



# Evaluation of Remotely Sensed Nighttime Light as Complementary Data Source for Economic Indicators in Pacific Island Economies

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# Presentation Outline

1. Introduction to Nighttime Light
2. Research Motivation and Framework
3. NTL for Economic Monitoring
  - GDP, Sectoral GDP, GFCF
  - Trends in Built-up Areas
  - Pixel-level Analysis





# Presentation Outline

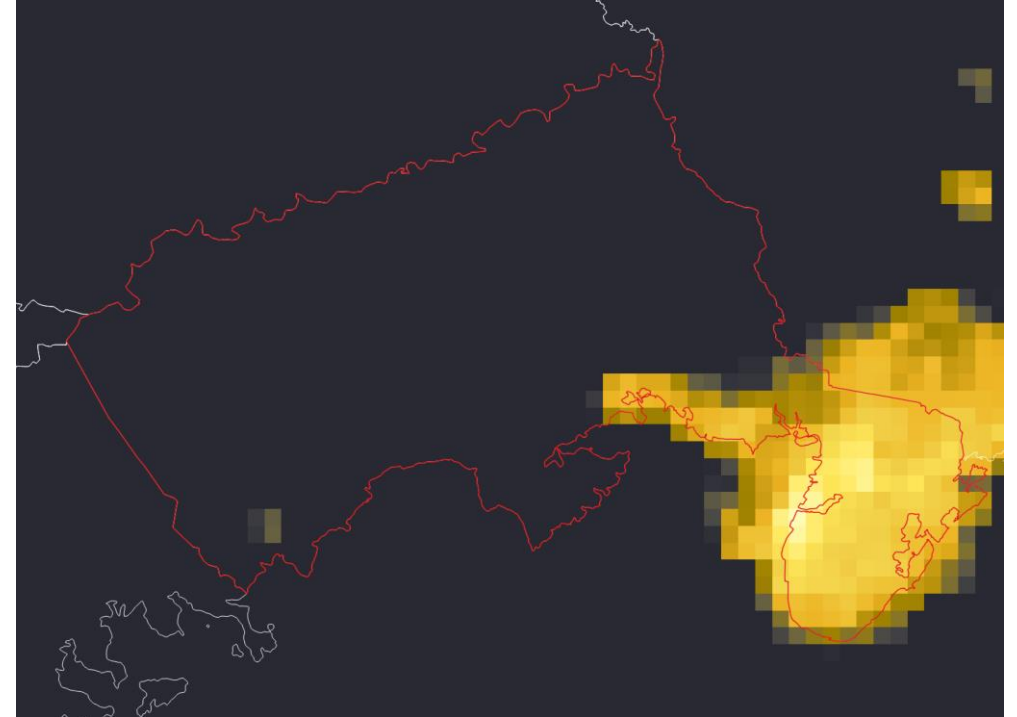
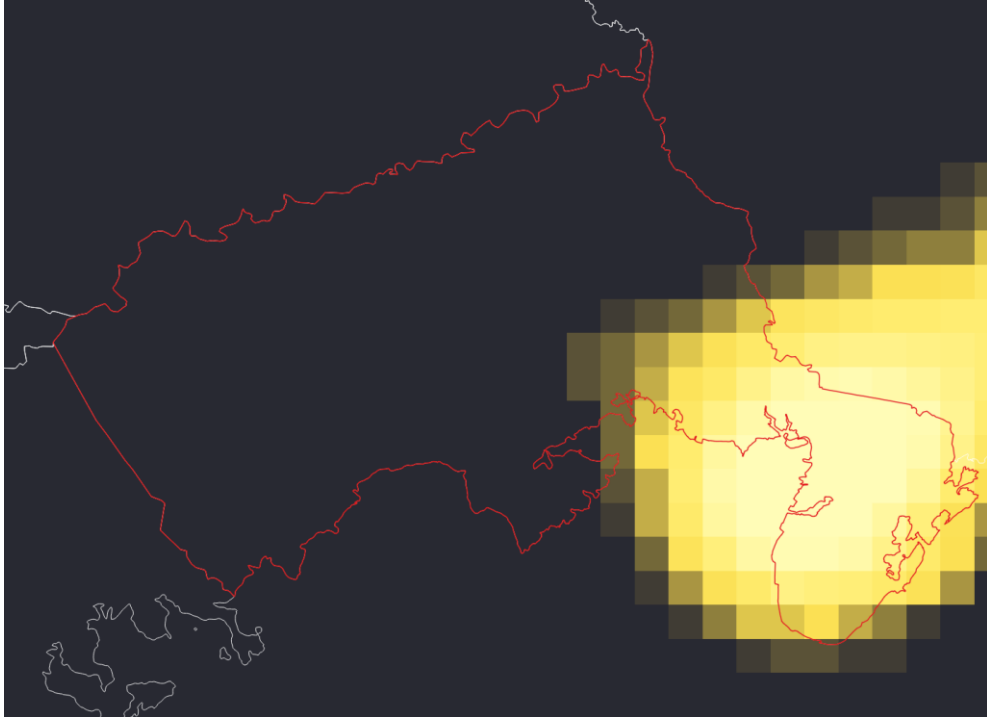
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# Nighttime Light (NTL)

observation of the Earth's surfaces illuminations from multiple sources, both natural and man-made, such as moonlight, cities (and its buildings, and transportation infrastructures), and ground reflection (snow, water, others; NASA)

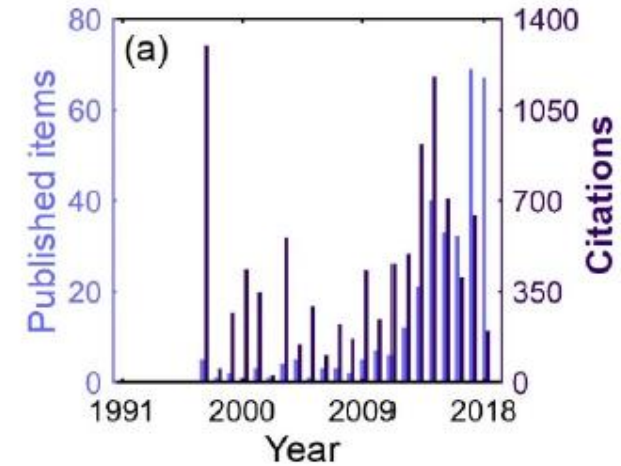
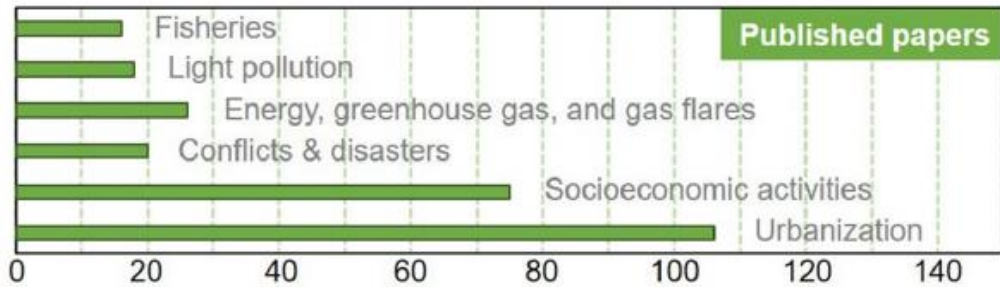
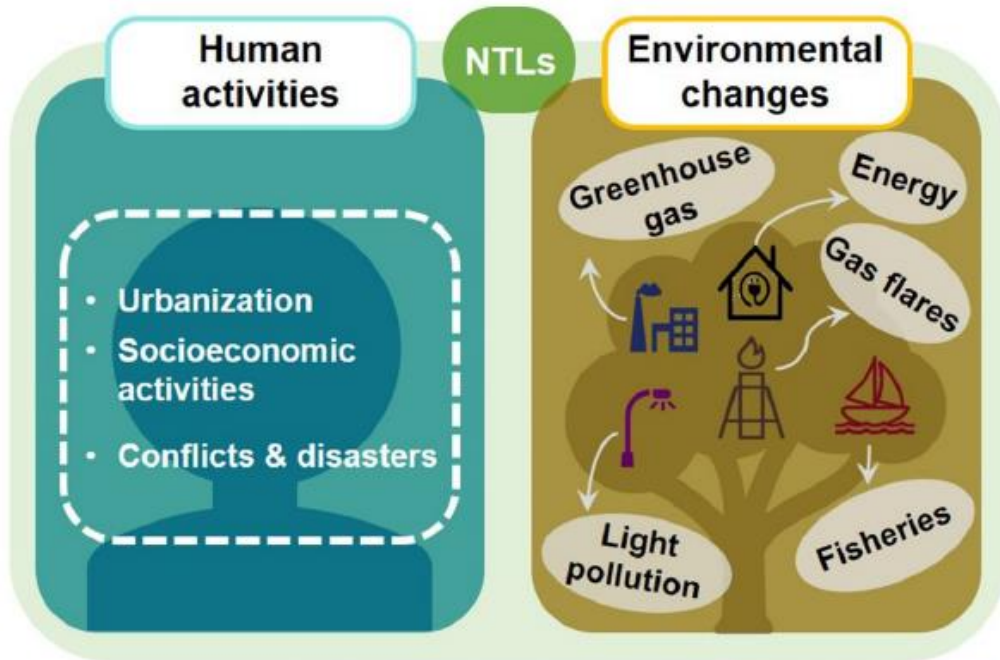


