

It's the "Lights" Stupid!



Clive Coetzee

IF

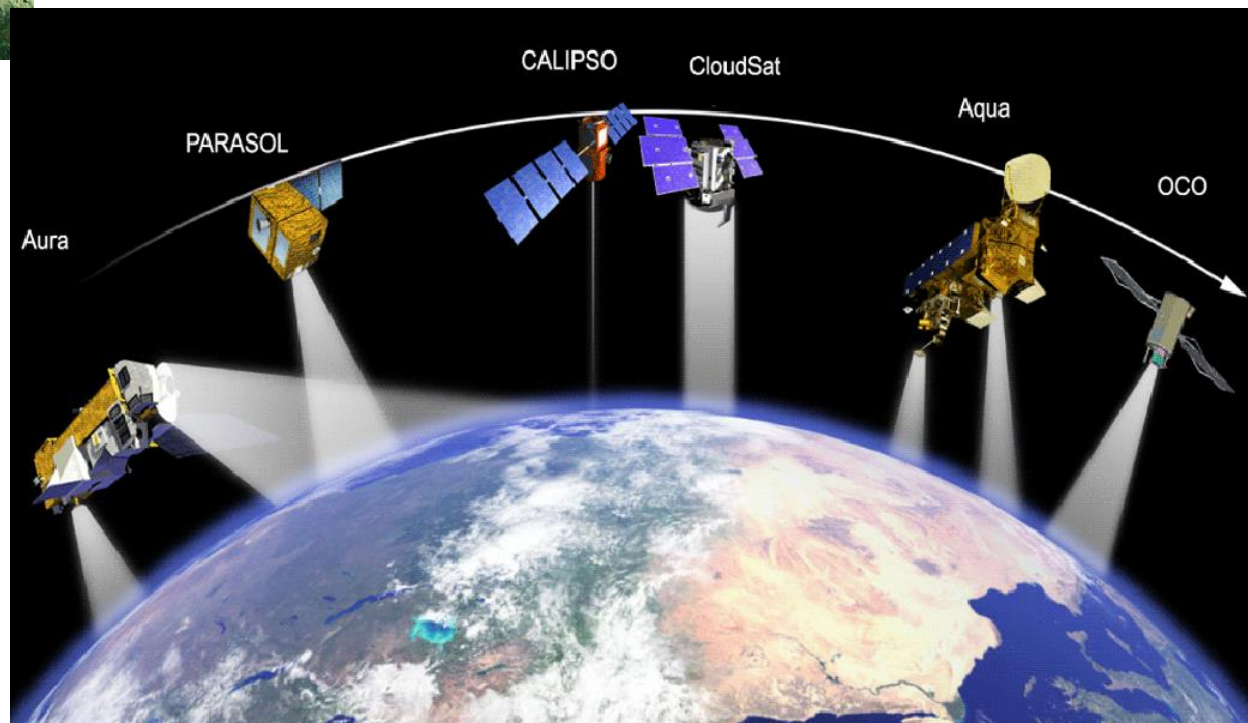
ARE ALIENS WATCHING US?



Are aliens real? We don't know for sure, but we want to believe.

Outer space is a vast expanse that we have so much more to learn about, which is why it's hard to flat-out deny the possibility that other intelligent lifeforms exist.

In the history of **satellites**, since the launch of first satellite Sputnik in 1957, around 8,378 **satellites** have been sent to **space**, as per the data by UNOOSA. These days there are 4,994 **satellites** in **orbit**, out of which only 7 are revolving around planets other than earth

