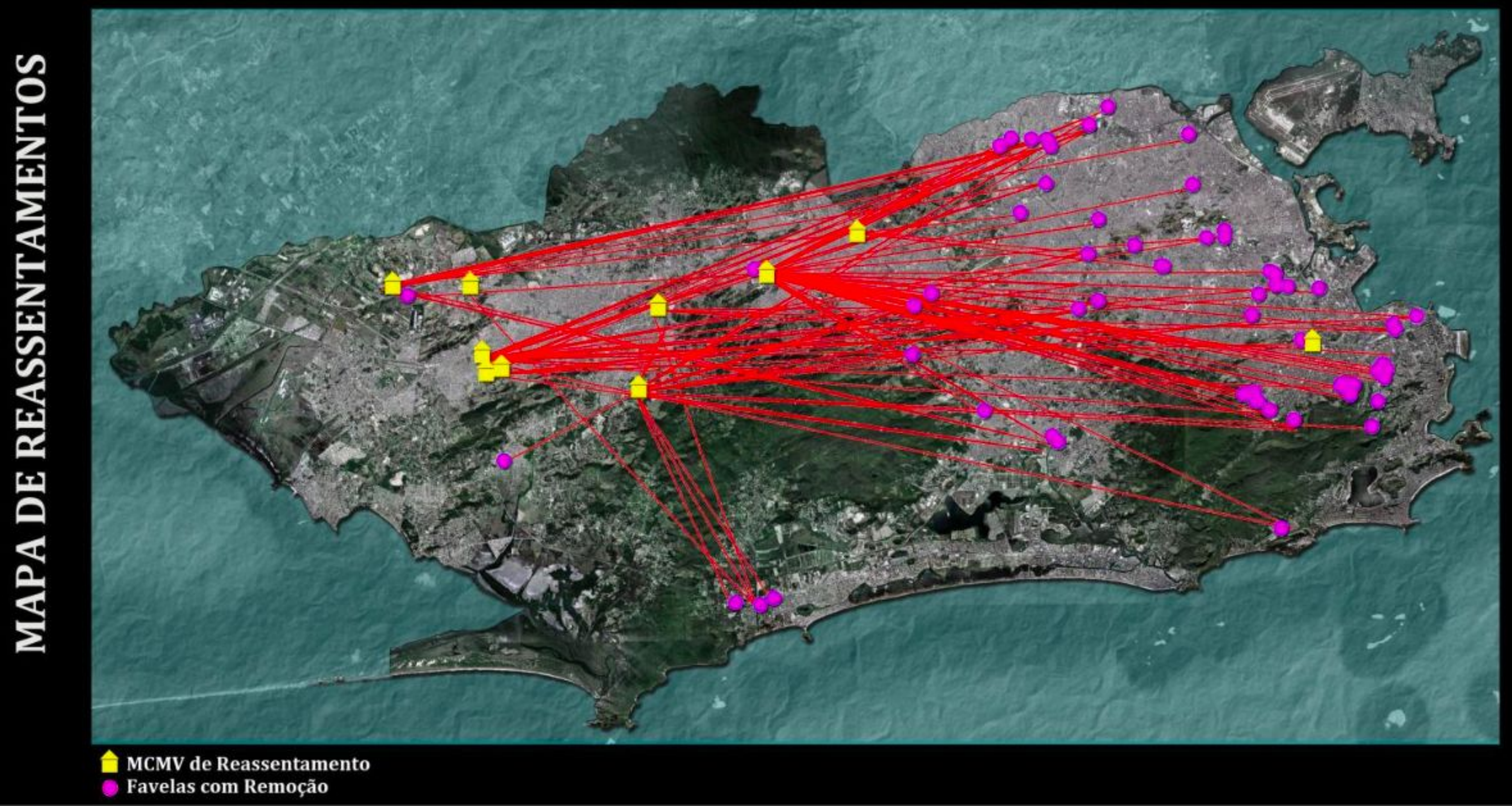
CS1 - Study Area (State of Rio de Janeiro)

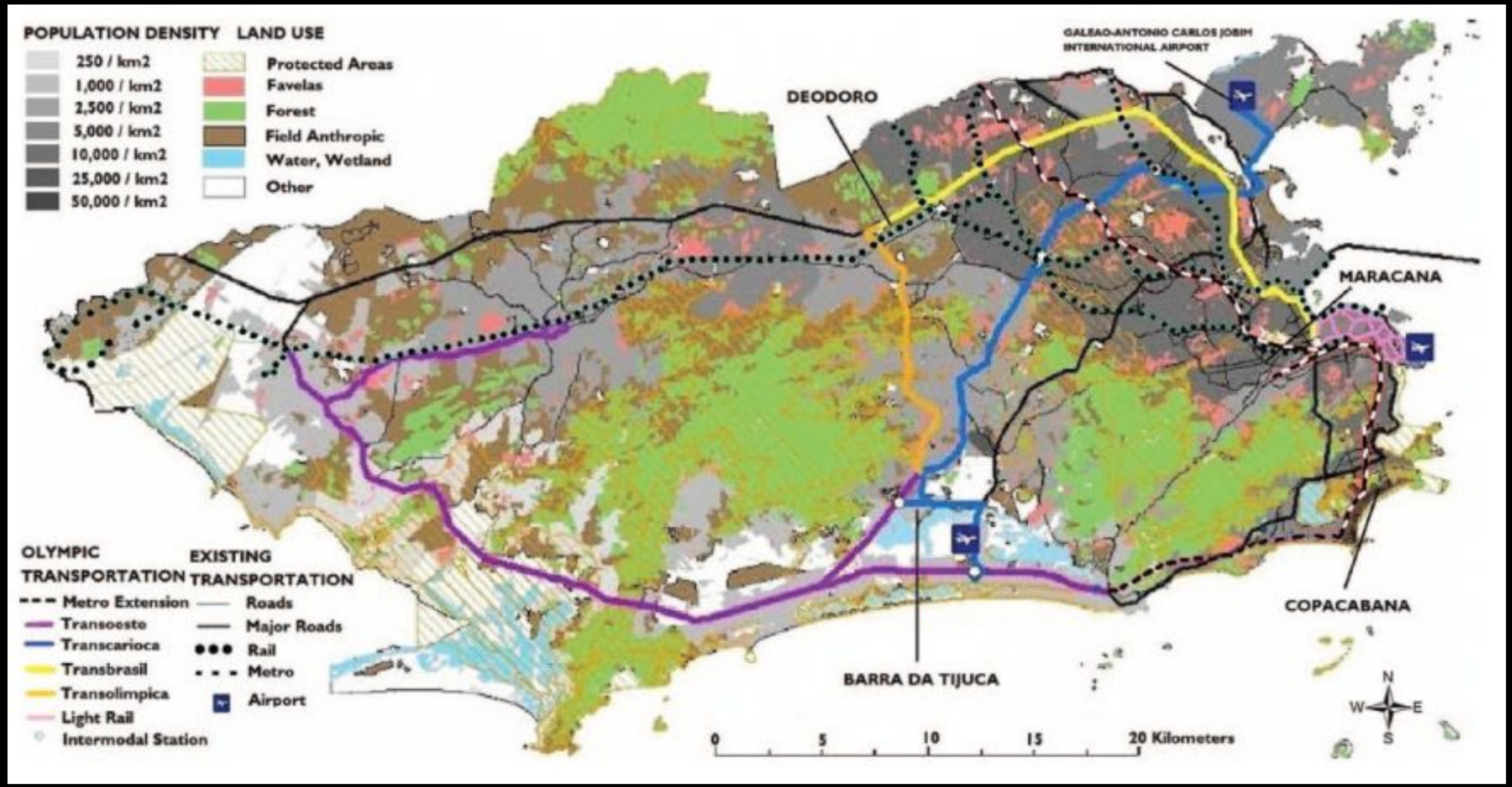
CS1 - Study Area (Guaratiba & Sepetiba)

Mangrove Forest

CS1 - Guaratiba Context

CS1 - Rio de Janeiro City Context





L. Faulhaber, “Rio Maravilha, projetos polític os e intervenção no território no início do século XXI,” Ph.D. dissertation, Universidade Federal Fluminense, Rio de Janeiro, Brazil, 2012. [Online]. Available: https://issuu.com/lucas.faulhaber/docs/tfg{ }lucasfaulhaber

E. Kassens-Noor, C. Gaffney, J. Messina, and E. Phillips, “Olympic Transport Legacies: Rio de Janeiro’s Bus Rapid Transit System,” Journal of Planning Education and Research, vol. 38, no. 1, pp. 13–24, mar 2018. [Online]. Available: http://journals.sagepub.com/doi/10.1177/0739456X16683228