	Defense Meteorological Satellite Program	Visible Infrared Imaging Radiometer Suite
Frequency	Annual	Daily, Monthly, Annual
Resolution	1km	500m
Availability	1992 – 2013	2012 – present



# Nighttime Light (NTL): Researches

## Applications of satellite-based NTL remote sensing (Zhao et al, 2019)



# Research Motivation

- Existing literature on the correlation of NTL with economic indicators focuses on big economies, with little work that includes Pacific Island Economies (PIEs).
- Recently, World Bank (2023) published a working paper highlighting their applications on NTL in their different projects in the Pacific – NTL as potential complementary data source to official statistics particularly in monitoring gas industries, supporting poverty mapping exercises, and generating detailed electrification statistics
- This study is designed to further address the research gaps on NTL applications in the PIEs. With the goal of assessing the potential of remotely sensed NTL as a complementary data source of economic conditions

# Research Framework

## Exploratory data analysis



### 1. Data Collection

- Downloading of NTL Data
- Collection of macroeconomic indicators



### 2. Panel Data Generation

- Geospatial analysis
- Linking of geospatial and macroeconomic datasets
- Conversion to tabular data format



### 3. Macrolevel Analysis

- Correlation between NTL data and macroeconomic indicators
  - GDP
  - Sectoral GDP
  - Gross Fixed Capital Formation



### 4. Built-up Area Analysis

- Subset analysis focusing on areas identified as building footprints and built-up areas



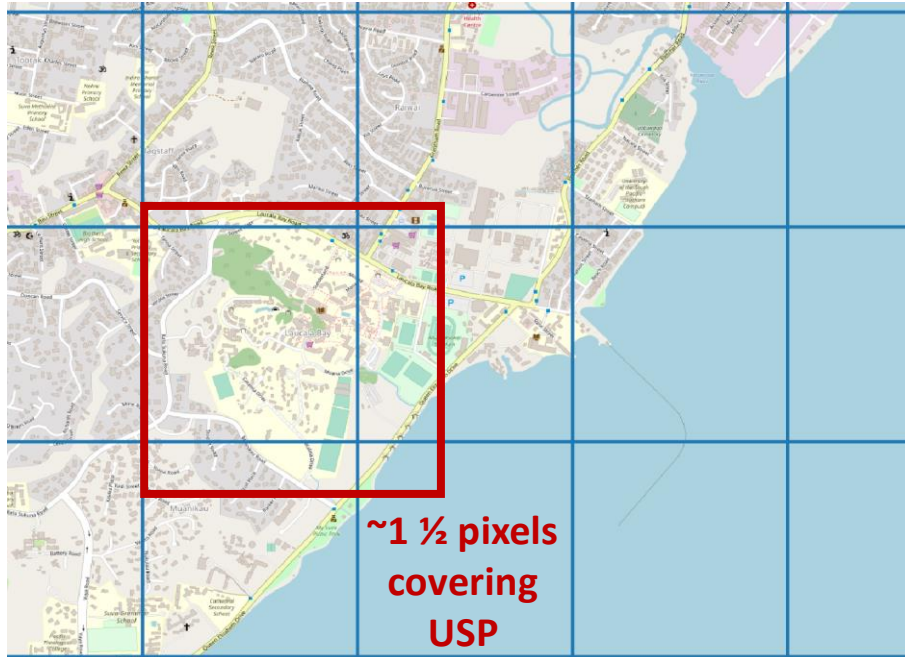
### 5. Pixel-level Analysis

- Subset analysis at the most granular level of NTL data

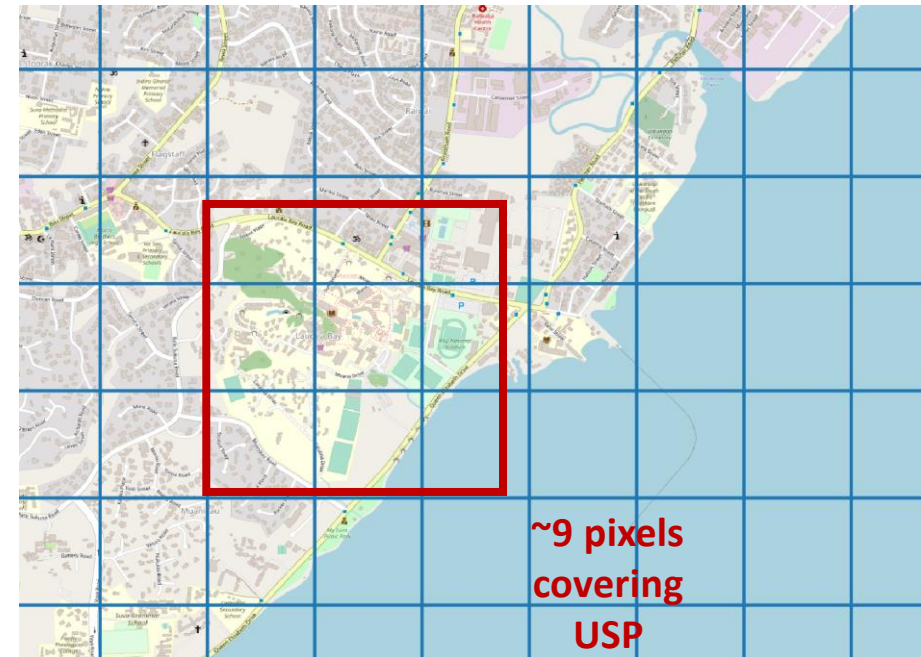


# Nighttime Light (NTL)

Comparing of pixel resolution of these NTL data shows that both are more ideal for macro-level analysis.



Defense Meteorological Satellite Program's  
Operational Line-scan System (DMSP-OLS)



Suomi National Polar Partnership Visible Infrared  
Imaging Radiometer Suite (SNPP-VIIRS)





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2. Research Motivation and Framework
3. **NTL for Economic Monitoring**
  - **GDP, Sectoral GDP, GFCF**
  - **Trends in Built-up Areas**
  - **Pixel-level Analysis**



# NTL for Economic Monitoring in the Pacific

Several iteration of NTL data were explored in the research. Among these, **natural log-transformed** will be discussed in the succeeding slides.

## Nighttime Light

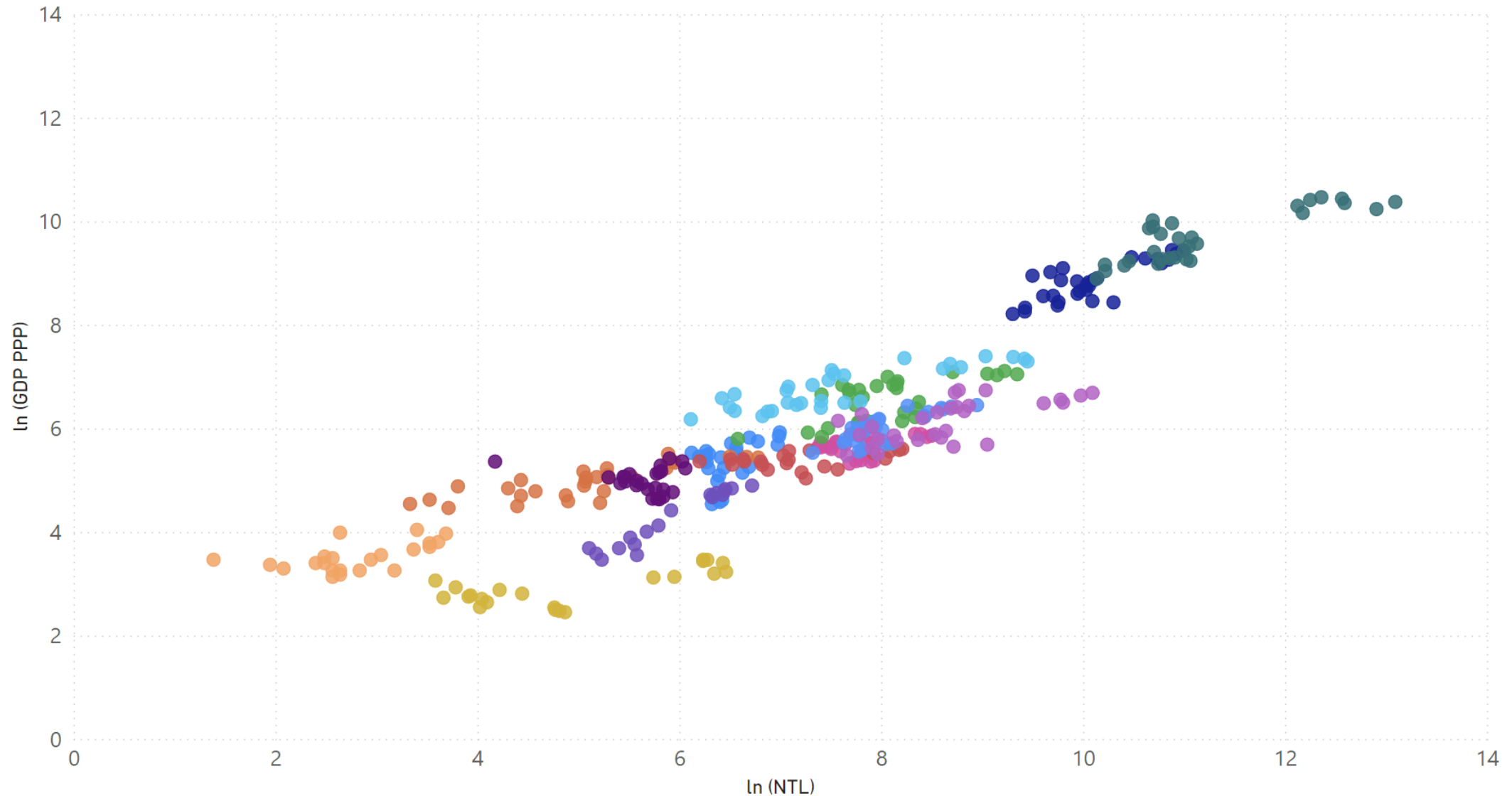
1. Harmonized NTL (DMSP-VIIRS)
  - a. Digital Number (DN) Value
  - b. Natural log-transformed DN**
  - c. Year-on-year difference
  - d. Year-on-year growth
2. VIIRS

