NASA LCLUC Spring Science Team Meeting: Synthesis Studies

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

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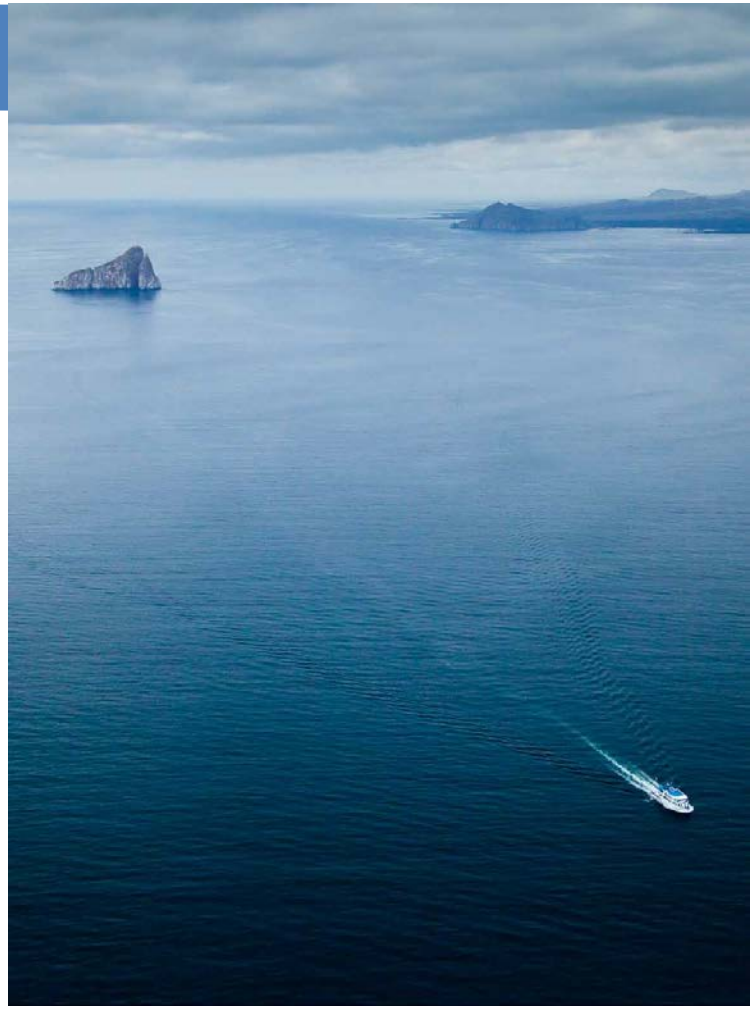
Synthesize LCLUC for Global Islands

- 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.



Challenges to Island Ecosystems

- ***Forces of Globalization***, e.g., international tourism, population migration, trade & economic development cause LCLUC through direct and indirect ways.
- ***Climate & Environmental Change***, e.g., sea-level rise, ENSO events, hurricanes and other natural hazards affect LCLUC and island ecosystems.
- ***Geographic Context***, e.g., often geographically remote, connected directly and/or indirectly to the mainland, relatively small in size, occurring singularly or arrayed in archipelagos, irregular in shape, and varied in their ecological, economic, cultural, and topographic settings
- ***Shaped over* time and through Human and Natural circumstances**, islands are acted upon by episodic and continuous forces of change, particularly LCLUC, through deforestation, agricultural extensification, urbanization.

Endemism & Species Richness of Islands

- ***Endemism and Species Richness*** are highly relevant to the global prioritization of conservation efforts in which oceanic islands have remained relatively neglected.
- When compared to mainland areas, ***oceanic islands are known for their high percentage of endemic species***, but only moderate levels of species richness.
- Comparison of different measures of ***past and future human impact and LCLUC*** reveal marked differences between mainland and island regions.
- ***Human Impact Index***, a measure of current threat, is significantly higher on islands.
- ***Projected LCLUC for the year 2100*** indicate that LCLUC on islands will be significantly higher on islands.

- *Kier, G., Kreft, H., Lee, T.M., Ibisch, P.L., Nowicki, C., Mutke, J., Barthlott, W. (2009). A global assessment of endemism and species richness across iosland and mainland regions. Proceedings of the National Academy of Sciences, 106 (23): 9322-9327.*

Islands Offer Unique Opportunities

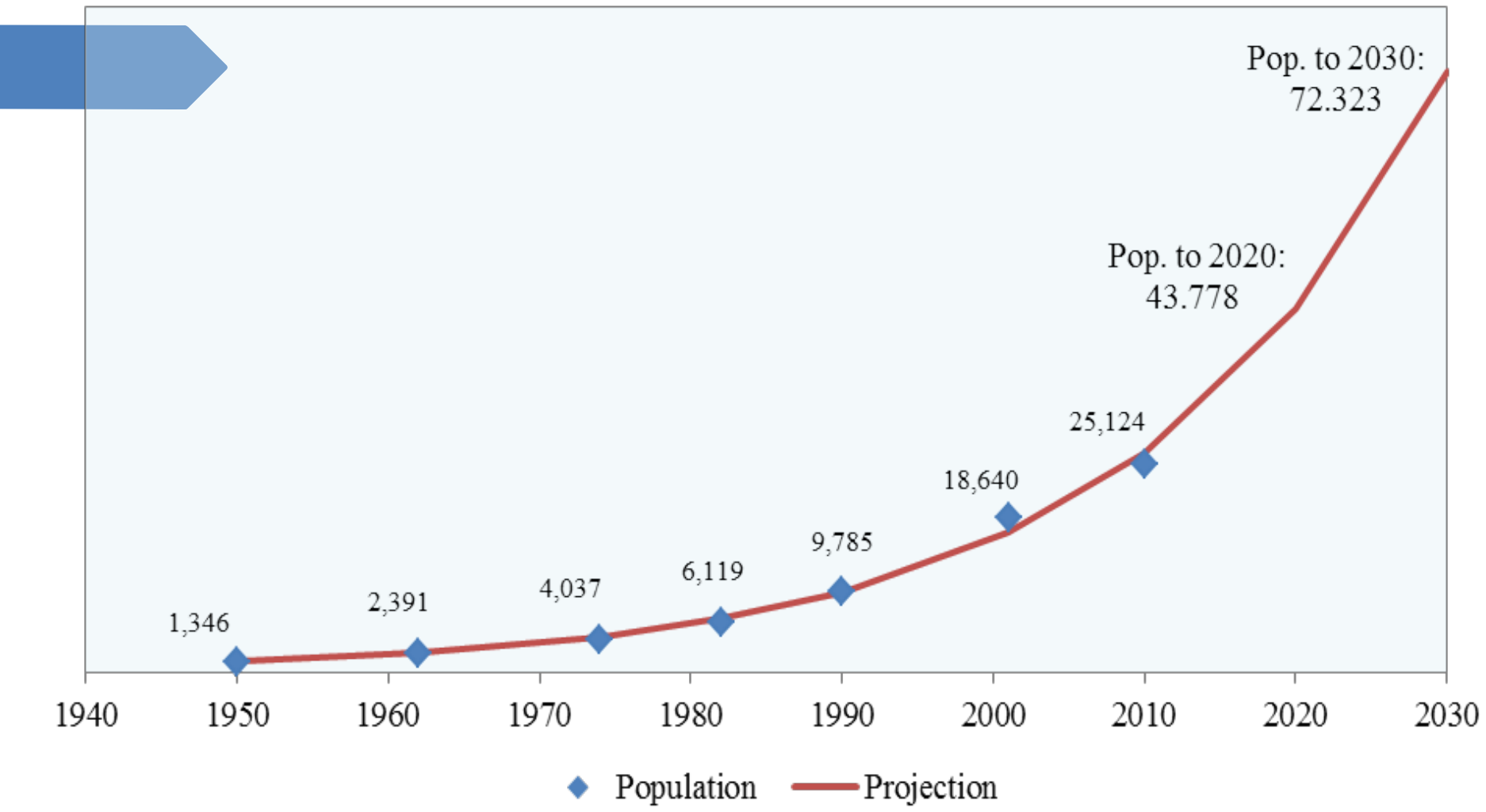
- Islands are ***microcosms of larger mainland systems***, but their smaller size, crisp boundaries, restricted access, and, often, historic isolation make them more manageable to study and to measure factors that threaten their social-ecological sustainability.
- Islands are ***home to vulnerable iconic species*** and unique habitats that are the focus of global tourism activities and conservation efforts.
- ***Climate change and extreme events***, for example, can profoundly affect island resources, household livelihoods, biodiversity & endemism, and LCLUC patterns.
- ***Human factors***, such as, population migration of residents and tourists frequently drive LCLUC, possibly, more strongly than ecology and geography.

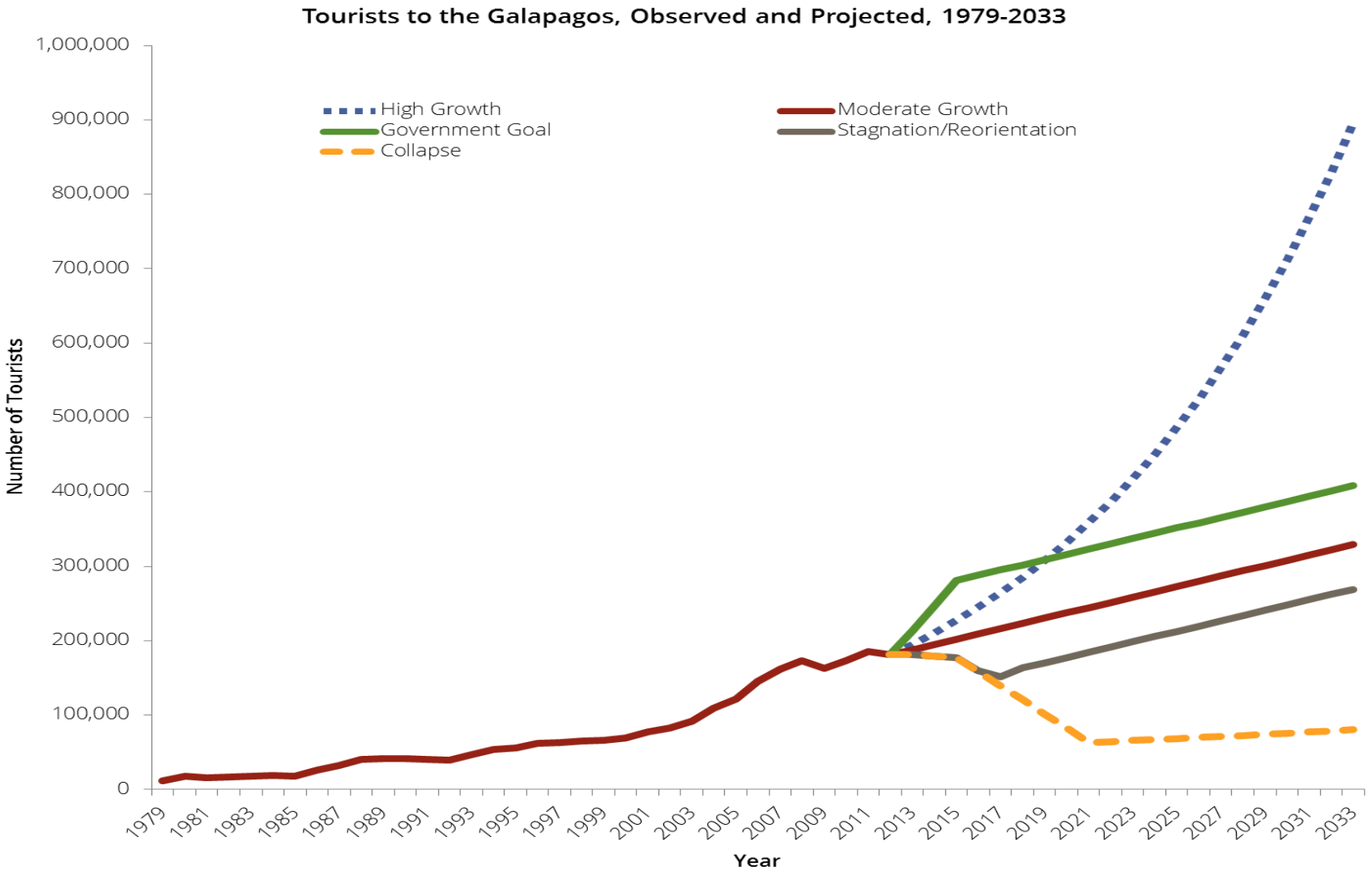
Tourism & Development

- Tourism has become one of the most important economic sectors in recent decades, and island tourism is one of the main components of world tourism
- ***In 2011, 980 million tourists*** traveled outside their borders, generating ***revenues of over $1B***, underlying the importance of tourism in the global economy, accounting for nearly 12% of GDP.
- Tourism is the most important and dynamic driving force of economic change on islands, especially those with high amenity qualities.
- In all our primary islands, tourism contributes to the island economy, as much as 60% of economic activity in the Galapagos, 7% in Puerto Rico, and 16% for Hawaii.