CS1 - Government Stakeholders

RIO PREFEITURA

Municipality

SMAC
SMU
IPP

RIO Plano de Desenvolvimento Sustentável

Climate Change Adaptation Strategy for the City of Rio de Janeiro

DATA.RIO

State

inea
instituto estadual do ambiente

Federal

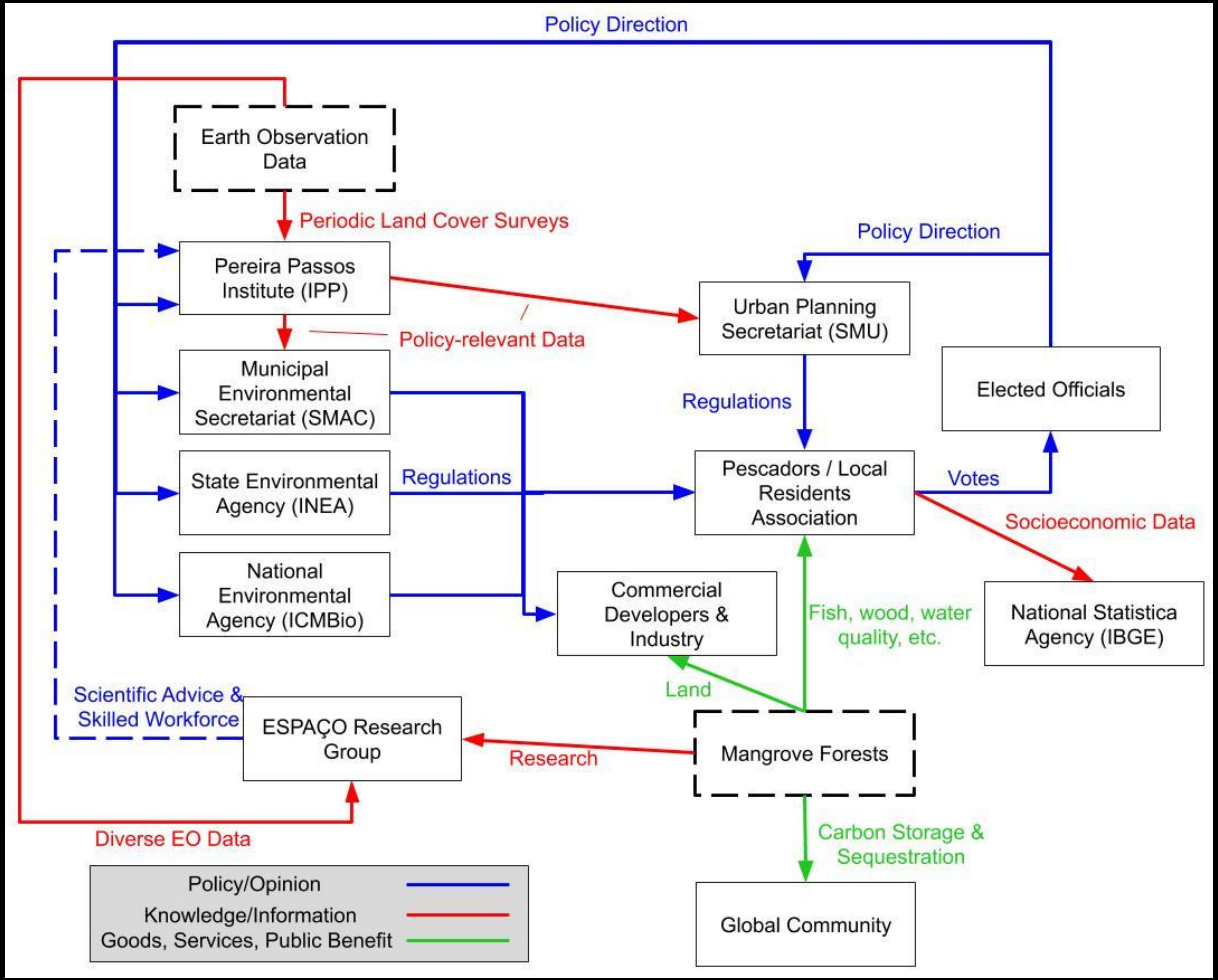
ICMBio
INSTITUTO CHICO MENDES
MMA

INPE

UFRJ

CS1 - Stakeholder Analysis

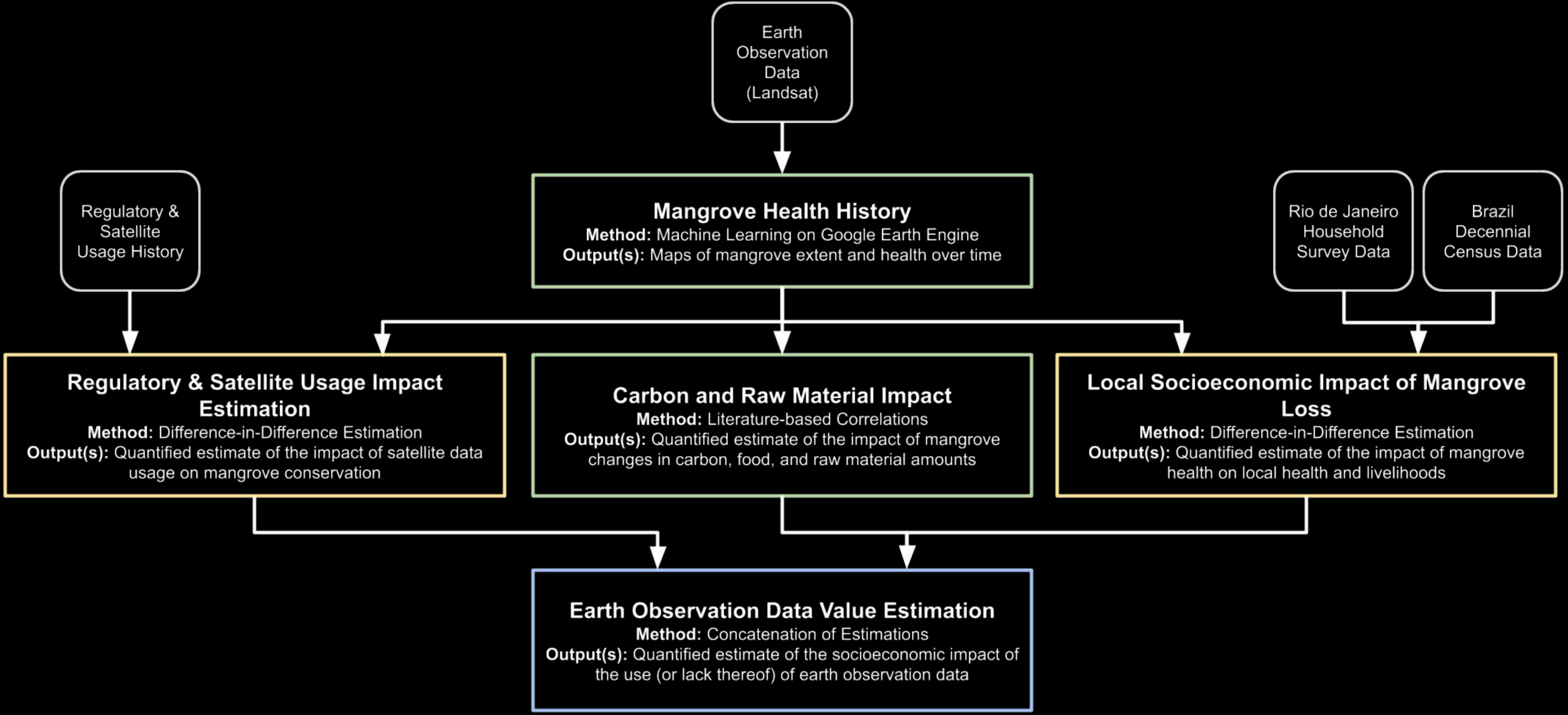
- Stakeholder Interviews
  - Local Fishing/Community Associations
  - Government Officials
  - Academic Researchers



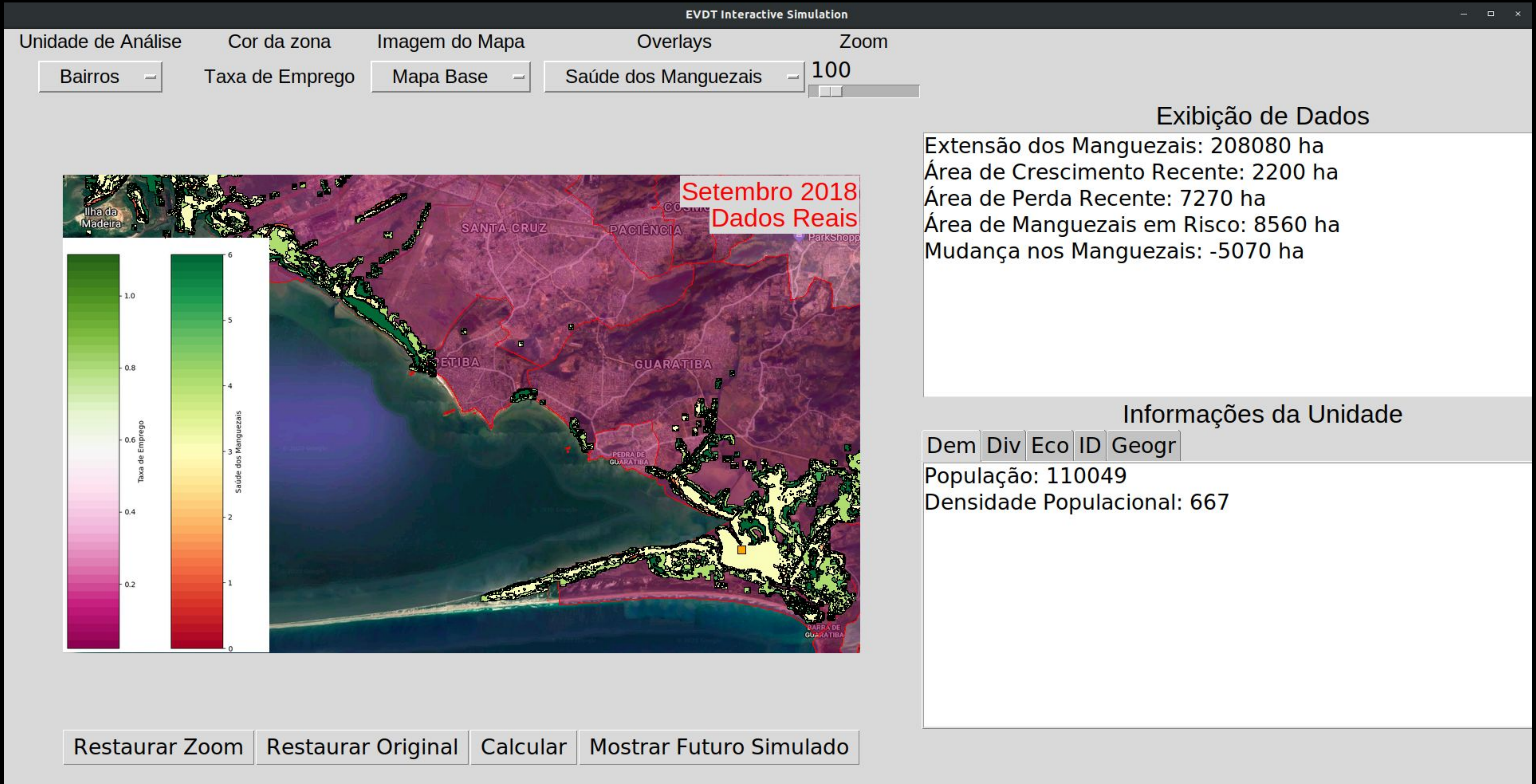
CS1 - (Incomplete) List of Important Factors

- Complicated regulatory framework
- Differing Priorities
  - Local Community: Sustainable use of trees, voice in siting of mangrove restoration
  - Municipal Environmental Agency: Valuation of mangrove trees
  - Municipal Urban Planning Agency: Zoning-relevant data
- Data Gaps
  - Household level economic and ecosystem services usage data
  - Local ecosystem service valuation
  - Detailed land use / land cover maps (LULC) outside of municipality

CS1 - Additional Data Generation

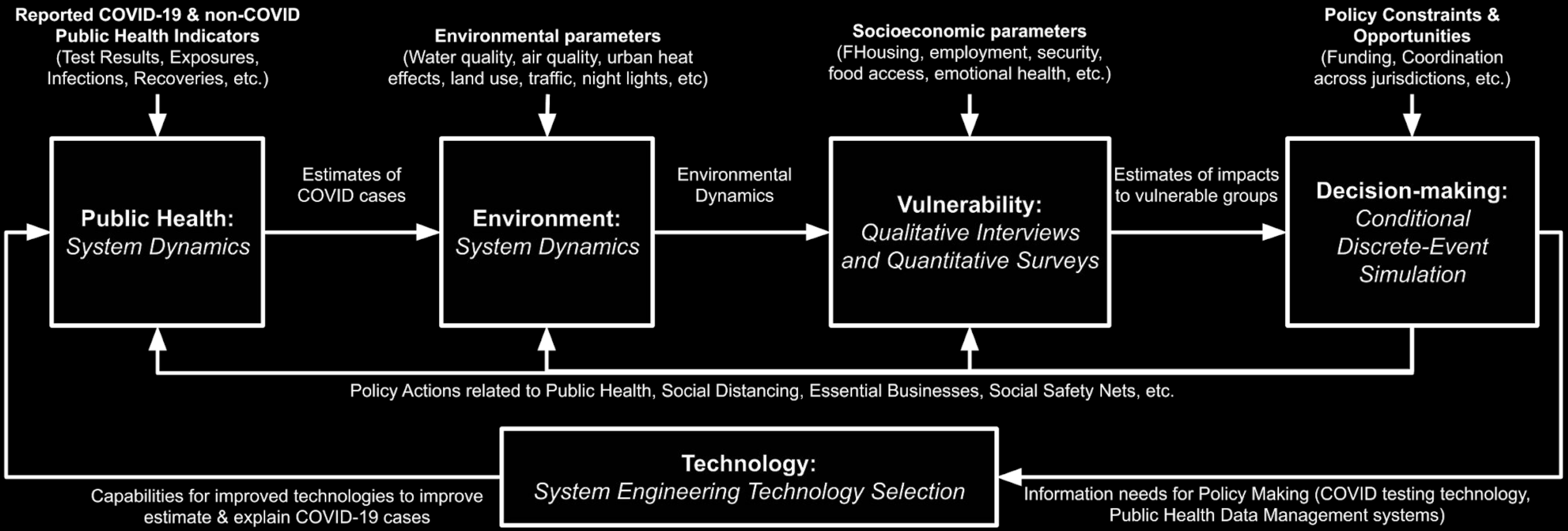


CS1 - Developing the Decision Support System



Case Study 2 (CS2) - The Vida COVID-19 Response Project

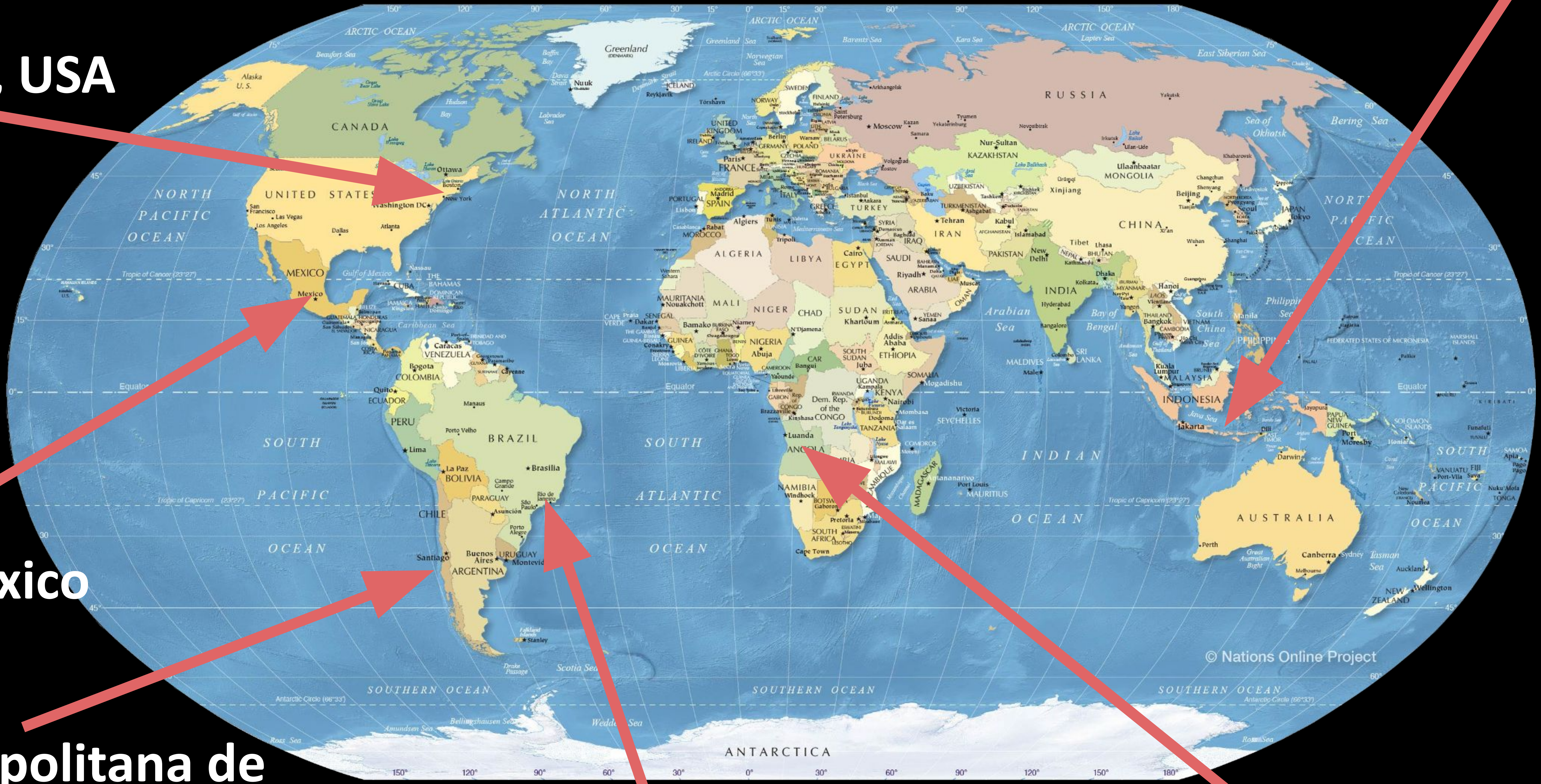
CS2 - The Vida Decision Support System



CS2 - Study Areas

Java & Sulawesi, Indonesia

Boston, USA



Querétaro, México

Región Metropolitana de Santiago, Chile

Rio de Janeiro, Brasil

Luanda, Angola

Map adapted from the Nations Online Project.