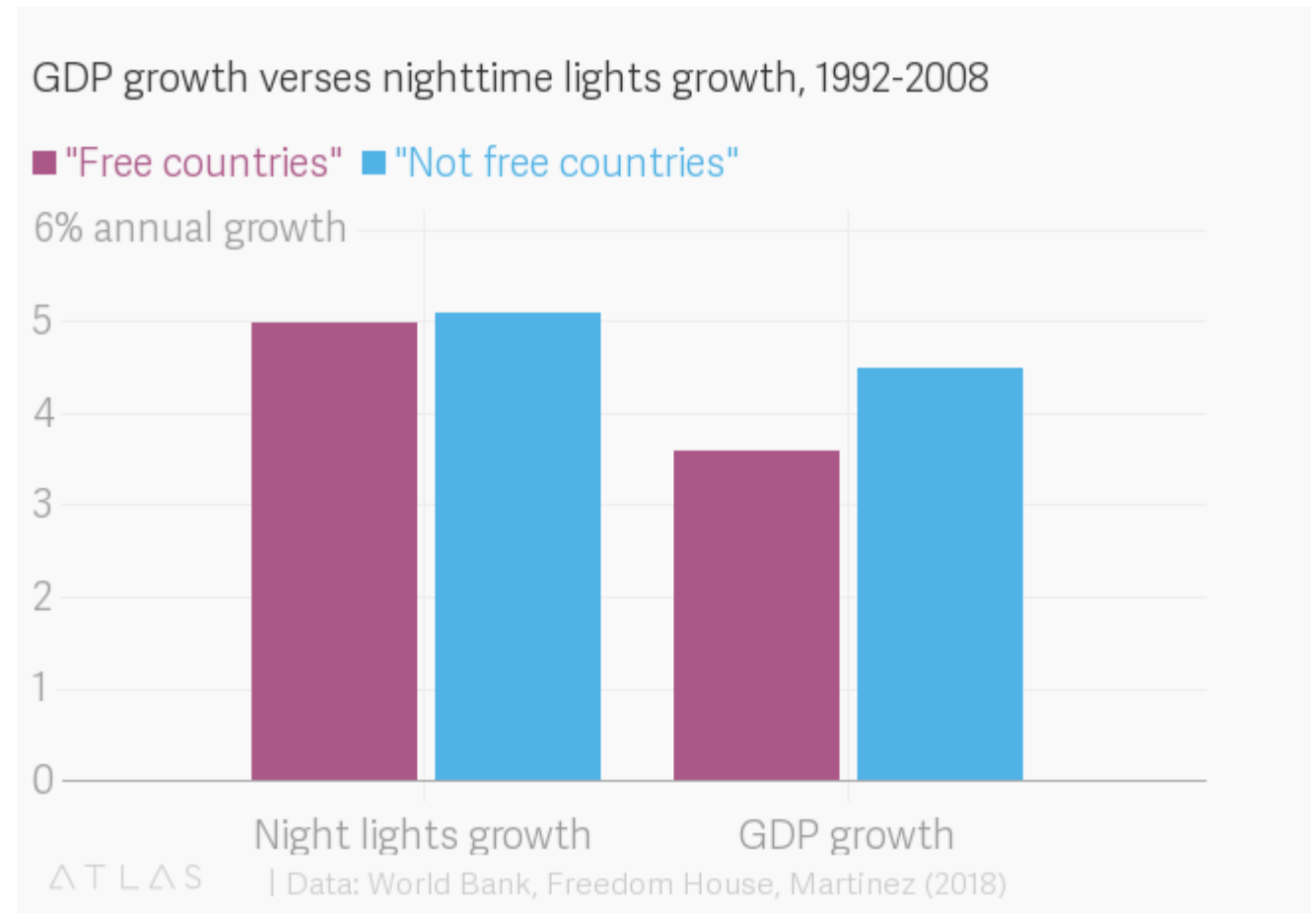


Remote Sensing data

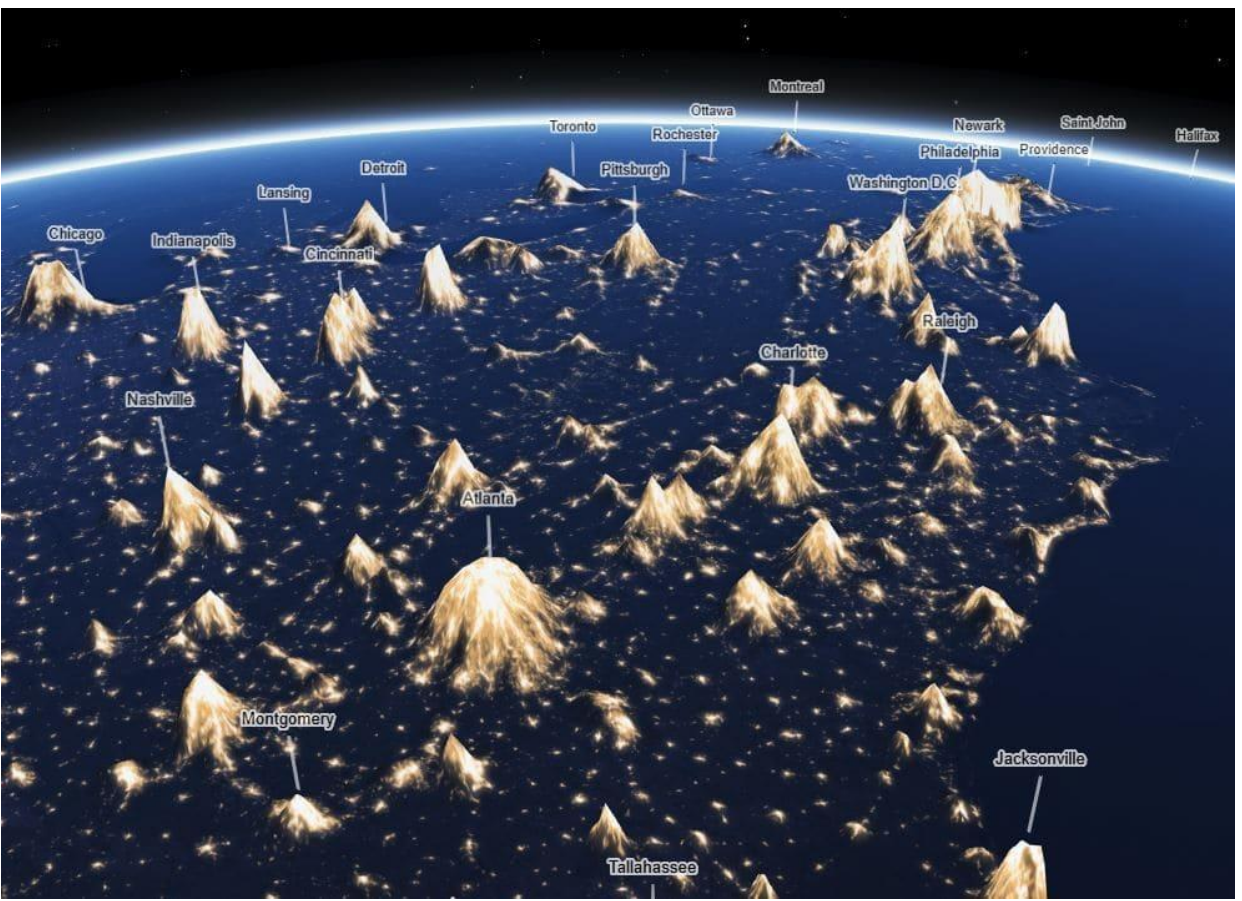
- *Remote Sensing is the science and art of obtaining information about an object/phenomena or area through the analysis of data acquired by a device that is not in contact with the object under investigation. This technology first emerged in 1840 and pictures were taken by balloon.*
- This technology includes both Satellite and aerial remote sensing. The basis source for this technology is electromagnetic radiation and this energy from the sun reaches the earth surface and again reflected or transmitted or absorbed by the objects which is collected by the satellite sensors or recorded in the photographic film

Satellite images reveal which countries cheat on their economic statistics

The chart shows the average growth of nighttime light brightness and GDP for governments that Freedom House designates as “free” and “not free.” Notice that the growth in nighttime light is almost identical, while GDP growth is much larger for countries considered “not free.”



Satellite images



Version 4 DMSP-OLS Nighttime Lights Time Series & Version 1 VIIRS Day/Night Band Nighttime Lights

