NASA LCLUC Spring 2019 Science Team Meeting: Synthesis Studies

Synthesis of Drivers, Patterns, and Trajectories of LCLUC in Island Ecosystems

Stephen J. Walsh, PI

Lyle V. Jones Distinguished Professor
Department of Geography

Director, Center for Galapagos Studies &
Galapagos Science Center, San Cristobal Island

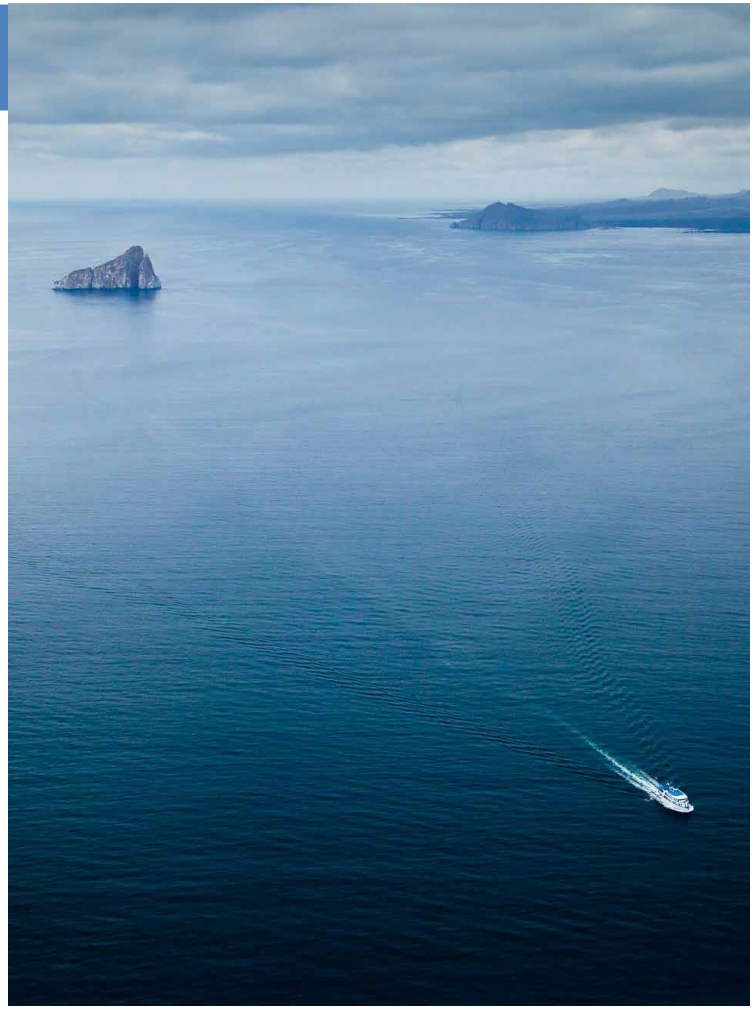
University of North Carolina at Chapel Hill

Islands Science Team

Richard Bilsborrow, UNC-Chapel Hill
Phil Page, UNC-Chapel Hill
Brian Frizzelle, UNC-Chapel Hill
Francisco Laso, UNC-Chapel Hill
Laura Brewington, East-West Center, Hawaii
Yang Shao, Virginia Tech University
Hernando Mattei, University of Puerto Rico

Synthesize LCLUC for Global Islands

- ***Perform a meta-analysis*** of socio-economic, demographic, tourism, community infrastructure, geographic and biophysical drivers of LCLUC as well as satellite imagery, analyses, and derived-products for global islands.
- ***Examine existing image archives*** for all available imagery for islands (e.g., USGS Global Visualization Viewer, USGS EarthExplorer, NASA Earth Exchange).
- ***Assess primary (i.e., Hawaiian Islands, Galapagos Islands, and Puerto Rico),*** secondary (e.g., Fiji, Azores, Canary, Madagascar) islands that are informed through the meta-analysis, and tertiary sites for generalizability.
- ***Develop spatial/statistical rules and relationships for the social-ecological drivers of LCLUC for islands; create dynamic systems models for the primary set of islands***, extended to the secondary set for testing; and generalize across diverse island ecosystems using globally available, gridded data to create a global island template of LCLUC and social-ecological drivers.



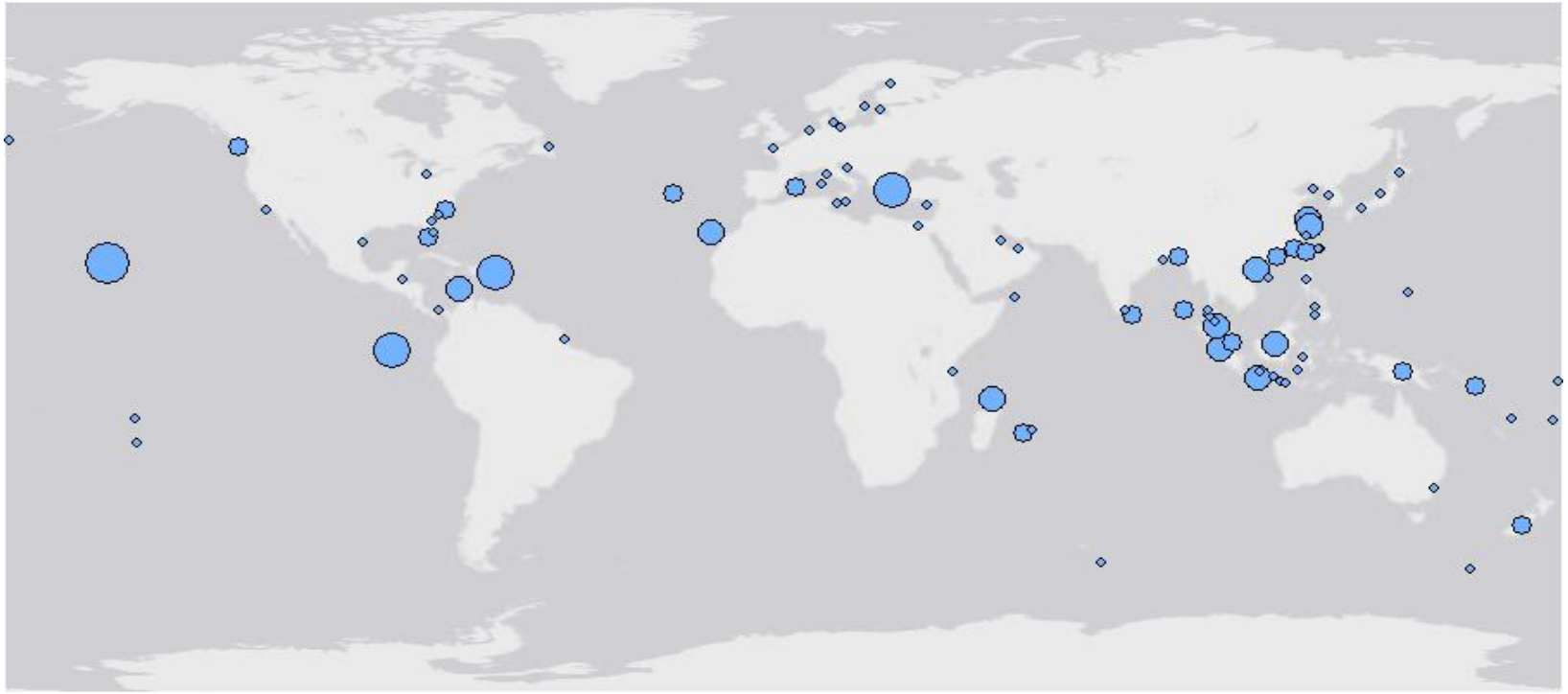
Socio-Economic Searches (1988-2018) Keyword Examples & Tiers 2/1 Findings (309 Papers)

- ***Search of Eight Databases – PubMed, Scopus, Web of Science, GEOBASE, GeoRef, PAIS, IBSS, Environment Complete***
- LCLUC (223/50)
- Agriculture, Deforestation, Reforestation (149/23)
- Population Migration & Fertility (81/15)
- Tourism & Household Impacts (99/20)
- Urbanization & Infrastructure (106/28)
- Climate Change (14/3)
- Trade (14)
- Econometric Modeling, Scenario System Modeling (164/34)
- Ecosystem Goods & Services (97)