CS2 - Partner Organizations

Brasil

Rio PREFEITURA INSTITUTO PEREIRA PASSOS

DATA.RIO INFORMAÇÕES SOBRE A CIDADE

México

Indonesia

UNIVERSITAS DIPONEGORO SEMARANG

Ministerio de Ciencia, Tecnología, Conocimiento e Innovación

Gobierno de Chile

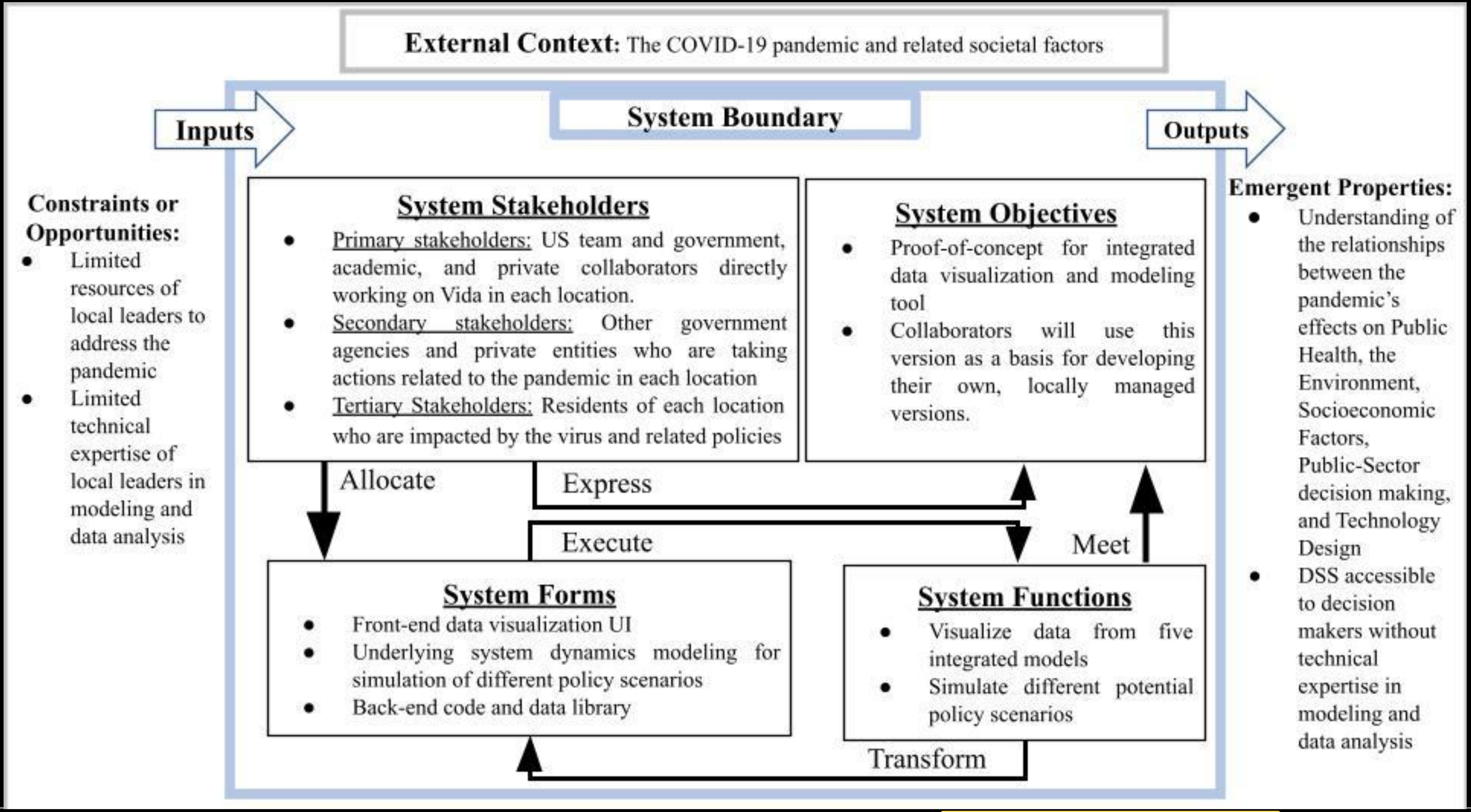
Chile

GGPEN Gabinete de Gestão do Programa Espacial Nacional

República de Angola

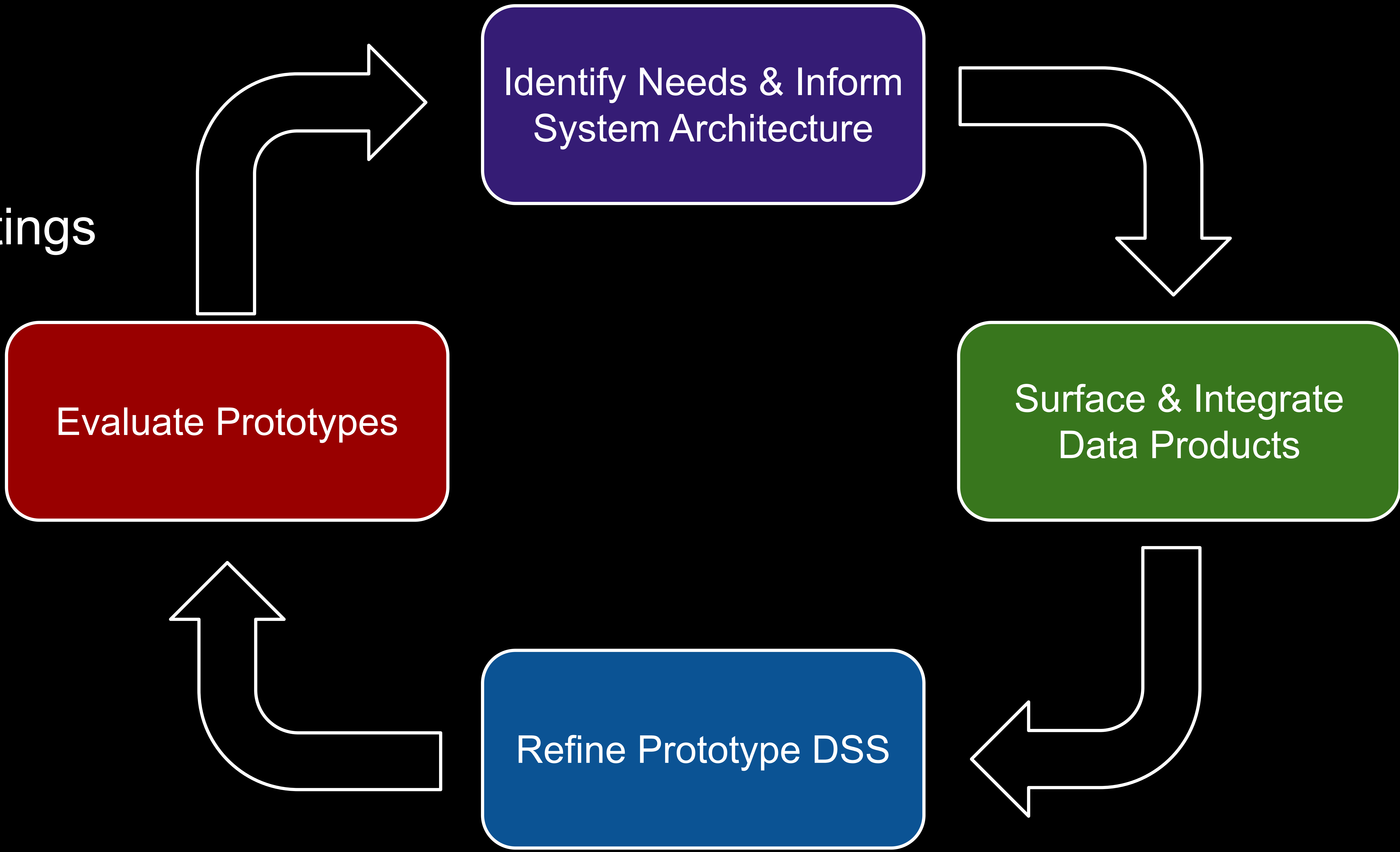
Angola

CS2 - System Architecture

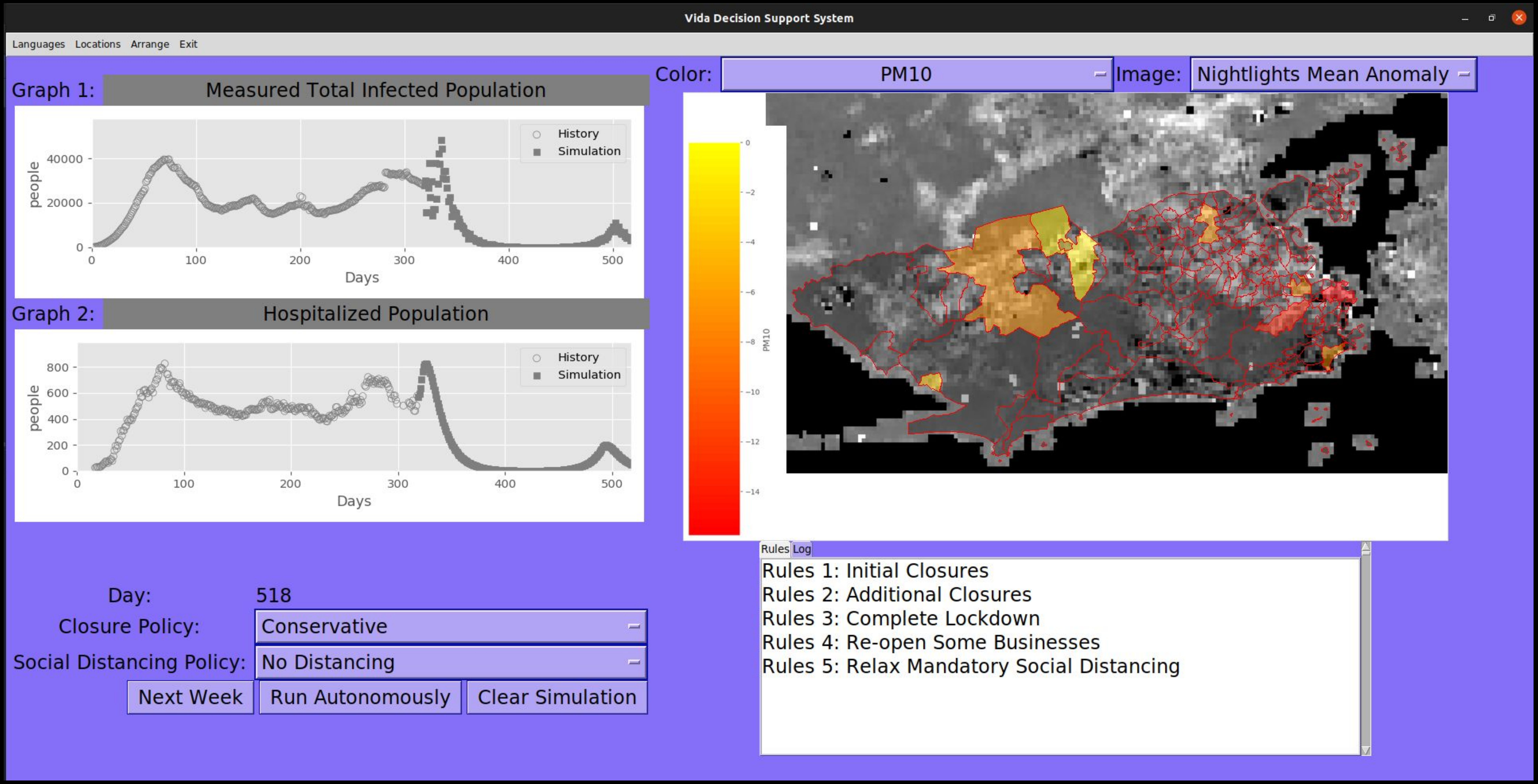


CS2 - Design Process

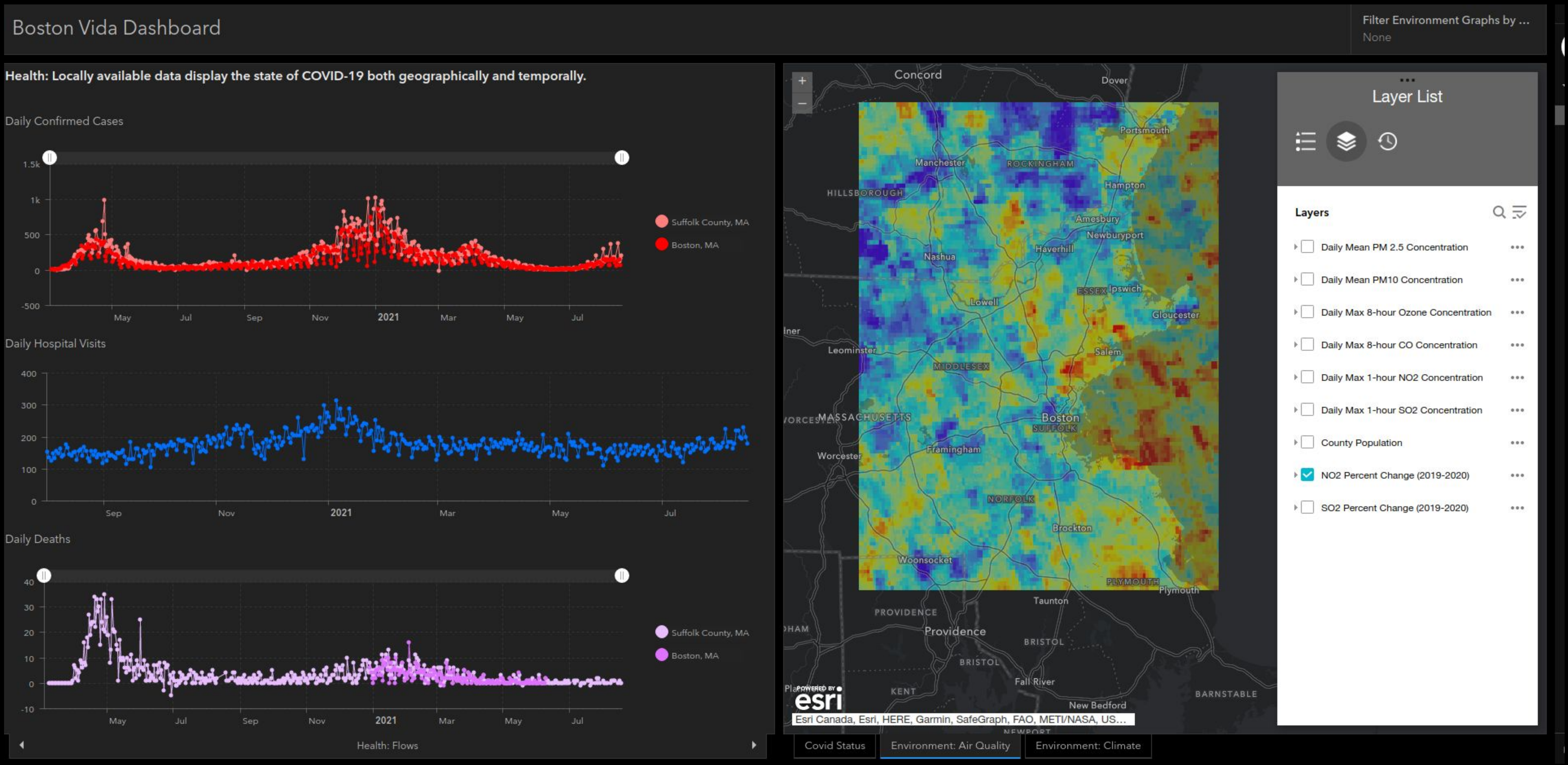
- Weekly/Biweekly 1-on-1 meetings
- Monthly full network meetings
- Online collaboration
  - Data Repositories
  - Github
  - Browser-based DSS