Galapagos Islands & Island Biocomplexity

- Combines complex adaptive systems with a new island ecology that incorporates human induced change on the environment, specifically, LCLUC.
- Encompasses the complex interactions within and among ecological systems, physical systems on which they depend, and human systems with which they interact.
- Island ecosystems are complex adaptive systems because their macroscopic properties merge from the interactions among the individual components of the ecosystem.
- Global changes, including the forces associated with tourism, migration, and LCLUC, exert exogenous pressure on island ecosystems, but their systems have their own spatially contingent endogenous dynamics.
- ***Walsh, S.J. & Mena, C.F. (2016). Interactions of social, terrestrial, and marine sub-systems in the Galapagos Islands, Ecuador. Proceedings of the National Academy of Sciences, 113(51): 14536-14543.***


Pop. to 2030:
72.323
Pop. to 2020:
43.778
25,124
18,640
9,785
6,119
4,037
2,391
1,346
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Population
Projection


Tourists to the Galapagos, Observed and Projected, 1979-2033
High Growth
Government Goal
Collapse
Moderate Growth
Stagnation/Reorientation
Number of Tourists
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
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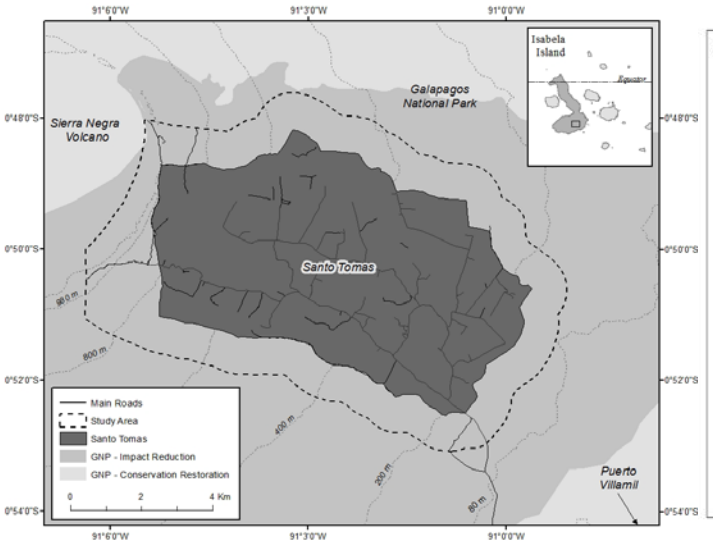
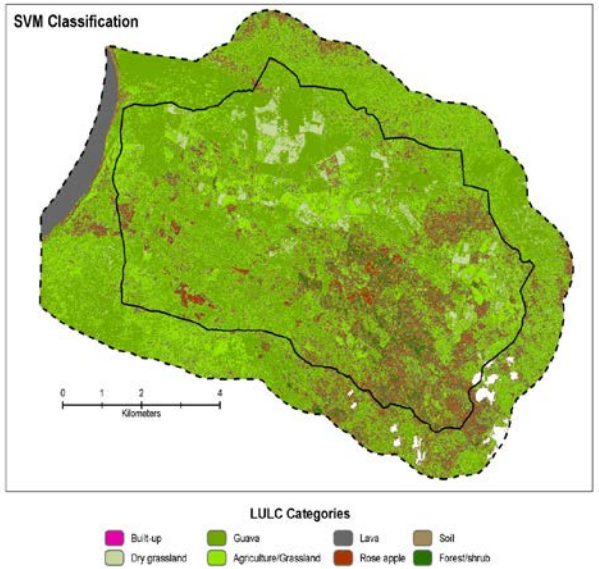
2027
2029
2031
2033
Year

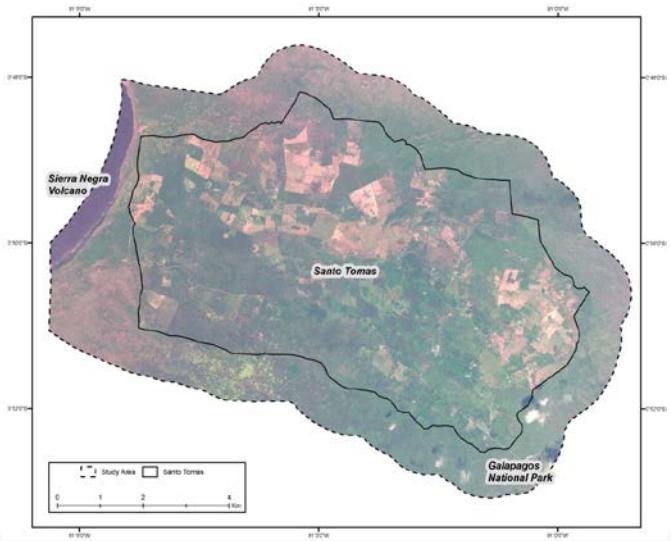
Santa Thomas, Isabela Island, Galapagos Archipelago, EC

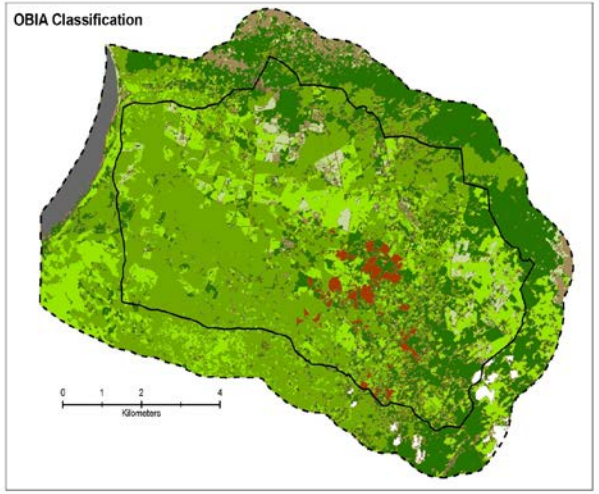




LULC Categories

Built-up | Guava | Lava | Soil
Dry grassland | Agriculture/Grassland | Rose apple | Forest/shrub

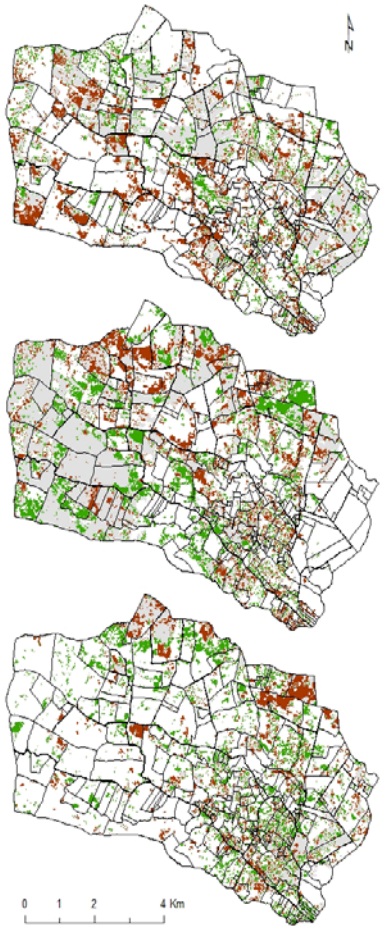




Agriculture Transitions
- Farm parcels
- Stable agriculture
- Agricultural abandonment
- Agricultural intensification

Guava Transitions
- Farm parcels
- Stable guava
- Guava contraction
- Guava invasion

Forest Transitions
- Farm parcels
- Stable forest
- Deforestation
- Forest expansion



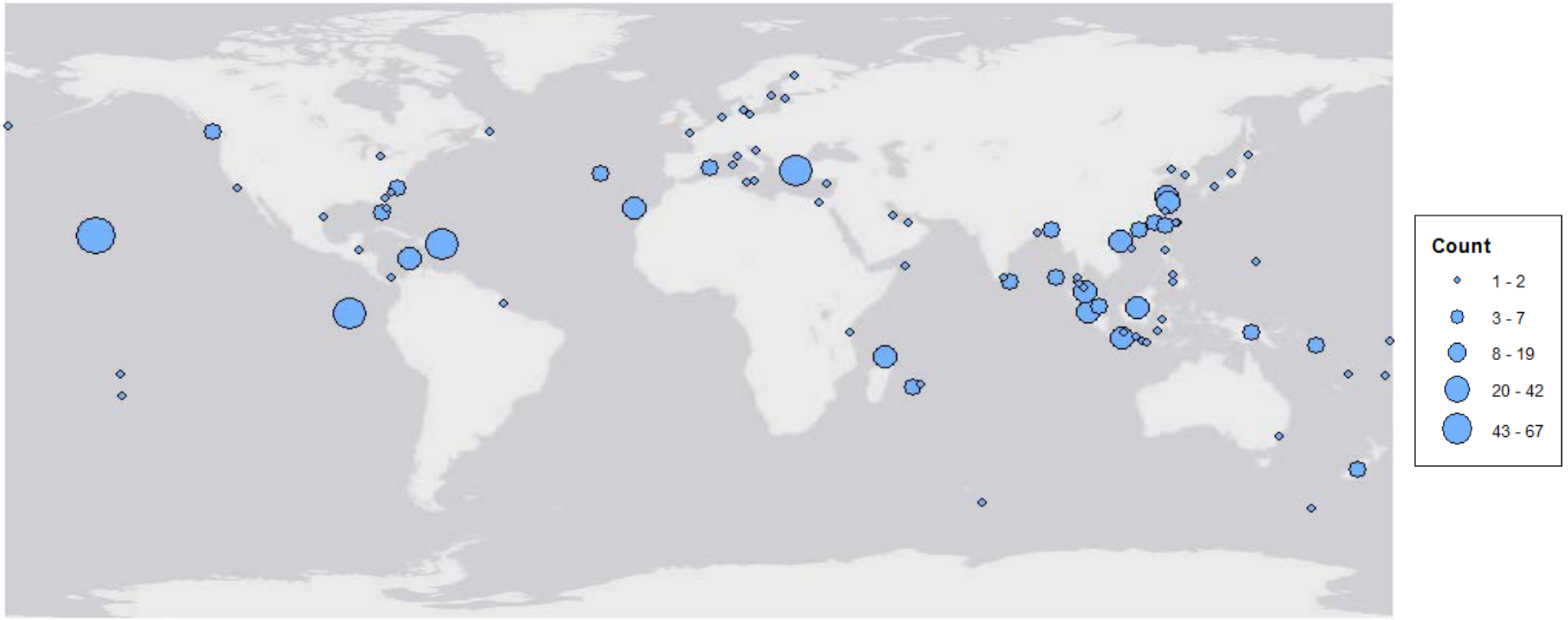
Socio-Economic Searches (1988-2018) Keyword Examples & Tiers 2/1 Findings (309 Papers)

- ***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)