DMSP-F10



Suomi-NPP satellite

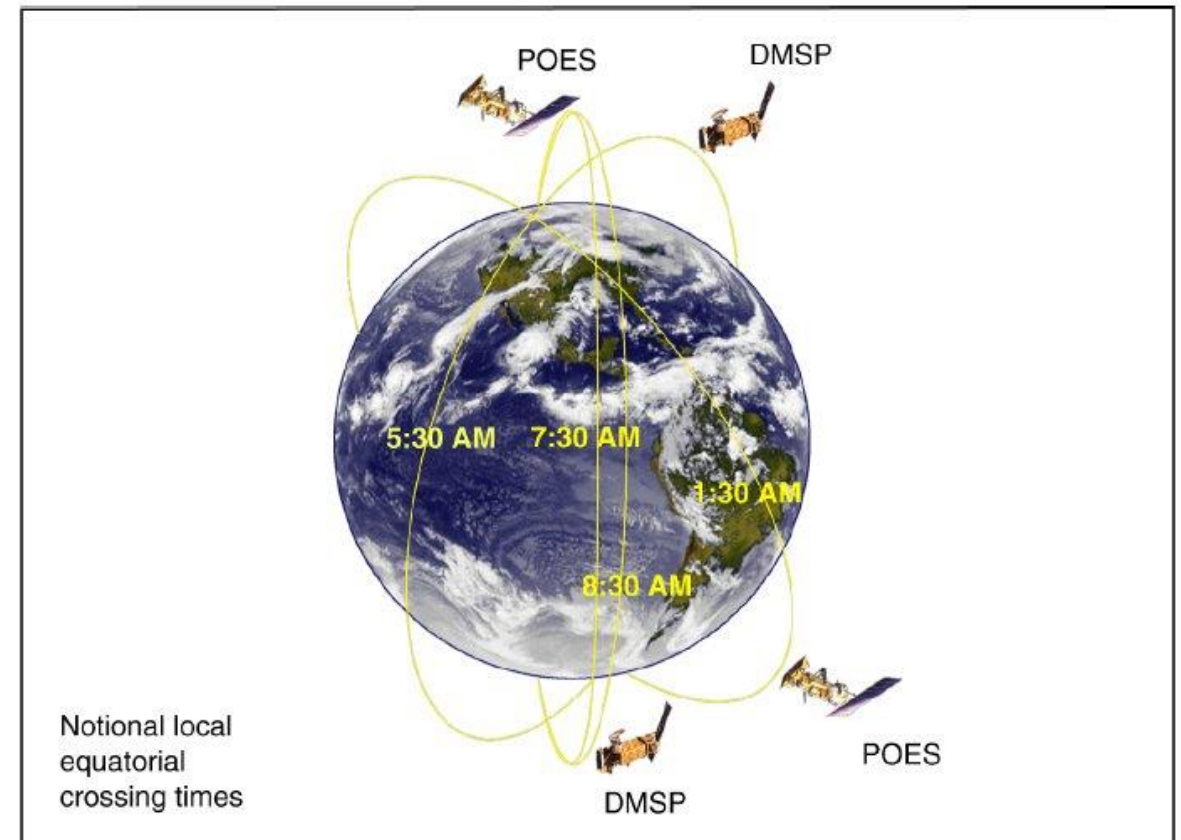


Satellite Remote Imagery

The screenshot shows a web browser window displaying the NOAA website for DMSP Sensors. The browser's address bar shows the URL ngdc.noaa.gov/eog/sensors.html. The page title is "DMSP Sensors". On the left side, there is a navigation menu for the "Earth Observation Group" (EOG) with links to "EOG Home", "DMSP Archive Description", "Description of DMSP Sensors", "Data Availability", "Data Services and Pricing", "Data Download", "Online Maps and Web Services", "Nighttime Lights Posters", "Presentations", "Publications", and "News & Media". The main content area lists several sensors with small thumbnail images and text labels: "OLS- Operational Linescan System", "SSM/I- Microwave Imager", "SSM/T2- Atmospheric Water Vapor Profiler", "SSJ/4- Precipitating Electron and Ion Spectrometer", "SSM/T- Atmospheric Temperature Profiler", "SSIES- Ion Scintillation Monitor", and "SSM - Magnetometer". The Windows taskbar at the bottom shows the system clock as 02:51 PM on 2019/09/17.

DMSP/OLS and VIIRS satellites are polar orbiting their orbits are perpendicular to the direction of Earth's rotation.

Figure 1: Configuration of Operational Polar Satellites



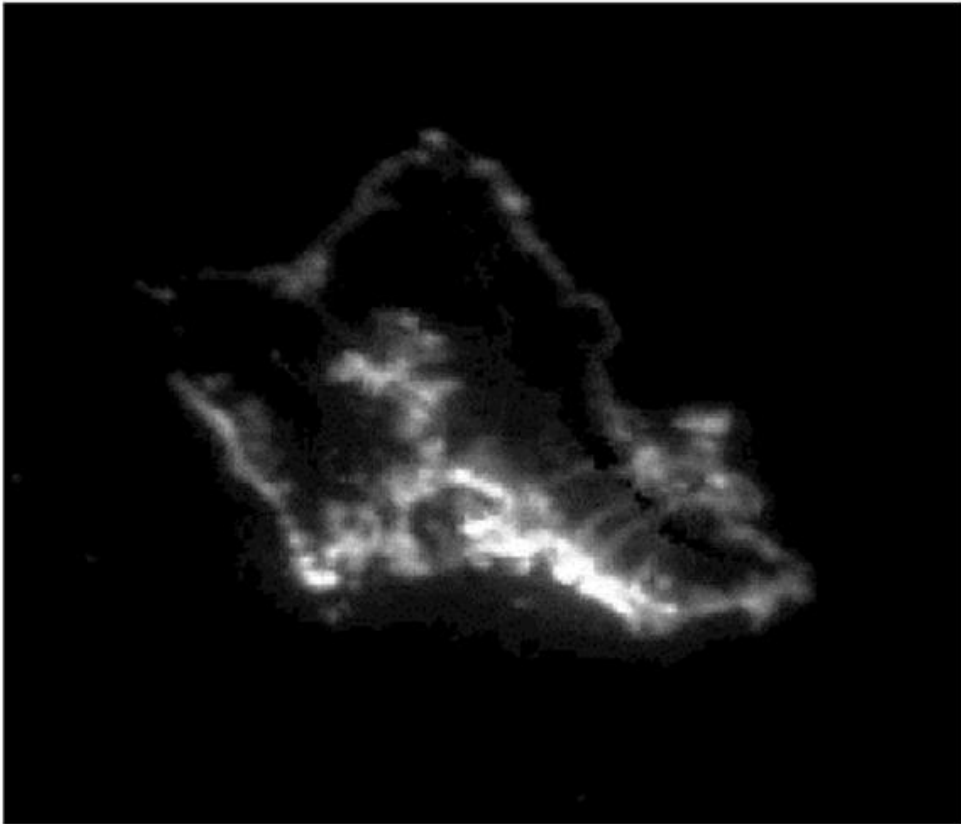
Source: NPOESS Integrated Program Office.