CS2 - Developing the Decision Support System



CS2 - Developing the Decision Support System



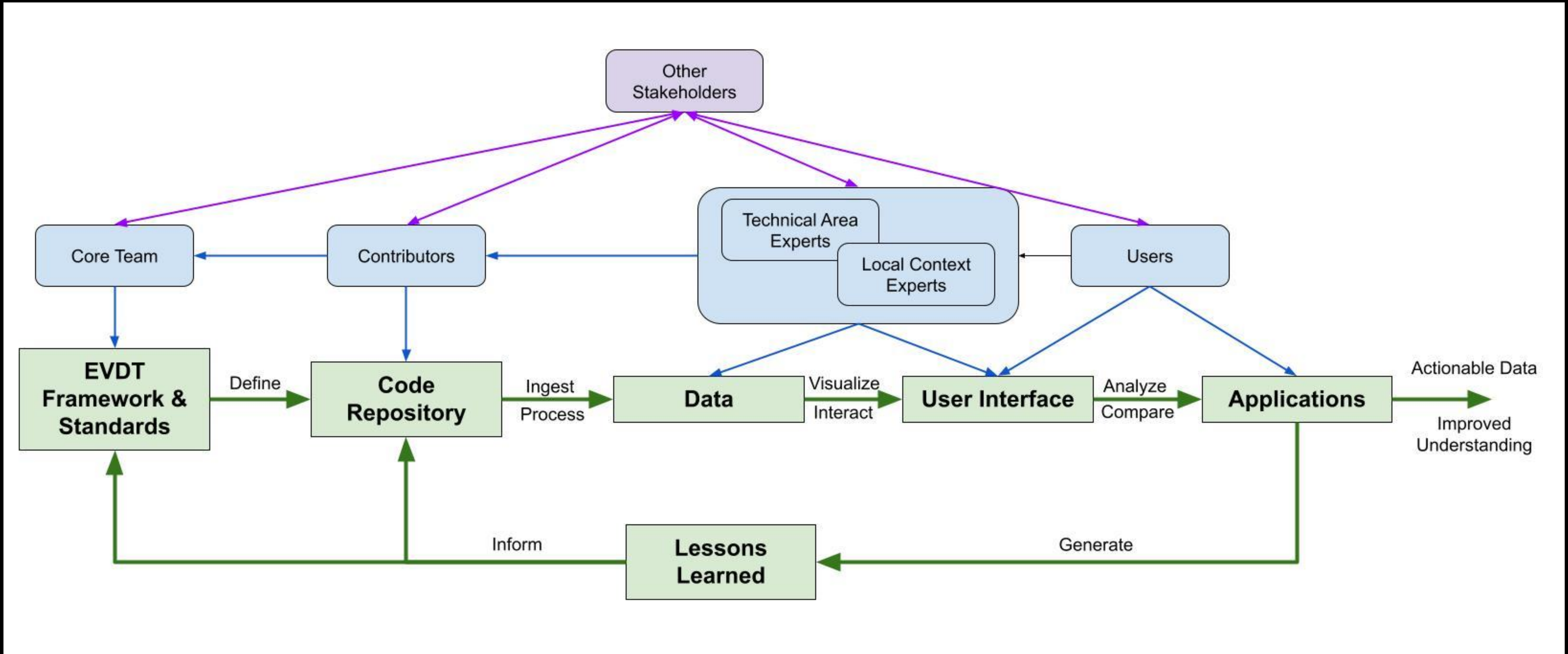
Research Question 3

3. **How can EVDT be established as a continually development framework, a community of practice, and a growing code repository?**
    a. An assessment of lessons learned from these DSS development processes
    b. An outline of potential future EVDT refinement and extension, such as using EVDT to inform the development of future earth observation systems that are better designed for particular application contexts

3a/b, lessons & future development

- Standardize framework and foundational code
- Develop a community of practice
- Extend to various potential applications:
  - To inform sustainable development policies.
  - To educate on the connections between the different EVDT domains.
  - To facilitate the exploration and evaluation of sensing technology architectures for particular applications.
  - To facilitate scientific research on ecosystem services and/or the impacts of human behavior on the environment.
  - To provide a basis for studies of the effectiveness of different DSS attributes (visualization techniques, workshop formats, etc.).

3b, future development: Potential Development Pipeline



Other Contributions

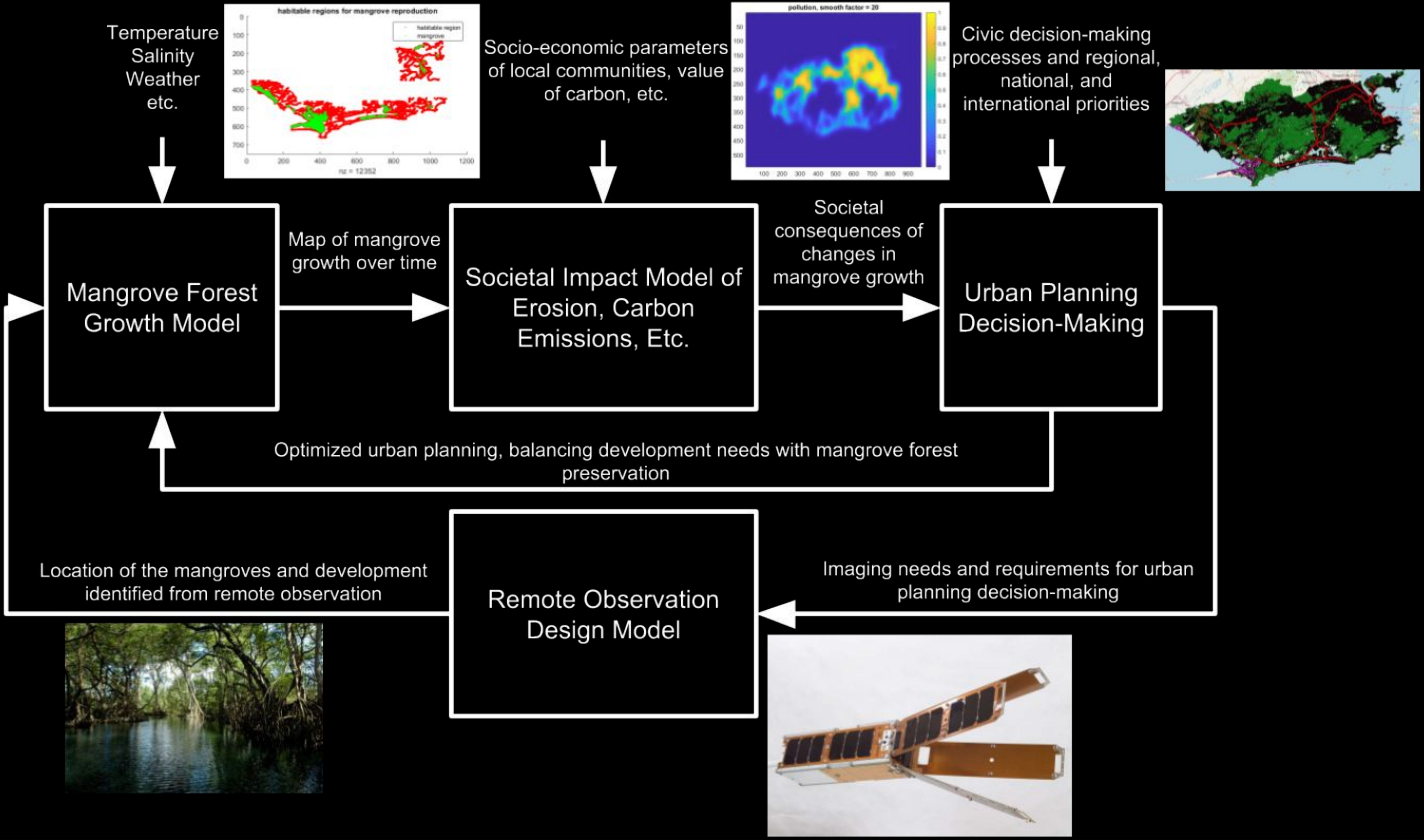
- Encourage the joint consideration of both human and environmental systems in a dynamic, continual fashion, thereby avoiding some of the negative consequences of siloed, static conservation mapping practices.
- Expand the population of EO data users by increasing accessibility and demonstrating utility of EO data to policymaking.
- Reduce burden of facilitation by space agencies.

Thank you! Any Questions?

space enabled

Research Questions

1. **What aspects of systems architecture (and systems engineering in general) are relevant and useful for approaching issues of sustainability in complex SETS? In particular, how can they be adapted using techniques from collaborative planning theory and other critical approaches to enable avoid the technocratic excesses of the past?**
    a. A critical analysis of systems engineering, GIS and the other technical fields relied upon in this work
    b. A proposed framework for applying systems engineering for sustainable development in an anticolonialist manner
2. **How can collaborative development of DSSs using the EVDT Modeling Framework in particular be relevant and useful to sustainability in such complex SETS?**
    a. System architecture analyses of each of the case studies
    b. Development of an EVDT-based DSS for each of the case studies
    c. An interview-based assessment of the development process and usefulness of each DSS
3. **How can EVDT be established as a continually development framework, a community of practice, and a growing code repository?**
    a. An assessment of lessons learned from these DSS development processes
    b. An outline of potential future EVDT refinement and extension, such as using EVDT to inform the development of future earth observation systems that are better designed for particular application contexts


Temperature
Salinity
Weather
etc.
habitable regions for mangrove reproduction
Socio-economic parameters of local communities, value of carbon, etc.
pollution, smooth factor = 20
Civic decision-making processes and regional, national, and international priorities
Mangrove Forest Growth Model
Map of mangrove growth over time
Societal Impact Model of Erosion, Carbon Emissions, Etc.
Societal consequences of changes in mangrove growth
Urban Planning Decision-Making
Optimized urban planning, balancing development needs with mangrove forest preservation
Location of the mangroves and development identified from remote observation
Remote Observation Design Model
Imaging needs and requirements for urban planning decision-making

Data & Methods: Environment

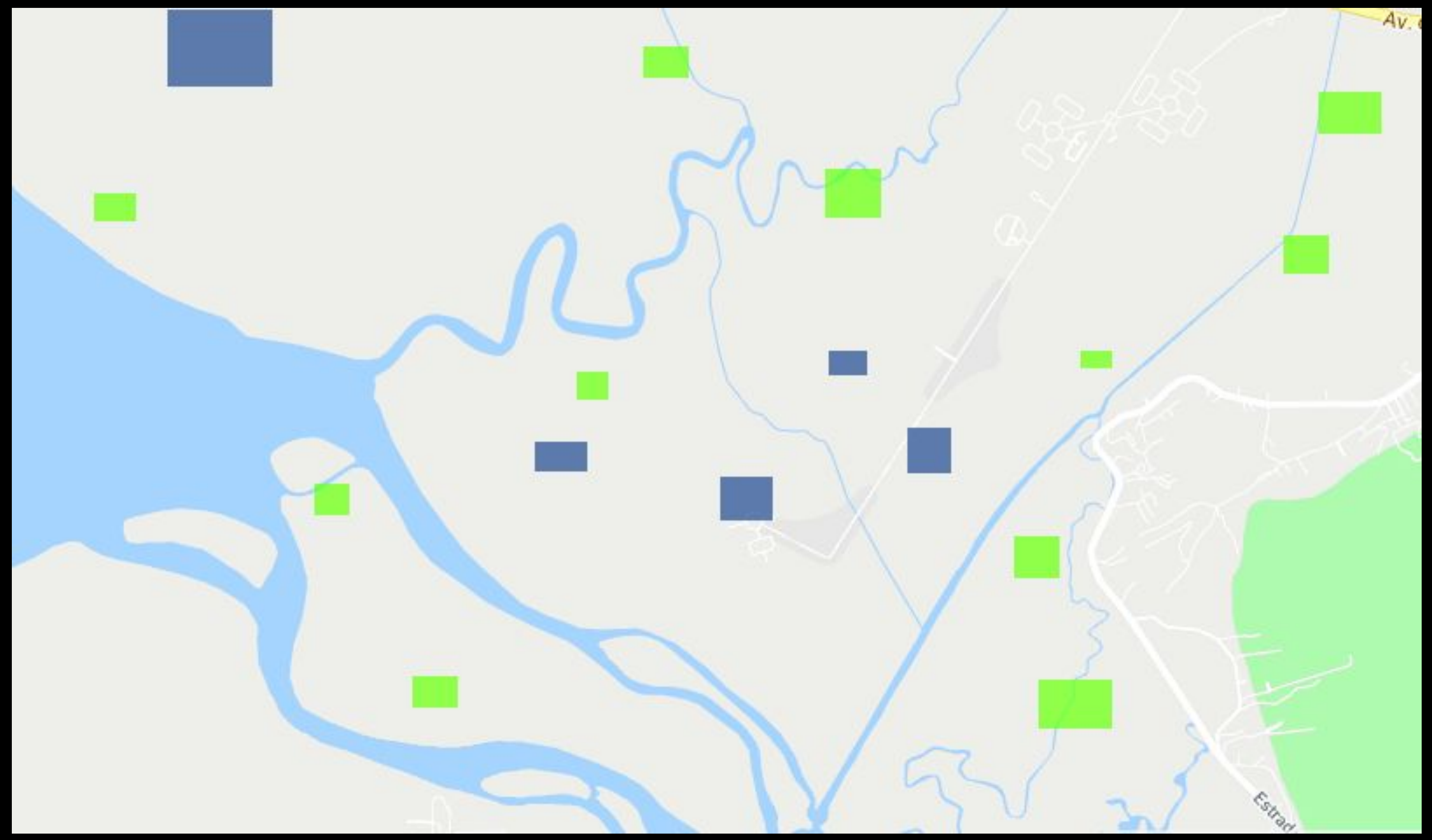
- Existing Mangrove Maps
  - Giri et al. & Global Mangrove Watch
- EO Data
  - Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Sentinel 2 MSI, and ALOS PALSAR
- Processing Techniques
  - Extent Tracking: Random Forest Classifier Algorithm
  - Health Tracking: NDVI Mean Anomaly

For more detail on a similar methodology than inspired and informed this one, see:

Lagomasino, David, Temilola Fatoyinbo, SeungKuk Lee, Emanuelle Feliciano, Carl Trettin, Aurélie Shapiro, and Mwita M. Mangora. “Measuring Mangrove Carbon Loss and Gain in Deltas.” *Environmental Research Letters* 14, no. 2 (January 2019): 025002. https://doi.org/10.1088/1748-9326/aaf0de.