## Economic Indicator

1. GDP PPP (in USD)
2. GDP at constant prices (in various currency units)
3. Sectoral GDP
  - a. Agriculture
  - b. Industry
  - c. Services
4. Gross Fixed Capital Formation
5. Government Spending

# NTL for Economic Monitoring in the Pacific

Cook Islands ● Fiji ● Kiribati ● Marshall Islands ● Micronesia ● Nauru ● Niue ● Palau ● Papua New Guinea ● Samoa ● Solomon Islands ● Tonga ● Tuvalu ● Vanuatu





# NTL for Economic Monitoring in the Pacific

- NTL series coincides with GDP levels across a 30-year observation period for most of the Pacific Island Economies.
- Year-on-year comparison yielded slightly higher correlation compared to a one-year lag comparison.

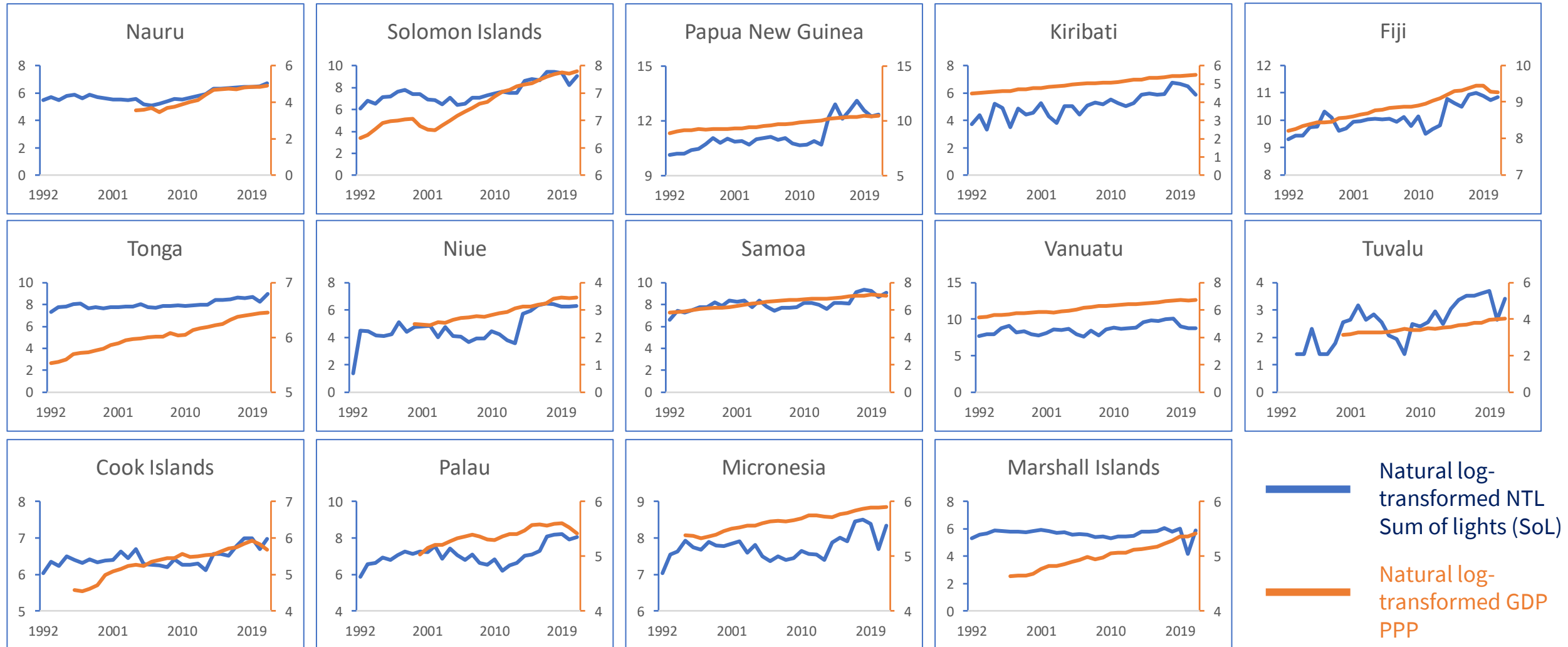
	GDP PPP, ln-transformed		GDP LCU (at constant prices) , ln-transformed	
	Correlation (Year-on-Year)	Correlation (1-Year lag)	Correlation (Year-on-Year)	Correlation (1-Year lag)
Nauru	0.97018	0.94836	0.96280	0.94159
Solomon Islands	0.85171	0.79974	0.90595	0.87837
Papua New Guinea	0.84632	0.82045	0.71199	0.68190
Kiribati	0.83344	0.82632	0.83970	0.71884
Fiji	0.80531	0.76854	0.52370	0.50782
Tonga	0.80329	0.79270	0.82113	0.78462
Niue	0.72236	0.68039	0.75250	0.63359
Samoa	0.66879	0.65035	0.43911	0.52443
Vanuatu	0.65570	0.68190	0.58609	0.42432
Tuvalu	0.56104	0.60443	0.77824	0.77751
Cook Islands	0.46144	0.37750	0.53587	0.45850
Palau	0.39601	0.29565	0.65346	0.58856
Micronesia	0.33772	0.30315	0.27197	0.32834
Marshall Islands	-0.20969	-0.31183	-0.21767	-0.21342

Source: Author's computation



# NTL for Economic Monitoring in the Pacific

- NTL series coincides with GDP levels across a 30-year observation period for most of the Pacific Island Economies.
- Year-on-year comparison yielded slightly higher correlation compared to a one-year lag comparison.



Source: Author's computation



# Sector-Level Analysis

- Similar trend in correlation was derived from GDP generated by the service sector. The sector contributes to at least 50% of total GDP for most economies except PNG.

	Services	
	Correlation (Year-on-Year)	Share of Sector
Nauru	0.95410	77%
Solomon Islands	0.90625	52%
Kiribati	0.81364	66%
Tuvalu	0.80571	68%
Tonga	0.77944	60%
Niue	0.75815	74%
Papua New Guinea	0.66380	39%
Vanuatu	0.61383	69%
Cook Islands	0.54756	85%
Fiji	0.49615	65%
Samoa	0.49253	66%
Palau	0.46856	85%
Micronesia	0.32426	68%
Marshall Islands	-0.12869	75%

	Industry	
	Correlation (Year-on-Year)	Share of Sector
Solomon Islands	0.90793	15%
Nauru	0.90362	17%
Kiribati	0.82946	10%
Tonga	0.74142	18%
Papua New Guinea	0.68849	34%
Niue	0.58470	4%
Fiji	0.55396	22%
Tuvalu	0.51322	12%
Micronesia	0.46297	6%
Vanuatu	0.42993	10%
Samoa	0.33059	21%
Marshall Islands	-0.22163	14%
Palau	-0.23706	11%
Cook Islands	-0.61949	8%

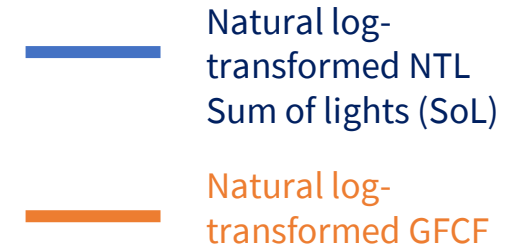
	Agriculture	
	Correlation (Year-on-Year)	Share of Sector
Papua New Guinea	0.76519	33%
Tonga	0.74809	6%
Kiribati	0.70918	24%
Solomon Islands	0.70417	22%
Tuvalu	0.63633	27%
Fiji	0.60976	23%
Vanuatu	0.55639	13%
Niue	0.37555	20%
Cook Islands	0.36901	26%
Nauru	0.34834	22%
Palau	0.29440	14%
Samoa	-0.08536	11%
Marshall Islands	-0.36829	4%
Micronesia	-0.39288	6%