Satellite Remote Imagery

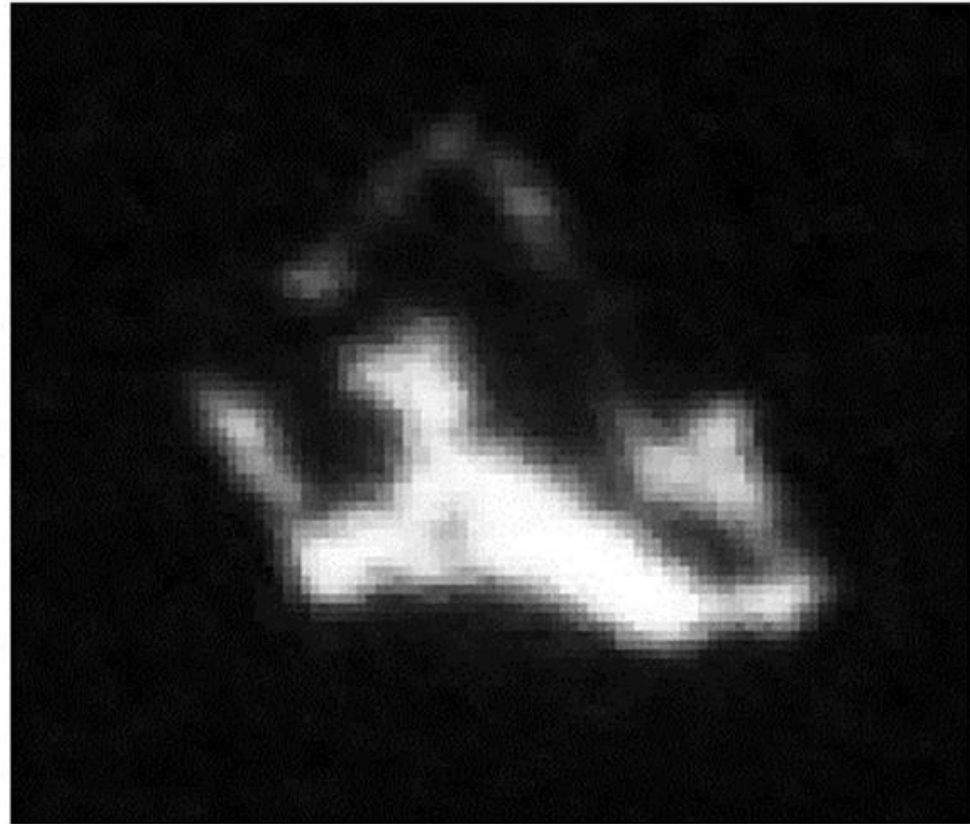
- These products show the locations where artificial lighting is present and a measure of the brightness as observed from space. From 1992 to 2013, there is a consistently processed annual time series of night-time lights processed from low-light imaging data collected by the US Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) (Baugh et al. 2010 Baugh, K., C. D. Elvidge, T. Ghosh, and D. Ziskin. 2010. “Development of a 2009 Stable Lights Product Using DMSP/OLS Data.” *Proceedings of the Asia Pacific Advanced Network* 30: 114–130. doi:10.7125/APAN.30.17.[Crossref] , [Google Scholar]).
- The follow on to DMSP for global low-light imaging of the Earth at night is the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB), flown jointly by NASA and NOAA.

VIIRS DNB versus DMSP-OLS cloud free composited average visible band images of Oahu

DNB Oahu



OLS Oahu



Satellite Remote Imagery

- To produce a night-time lights product, the low-light imaging data need to be filtered to exclude low-quality data and extraneous features through a cascading series of filtering steps prior to temporal averaging. The resulting average radiance product has null values (zero) in areas where surface lighting was not detected.
- The satellites circle the earth 14 times per day, recording the intensity of Earth-based lights. Each satellite observes every location on the planet every night at some instant between 8:30 and 10:00 pm local time
- Data from all orbits of a given satellite in a given year are averaged overall valid nights to produce a satellite-year dataset

Satellite Remote Imagery

- Each satellite-year dataset is a grid reporting the intensity of lights as a six-bit digital number, for every 30 arc-second output pixel (approximately 0.86 square kilometers at the equator) between 65 degrees south and 75 degrees north latitude.
- Datasets currently exist for 30 satellite-years covering the years 1992 to 2019, for a total of about 22 billion satellite-year-pixels, 6.4 billion of which fall on land.