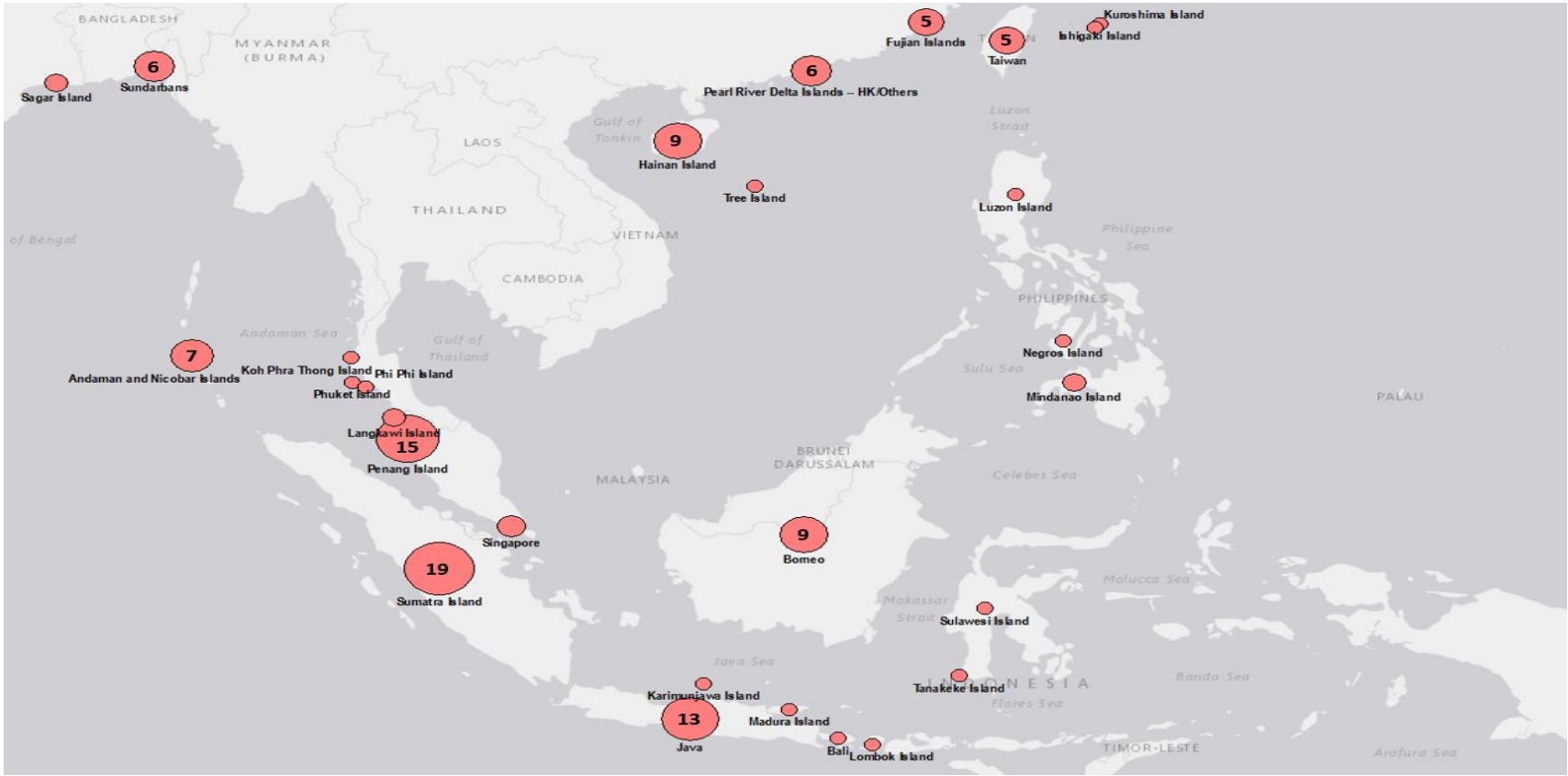
Remote Sensing of LCLUC (1988-2018) Keyword Examples & Tiers 2/1 Findings (406 Papers)

- ***Categorization by Archipelago, Country, RS Data, Drivers, Methods & Products, Latitude/Longitude***
- ***Papers Summarized by processes (e.g., deforestation) & variables (e.g., land tenure); analysis methods (e.g., logistic regression); findings & recommendations***
- Satellites
- Classification
- Change-Detections
- Sensor Fusion
- Pixel vs. Object Based Image Analysis
- Time-Series Analysis
- Vegetation Indices