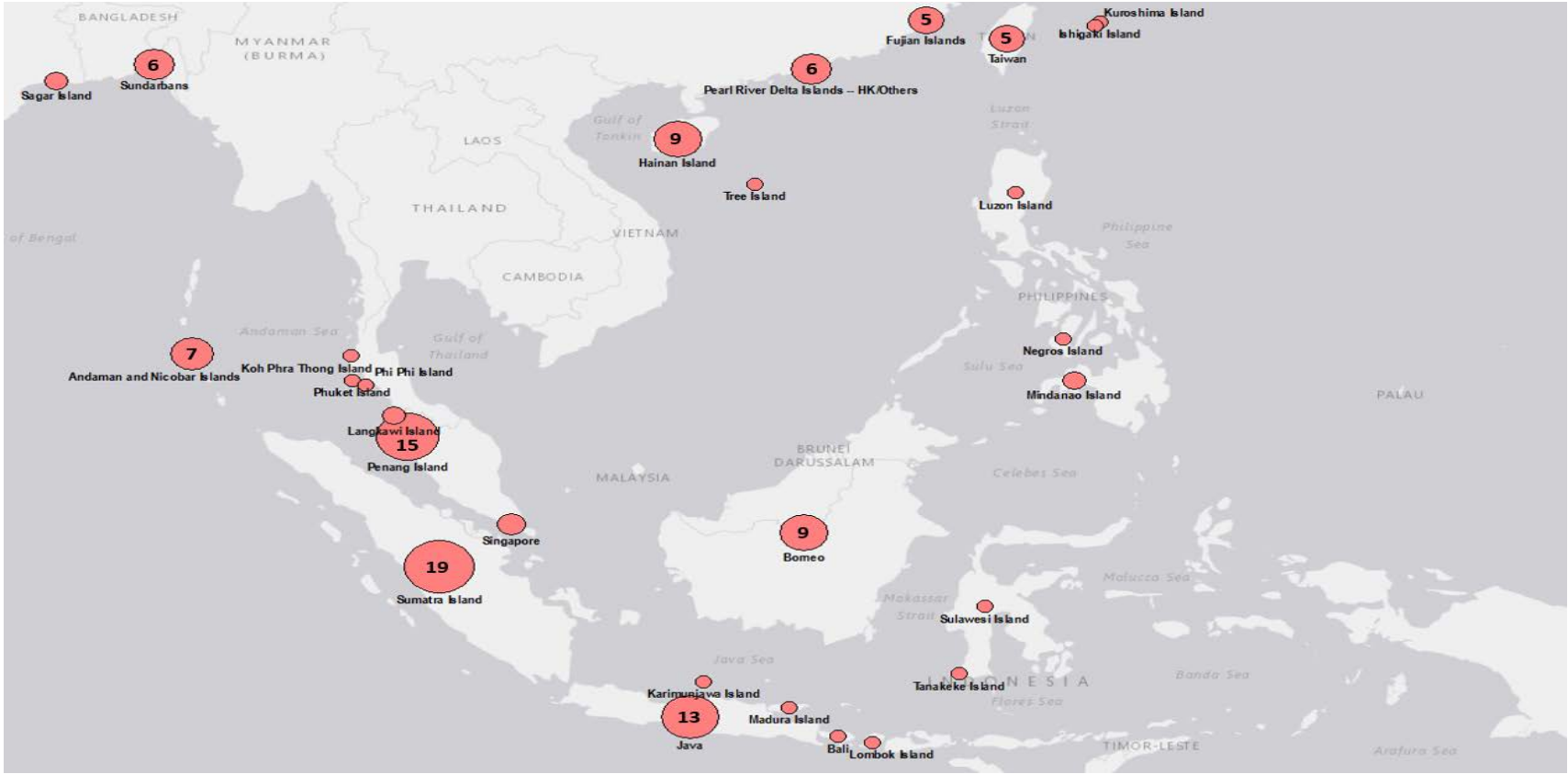
Remote Sensing of LCLUC (1988-2018) Keyword Examples & Tiers 2/1 Findings (406 Papers)