Literature Review

- **MEASURING ECONOMIC GROWTH FROM OUTER SPACE – Henderson et al 2012**

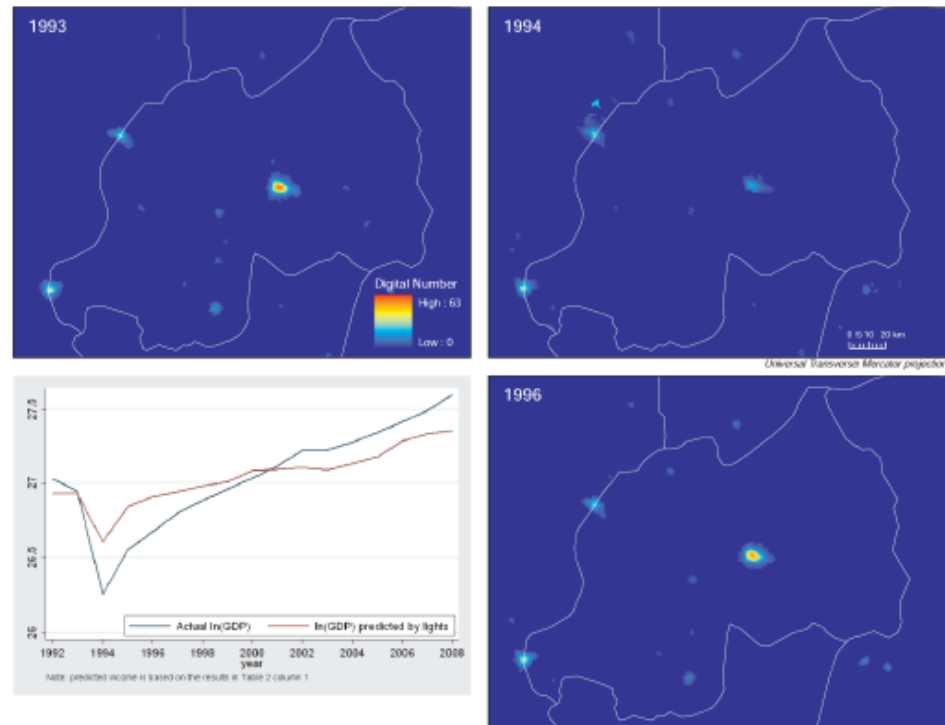


Figure 4.
Genocide event: Rwanda

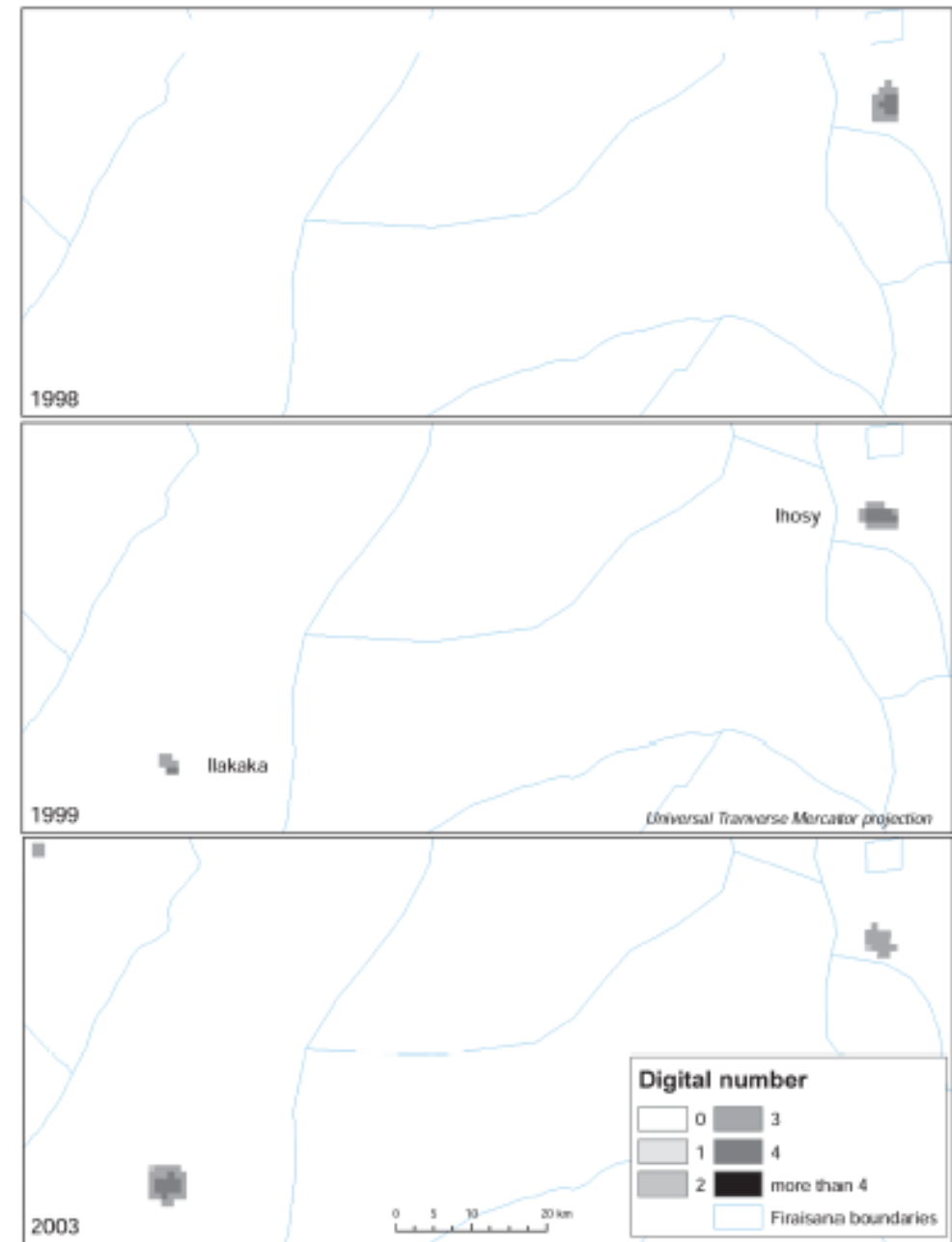
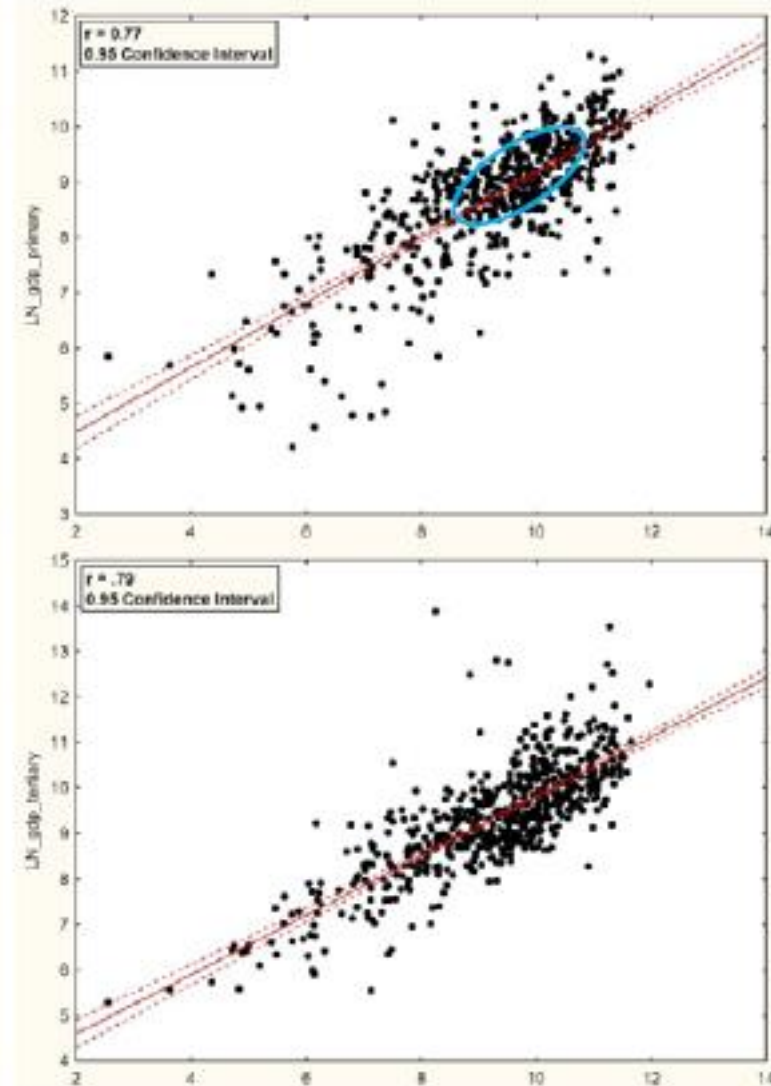
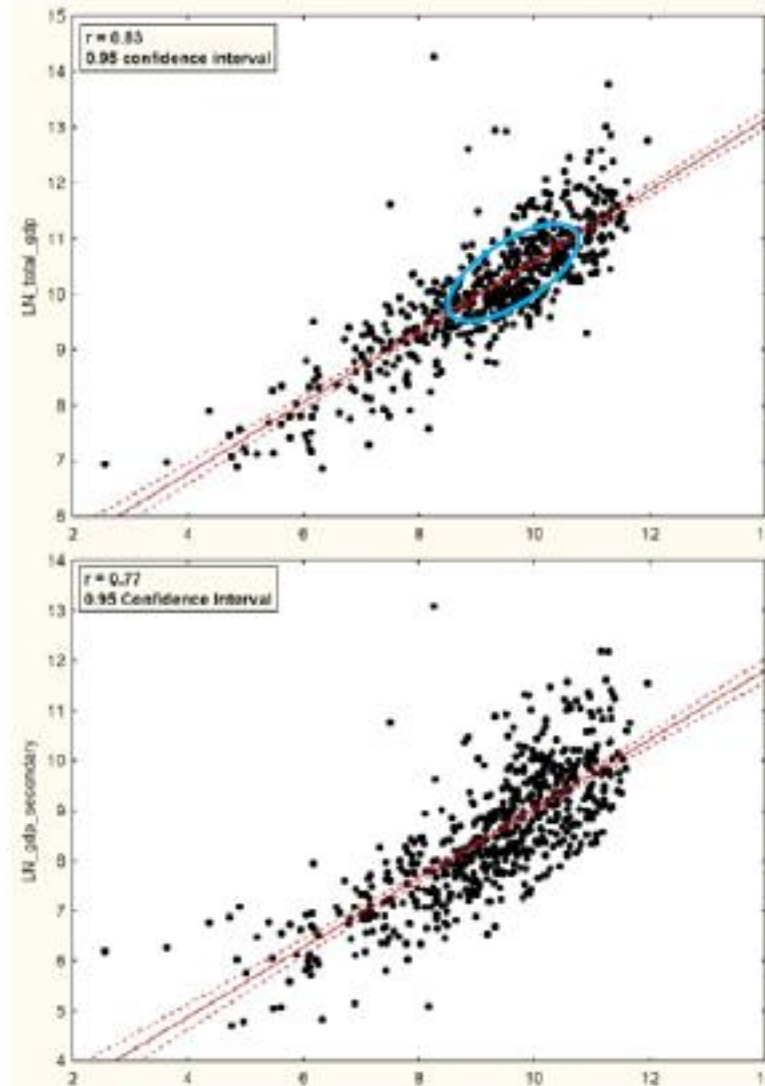