Source of Sector Share: ADO database



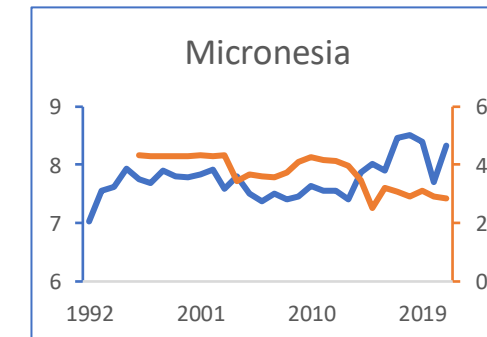
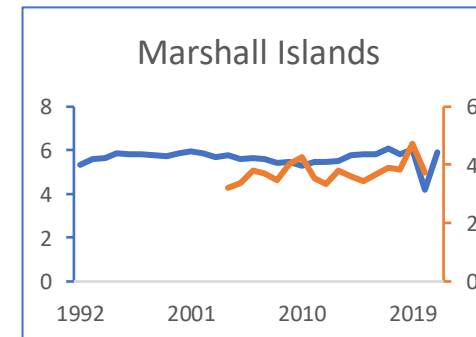
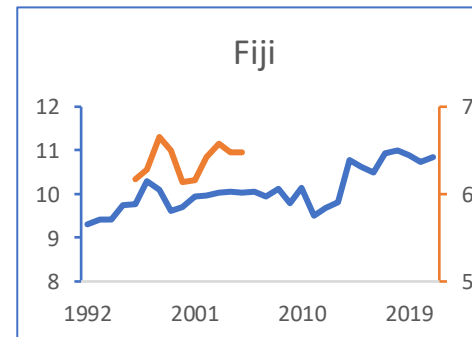
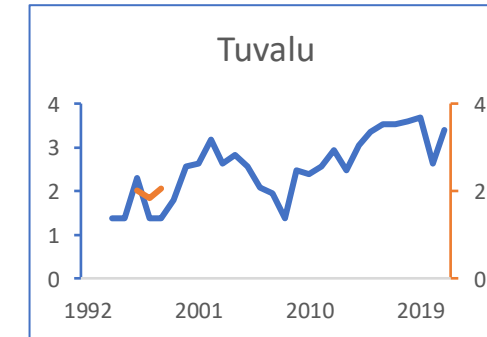
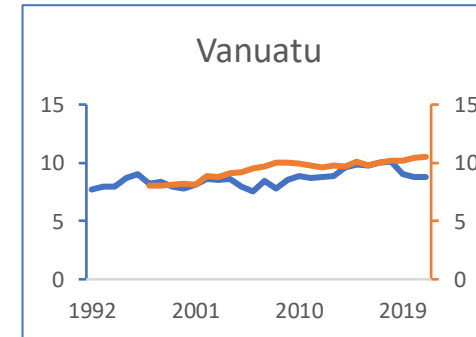
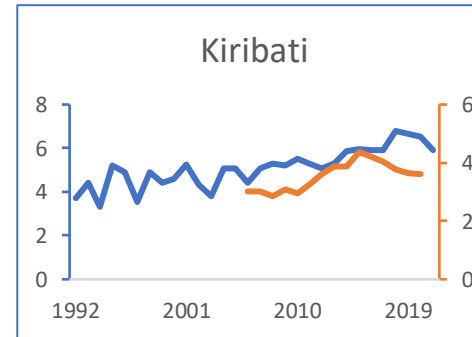
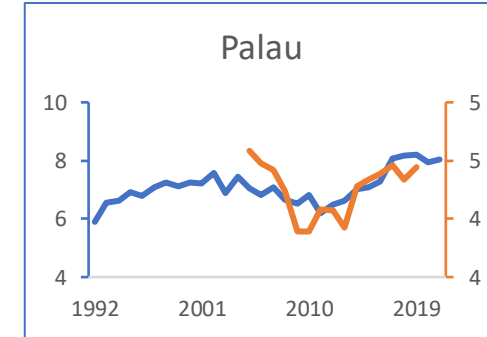
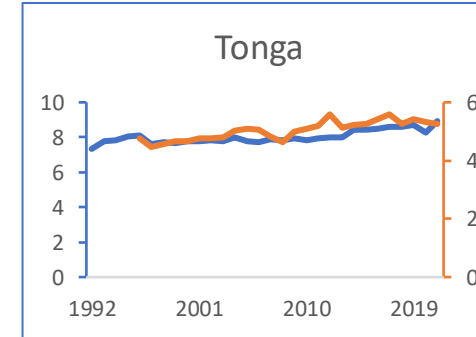
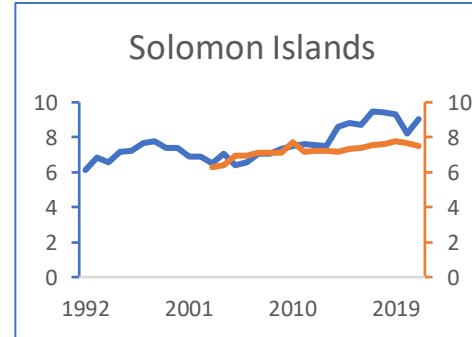
# Gross Fixed Capital Formation

- Trends in GFCF also coincides with NTL growth for those economies with available data, albeit not as strong as GDP.



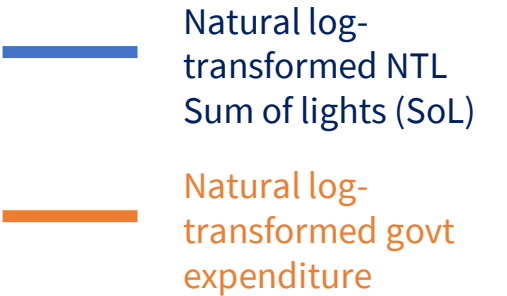
	Correlation (Year-on-Year)	Data Points
Solomon Islands	0.72041	19
Tonga	0.71544	26
Palau	0.58944	15
Kiribati	0.54386	15
Vanuatu	0.54006	25
Tuvalu	0.37516	3
Fiji	0.28052	10
Marshall Islands	0.10609	17
Micronesia	-0.54170	26

Source of GFCF: ADO database

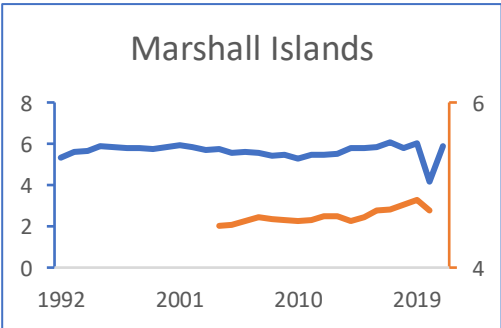
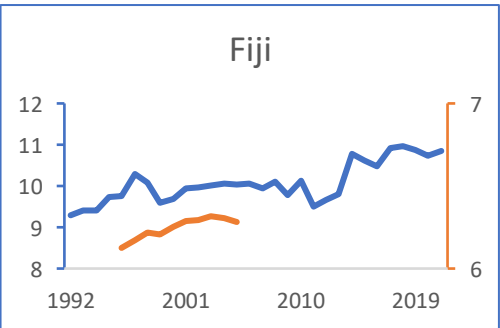
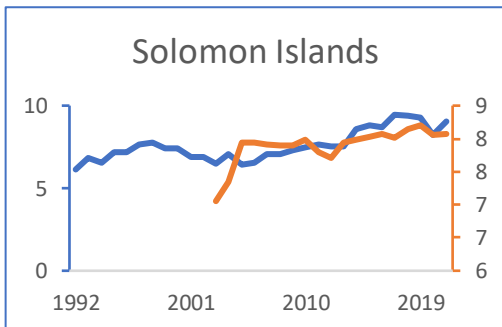
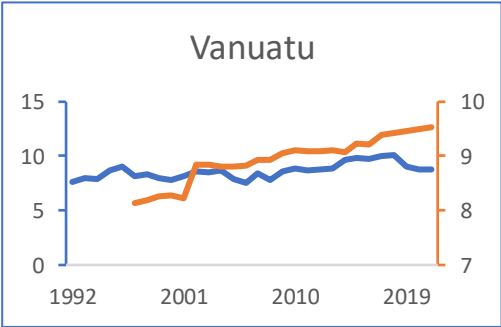
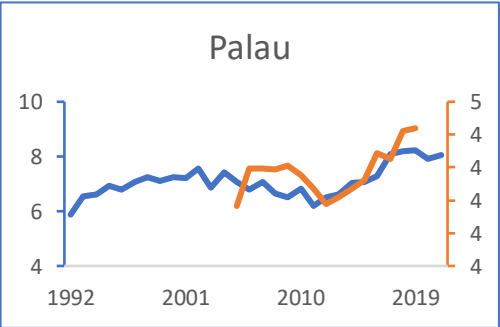
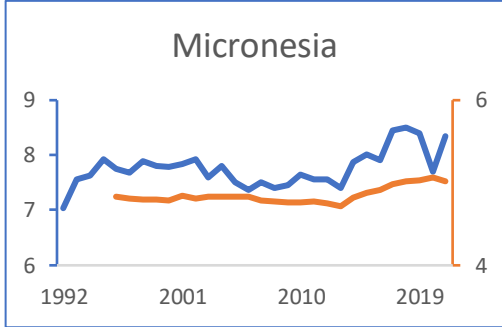
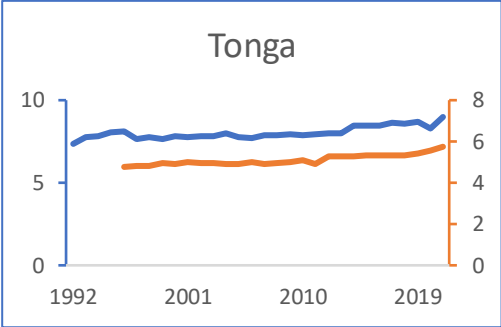
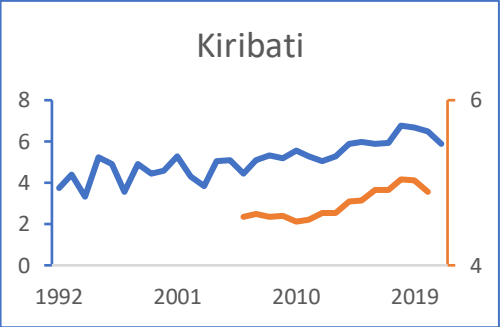




# Government Expenditure



	Correlation (Year-on-Year)	Data Points
Kiribati	0.87632	15
Tonga	0.83530	26
Micronesia	0.75251	26
Palau	0.74453	15
Vanuatu	0.65527	25
Solomon Islands	0.61117	19
Fiji	0.17607	10
Marshall Islands	0.13722	17



Source of GFCF: ADO database



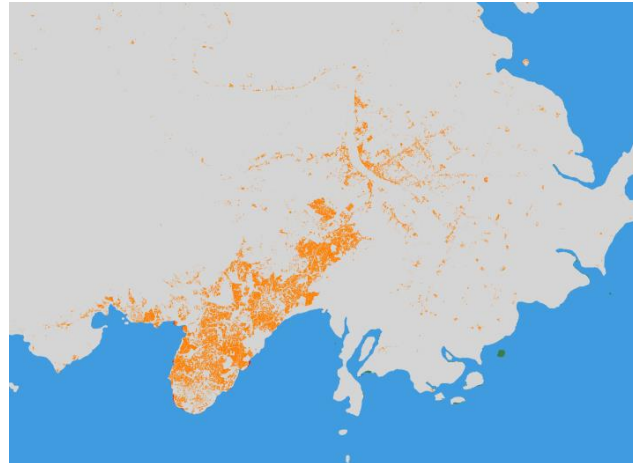
# Is growth concentrated in built/urban areas?