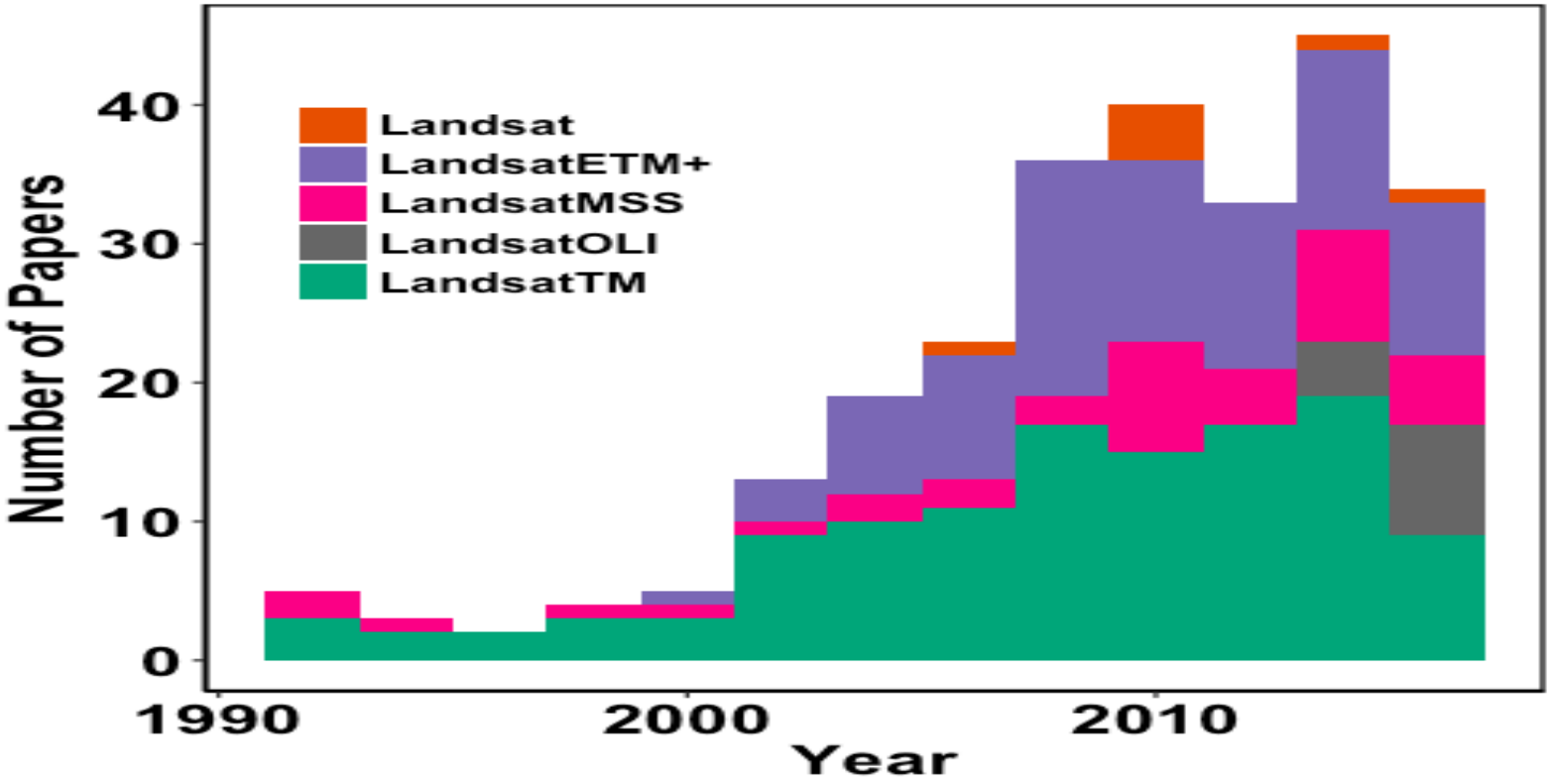
Global Islands – Studies & Papers



Southeast Asian – Studies & Papers by Island



Landsat Papers by Year

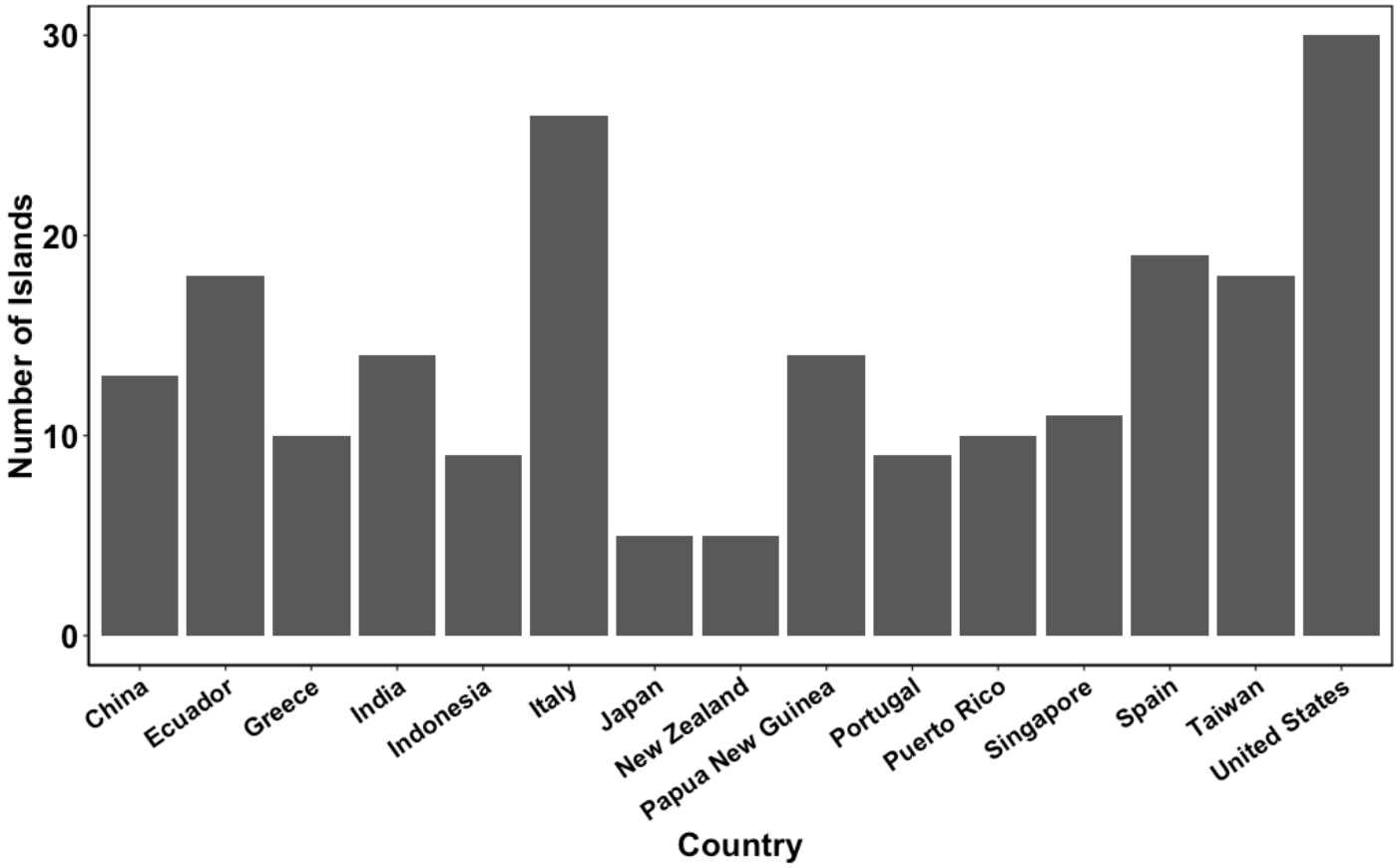


Orange – not sensor specific

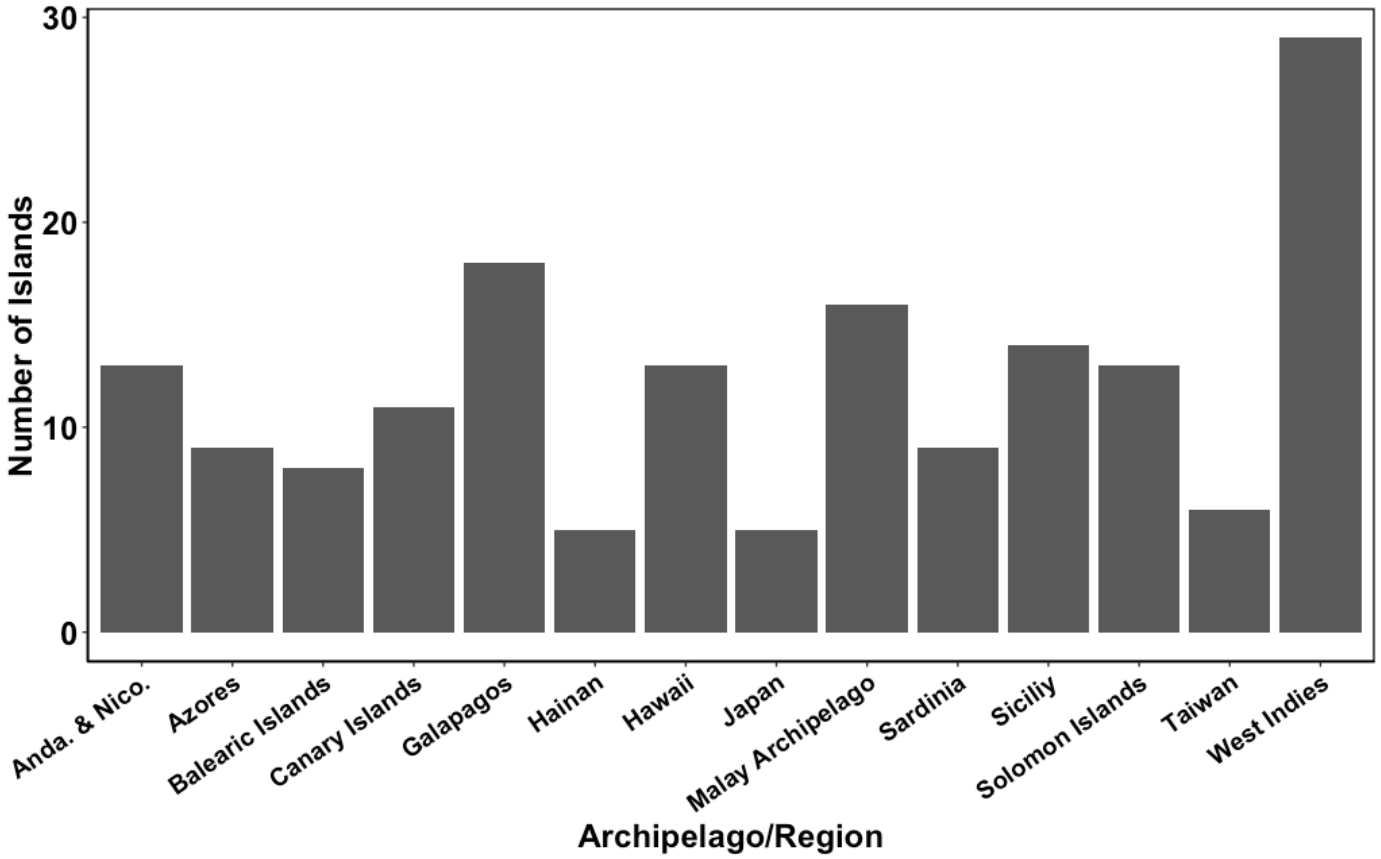
Weigelt, P., Jetz, W., & Kreft, H. (2013). Bioclimatic and Physical Characterization of the World's Islands. Proceedings of the National Academy of Sciences, 110(38): 15307–15312.

- Bioclimatic and physical characterization of the world's islands – standardized dataset to perform a comprehensive global environmental characterization for 17,883 of the world's marine islands >1 km^2 (~98% of total island area). We use island area, mean temperature, mean precipitation, seasonality in temperature and precipitation, past climate change velocity, elevation, isolation, and past connectivity as key island characteristics and drivers of ecosystem processes.