Figure 5.
Discovery of sapphire and ruby deposits in Madagascar

$$\ln GDP = \ln SOL + \ln POP + DMetro + DSubmetro + DCapital + DLargeCity + DSnow \quad (1)$$

Literature Review

- **Night Lights and Economic Activity in India: A study using DMSP-OLS night time images – Bhandari and Roychowdhury 2011**



Literature Review

- **Night-time lights: A global, long term look at links to socio-economic trends - Proville, Zavala-Araiza and Wagner 2017**

Over the course of a twenty-year data record and at aggregated scales, we find high correlations between the area lit from night-time lights on the one hand, and GDP, electricity consumption, and CO₂ emissions on the other. Correlations with population, N₂O, and CH₄ emissions are still slightly less high, while we find moderate correlations with F-gas emissions and an inverse measure of poverty. To this end, our findings are largely consistent with prior studies having a narrower geographical or temporal focus.

Table 1. Comparison of regression models between DMSP (logarithm) and electricity consumption (logarithm). Describes regression outputs when fixing effects for various dimensions in the data, both individually and in combination.

Fixed Effects:	None	Regions	Countries
β_1	0.907 *** (0.0056)	0.965 *** (0.0062)	0.803 *** (0.0175)
α	4.89 ***	-	-
β_{region}	-	[4.18 to 5.18] ***	-
$\beta_{country}$	-	-	[1.35 to 7.03] ***
ε	0.878	0.826	0.393
R^2_A	0.864	0.986	0.997
Fixed Effects:	Years	Regions & Years	Countries & Years
β_1	0.908 *** (0.0055)	0.966 *** (0.0061)	0.466 *** (0.0227)
β_{region}	-	[-1.01 to -0.158] ***	-
$\beta_{country}$	-	-	[-3.79 to 4.14] ***
β_{year}	[4.59 to 5.24] ***	[4.86 to 5.18] ***	[4.59 to 5.43] ***
ε	0.864	0.811	0.333
R^2_A	0.984	0.986	0.998

Signif. codes:

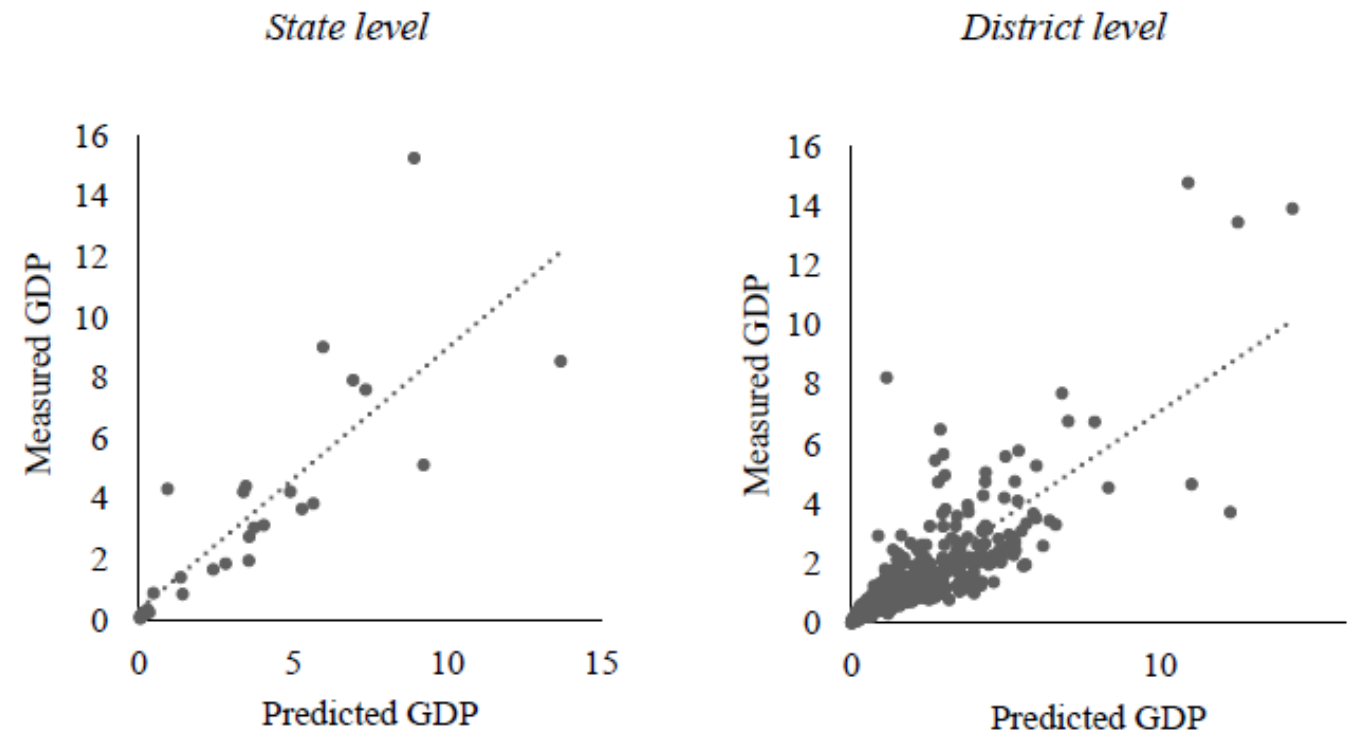
*** 0.001. $n = 4,197$

Literature Review

- **Measuring Districts' Monthly Economic Activity from Outer Space – Beyer et al 2018**

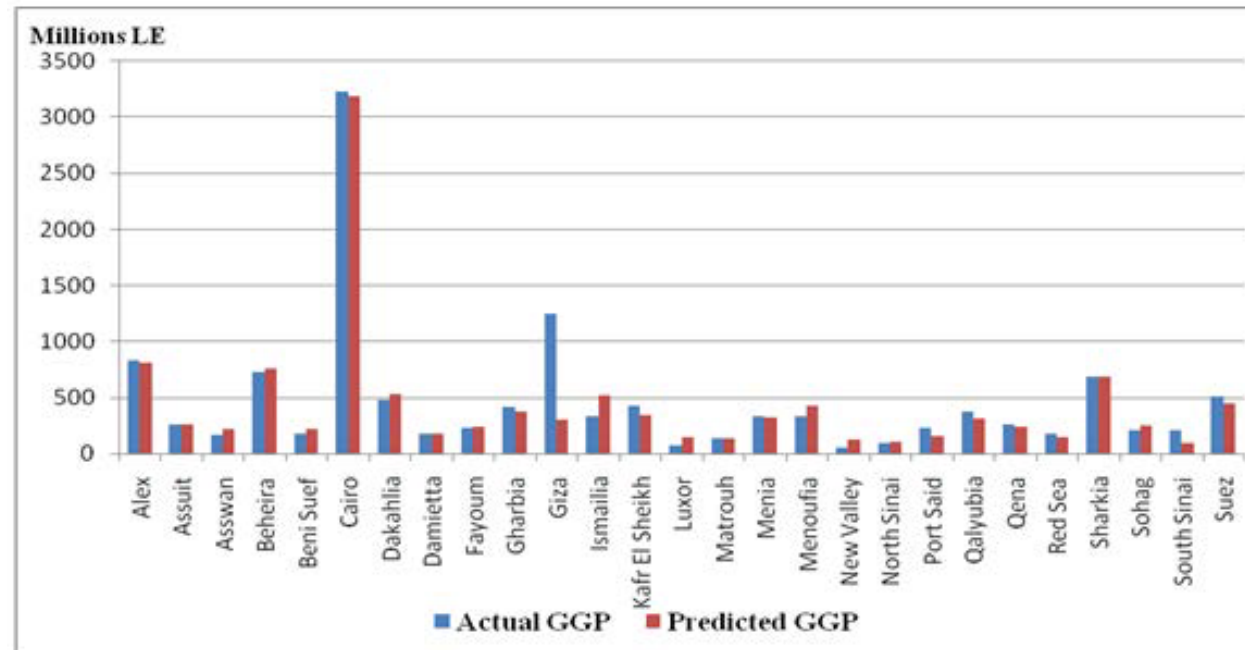
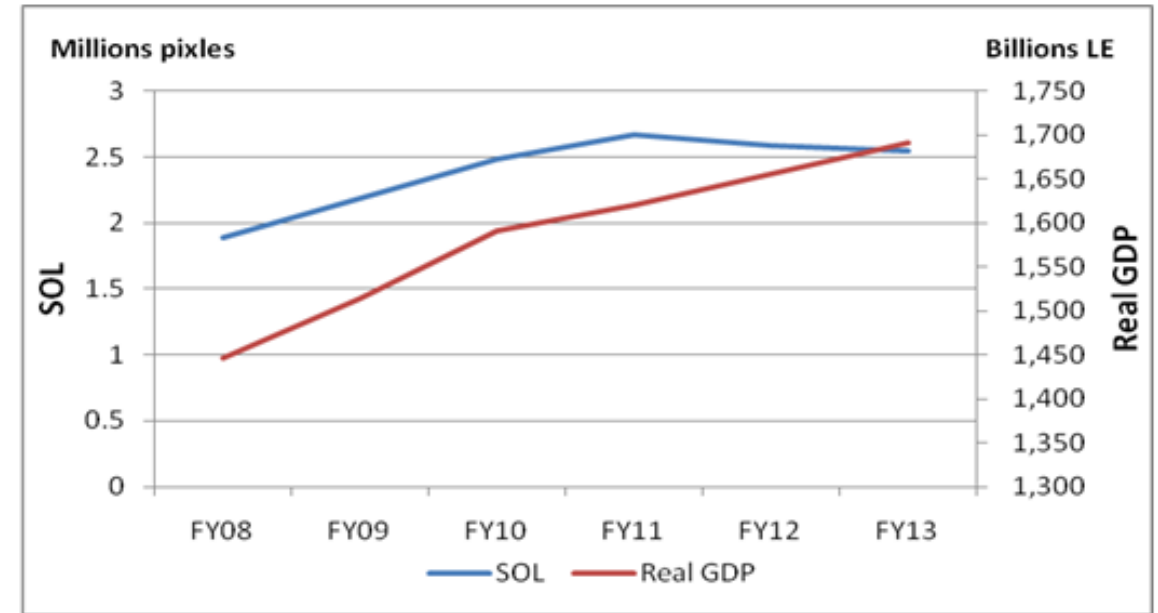
In addition to the fact that nightlight data are easy and inexpensive to collect, measures of economic activity based on nightlights have some crucial advantages. Nightlight observations include informal activity, are available in near real-time, are independent of official sources, and can be aggregated to arbitrary spatial groupings.