Using datasets that represent built environment where human activities are concentrated, will NTL better describe a country's economic activity?

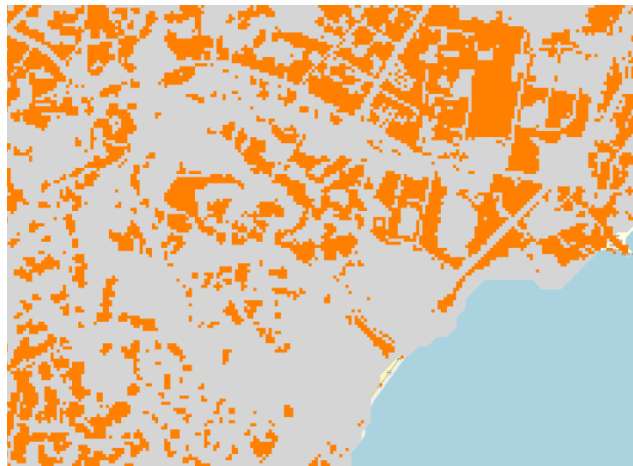
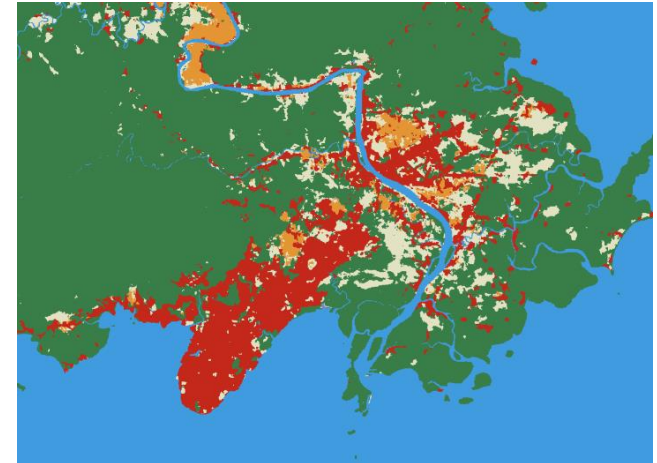
**Open Street Map**



**World Settlement Footprint**



**ESRI/Sentinel-2 Land Cover**



 buildings

 built area



# Is growth concentrated in built/urban areas?

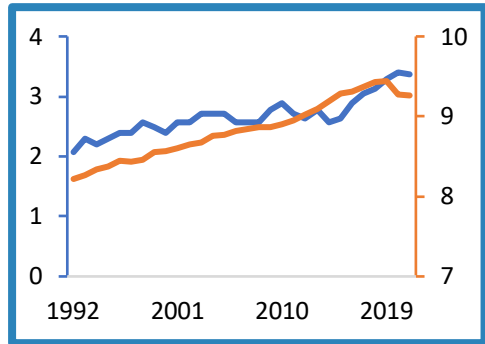
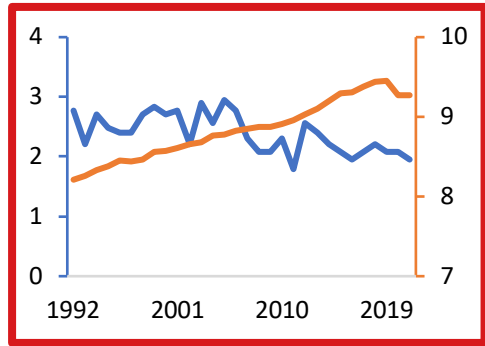
- Less than half of the countries showed higher correlation when limiting the analysis to built-up areas only.
- Most significant improvement is in Vanuatu due to increased NTL from volcanic eruptions.

	Sum of Lights - All Areas	Sum of Lights - WSF Buildings Only	Sum of Lights - Builtup Areas Only
	Correlation (Year-on-Year)	Correlation (Year-on-Year)	Correlation (Year-on-Year)
Nauru	0.97018	0.96015	0.96354
Solomon Islands	0.85171	0.77464	0.85100
Papua New Guinea	0.84632	0.82680	0.85856
Kiribati	0.83344	0.40621	0.46862
Fiji	0.80531	0.74002	0.76534
Tonga	0.80329	0.08920	0.51525
Niue	0.72236	0.38825	0.55554
Samoa	0.66879	0.73010	0.76078
Vanuatu	0.65570	0.44553	0.84314
Tuvalu	0.56104	0.56909	0.59503
Cook Islands	0.46144	-0.00631	0.03843
Palau	0.39601	-0.66872	-0.37992
Micronesia	0.33772	0.49574	-0.29960
Marshall Islands	-0.20969	-0.38800	-0.43588

Source: Author's computation

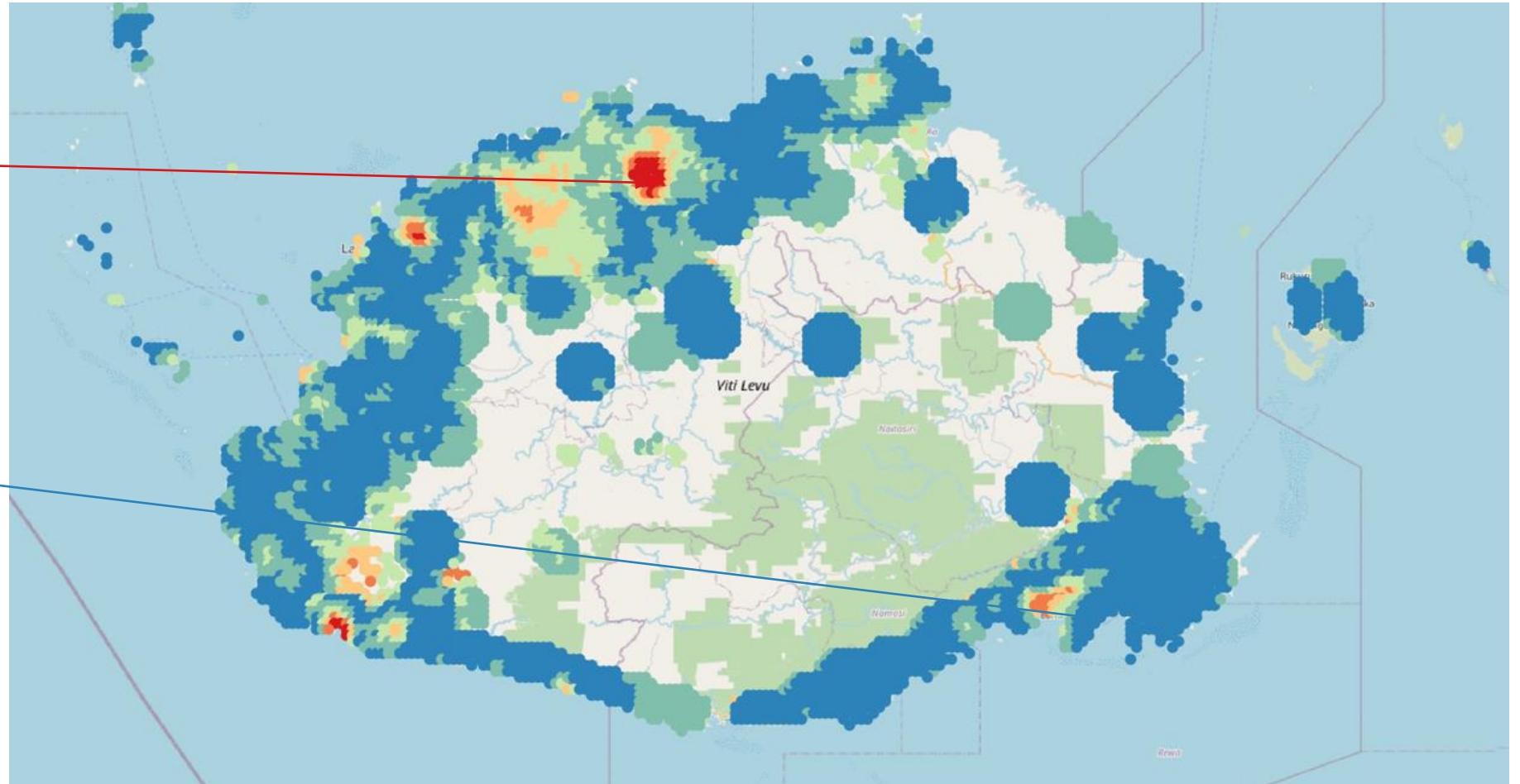
# Pixel-level Analysis

- Blue and green areas are pixels with positive correlation to national GDP, while red and orange areas are those with negative correlation.