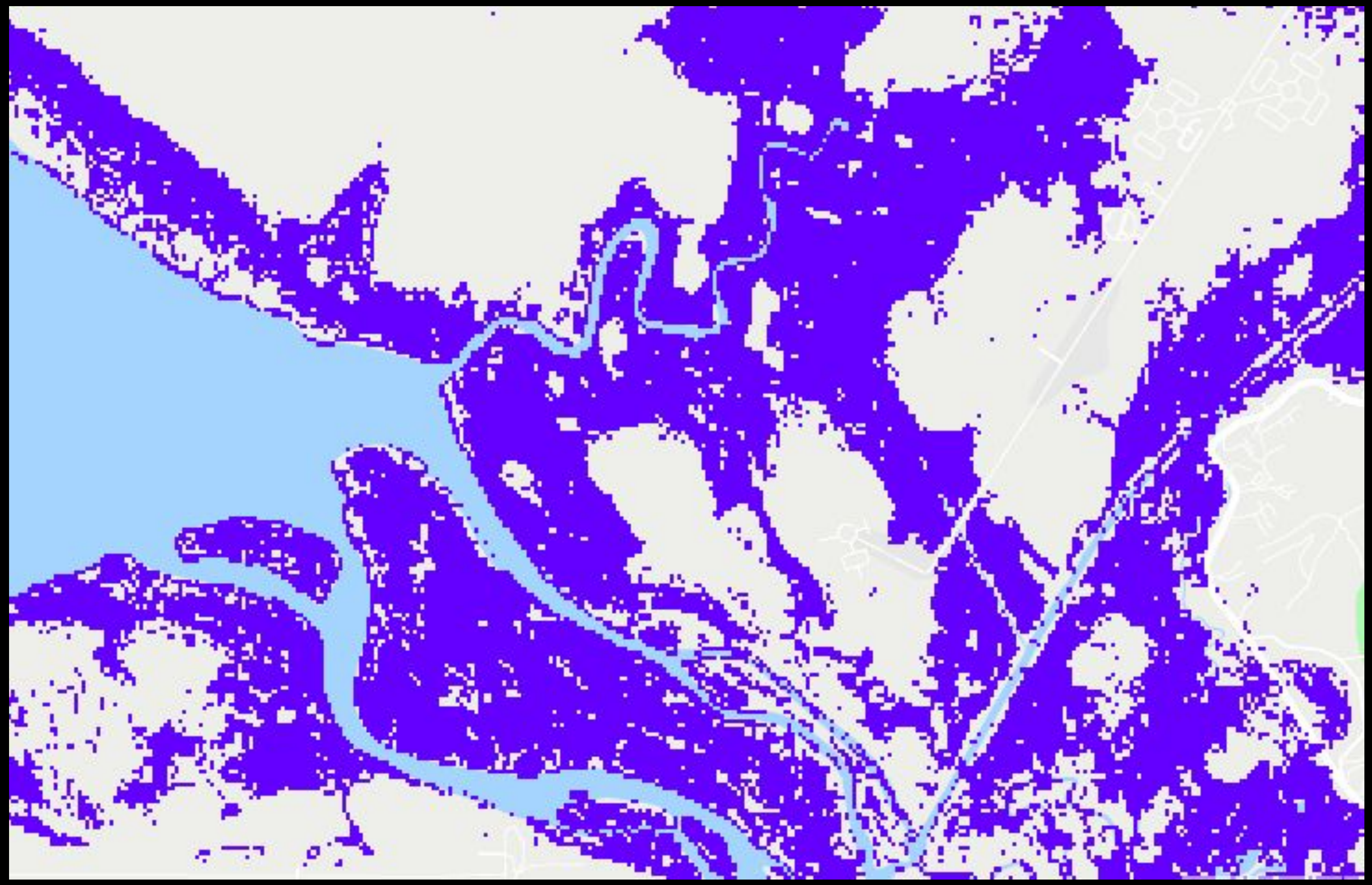
Data & Methods: Environment (cont.)

Training Data from Giri and GMW

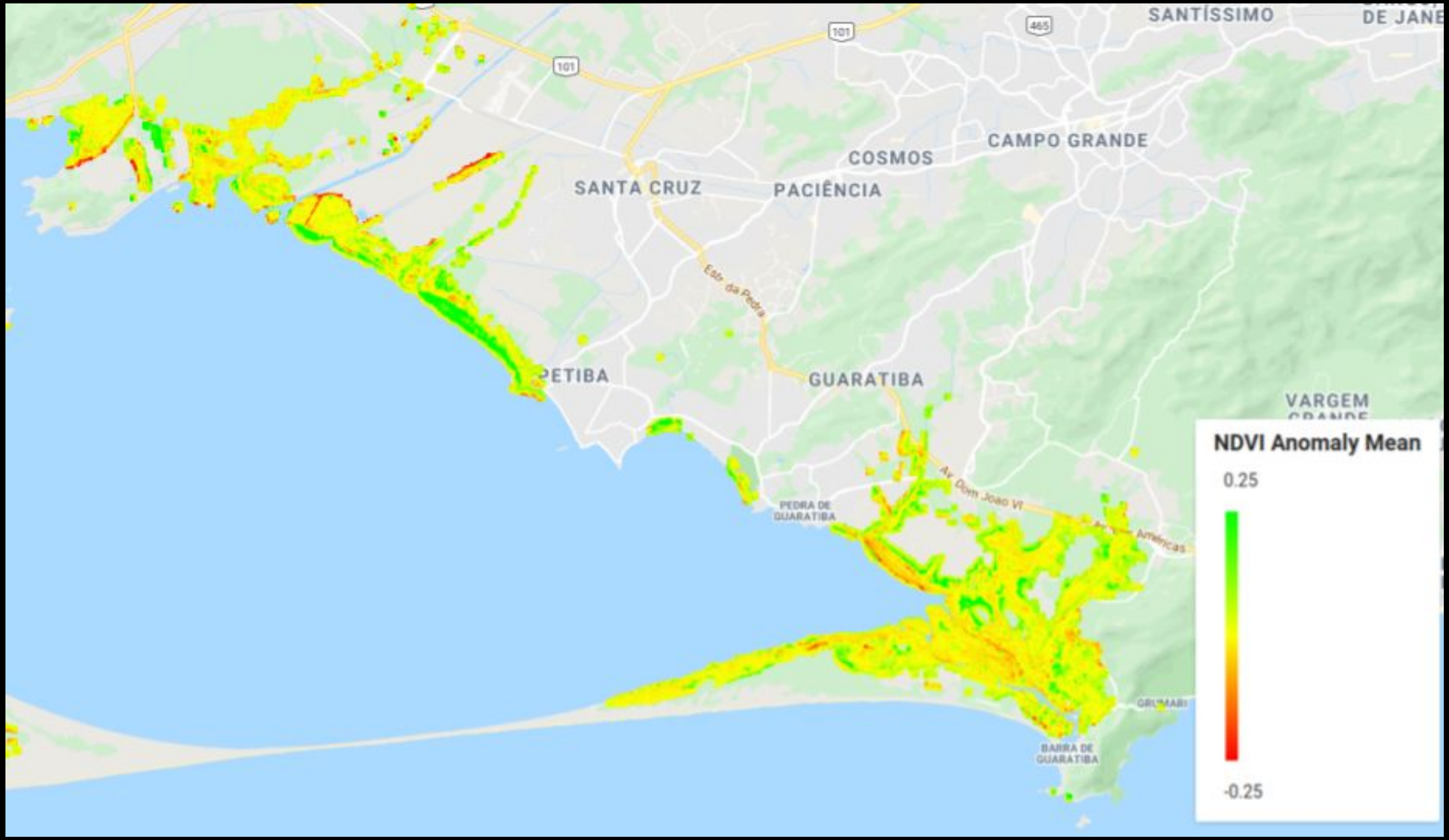


Sentinel, Landsat, and PALSAR Imagery

Classified Mangroves



Data & Methods: Environment (cont.)



- Reference period: 31/Aug/1999 to 31/Aug/2001
- Observation period: 1/Sep/2001 to 1/Sep/2018

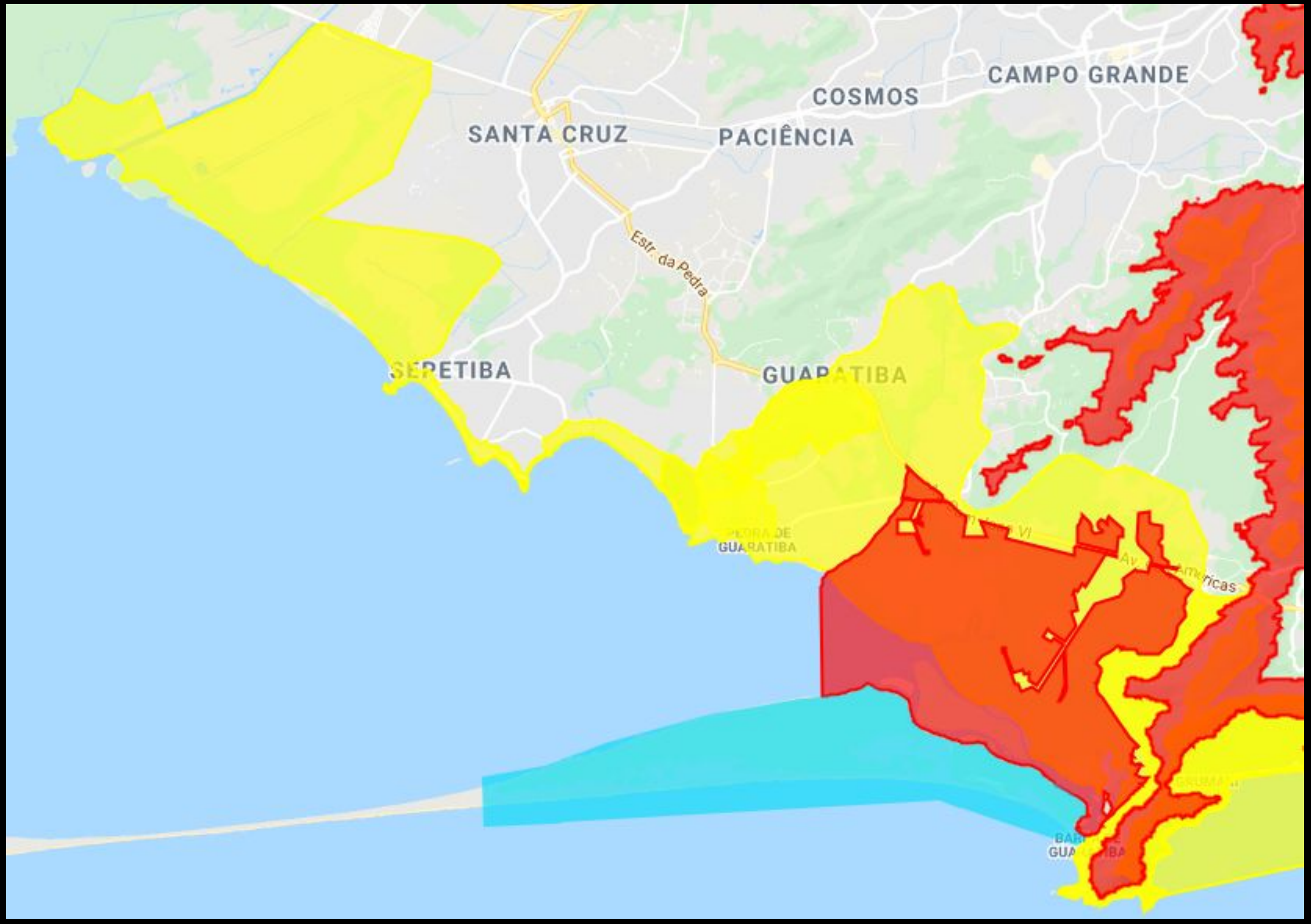
Data & Methods: Vulnerability

- Brazilian Institute of Geography and Statistics
  - Population Density, Employment (by industry), Household Size, Sewage Infrastructure, etc.
- Pereira Passos Municipal Institute of Urbanism
  - Detailed land use maps, Multidimensional Poverty Index, Informal Settlement Maps
  - Data.Rio Platform
- Literature & Planned Information To be Collected
  - Social value of carbon
  - Raw material value of mangrove ecosystem services

Data & Methods: Decision-making

- Conservation and Preservation Areas
  - Explicitly protected areas
  - Categories of urban conservation policies
- Urban Zoning Policy
  - Types of construction and industry allowed

Protected Areas	Authority
Ambiental das Brisas	Municipal
Orla da Baia de Sepetiba	Municipal
Parque Natural Municipal da Serra da Capoeira Grande	Municipal
Parque Nacional Municipal da Prainha	Municipal
Parque Nacional Municipal de Grumari	Municipal
Sepetiba II	State
Parque Estadual da Pedra Branca	State
Reserva Biológica Estadual de Guaratiba	State
Army Technological Center	National