- ***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

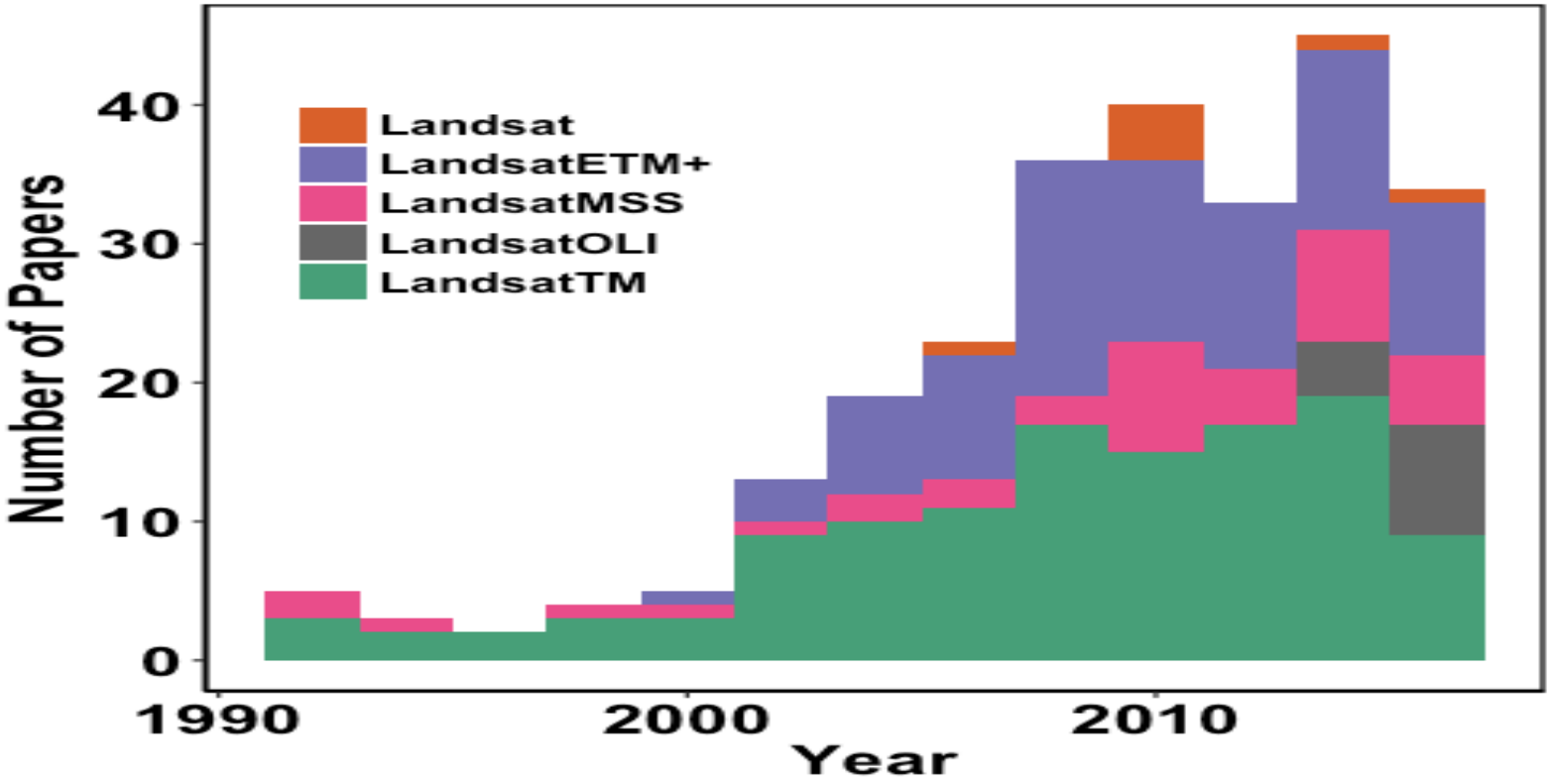
Global Islands – Studies & Papers



Southeast Asian – Studies & Papers by Island

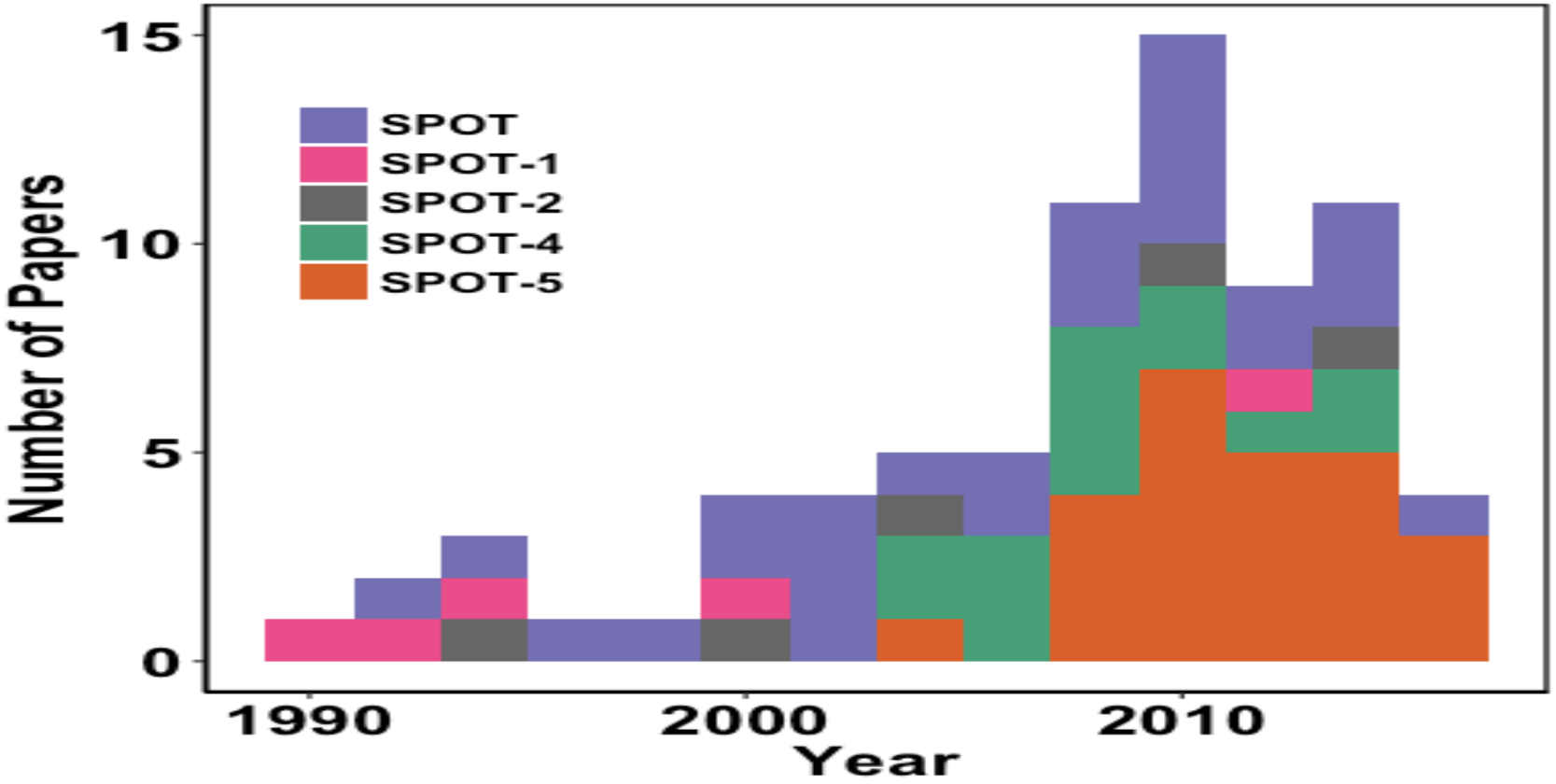


Landsat Papers by Year



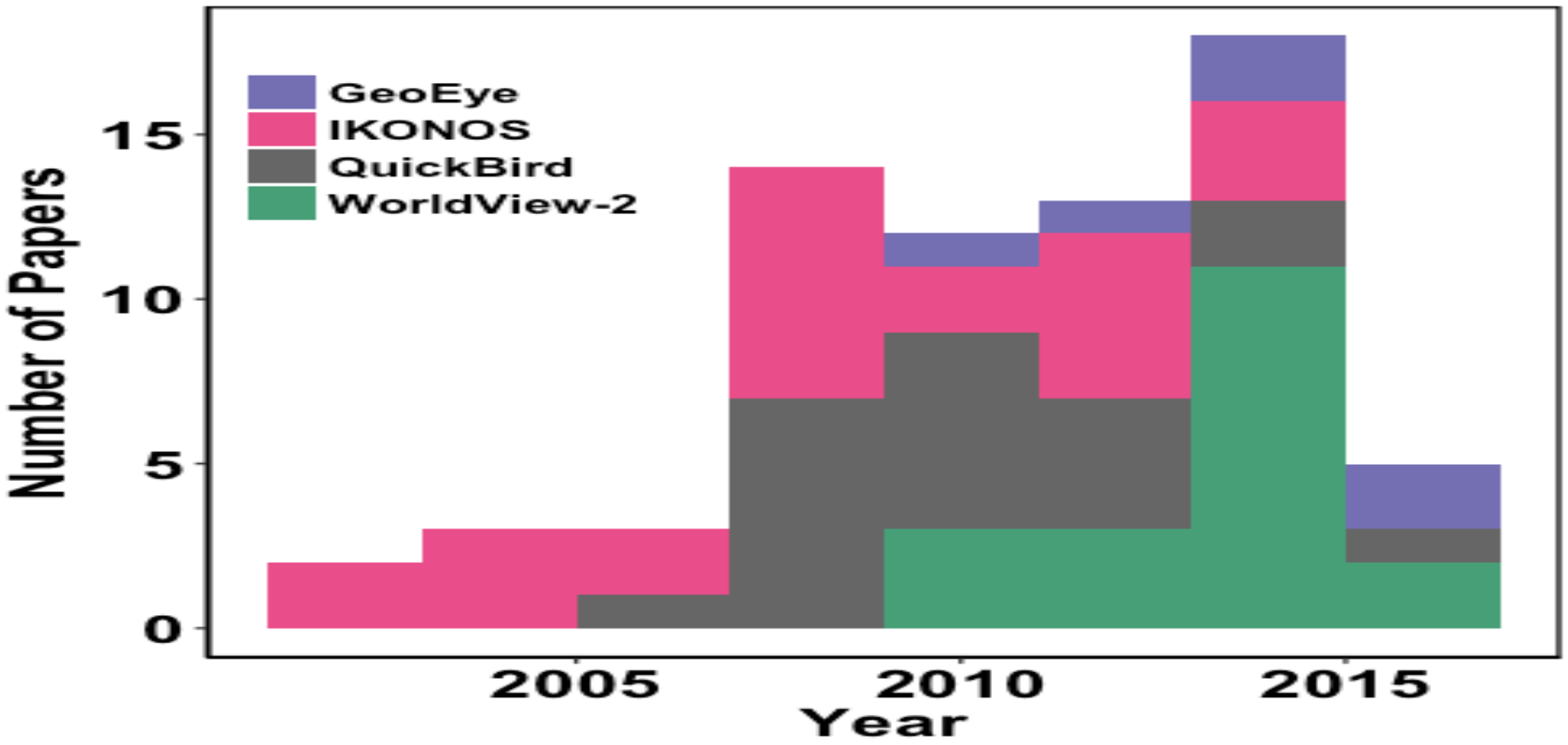
Orange – not sensor specific

SPOT Papers by Year



Purple – not sensor specific

High Spatial Resolution Data & Papers



UNEP-WCMC, Depraetere & Dahl (2010). Global distribution of islands. Global Island Database. Based on Wessel & Smith (1996). Full technical documentation in Depraetere (2007), Cambridge (UK): UNEP World Conservation Monitoring Centre

- UNEP's Global Distribution of Islands (2010) contains boundaries and global distribution of islands greater than about 0.06 sq.km. This dataset, also known as the IBPow (Island Biodiversity Programme of Work) database, has been developed in collaboration with the Institut de recherche pour le dévelopement (IRD) since 2005. The shapefile is based on the GSHHS Database (Global, Self-Consistent, Hierarchical, High-Resolution Shoreline Database, Wessel & Smith, 1996).

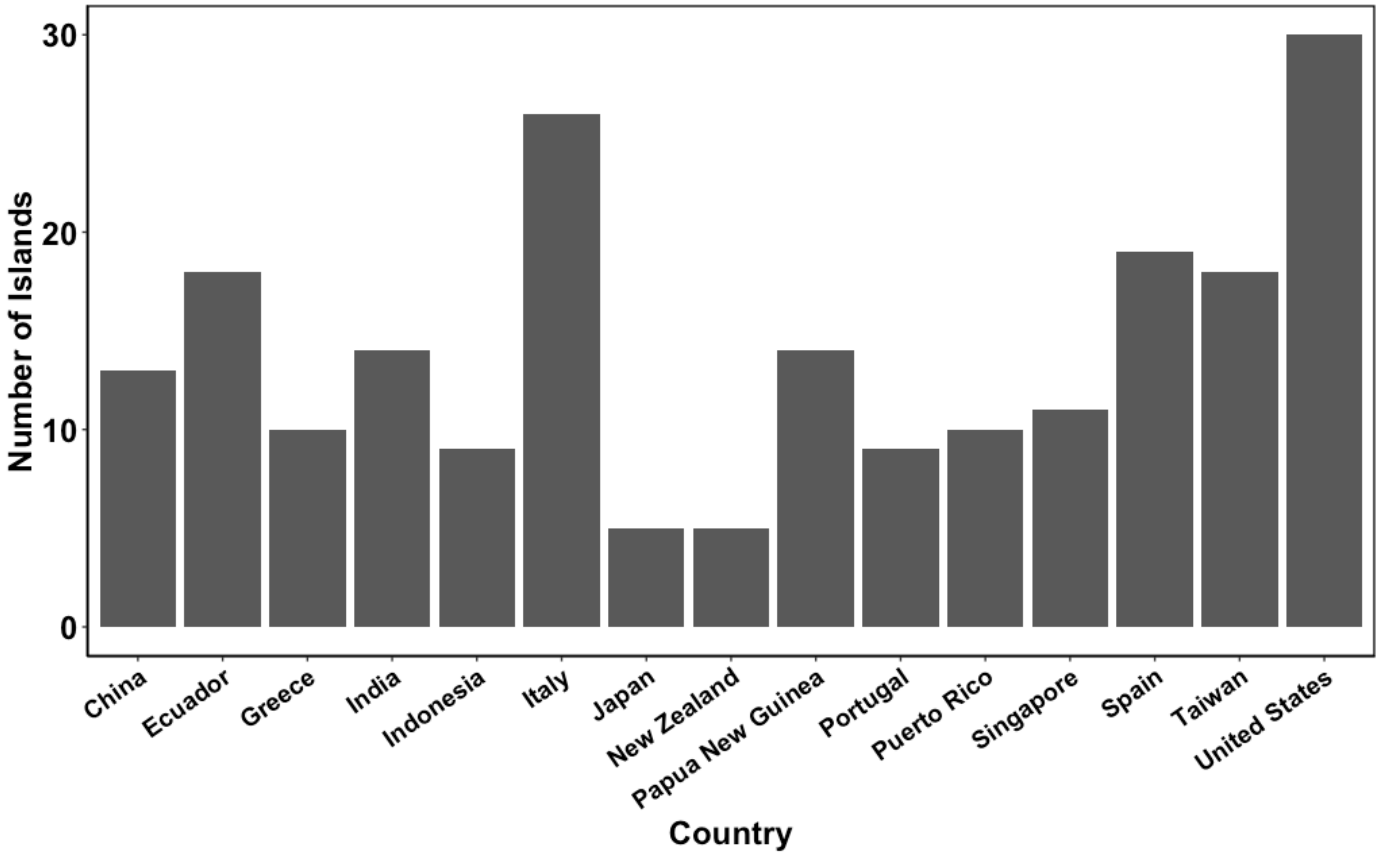
Spatz, D. R., Zilliacus, K. M., Holmes, N. D., Butchart, S. H. M., Genovesi, P., Ceballos, G., Croll, D. A. (2017). Globally Threatened Vertebrates on Islands with Invasive Species. Science Advances, 3(10): e1603080

- The Threatened Island Biodiversity database includes almost 2000 islands for nearly 1200 Critically Endangered and Endangered terrestrial vertebrate species, collated from almost 1500 scientific literature sources, management documents, and databases, and from the contribution of more than 500 experts. The dataset also contains data on vulnerable seabirds, the presence of invasive vertebrates, and important island characteristics, such as island size and human habitation that are often used in setting conservation priorities.

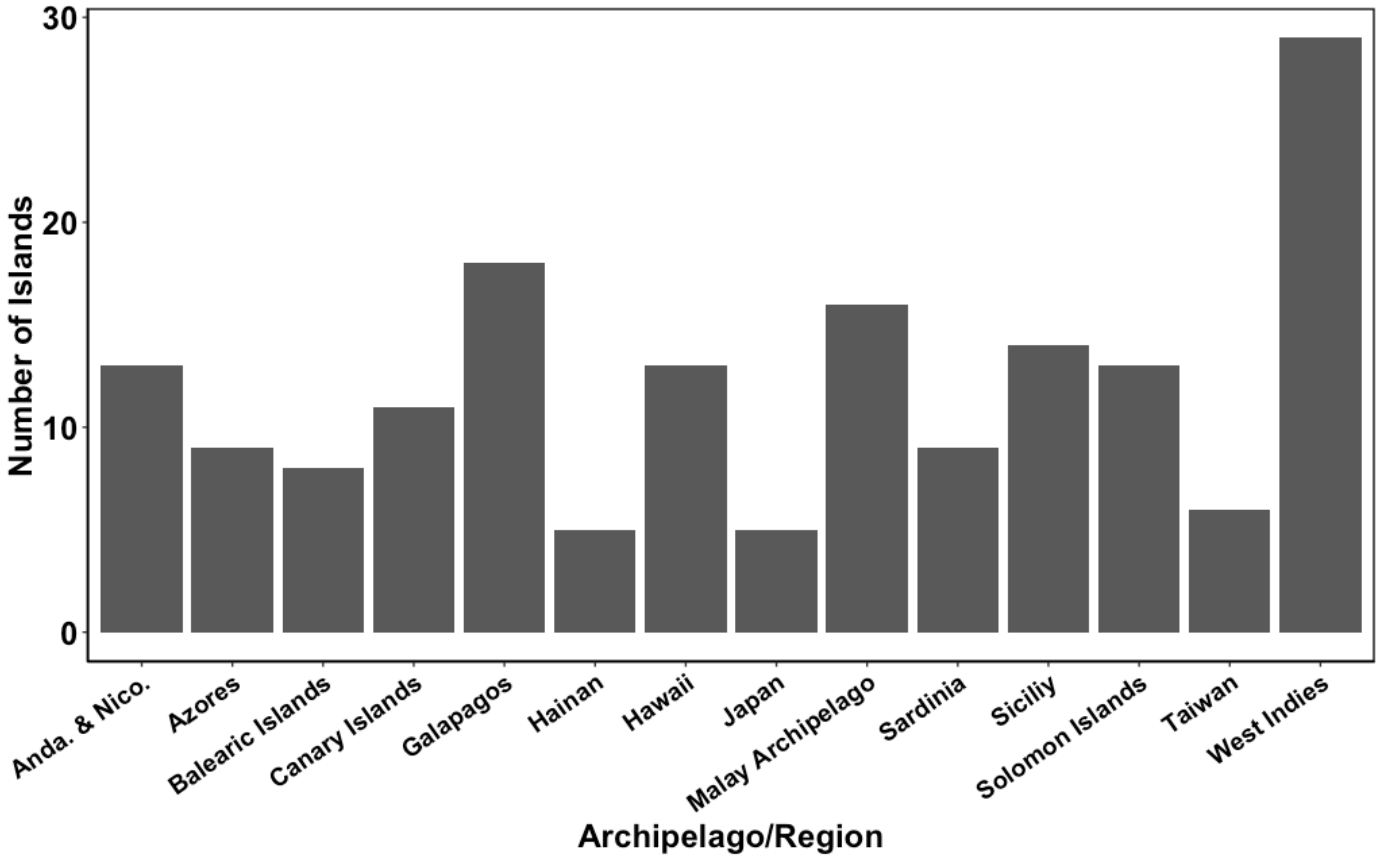
Weigelt, P., Jetz, W., & Kreft, H. (2013). Bioclimatic and Physical Characterization of the World's Islands. Proceedings of the National Academy of Sciences, 110(38): 15307–15312.

- 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.