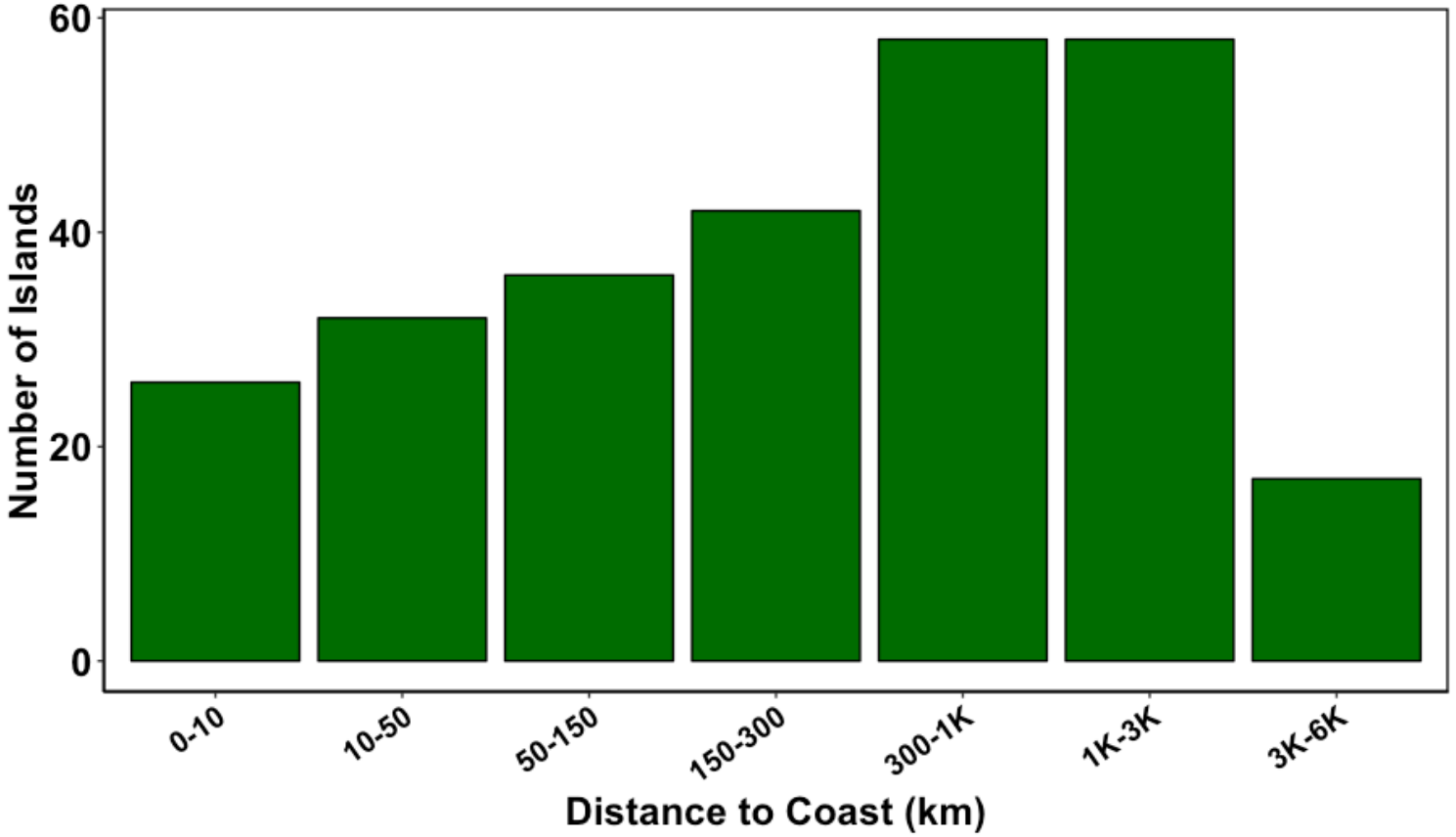
Number of Islands in our Study by Country, only Countries with >5 Islands



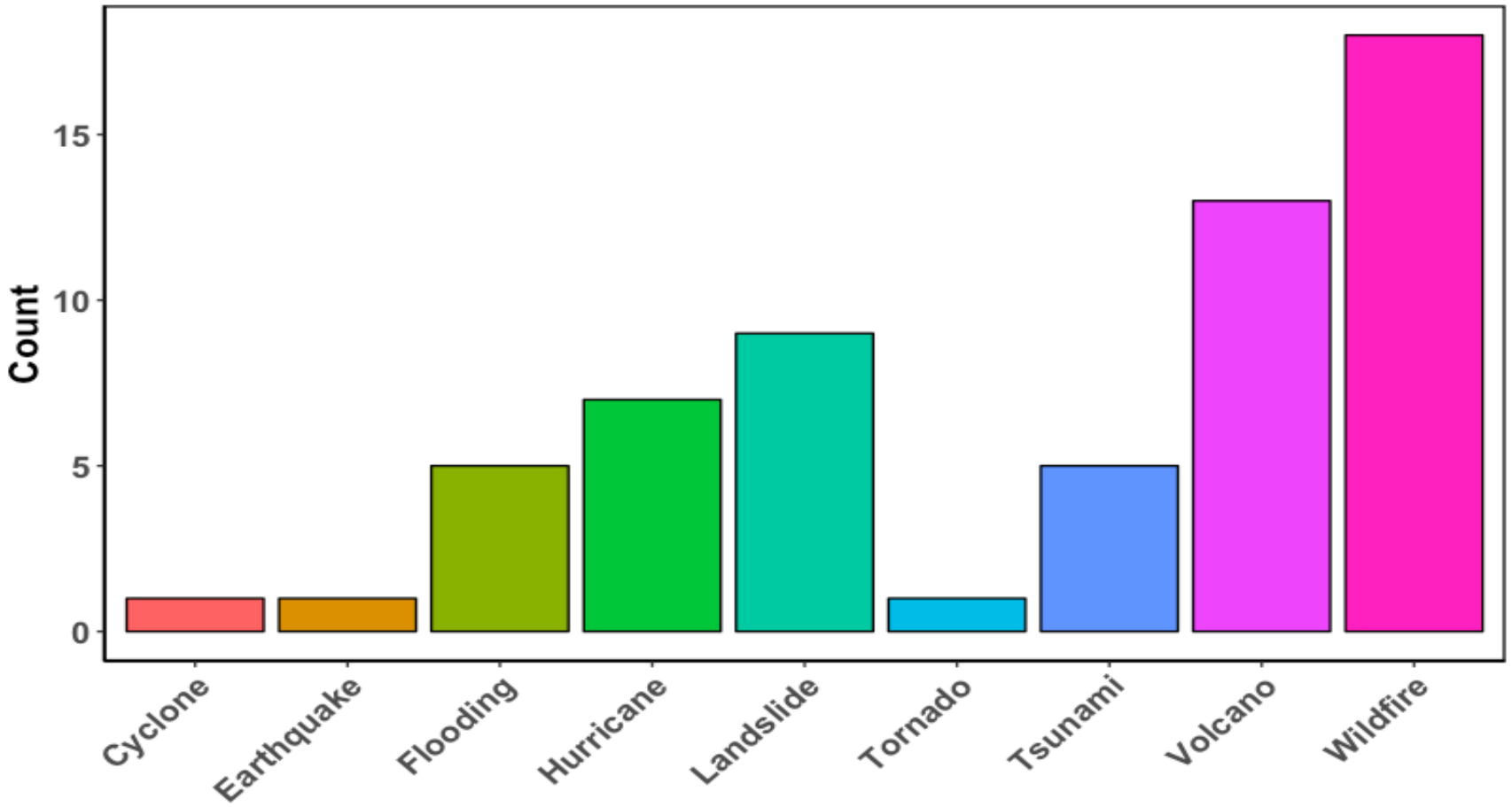
Number of Islands in our Study by Island Group/Archipelago, only Groups with >5 Islands