Data & Methods: Technology

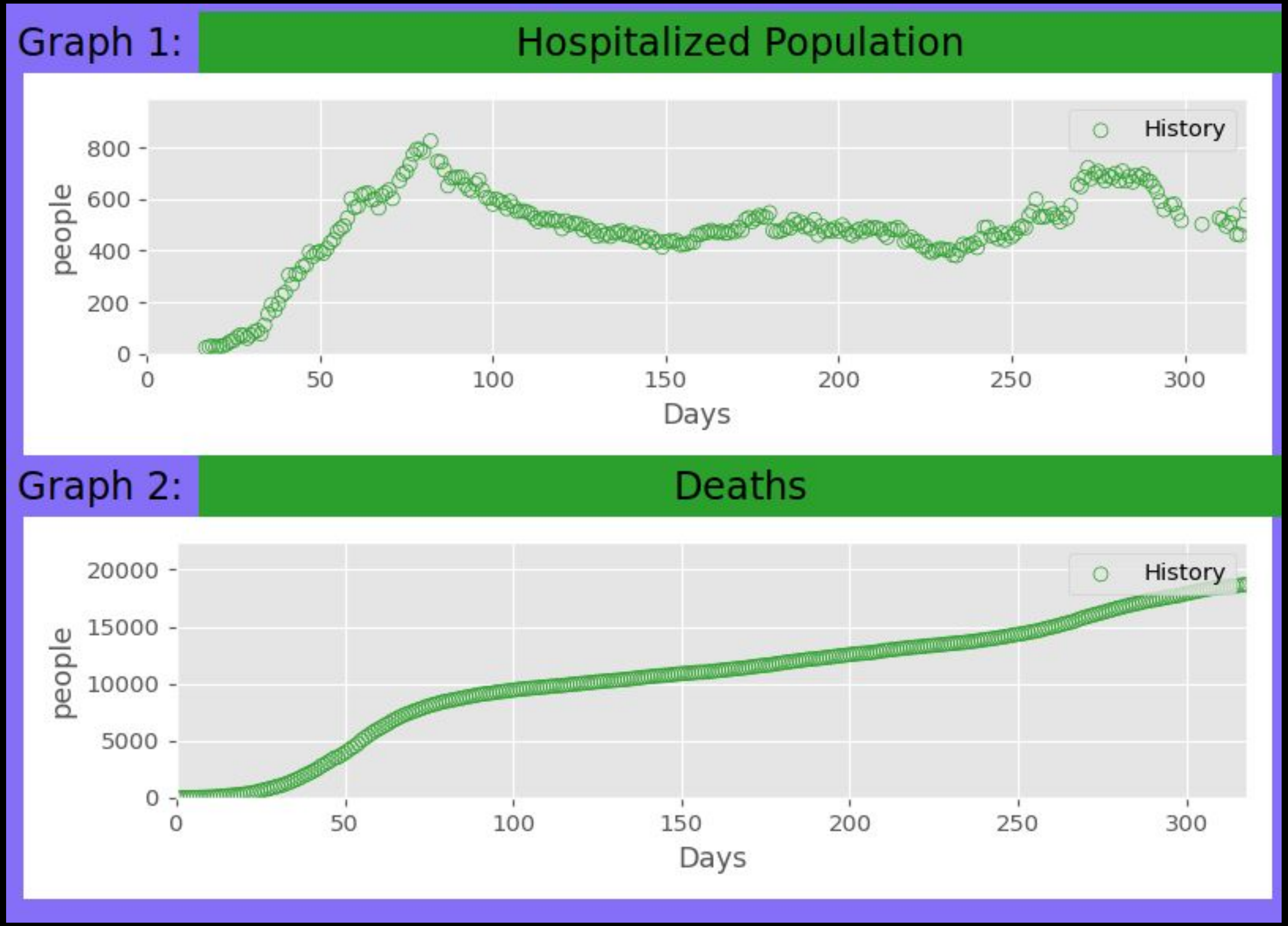
- History of EO Data Collection and Usage
  - Pereira Passos Municipal Institute of Urbanism
  - Environmental Secretariat
  - Urban Planning Secretariat
  - State Environmental Institute
  - Chico Mendes Institute for Biodiversity Conservation

IPP & SMU Usage

Year	Type of product	Platform
1975	Ortophoto	Aerial (???cm)
1999	Ortophoto	Analog camera (scanned to 85cm)
2004	Ortophoto	Analog camera (scanned to 50cm)
2006	Satellite imagery	Quickbird (60 cm)
2008	Satellite imagery	Quickbird (60 cm)
2009	Ortophoto	Digital camera (25 cm)
2010	Lidar survey	Aerial (10 pts/m2)
2010	Ortophoto	Digital camera (25 cm)
2011	Ortophoto	Digital camera (20 cm)
2012	Ortophoto	Digital camera (20 cm)
2013	Lidar survey	Aerial (2 pts/m2)
2013	Ortophoto	Digital camera (10 cm)
2015	Ortophoto	Digital camera (15 cm)
2016	Satellite imagery	Worldview 3 (30 cm)
2017	Satellite imagery	Worldview 2 (46 cm)
2018	Satellite imagery	Worldview 3 (32 cm)
2019	True Ortophoto	Digital camera (15 cm)
2019	Lidar survey	Aerial (8 pts/m2)

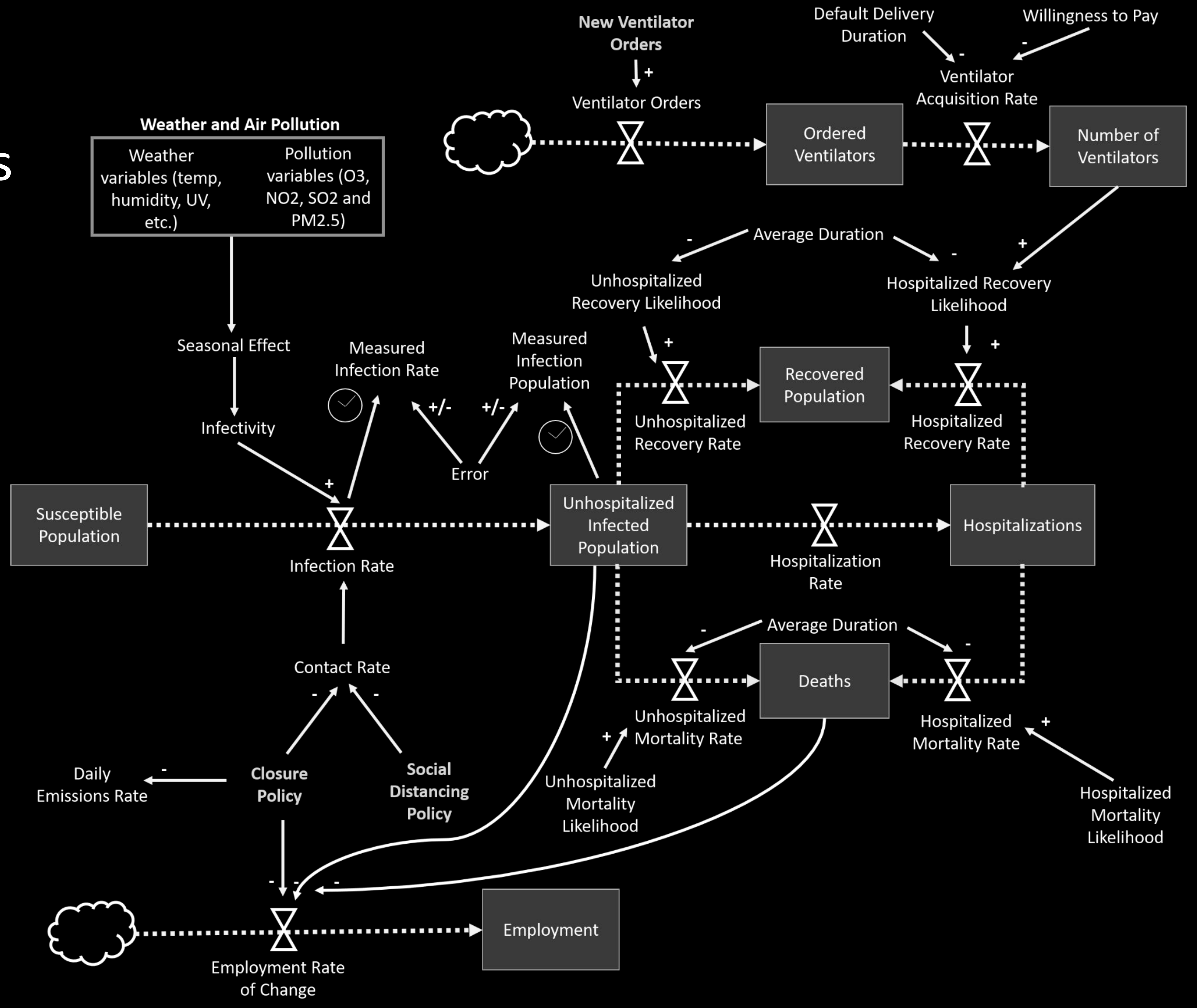
Data & Methods: Public Health

- COVID-19 health data collected by local authorities
  - Daily infections, hospitalizations, deaths, and recoveries
  - Daily PCR tests
  - Hospital bed capacity and availability
  - Ventilator use and availability
  - Vaccination rates



Data & Methods: Public Health

- Epidemiological Model: SEIR
- Modeling Approach: System Dynamics
- Integrates aspects of other Vida components
- Current version is non-spatial
- Adjusting assumptions and policy decisions can generate alternative scenarios

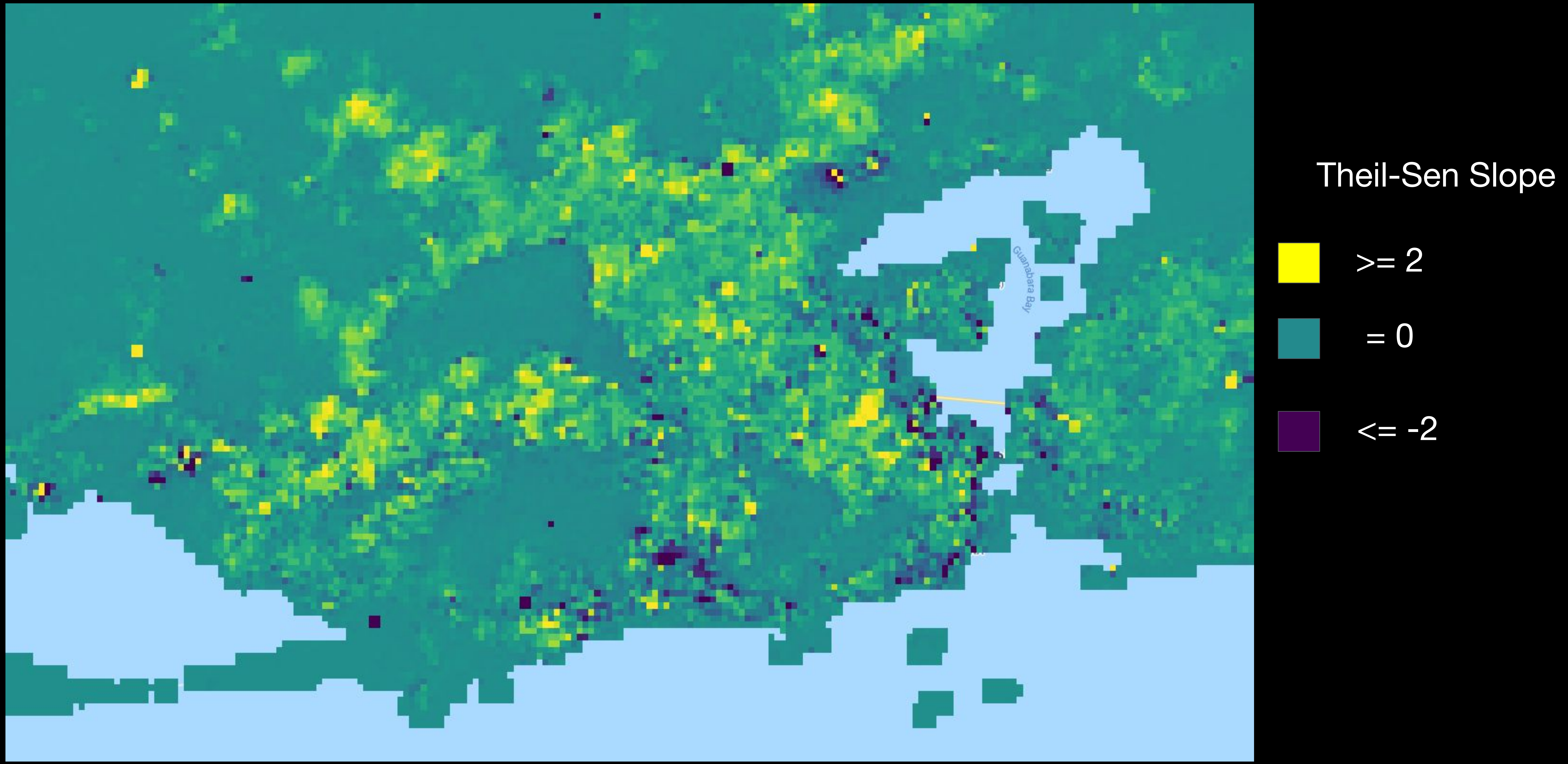


Data & Methods: Environment

- Air Quality (O3, NO2, SO2, PM2.5, PM10)
  - Remote: Sentinel 5P
  - In-Situ: Monitoring Stations (Brazil & Chile)
- Nightlights
  - VIIRS: VNP46A2 & VNP46A3
- Water Quality (NDTI, NDWI, other indices)
  - Landsat 7 ETM+, Landsat 8 OLI, and PlanetScope