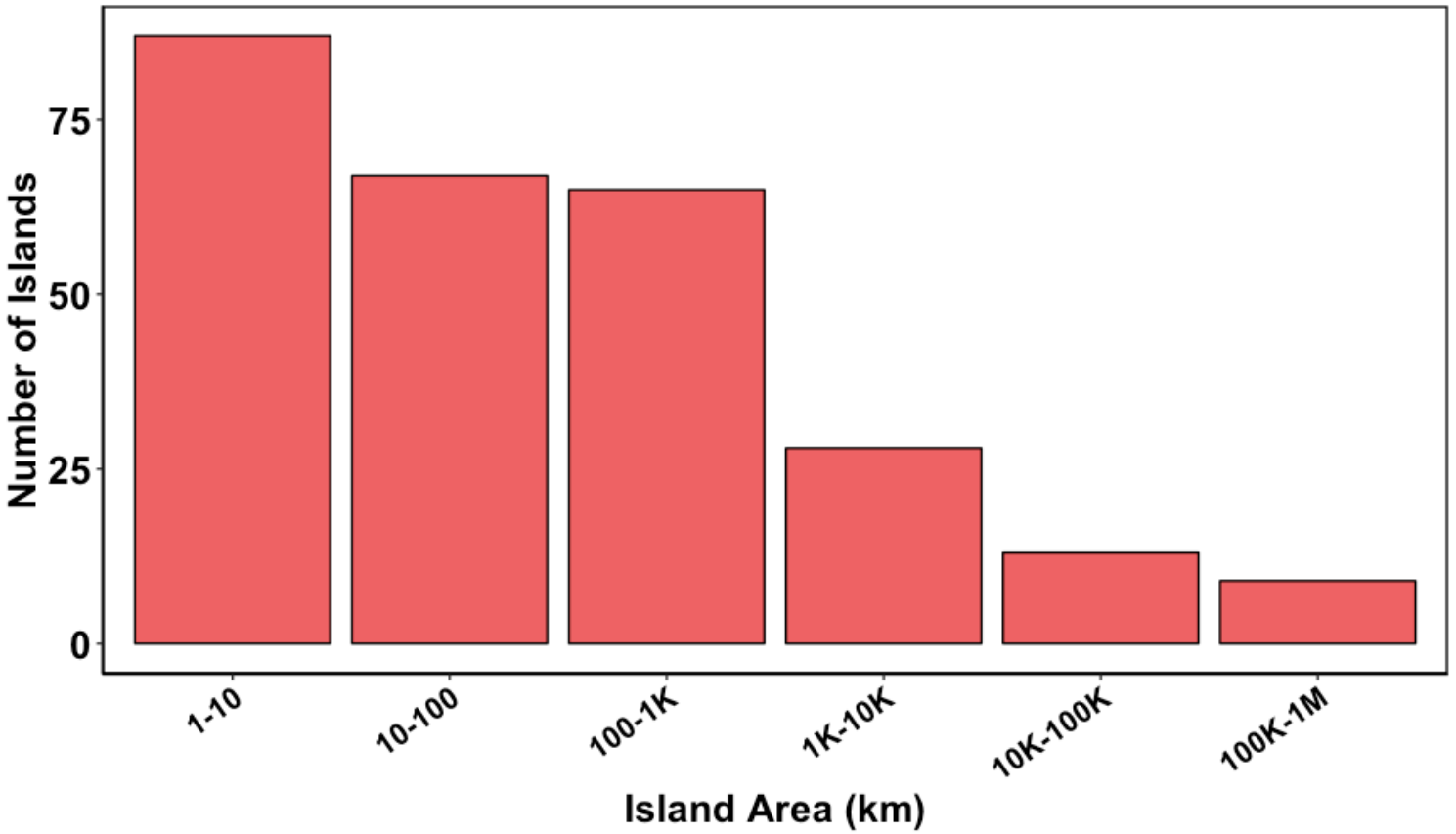
Number of Islands in our Study by Country, only Countries with >5 Islands



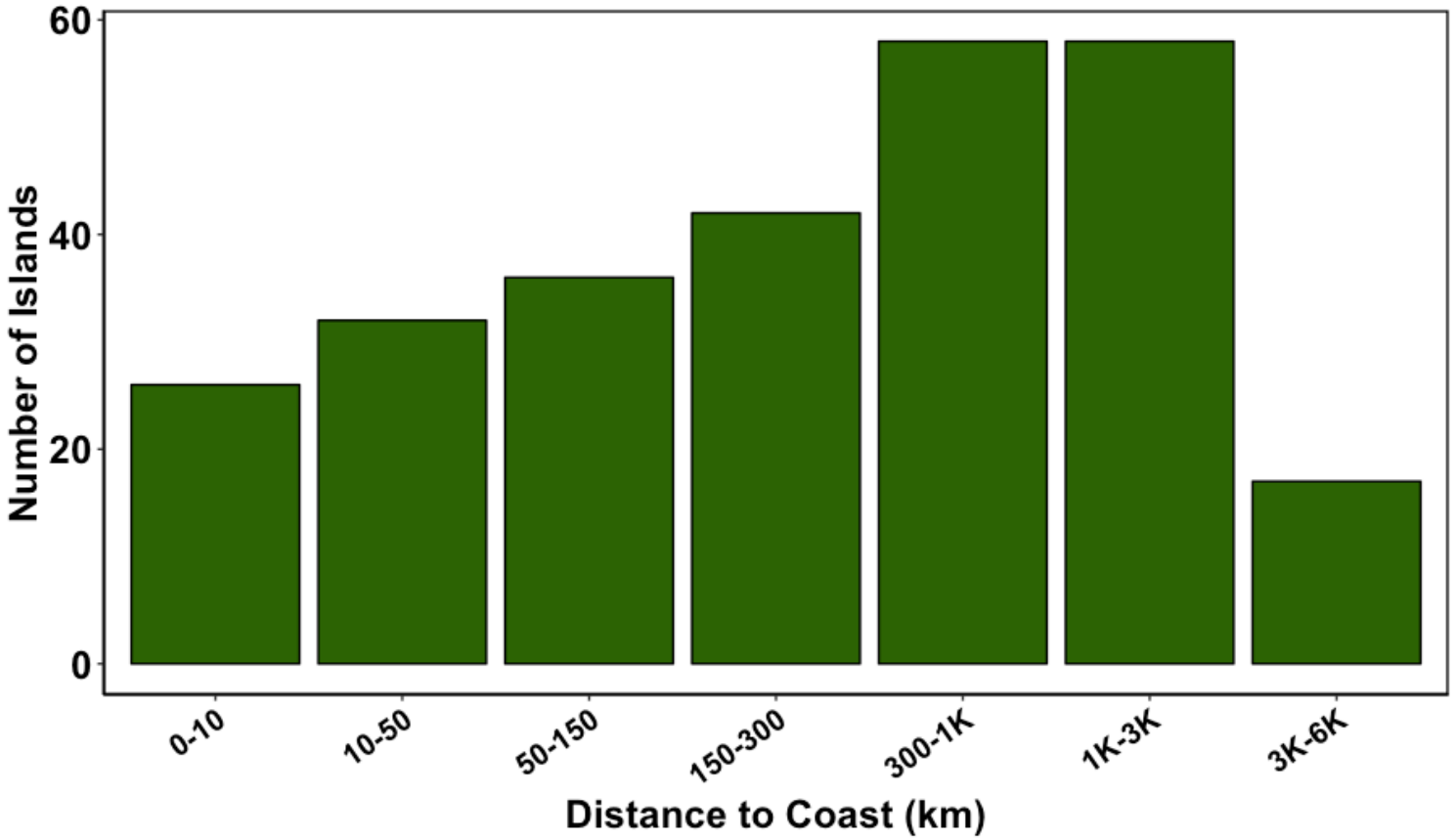
Number of Islands in our Study by Island Group/Archipelago, only Groups with >5 Islands



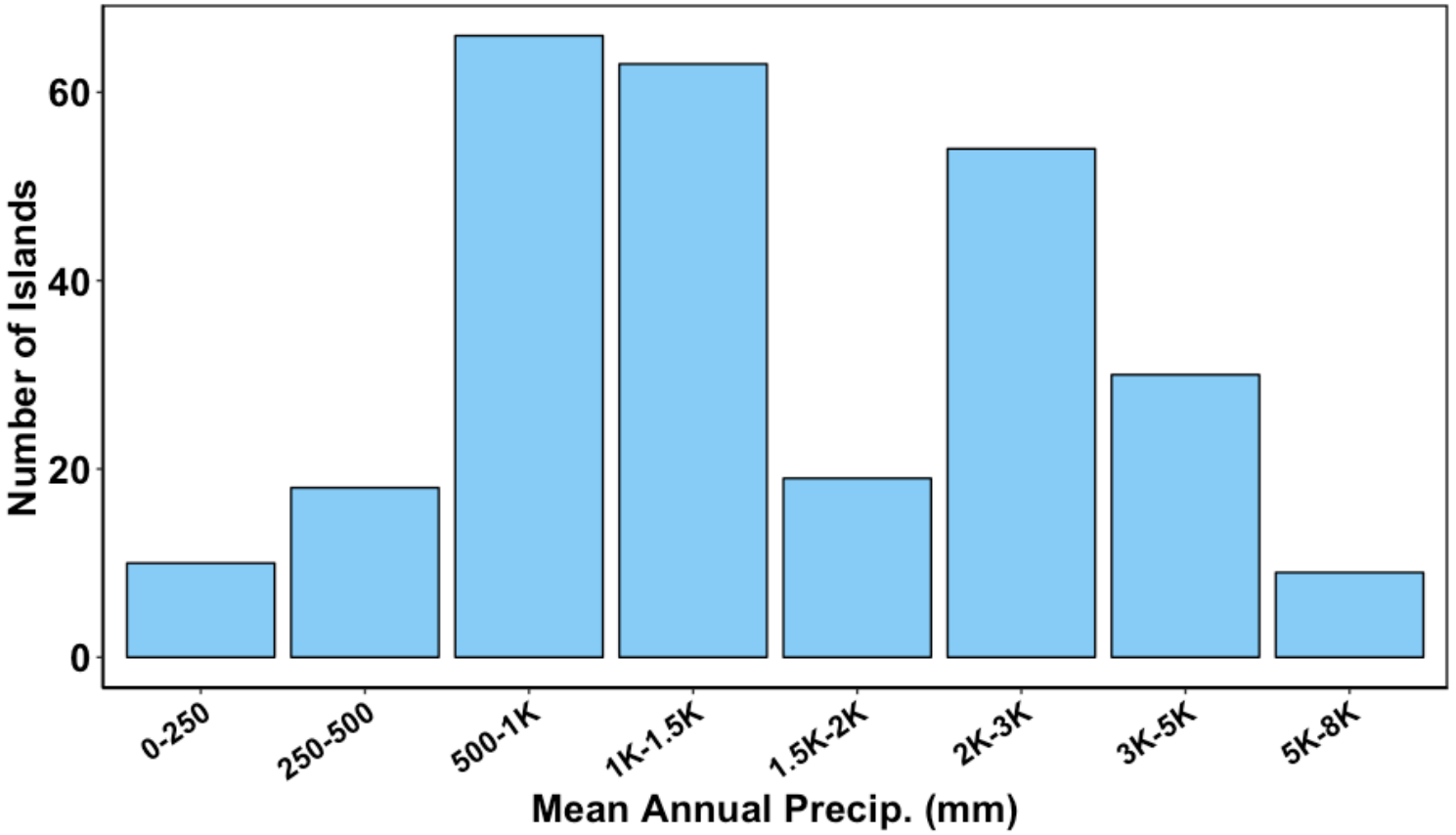
Area of Islands in our Study



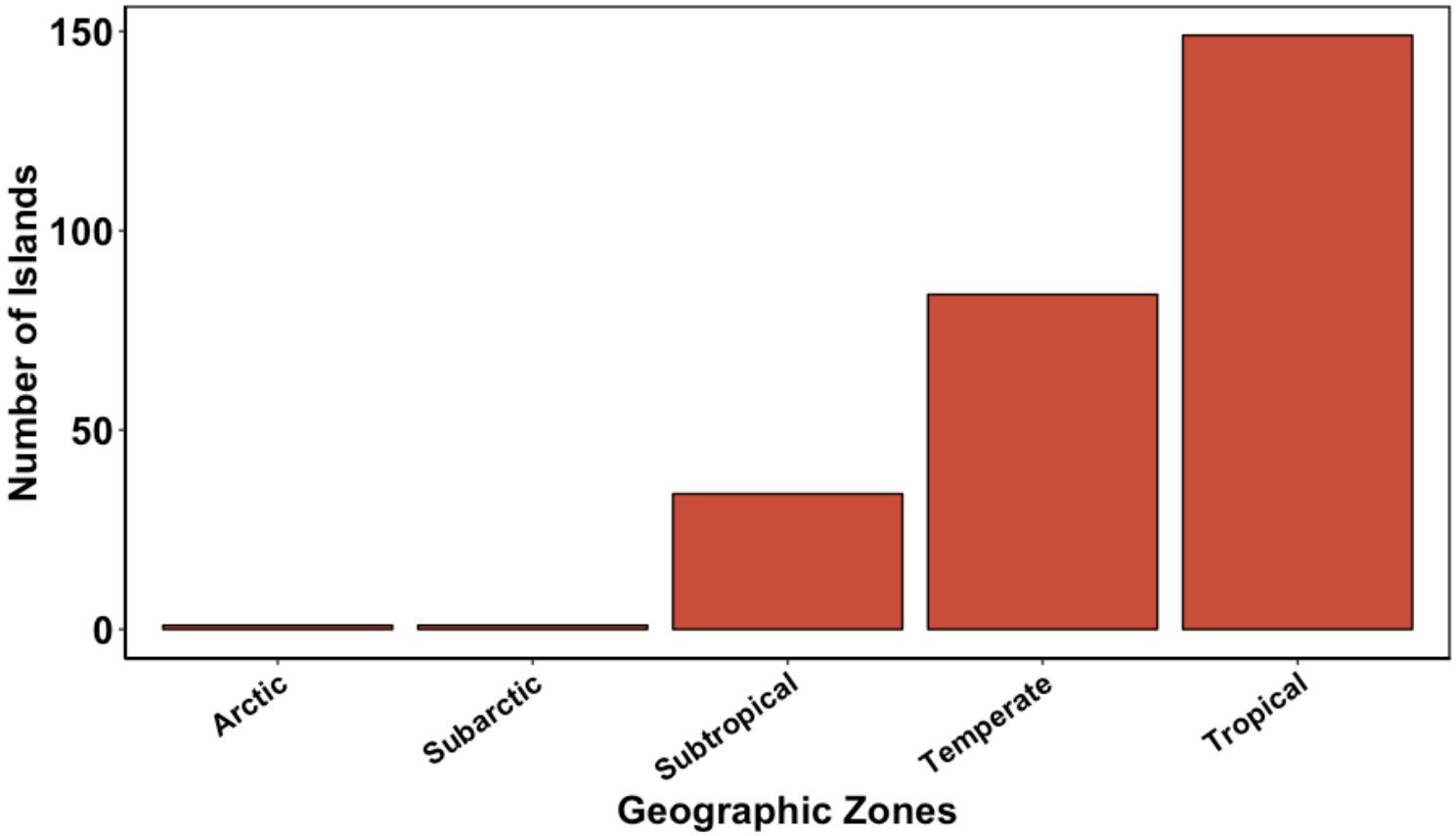
Distance to Mainland of Islands in our Study