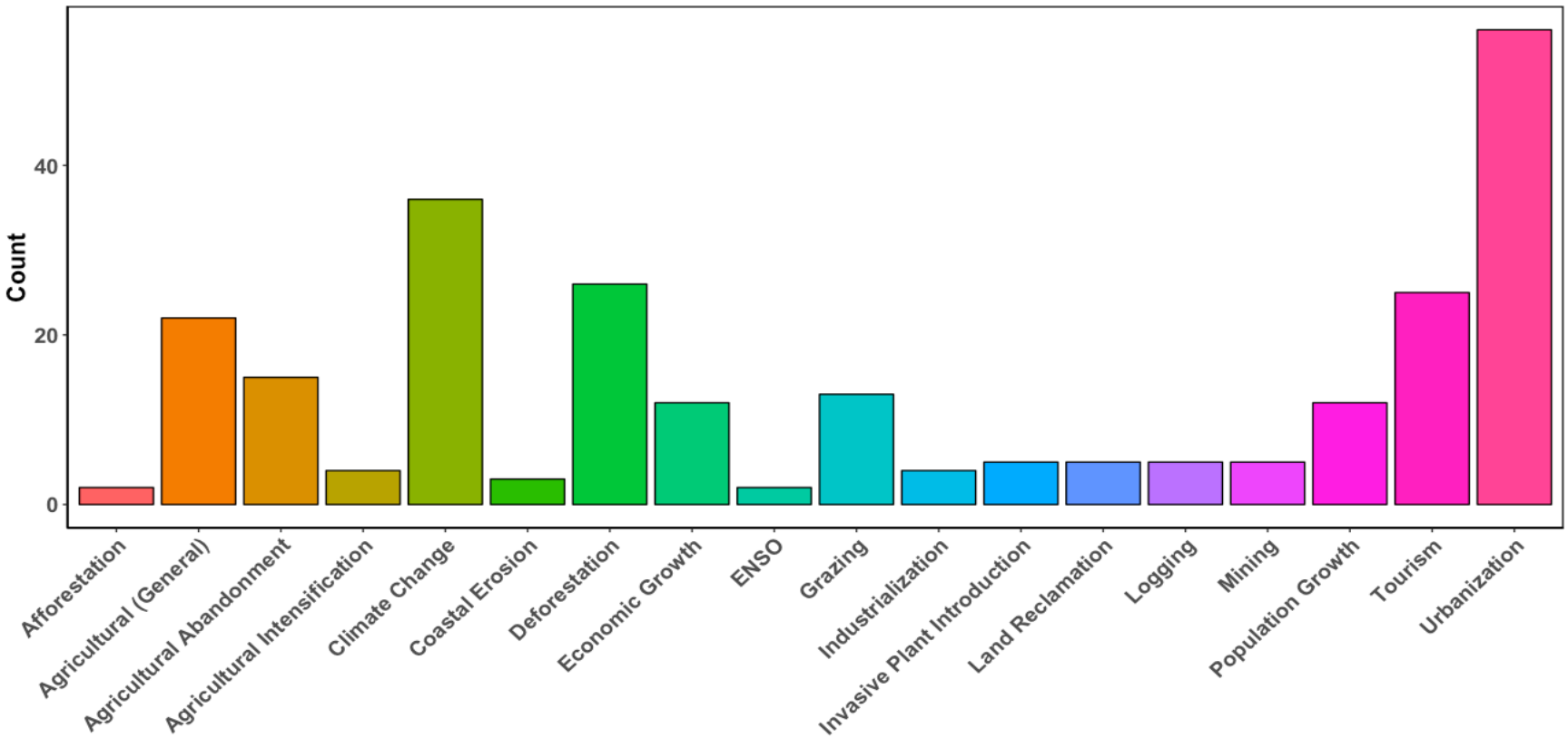
Distance to Mainland of Islands in our Study



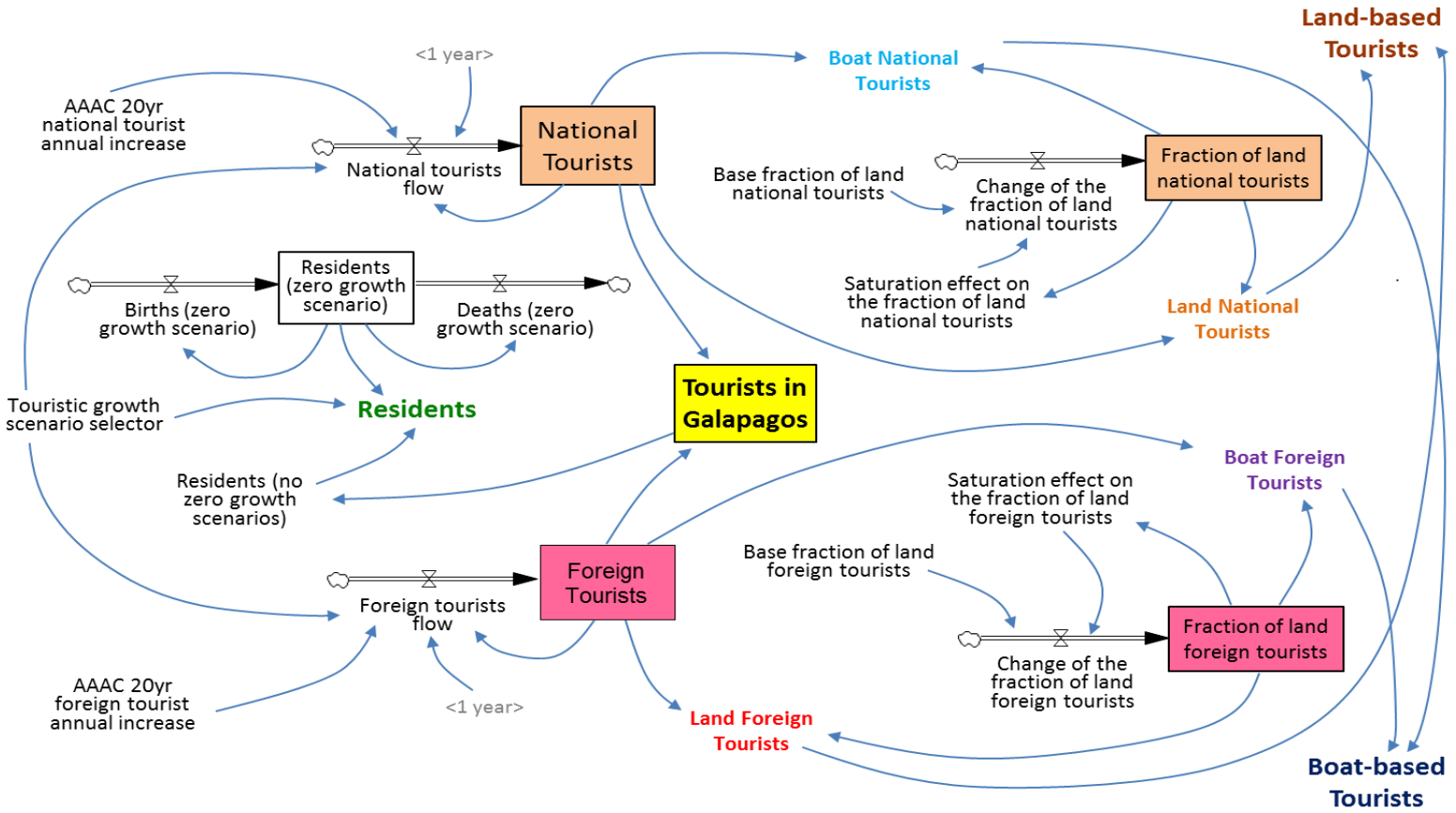
Disaster-Related – Studies & Papers



Anthropogenic-Related – Studies & Papers



Stock-Flow Diagram of the Number of Yearly Tourist Arrivals & Resident Populations

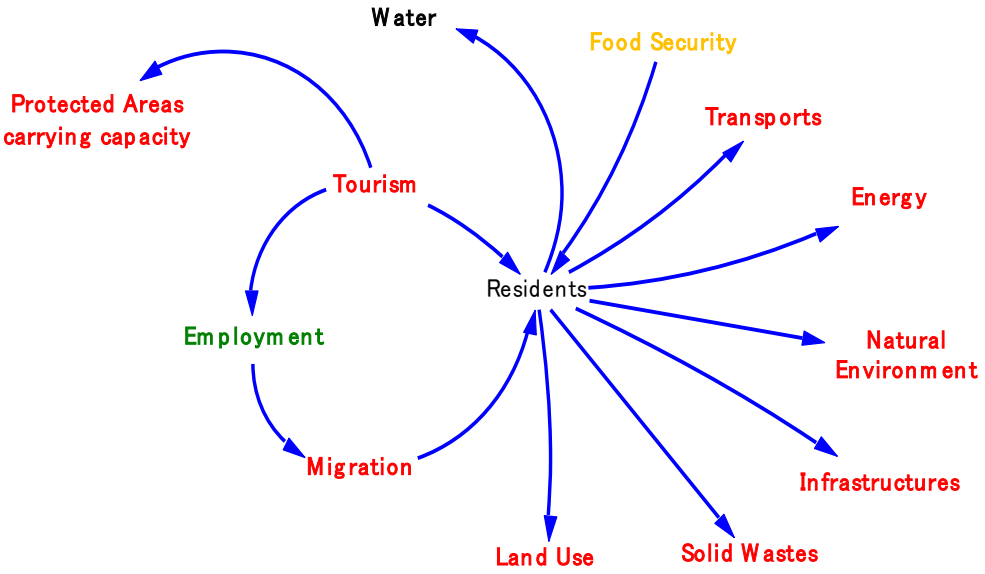


P of P Models - Taxonomy

P of P 1.0 (2013)