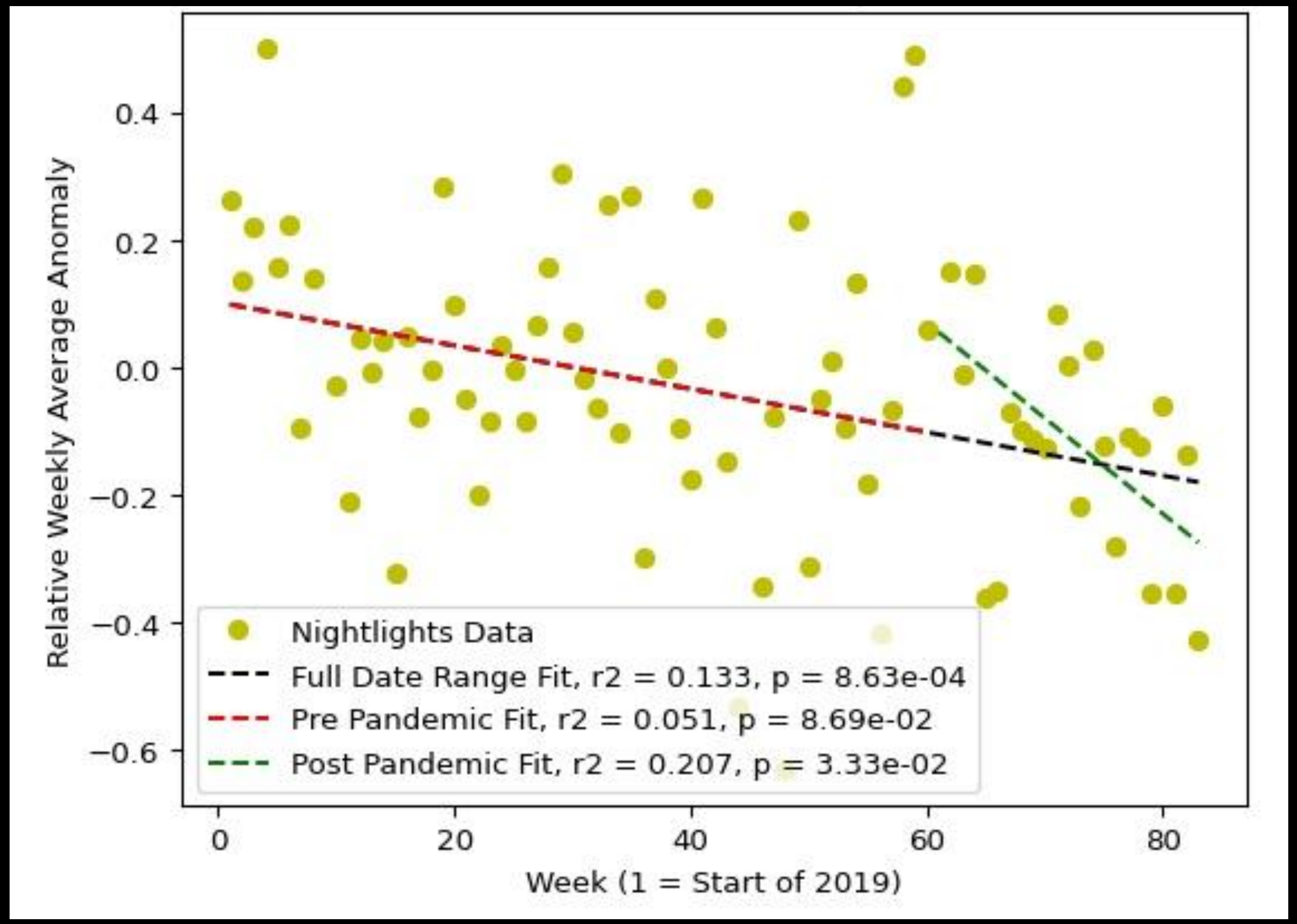
Methodology

Ex) Rio de Janeiro Nightlight Changes (March - July, 2020)