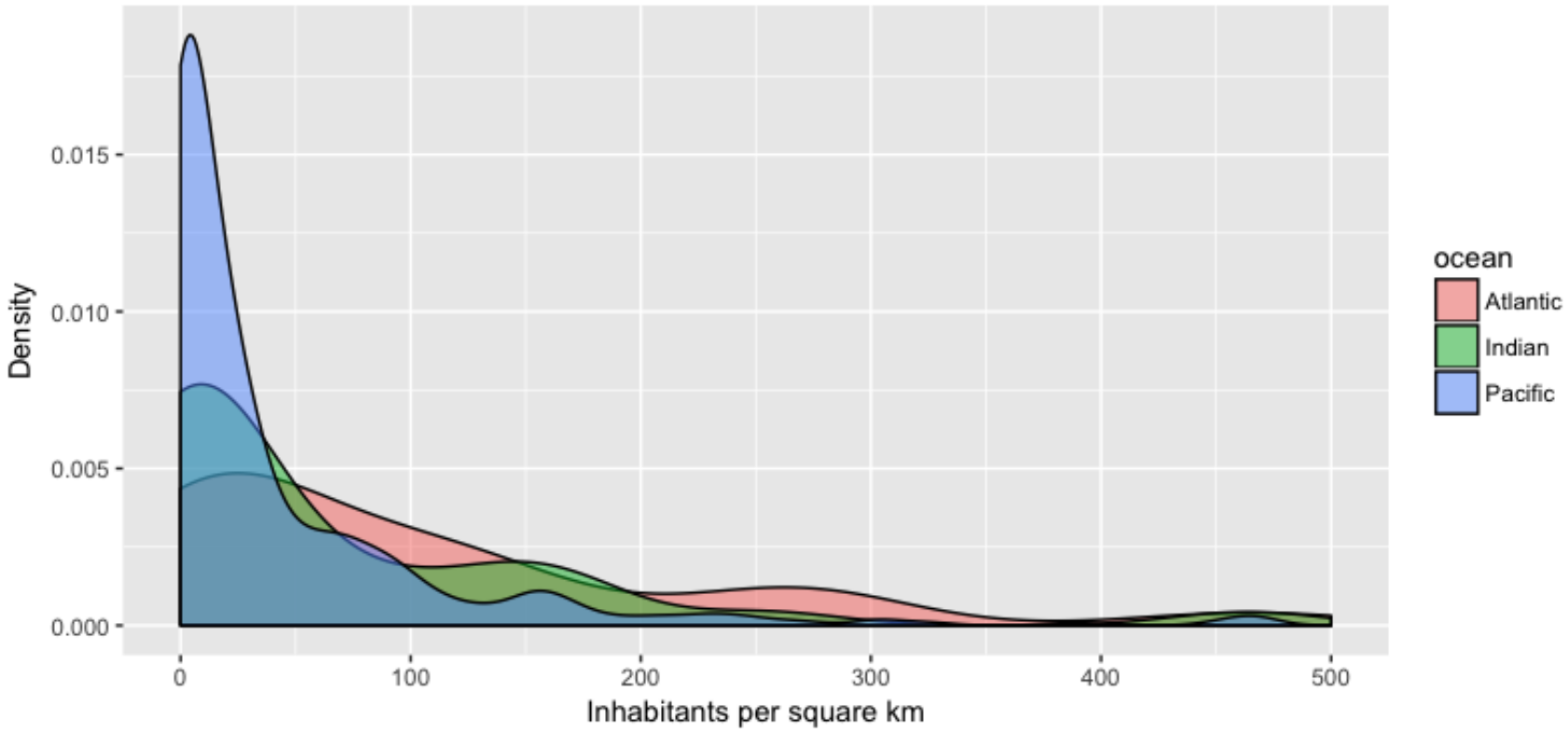
Mean Annual Precipitation of Islands in our Study



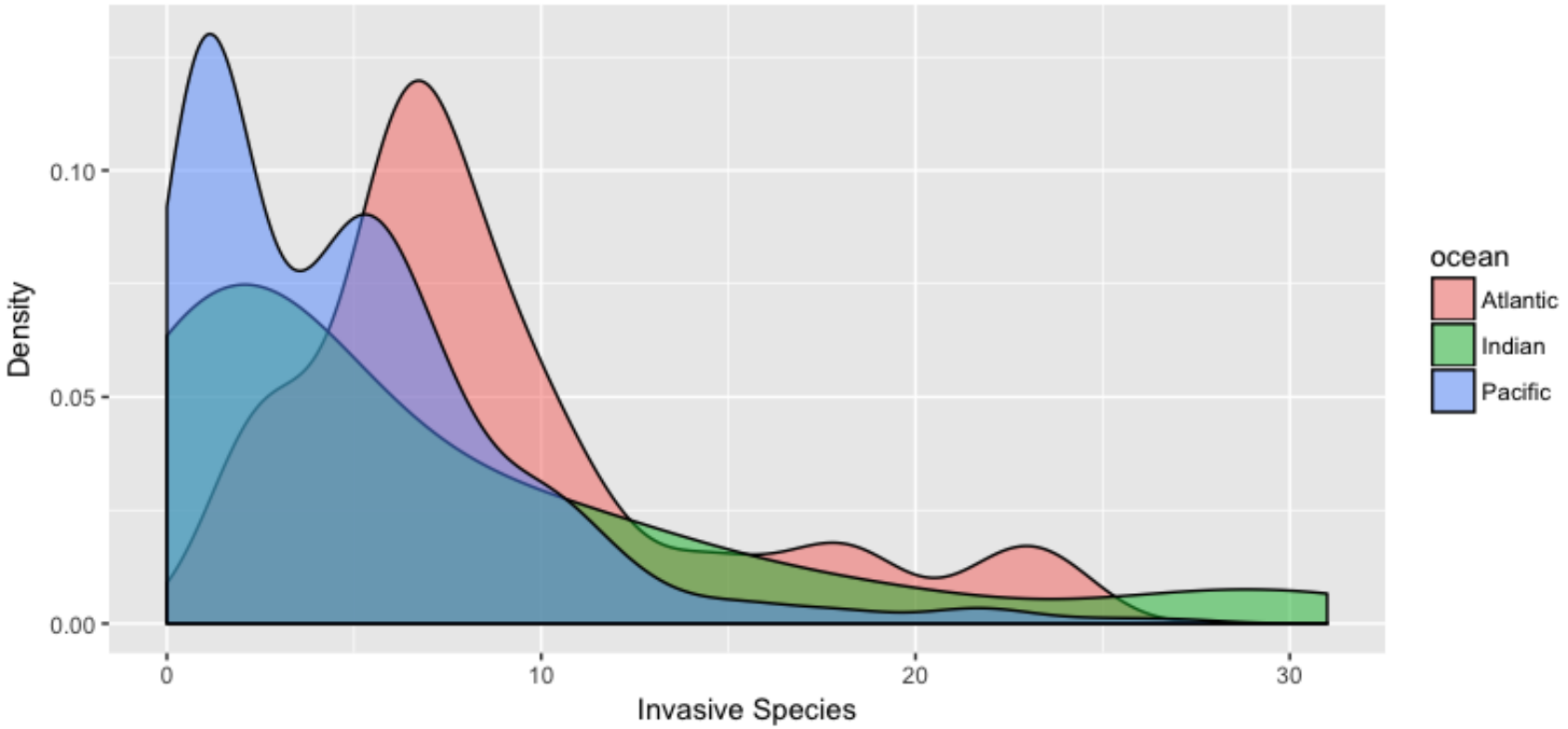
Distribution of Islands by Geographic Zone



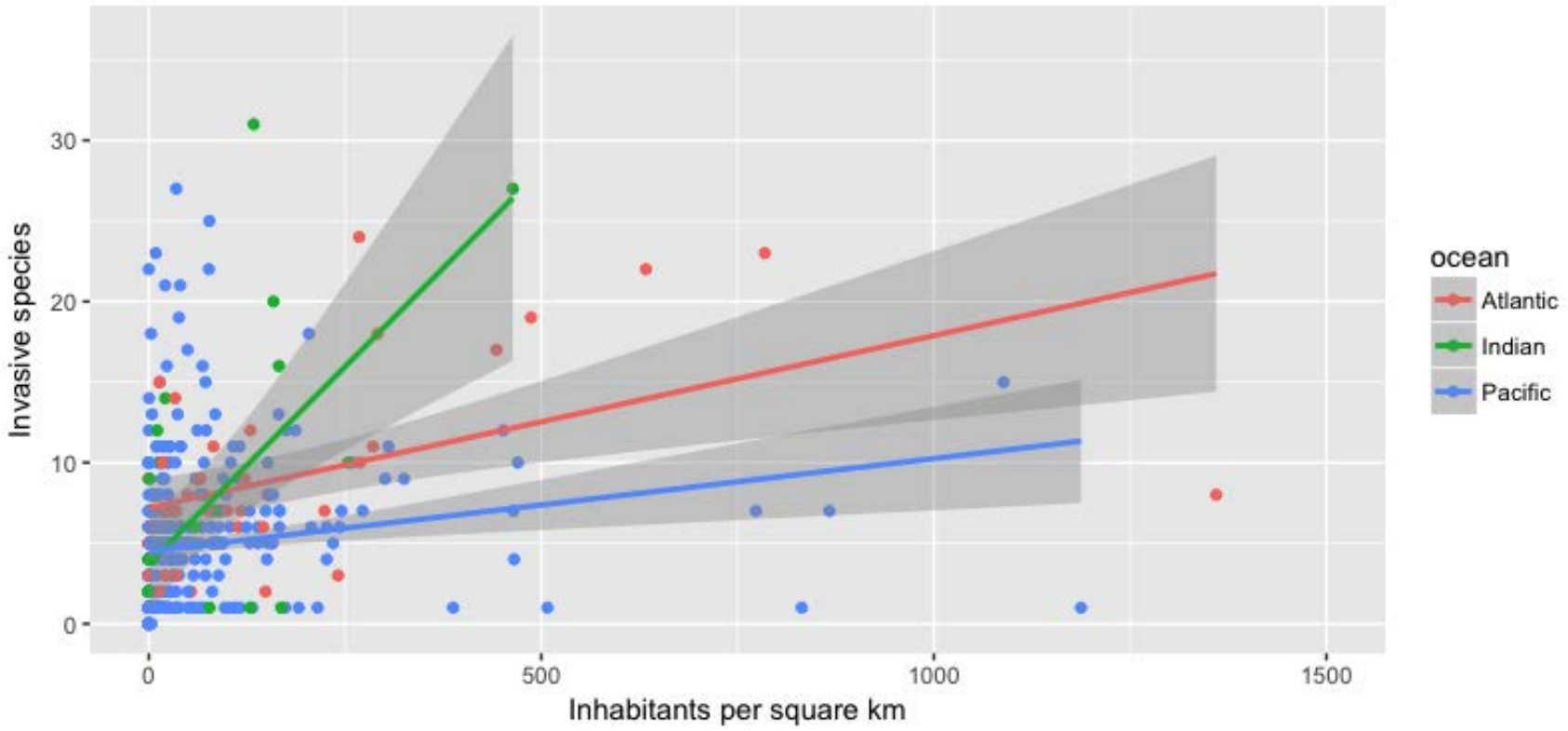
Distribution of Human Population Density by Ocean