Pizzitutti, F., Walsh, S.J., Rindfuss, R.R., Reck, G., Quiroga, D., Tippett, R., Mena, C.F. (2016). Scenario Planning for Tourism Management: A Participatory and System Dynamics Model Applied to the Galapagos Islands of Ecuador. Journal of Sustainable Tourism.

Pizzitutti, F., Mena, C.F., Walsh, S.J. (2014). Modeling Tourism in the Galapagos Islands: An Agent Based Model Approach. Journal of Artificial Societies and Social Simulation (17(1).



Touristic arrivals

1. Resident
2. Natural environment
3. Infrastructure
4. Transports
5. Solid wastes
6. Energy
7. Land use
8. Protected areas carrying capacity

P of P 2.0 (2016)

Espin, P., Mena, C.F., Pizzitutti, F. (2018). A Model-Based Approach to Study Tourism Sustainability in an Island Environment: The Case of Galapagos Islands. Urban Galapagos: Transition to Sustainability in Complex Adaptive Systems , Springer Nature.

1. Employment & Migration

P of P 3.0 (2017)

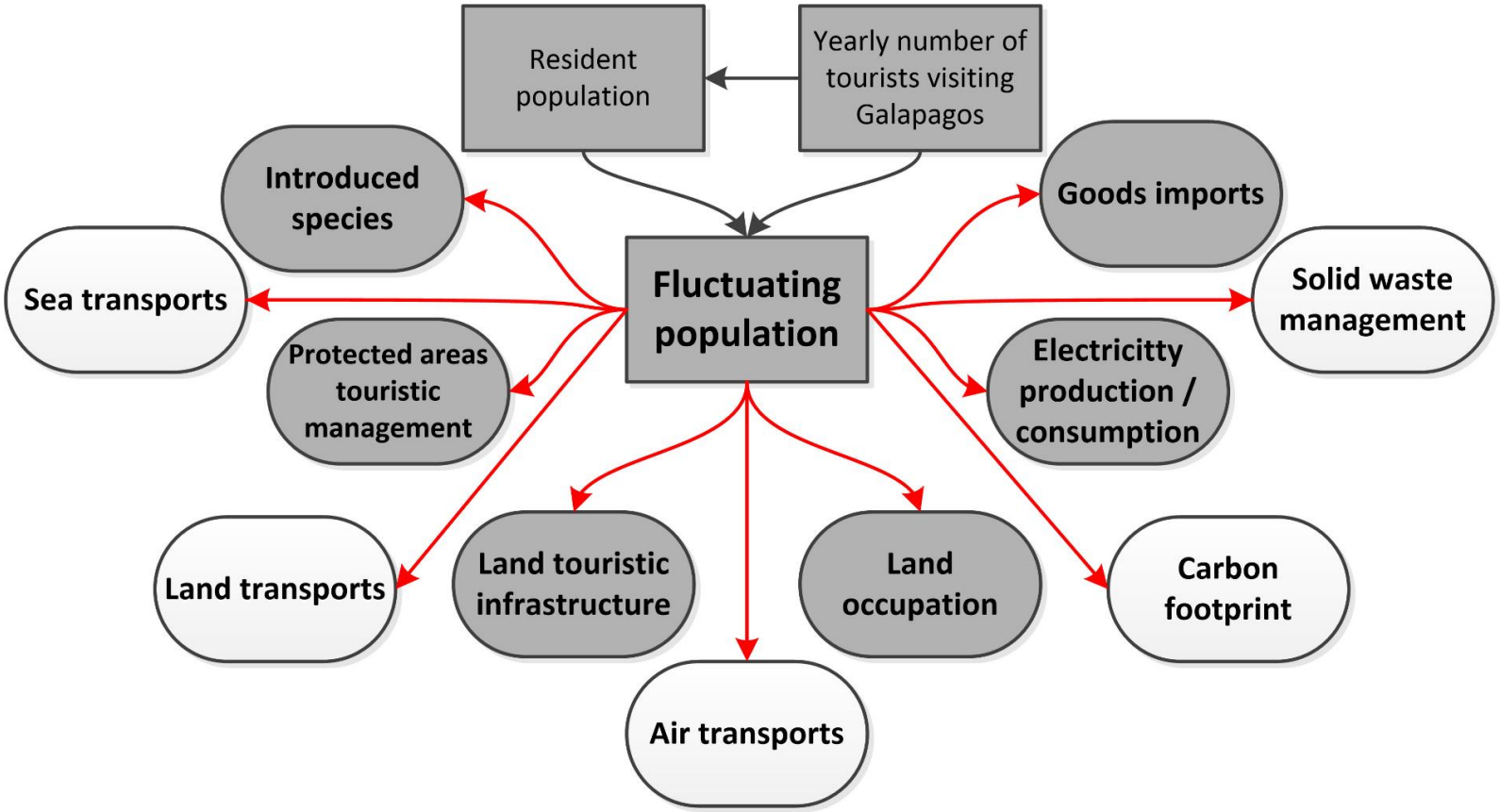
C. Sampedro, F. Pizzitutti, D. Quiroga, S.J. Walsh, C.F. Mena 2018 " Food Supply System Dynamics in in the Galapagos Islands: Agriculture, Livestock, and Imports", in press. Applied Geography.

1. Food Security

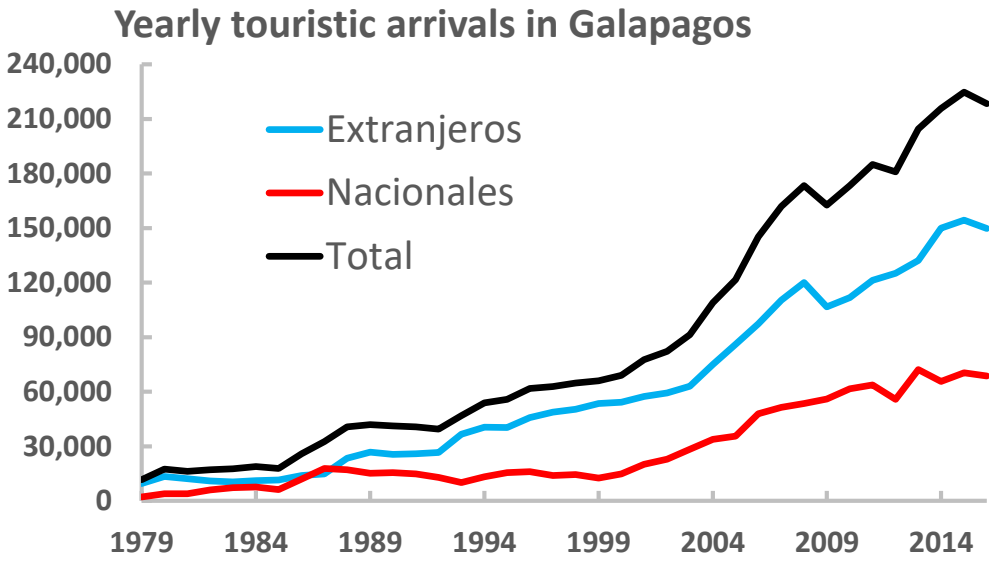
P of P 4.0 (2019)

Generalizability of Core Model and Development of Modular Subsystems by Island Types & Contexts

Tourism is the Main Driver of change in Galapagos; Impacts the Resident Population through Migration



Tourism Trends in Galapagos



NUMBER OF TOURISTS SINCE 1979:
3.3 M

TOURISM GROWTH RATE IN THE LAST 10 YEARS:
7.2%

218,365
Tourists
2015

FOREIGN TOURISTS:
69%

DOMESTIC TOURISTS:
31%

Analysis by tourist typology shows that the increase of tourist arrivals in the last 7 years is due exclusively to the increase of land-based tourism.