— Natural log-transformed  
NTL Sum of lights (SoL)

— Natural log-  
transformed GDP PPP

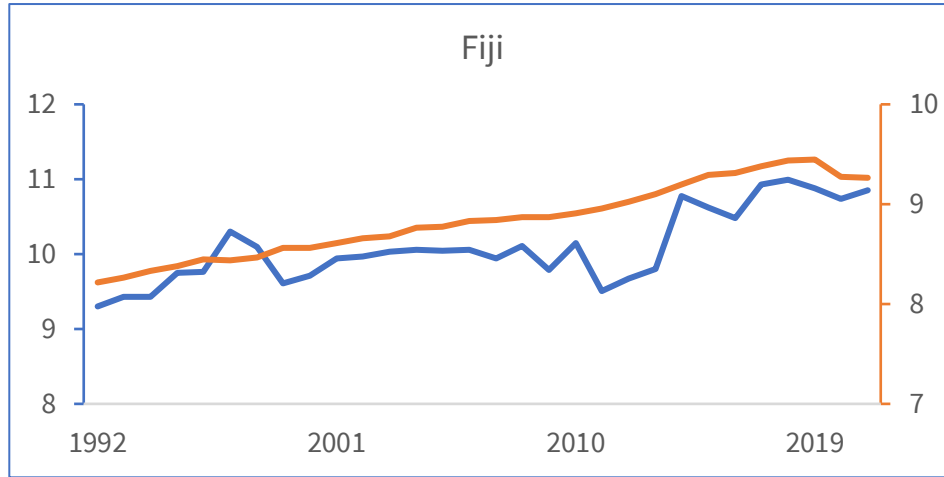


# Pixel-level Analysis: Fiji

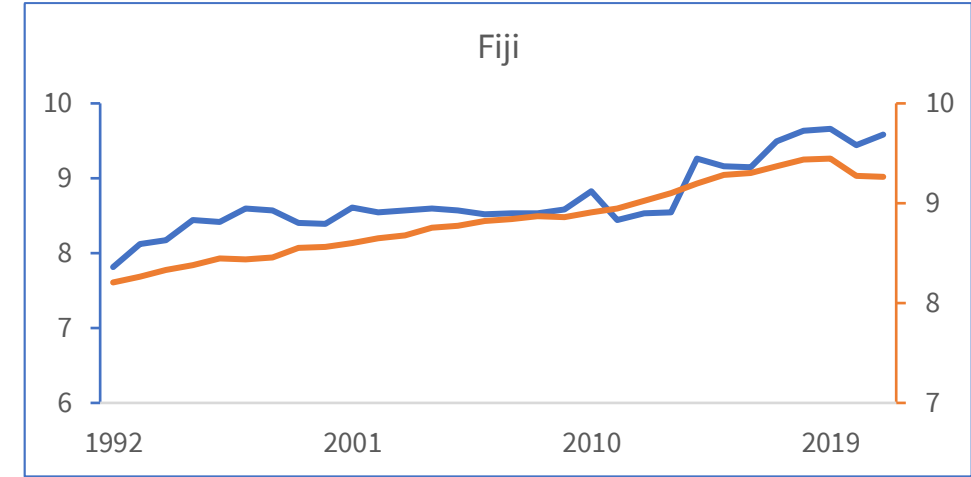
— Natural log-transformed  
NTL Sum of lights (SoL)  
— Natural log-transformed GDP PPP

- Limiting analysis to positively correlated pixels showed better correlation with national GDP levels

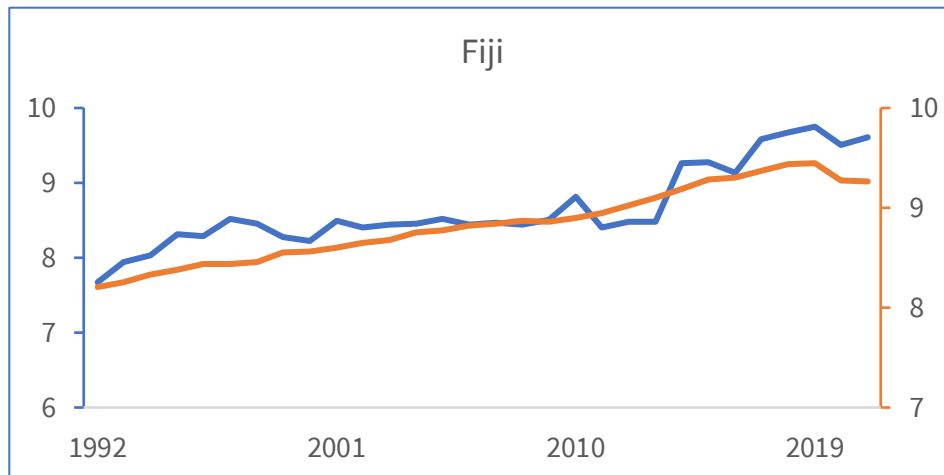
**Sum of Lights (SoL) from All Areas; Correlation: 0.80531**



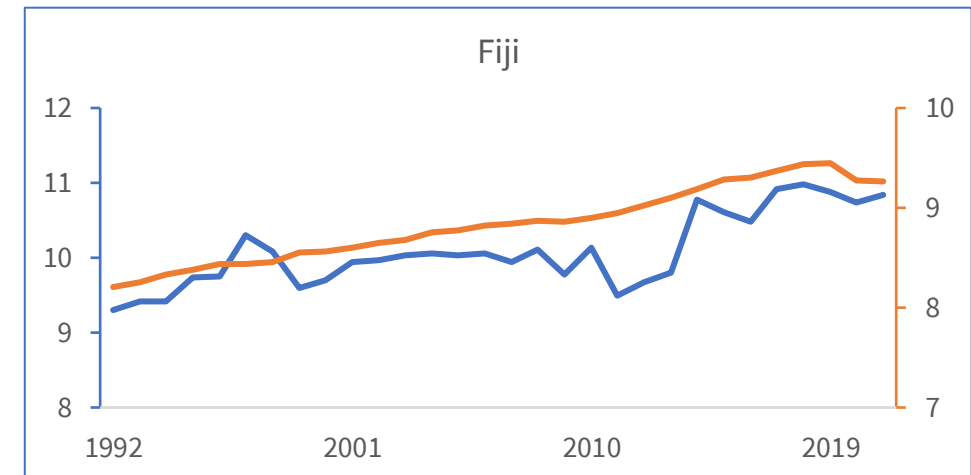
**SoL from pixels with least +0.25 correlated, n = 8,419; Correlation: 0.88558**



**SoL from pixels with least +0.50 correlated, n = 4,969; Correlation: 0.90041**



**SoL from pixels with least +0.70 correlated, n = 2,131; Correlation: 0.91743**



Source:  
Author's  
computation

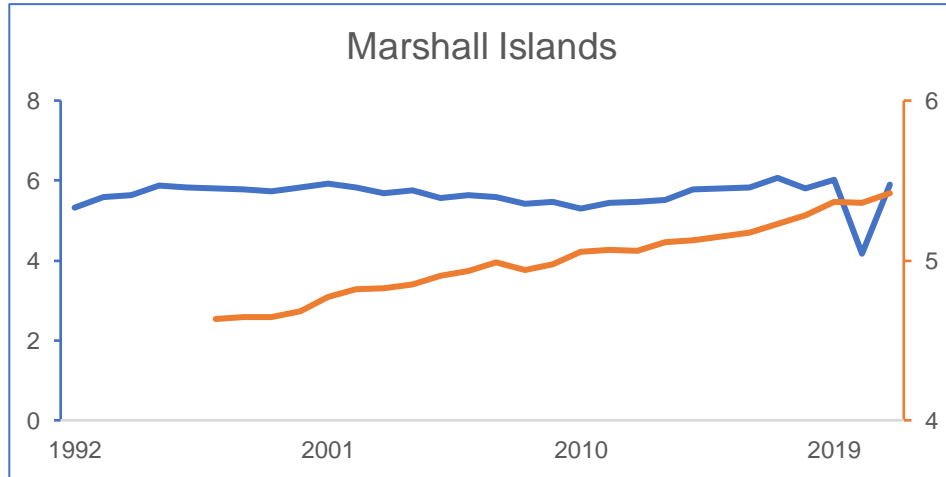


# Pixel-level Analysis: Marshall Islands

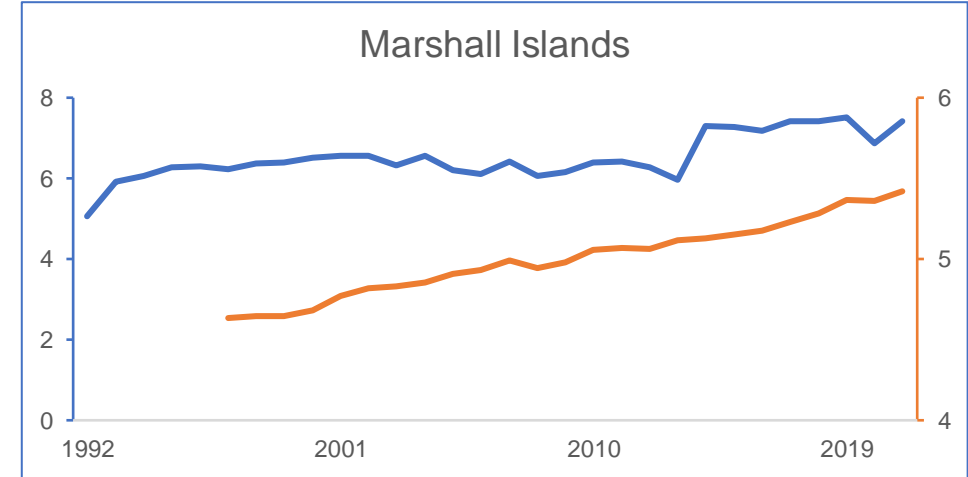
— Natural log-transformed  
NTL Sum of lights (SoL)  
— Natural log-transformed GDP PPP