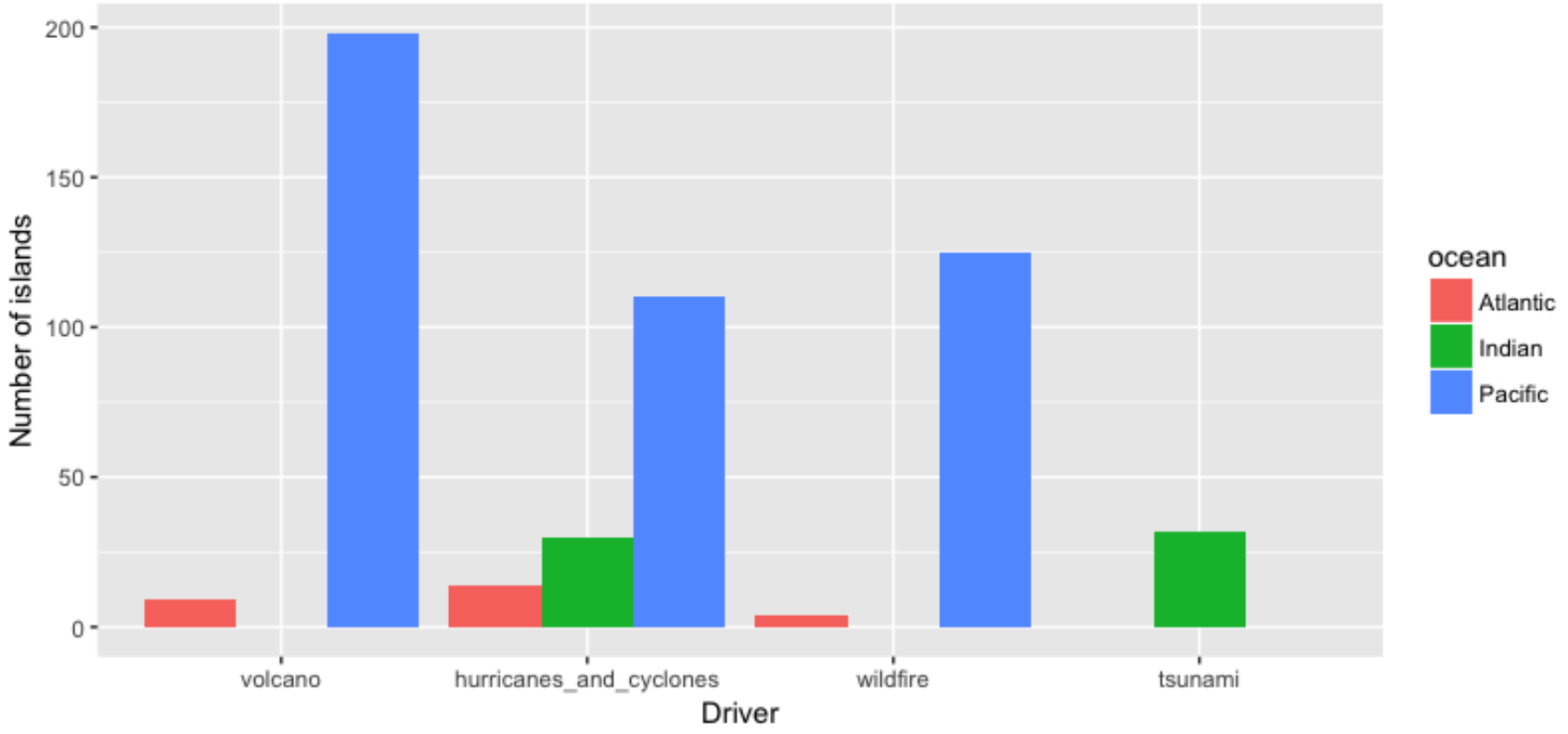
Distribution of Invasive Species



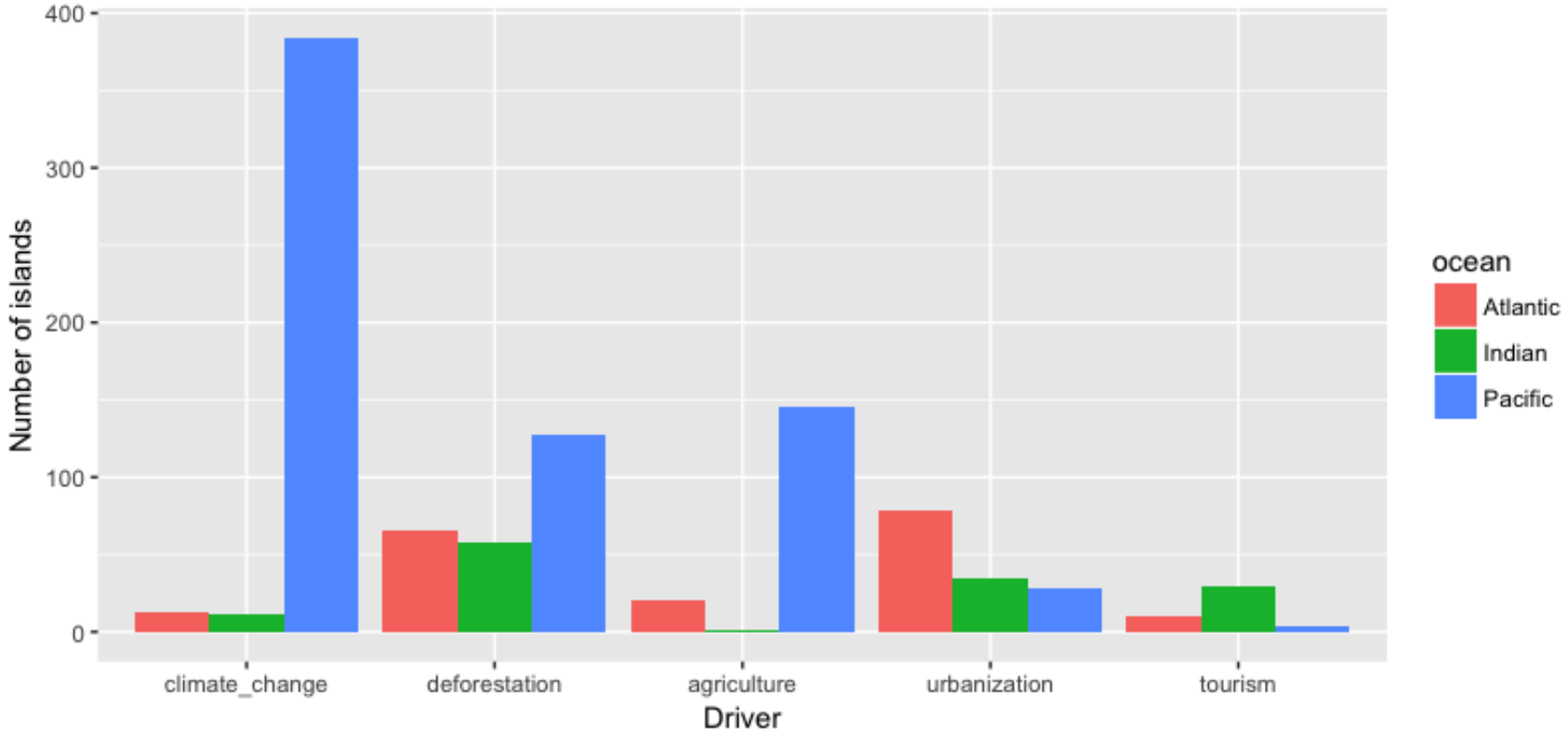
Regression of Invasive Species by Population Density



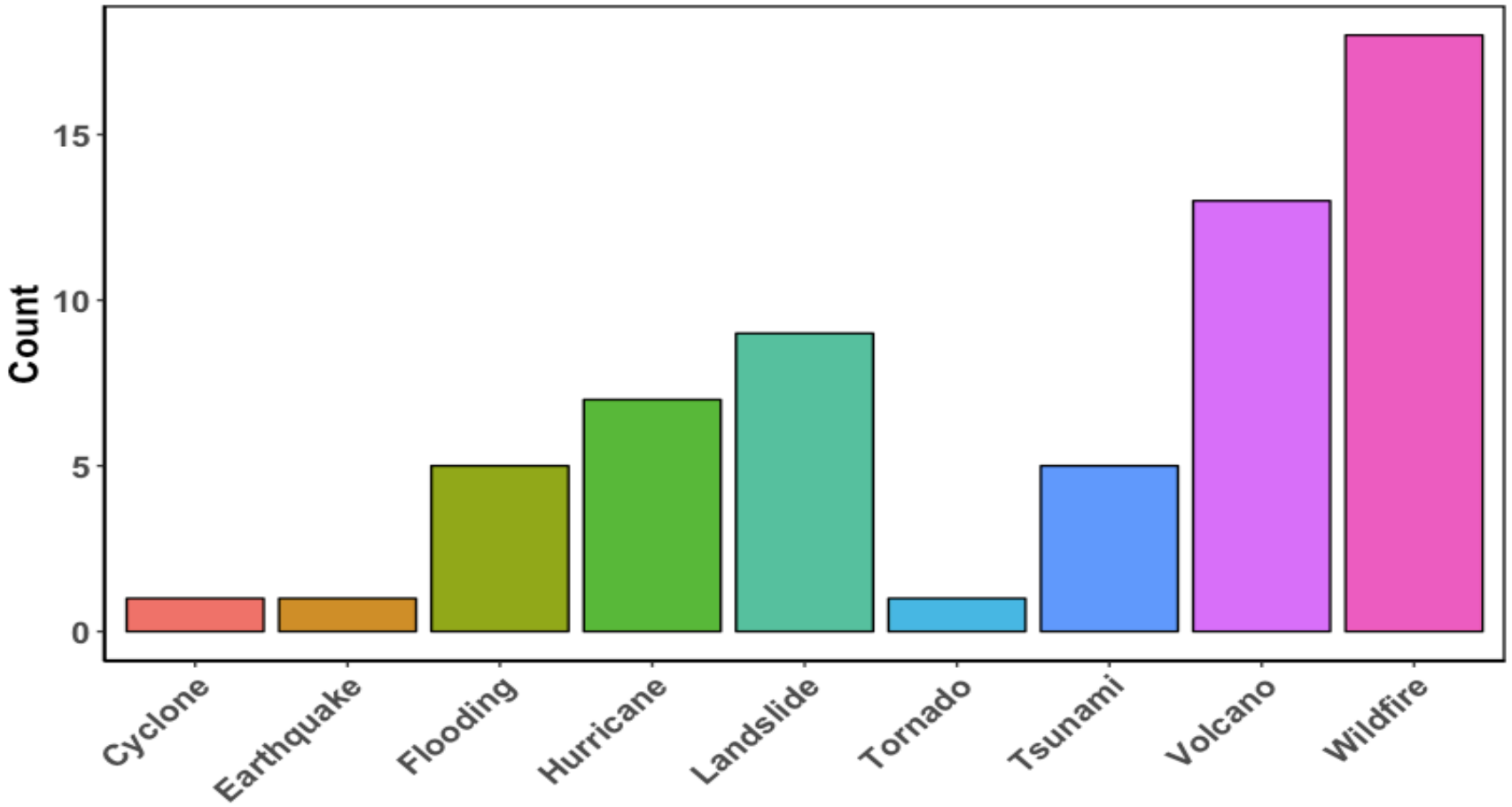
Biophysical Drivers of LCLUC on Islands by Ocean