Outcomes – Fluctuating Population

Tourists at the same time

Year **2015:** **3,460** people

Scenario	2035	Change
High touristic growth	15,927	+361% +18% /year
Moderate touristic growth	6,910	+100% +5% /year
Zero touristic growth	3,947	+14% +0.7% /year

Fluctuating population

= residents +
tourists in Galápagos at the same time

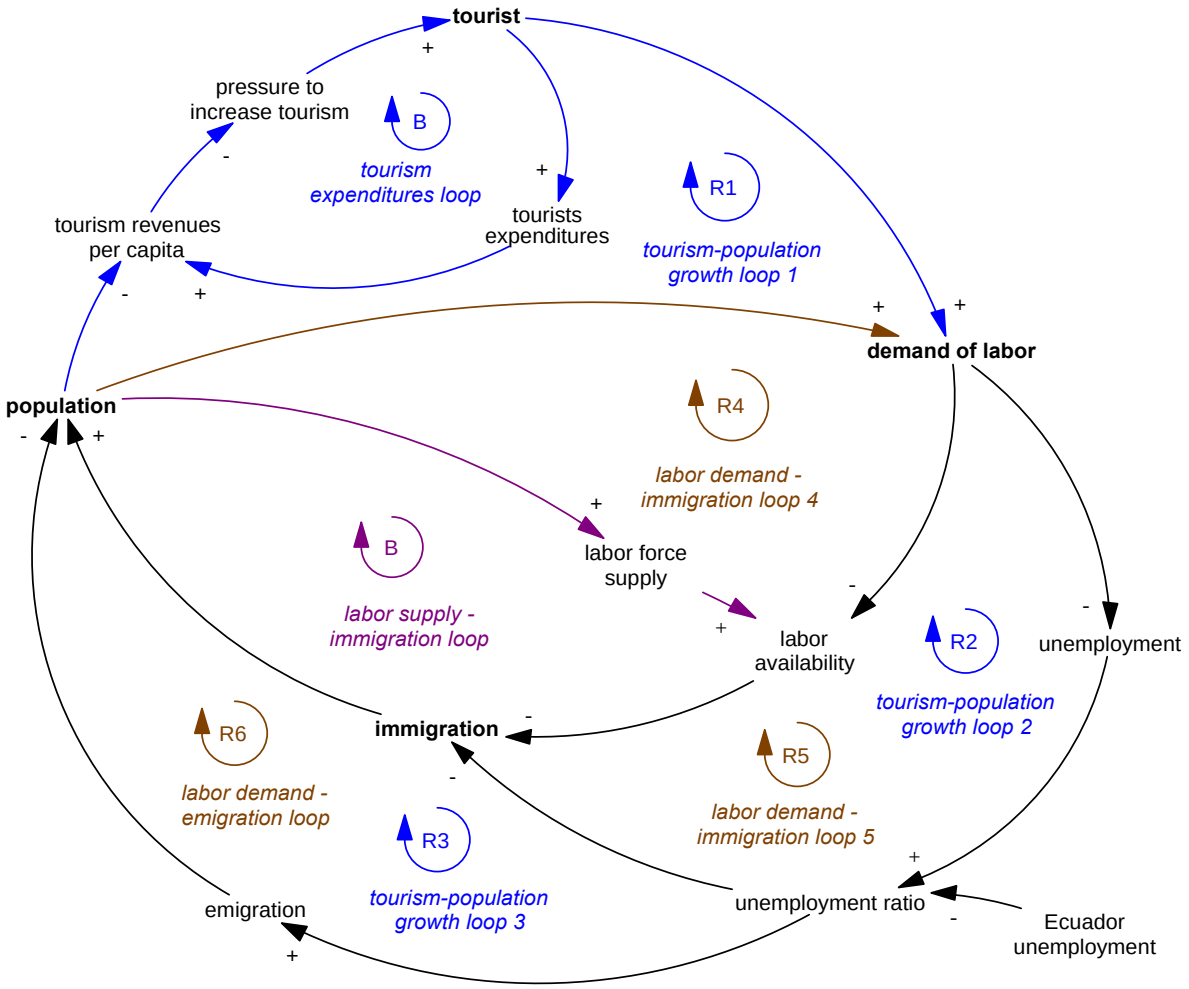
Year **2015:** **33,453** people

Scenario	2035	Change
High touristic growth	86,861	+160% +8.1% /year
Moderate touristic growth	60,680	+81% +4% /year
Zero touristic growth	50,927	+52% +3% /year

Model Processes

Additional subsystems:

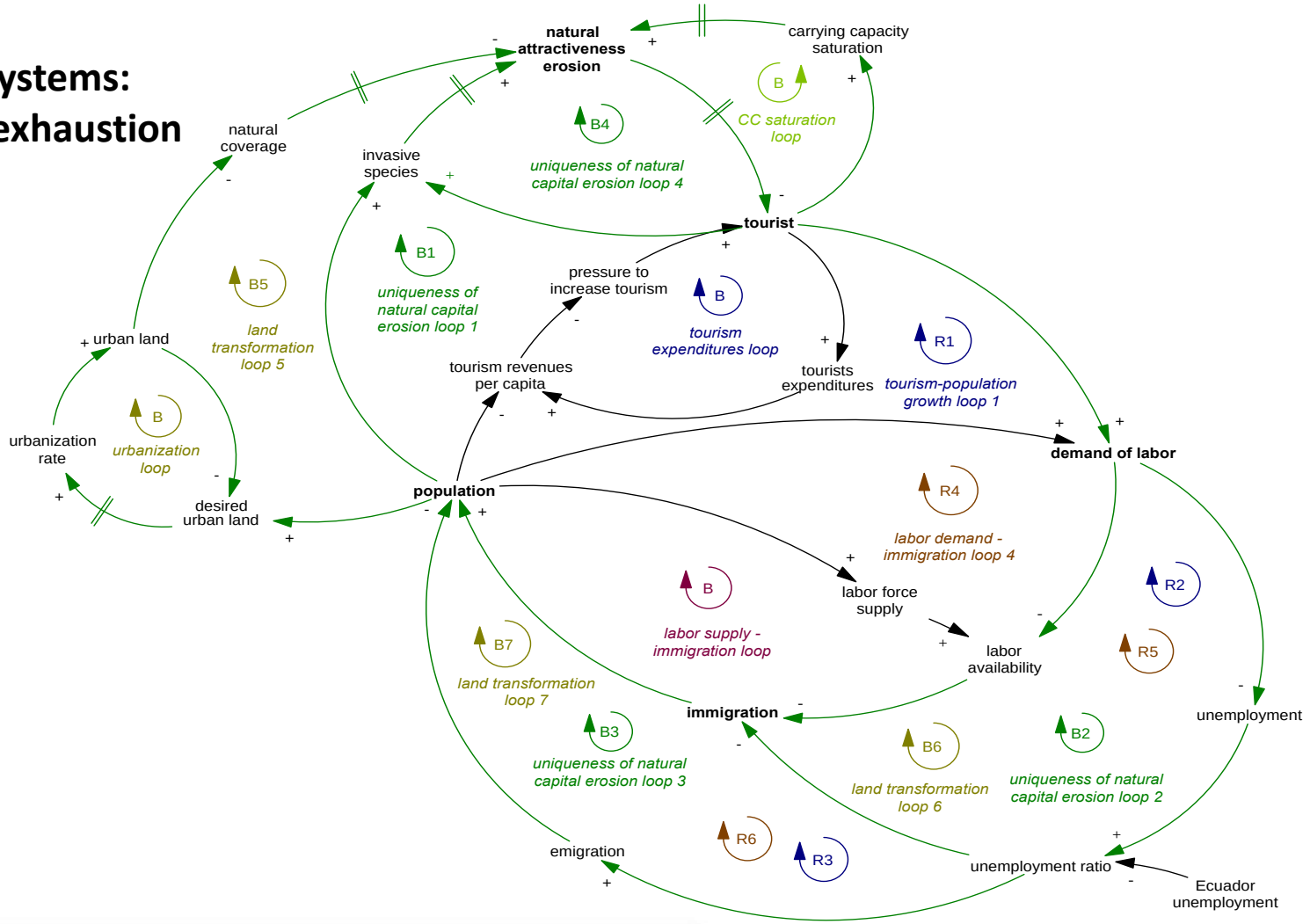
- Population & employment
- Tourism expenditures
- Tourism and natural capital erosion