- Limiting analysis to positively correlated pixels showed better correlation with national GDP levels

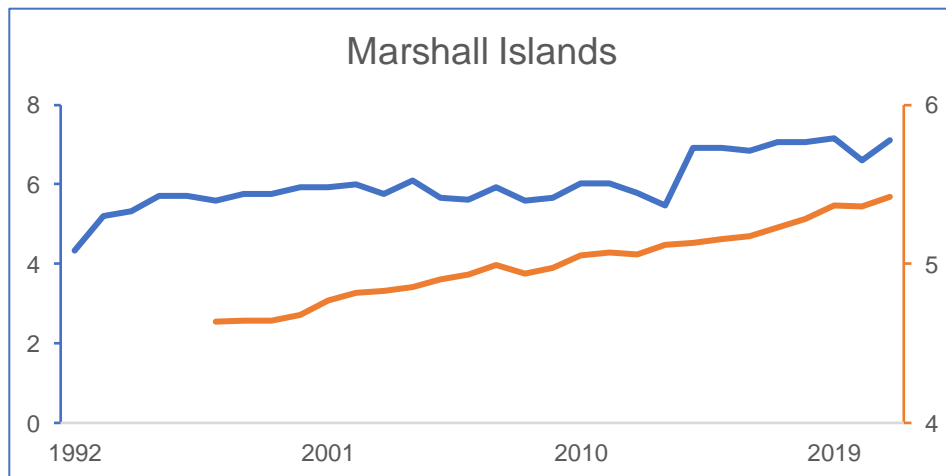
Sum of Lights (SoL) from All Areas; Correlation: -0.2097



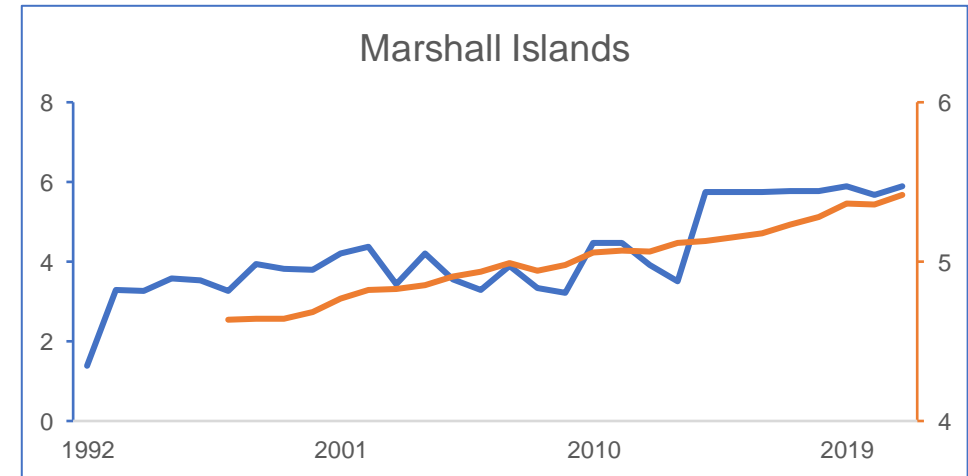
SoL from pixels with least +0.25 correlated, n = 260; Correlation: 0.6663