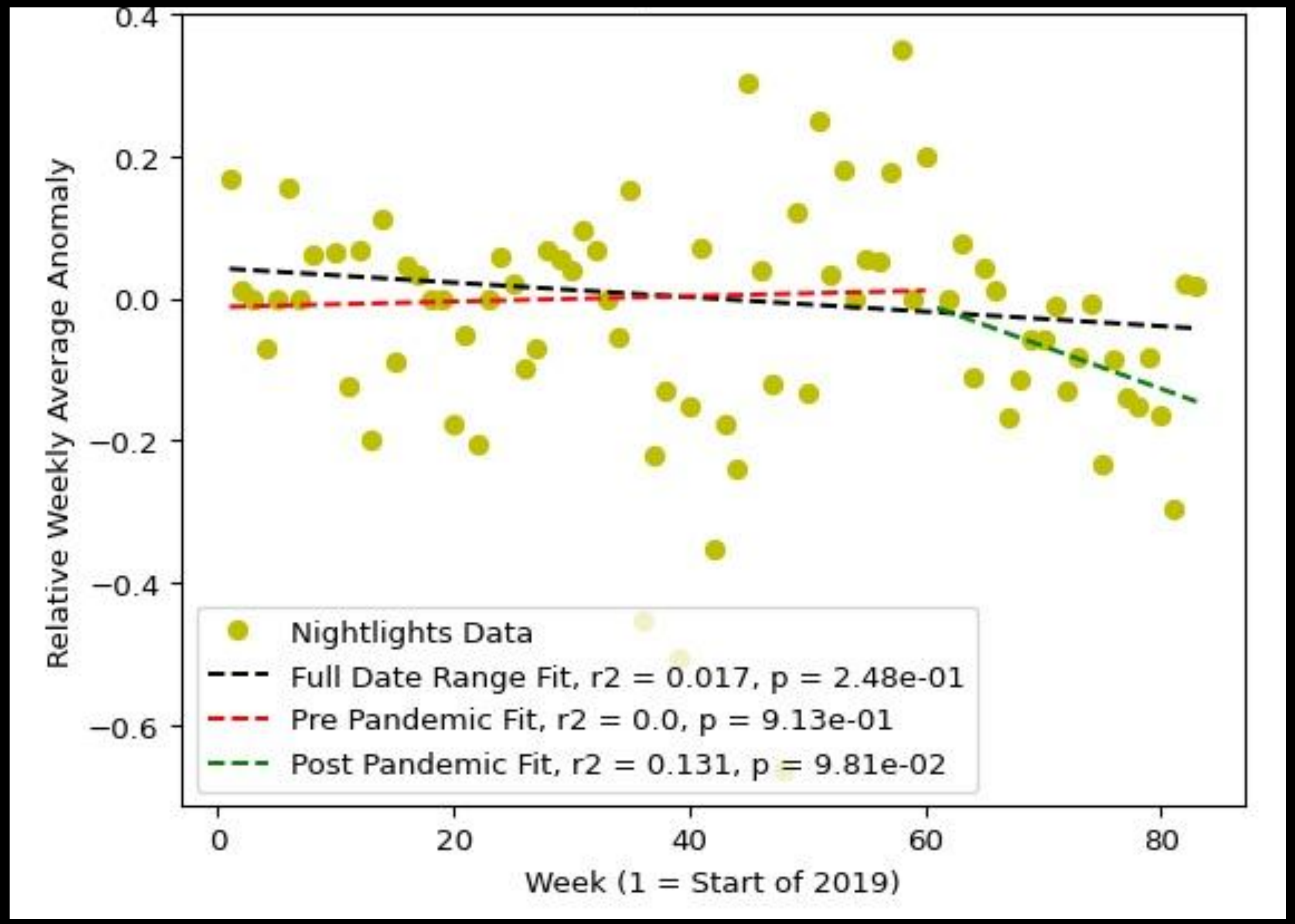


Rio de Janeiro, Brazil

Santos Dumont Airport

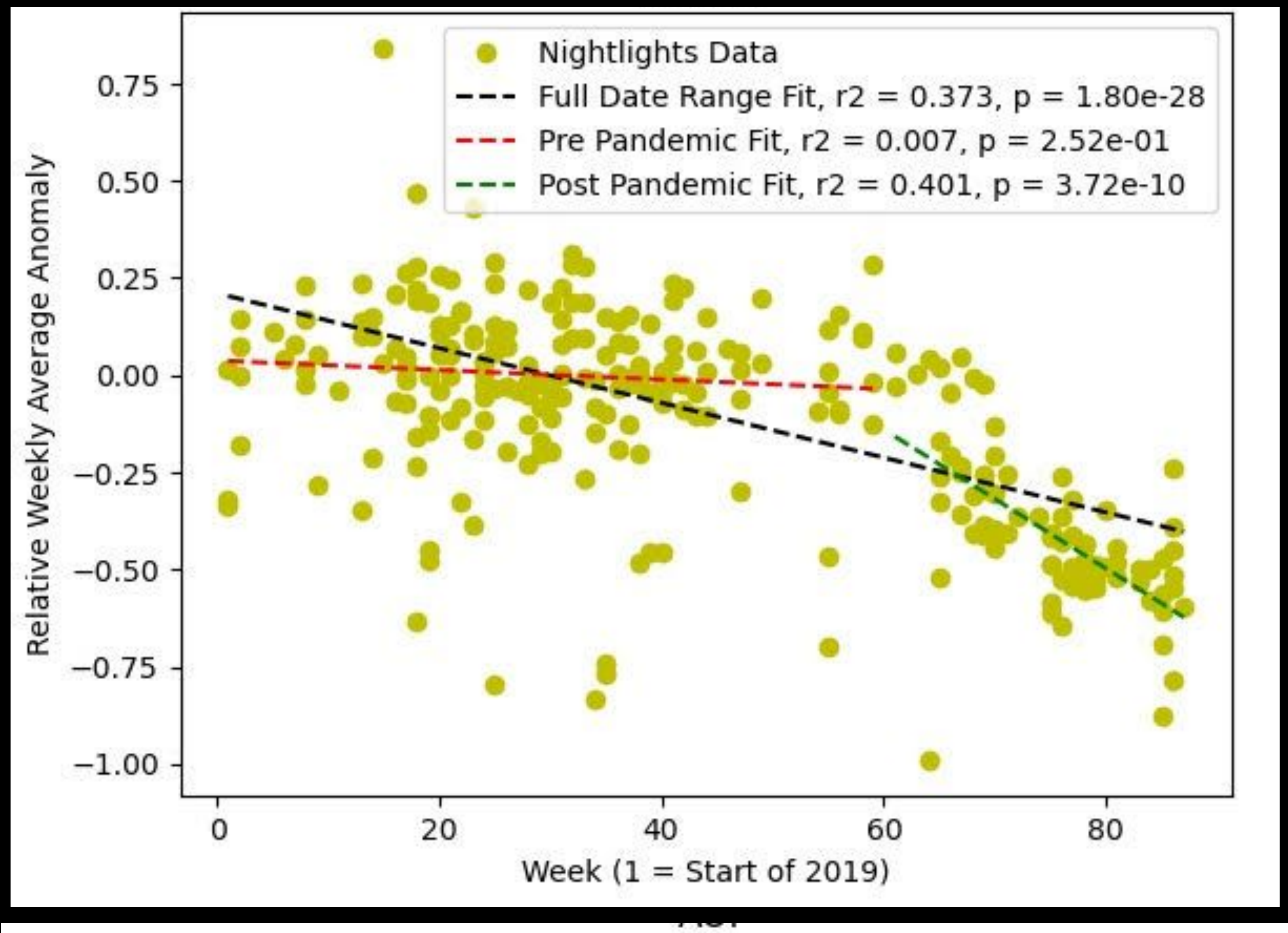


Ipanema

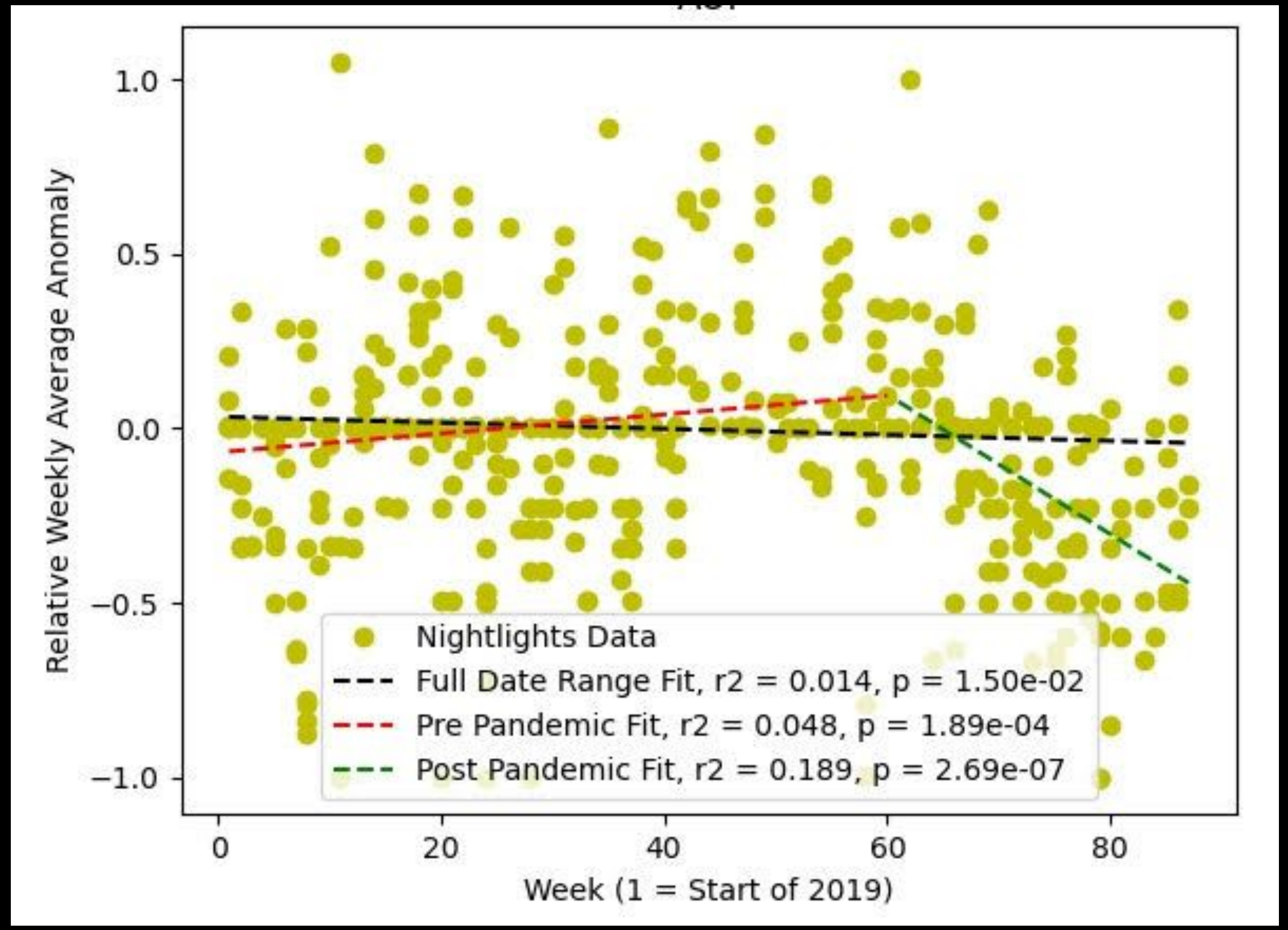


Bali, Indonesia

Ngurah Rai Airport



Island

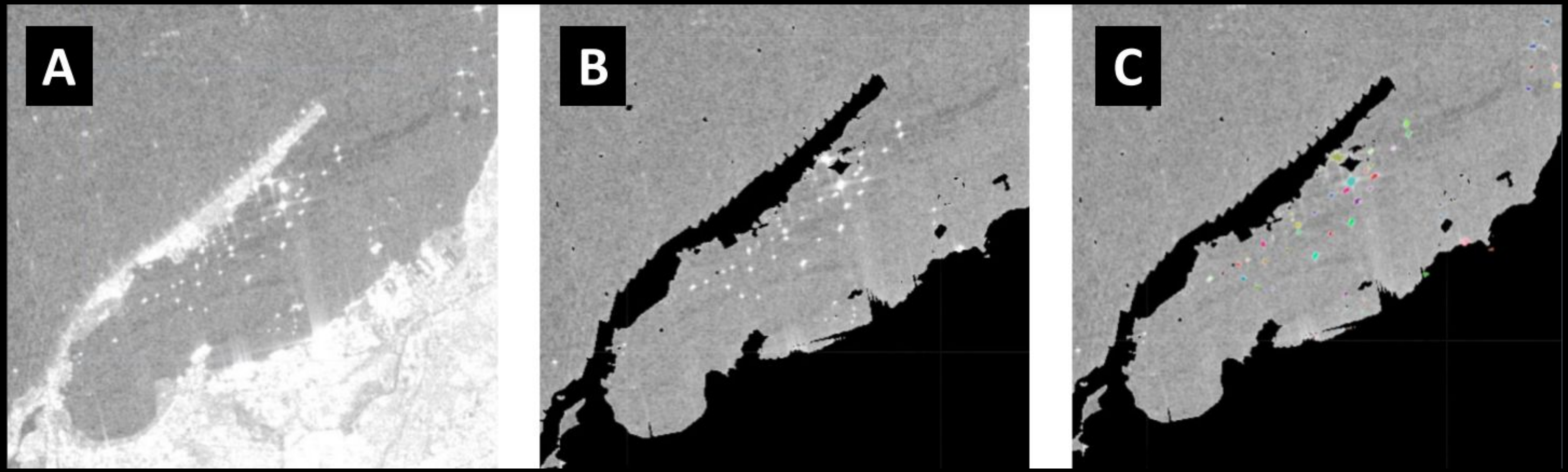


Ex) Rio de Janeiro PM10 Changes

- Relatively small changes in air quality detected once seasonal and long-term trends are taken into account
- What changes do exist point to an increase in PM10

Barrio	Code	Type	Pre vs Post T-Test P-Value	Anderson Darling P-Value	Change in Mean (Pre vs Post COVID)
Copacabana	AV	Tourist	0.956	0.1438	-0.0003
Bangu	BG	Mixed Use/Residential	0.2645	0.001	0.0042
Centro	CA	Downtown/Business District	0.0119	0.00002	0.0138
Campo Grande	CG	Mixed Use/Residential	0.3806	0.0217	0.0051
Irajá	IR	Urban/Residential	0.6295	0.0023	0.0022
Pedra de Guaratiba	PG	Rural	0.7844	0.0801	0.0014
São Cristóvão	SC	Downtown/Recreational	0.3913	0.0015	0.0041
Tijuca	SP	Mixed Use/Residential	0.0839	0.00003	0.0097

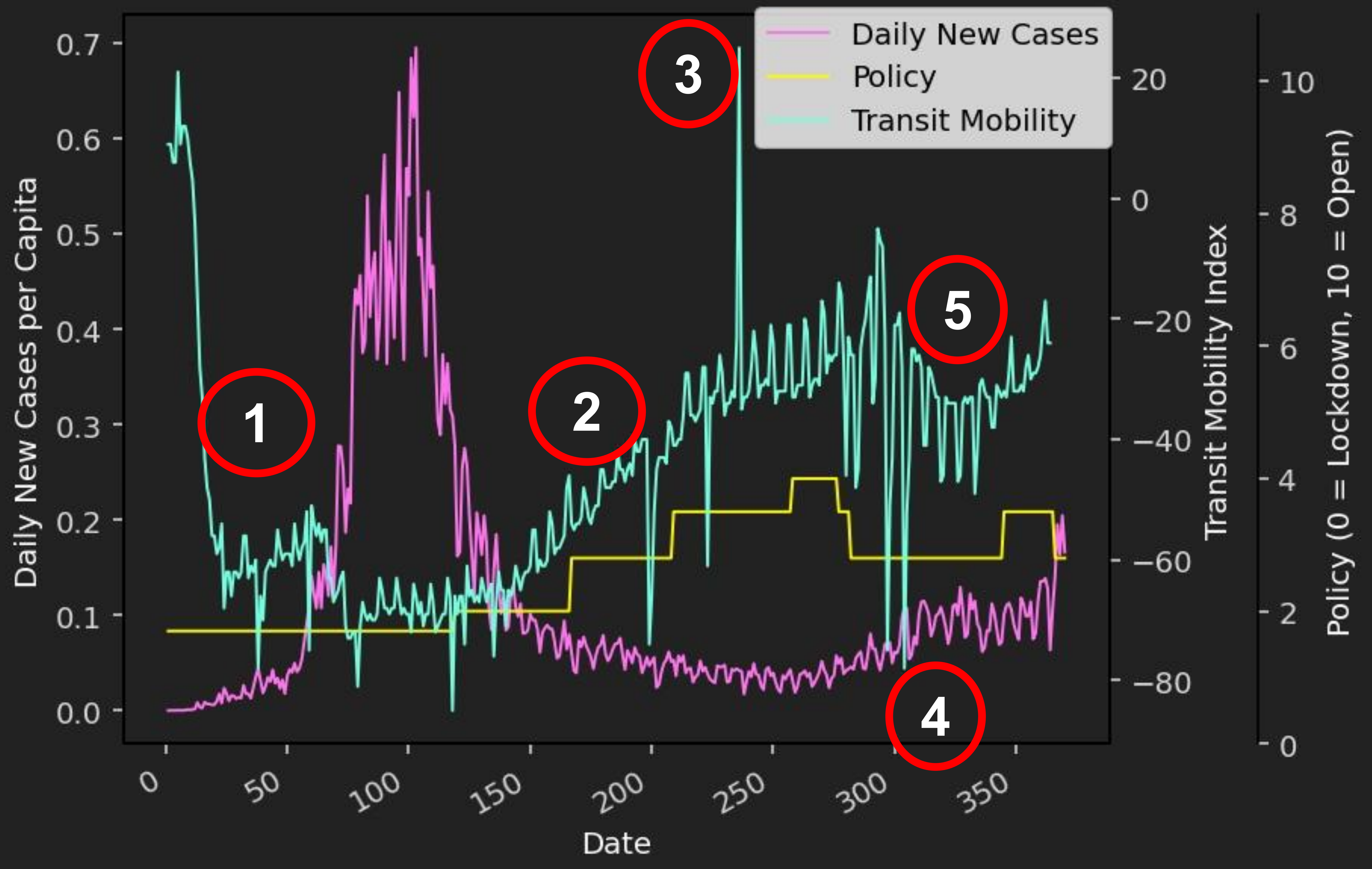
Data & Methods: Vulnerability



Images and analysis done by Amanda Peyton

- Socioeconomic Data
  - Ex) Poverty Rates, Employment Rates, GDP
  - Sources: Local government authorities, NASA SEDAC
- Mobility & Transit Data
  - Telecoms-based mobility data (as reported by Google and local authorities)
  - Public transit usage (as reported by local authorities)
  - Airline Flights (as reported by local authorities)
  - Ship counts and wait periods (as detected in Sentinel radar imagery)

Ex) Metropolitana, Chile Mobility Changes



1. Mobility falls, notably *after* the initial wave of policy restrictions went into effect
2. As New Cases decline and policy relaxes, mobility rises
3. Chile has a constitutional referendum
4. Christmas & New Years
5. A rise in new cases prompts a policy restriction, decreasing mobility temporarily

Data & Methods: Decision-making

- COVID-19 Social Distancing Requirements & Closures
  - Announcements, histories, definitions, and conditions created by local authorities
  - Ongoing effort to compare policies using standardized, quantitative comparisons based on the CoronaNet Research Project

Recovery Plan Indicators — updated 01/10/2020

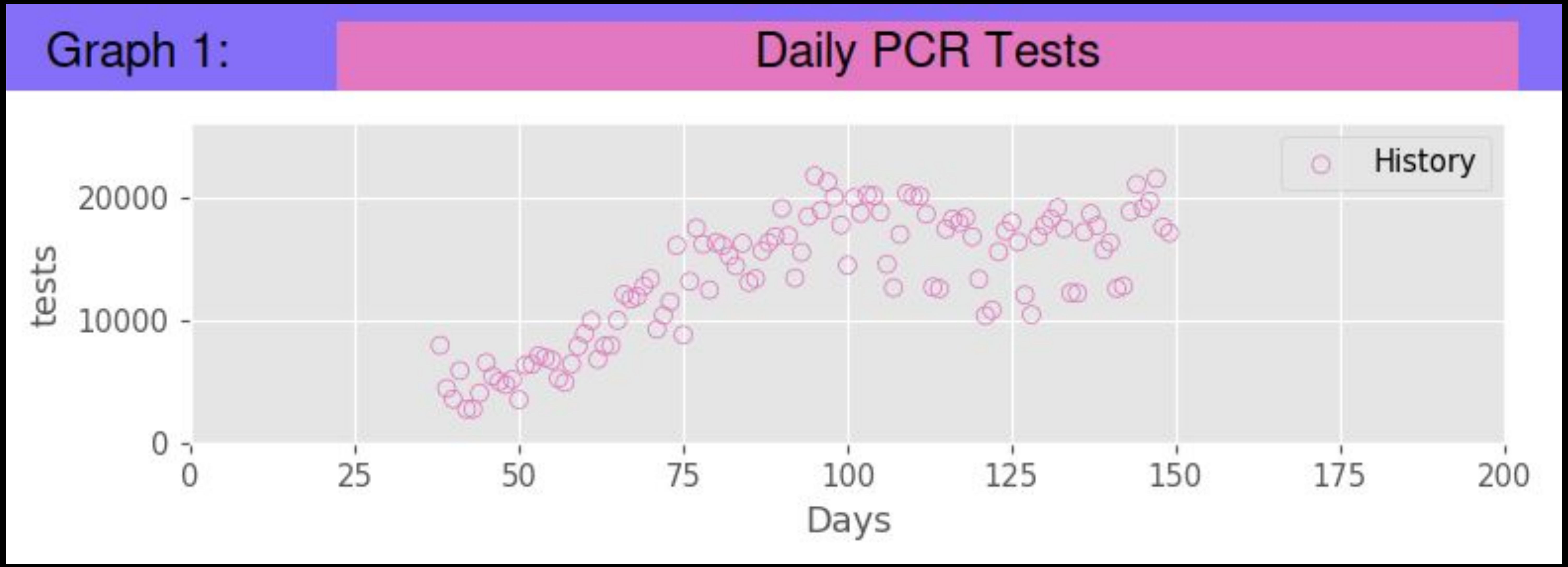
Reference Date: 07/29/2020

GROUP	ANALYSIS PARAMETERS	#	PRIMARY INDICATORS	Comparison with previous days: F-1	D-5	D-4	D-3	D-2	D-1	07/16/2020 Ref. Previous Phase	7/29/2020 Result	WE ARE IN PHASE 6B (Since 01/10/2020): PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
HEALTH SYSTEM RESPONSE CAPACITY	Capacity of ICU beds	1	Percentage of occupancy of dedicated adult ICU beds COVID (ICU SRAG) METRO I SUS bed (7-day moving average)	✗	✓	✓	✓	✓	✓	69.4	71.2	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
		2	Occupancy rate of supplementary sector ICU beds (moving average 7 days) (a)	✗	✗	✗	✗	✗	✗	67.9	70.0	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
		3	Percentage of occupancy of life support beds REDE SUS Territory of the municipality (moving average 7 days)	✗	✓	✓	✓	✓	✓	76.0	77.0	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
		4	ICU COVID beds (REDE SUS) per 100k inhabitants (b)	✗	✗	✗	✗	✗	✓	6.59	6.41	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
TRANSMISSION LEVEL	Variation of deaths	5	Death Variation Rate by COVID19 in each period (Information released at 6 pm on the day, referring to the previous day) (c)	✗	=	✗	=	✓	✓	0.92	0.95	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
	Growth of hospitalized cases	6	Rate of Variation of Inpatients (Clinical + ICU) in each period (Information released at 6 pm on the day, referring to the previous day) (c)	✗	✓	✓	✓	✓	✓	0.92	0.95	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
	Variation of new cases	7	Number of cases reported by Influenza Syndrome (SG) in the last two epidemiological weeks of notification (d)	✓	✓	✓	=	=	=	16,554	13,931	Favorable	Favorable	Favorable	Favorable	Favorable	Not Favorable
OPINION FOR OPENING PHASE ACCORDING TO PRIMARY INDICATORS												Favorable	Favorable	Favorable	Favorable	Favorable	Not Favorable

For more information, see https://riocontraocorona.rio/ and http://inteligencia.rio/planoretomada

Data & Methods: Technology

- Earth observation systems are still relevant!
  - Additional relevant platforms like VIIRS, MODIS, Planet, Maxar, etc.
- Various public health sensing technologies and regimes
  - PCR and other tests to identify the actively infected
  - Antibody tests to identify those previously infected



User Interface

User Interface