Tourism, population and labor dynamics

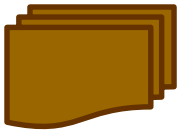
Model Processes

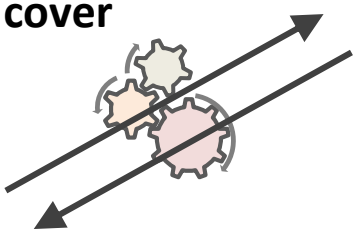
Additional Subsystems:
Natural capital exhaustion



Classes of Land Cover

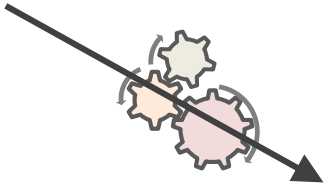
Types of Land cover





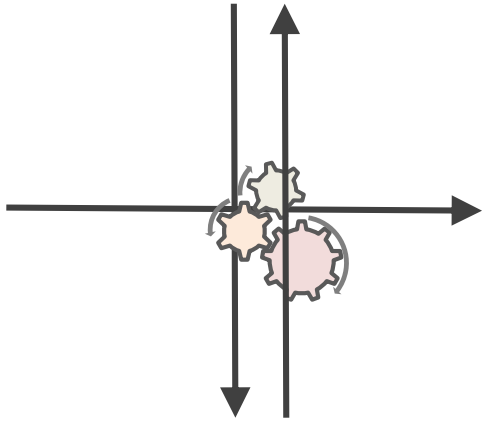
Native

Primary ecosystems,
Beaches



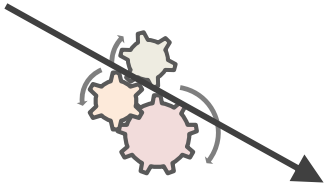
Agricultural

Subsistence Crops,
Cash Crops,
Trees cultivations
Abandoned lands



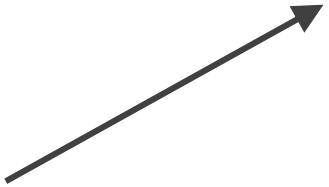
Urban

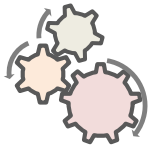
Houses, Sport infrastructures,
Transport infrastructure,
Production Plants



Infrastructures

Not urban roads, Ports,
Airports, Landfills, Mines

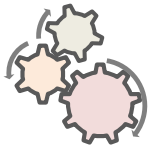




Drivers of change

Classes of Drivers of Land Cover Change

Types of Drivers of Land Cover Change



Primary Drivers (determining when, why and how changes happen)

- **Socioeconomic:** Demography (growth, migration, density, distribution (rural-urban), transition rates, temporary migrants, vulnerability indicators), Economy (labor market, tourism, import-export, production, illegal activities , etc.)
- **Biophysical:** Climate (hurricanes, tsunamis, floods, ENSO), Climate Change (droughts, costal line erosion, costal storms), Volcanoes, Fire, Mineral Resources, Natural capital, Invasive Species
- **Management:** Government interventions (economy, agriculture policies, nature conservation public policies), Private interventions (Natural Reserves)
- **Exogenous:** Geographic accessibility and connectivity, Global markets (demands for import and export, investments), Main land of reference socioeconomic indexes, biophysical and political conditions

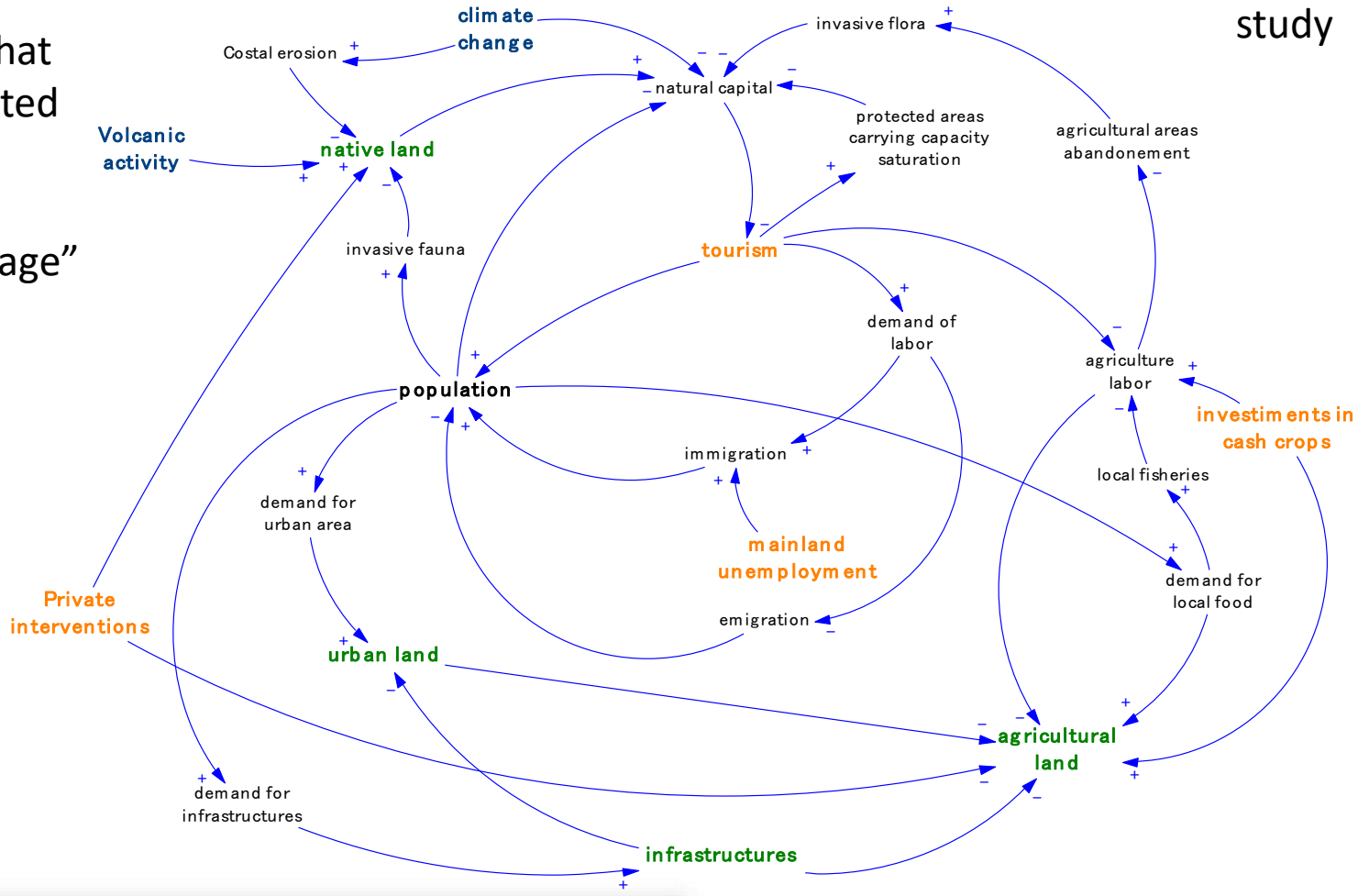
Secondary Drivers (determining where changes happen -> important to be included only in a spatially explicit model): roads, rivers, topography, urban areas, coasts, soil fertility

Limiting Drivers (determining thresholds of change): soil fertility, topography, total island surface, areas suitable for infrastructures, climate, natural capital, etc.

System Dynamics model of LCLUC in island ecosystem first drafts

Level 0 diagram
Galapagos case study

- Governmental policies drivers that are not represented explicitly
- Exported to "development stage" islands types



Model Transfers from Island to Island

- Matrix of drivers of change can be tuned to switch on and off to reflect different island typologies.
- Galapagos Islands can be the prototype of the “development stage” type of island. Can we define types of islands depending on the development stage in a generalized model of islands development where tourism is substituted with economic development? Hawaiian Islands may be in the stagnation stage? What about Puerto Rico? Can we identify islands in the decline stage?