SoL from pixels with least +0.50 correlated, n = 183; Correlation: 0.7540



SoL from pixels with least +0.70 correlated, n = 54; Correlation: 0.7600



# Pixel-level Analysis: Marshall Islands

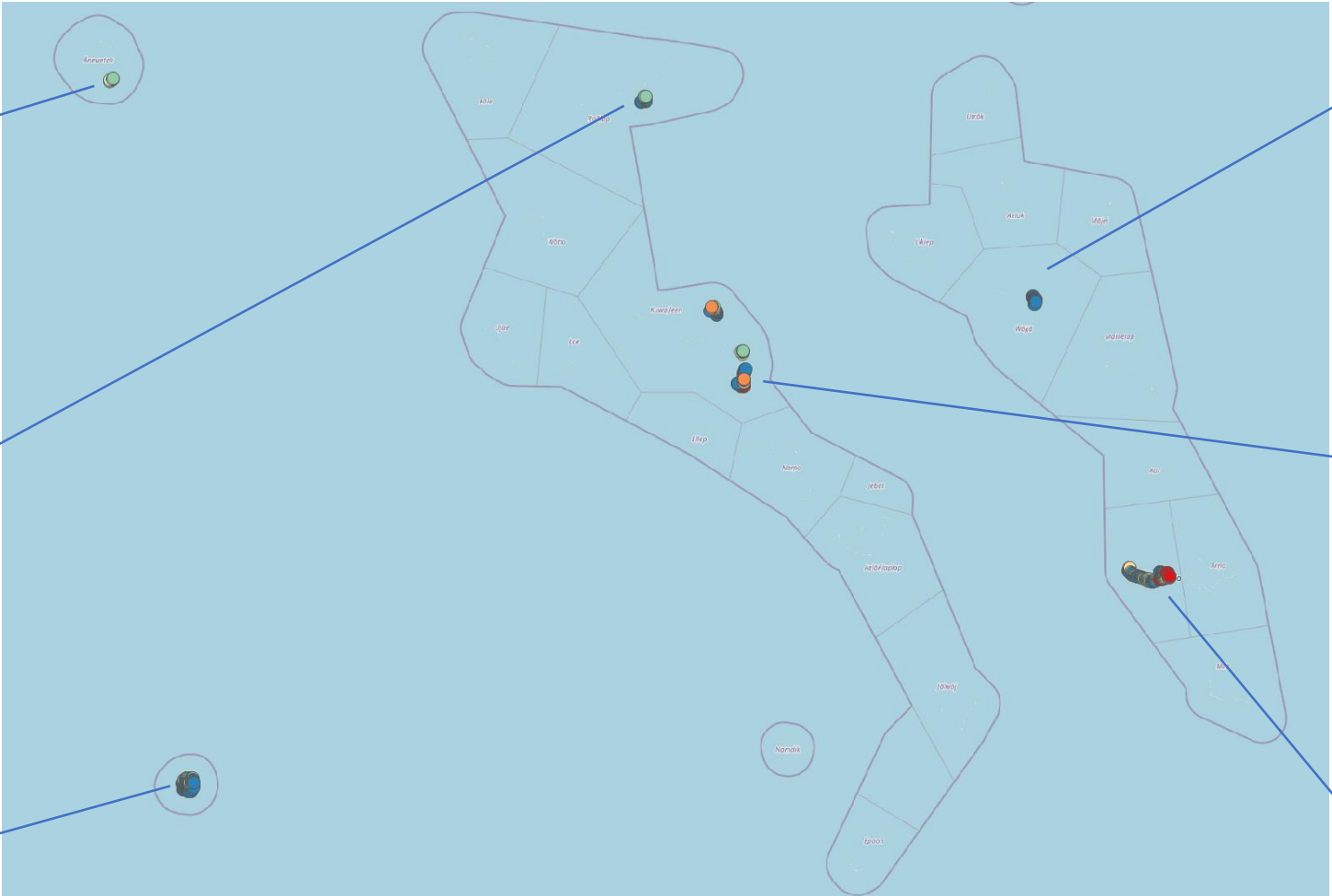
Enewetak



Rongelap



Kosrae



Wotje



Kwajalein

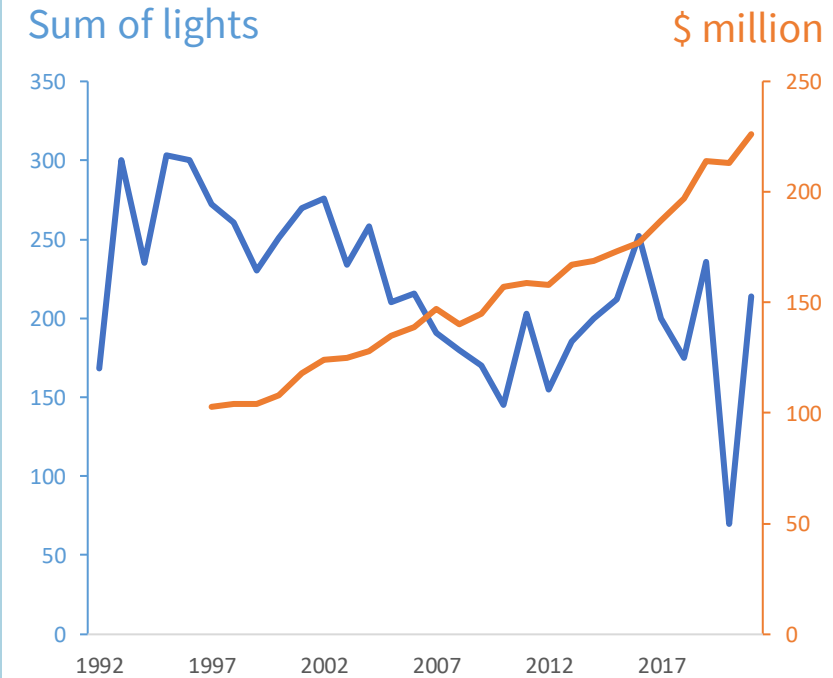
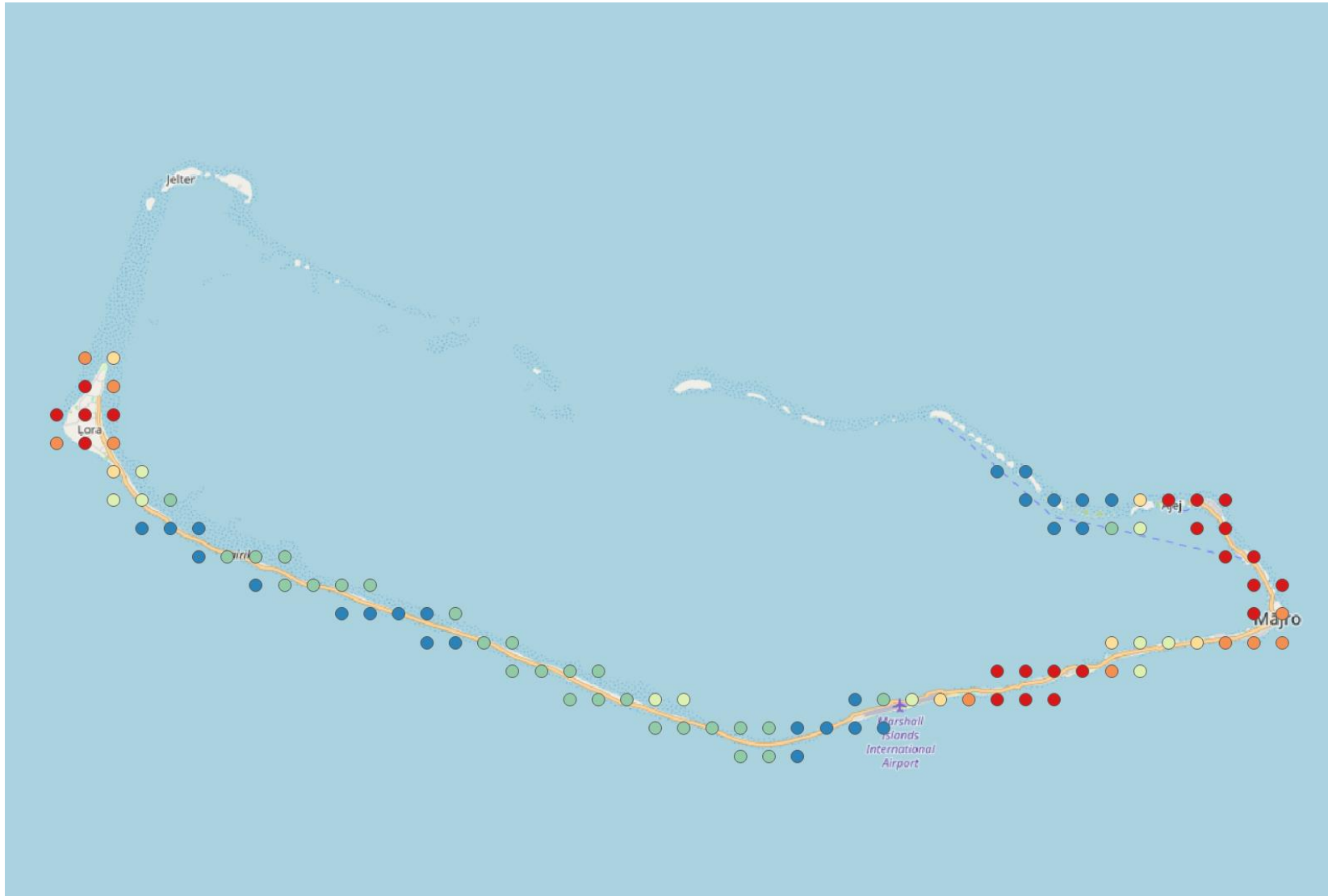


Majuro (capital)



# Pixel-level Analysis: Marshall Islands

- For RMI, historical nighttime lights in the capital of Majuro city is inversely proportional with the country's GDP



Positive Correlation

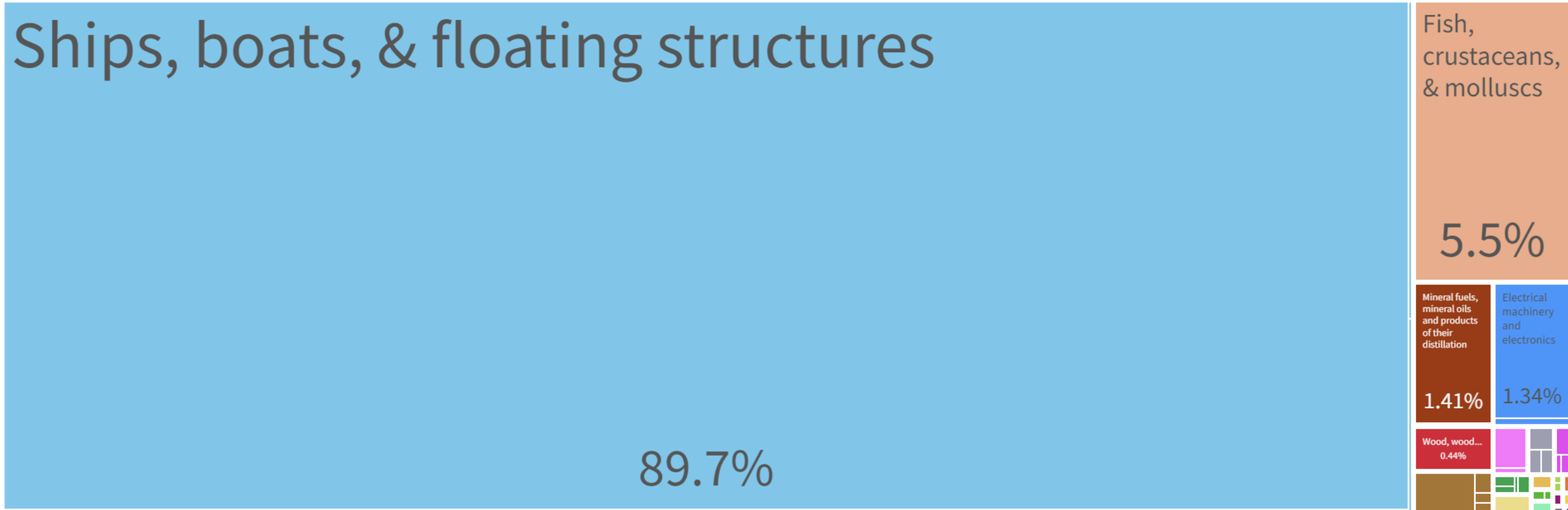


Negative Correlation



# Pixel-level Analysis: Marshall Islands

Exports Composition



Source: Observatory of Economic Complexity

# Pixel-level Analysis

- Limiting analysis to positively correlated pixels showed better correlation with national GDP levels

NTL vs GDP PPP, natural log transformed				
PIE	Sum of Lights - All Areas	Sum of Lights - Pixels at least + 0.25 correlated	Sum of Lights - Pixels at least + 0.5 correlated	Sum of Lights - Pixels at least + 0.7 correlated
Nauru	0.97018	0.96291	0.96291	0.96291
Vanuatu	0.6557	0.74645	0.92265	0.9356
Papua New Guinea	0.84632	0.89939	0.91244	0.93138
Fiji	0.80531	0.85585	0.88532	0.91743
Solomon Islands	0.85171	0.86211	0.86289	0.88572
Samoa	0.66879	0.74218	0.80612	0.85981
Kiribati	0.83344	0.8002	0.80727	0.85511
Tonga	0.80329	0.81981	0.81736	0.84361
Palau	0.39601	0.51721	0.53246	0.80517
Micronesia	0.33772	0.60448	0.69751	0.78026
Niue	0.72236	0.71374	0.72258	0.77587
Marshall Islands	-0.20969	0.66631	0.75398	0.75996
Cook Islands	0.46144	0.57175	0.62028	0.67251
Tuvalu	0.56104	0.56123	0.56123	---

*Source: Author's computation*

# Summary

- Integrating DMSP's longer availability and VIIRS higher resolution, the harmonized dataset was able to produce a 30-year annual NTL series. Total sum of lights from the corresponding administrative boundaries showed moderate to strong correlation with GDP to 9 out of 14 PIEs.
  - Limiting the area of interest to buildings and built-area improved correlation minimally.
- Pixel-level correlation improved results among all PIEs, each one yielding moderate to strong correlation. The number of excluded grids only reached up to around 30% maximum and seven PIEs only need to remove 10% or less.
- With significant correlation established between NTL and GDP, taking advantage of this publicly available dataset can be a focus of research in the subregion. Aside from GDP, NTL's relationship with other macroeconomic indicators can be evaluated if macroeconomic data is available.
- Like other remote sensing data, NTL is not designed to replace conventional datasets. Rather, different applications of NTL are studied to complement traditional datasets and methods.