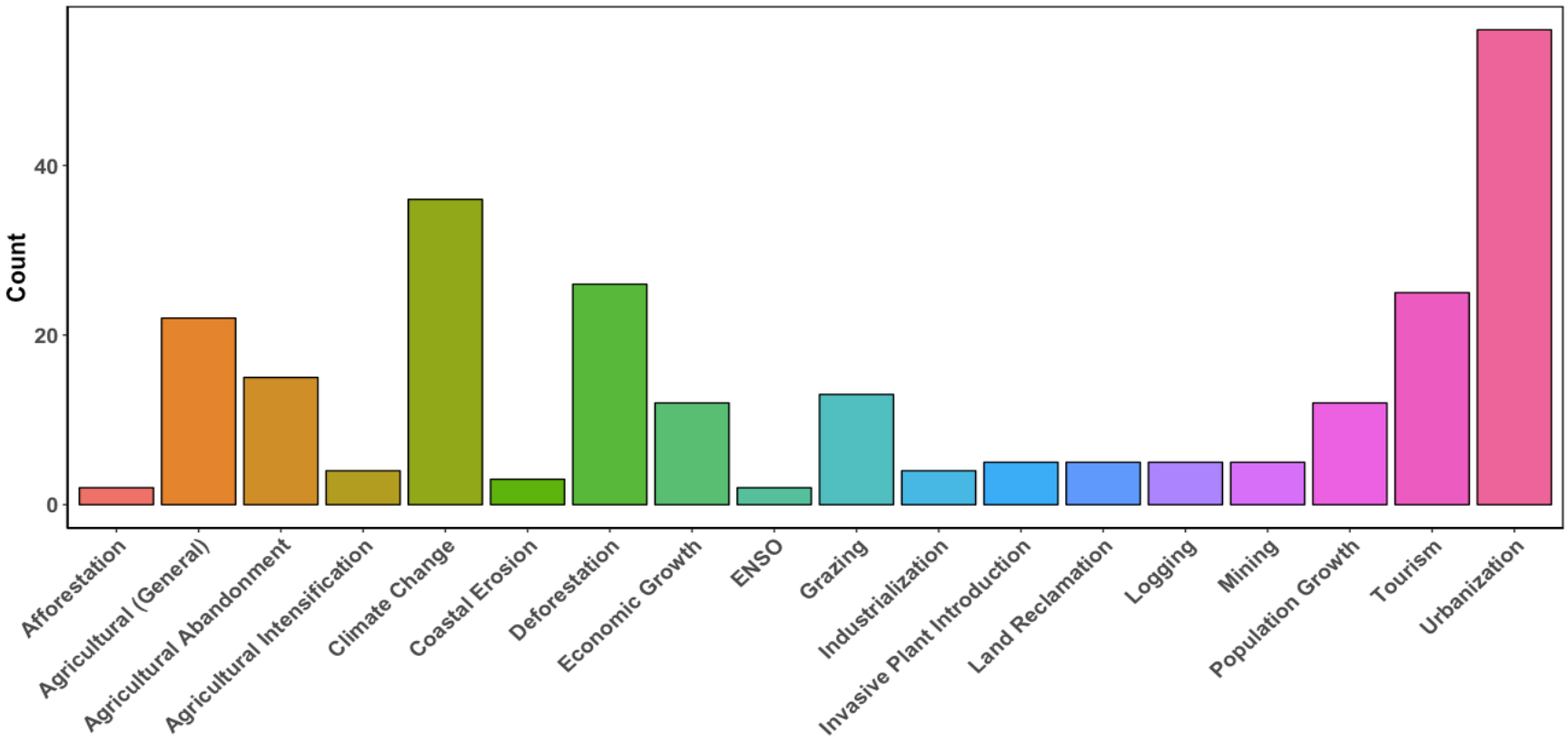
Anthropogenic Drivers of LCLUV on Islands by Ocean

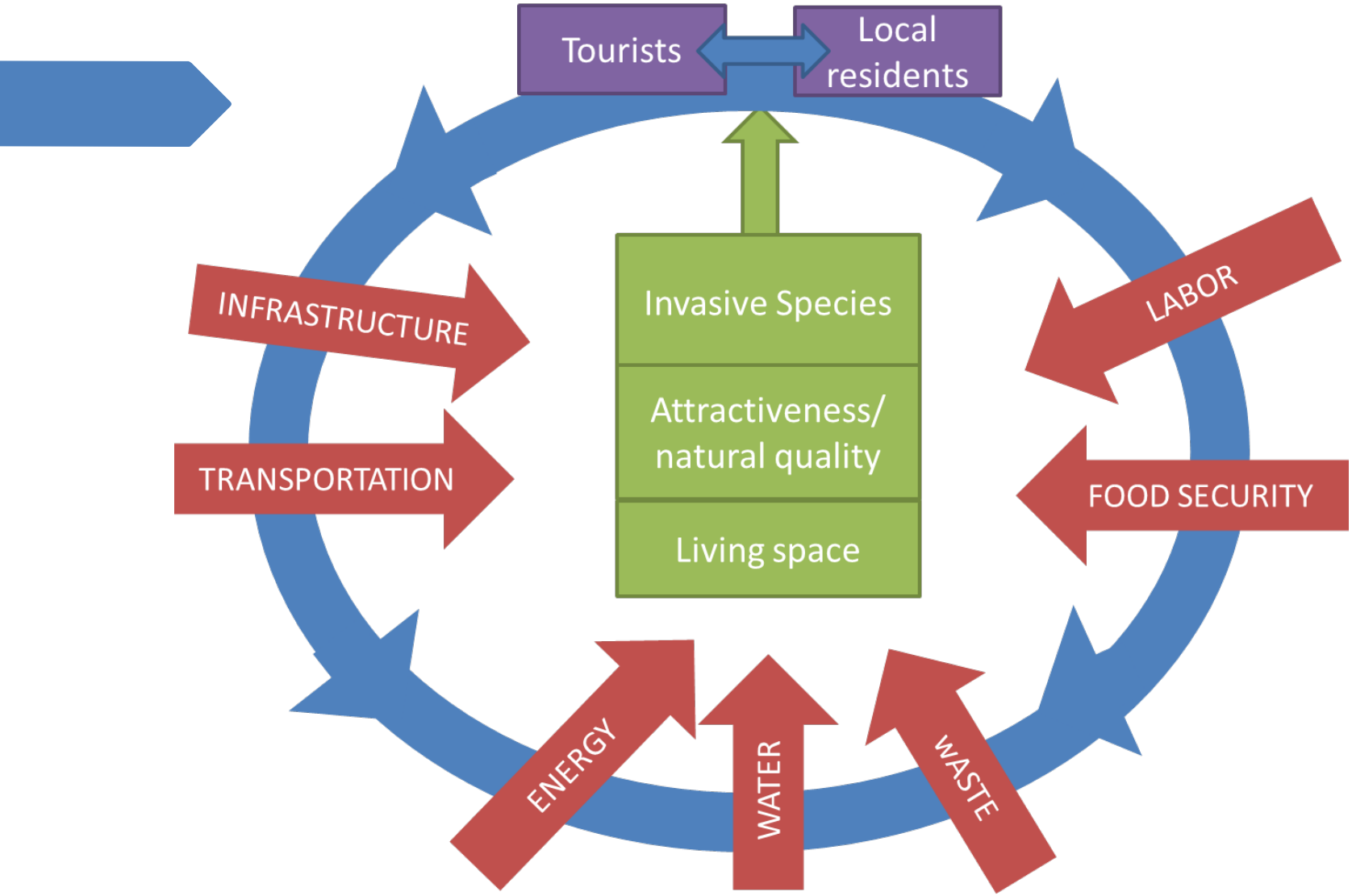


Disaster-Related – Studies & Papers



Anthropogenic-Related – Studies & Papers

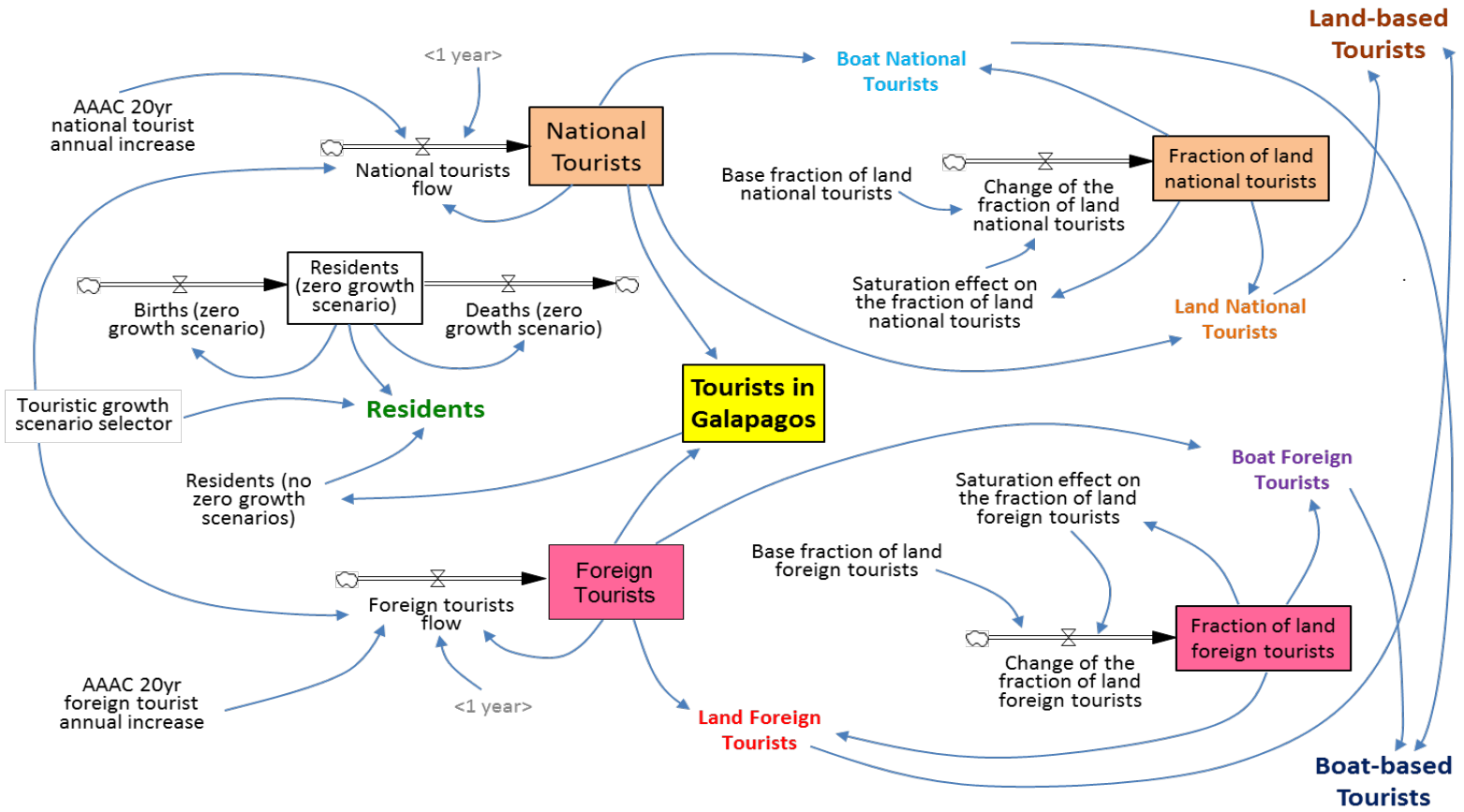



Tourists
Local residents
Invasive Species
Attractiveness/ natural quality
Living space
INFRASTRUCTURE
TRANSPORTATION
LABOR
FOOD SECURITY
ENERGY
WATER
WASTE

What is Dynamic Systems Modeling?

- Designed to study and manage complex feedback systems through the collection of interacting elements that function together in a specified system.
- Properties include quantities that vary over time, whose variability is described causally, and whose influences are contained within a closed system feedback loop.
- The casual graph is augmented with information on stocks, flows, rates of change, feedback loops, and rules of behavior that are translated into a system dynamics flow graph and then into programs and/or equations.
- Feedback loops are the key to understanding system dynamics as an initial cause can ripple through a chain of causation factors ultimately to “re-affect” itself.

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



International Islands Network (I^2N)

A Membership Organization to Study LCLUC and the Threats to Island Sustainability

- Islands may be conceptualized along a conservation – development gradient that is shaped by exogenous and endogenous dynamics as well as social and ecological processes & patterns of LCLUC.
- Tourism has become one of the most important industries in recent decades, and island tourism is one of the main components of the world tourism industry, a global sector generating revenues in excess of $1.5 Billion.
- ***I^2N*** is designed to create an interdisciplinary science team that extends across multiple institutions with expertise on particular island settings from around the globe, conceptual models that link people and environment through an integrated systems approach, and a diversity of islands that compare LCLUC and social-ecological drivers through multi-scale perspectives.