Figure 3: In India, nightlight intensity predicts subnational GDP relatively well.



Literature Review

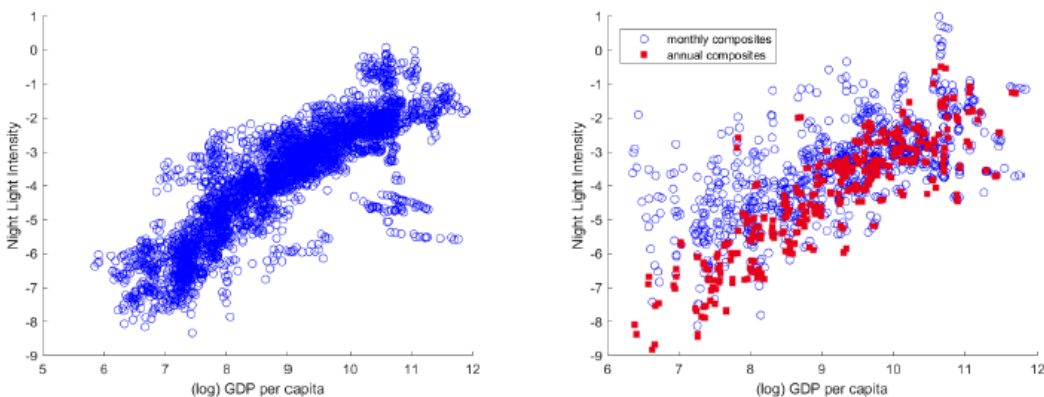
- Night Lights and Economic Performance in Egypt - Omar and Ismal 2019



Literature Review

- **Illuminating Economic Growth – Hu & Yao 2019**

Figure 3: Nighttime Lights vs. GDP (1992-2017)



(a) DMSP/OLS 1992-2013

(b) VIIRS 2013-2017

Notes: Each dot/square represents a country-year observation. On right, blue dots are annual averages of VIIRS monthly composites.

Table 4: Correlation between GDP per capita and Night Light Intensity

	DMSP/OLS 1992-2013 (A)	VIIRS 2015-2016 (A)	VIIRS 2013-2017 (M)
Low income	0.70	0.47	-0.02
Lower middle income	0.66	0.42	0.29
Upper middle income	0.40	0.50	0.42
High income	0.09	0.20	0.15
All countries	0.85	0.87	0.66

Notes: In parentheses, A indicates annual data and M annual average of monthly data. Variables are in logarithms.

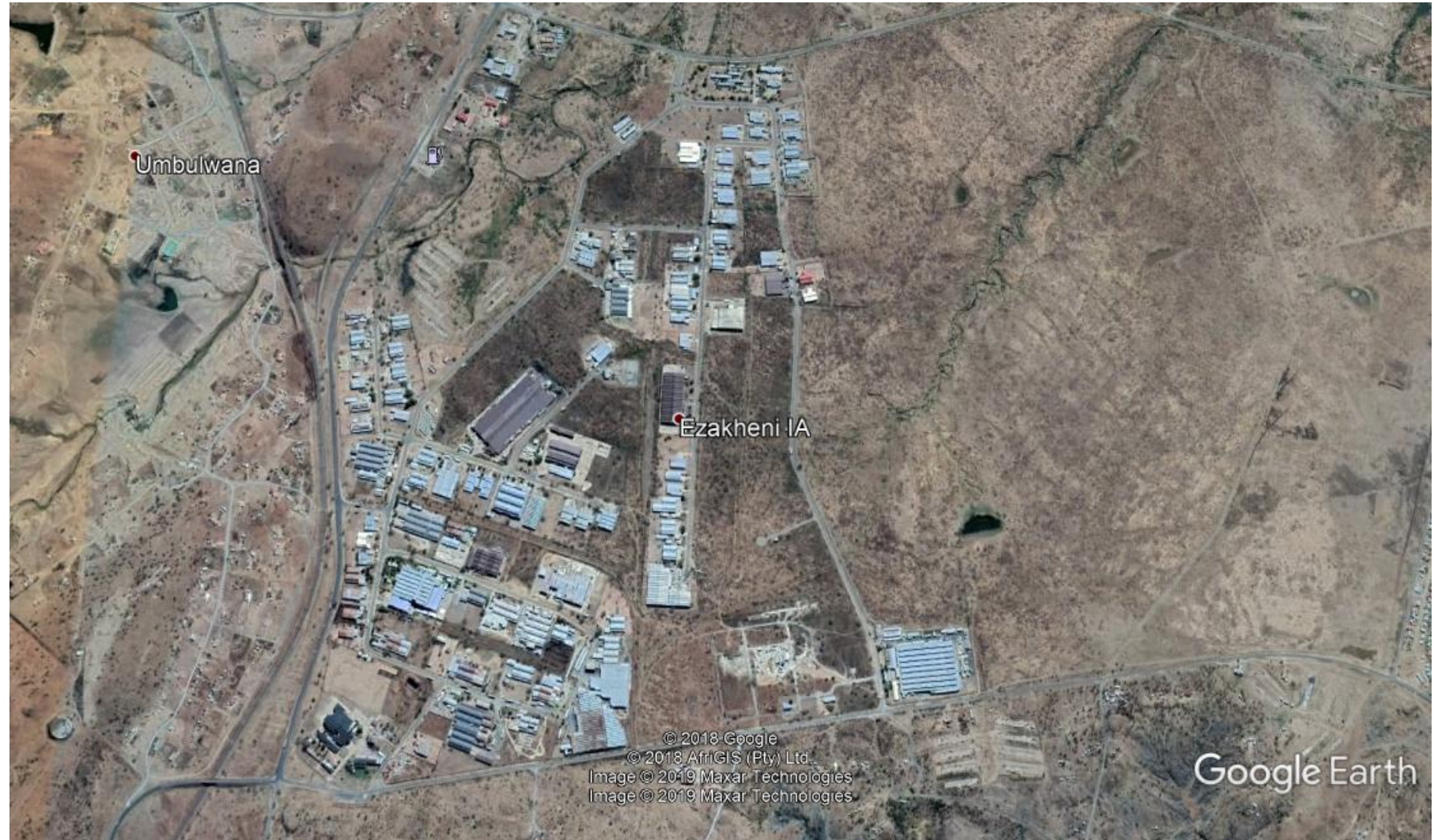
Table 11: Real Economic Growth: Selected Emerging Markets

Real GDP Growth	1992-2008		2009-2013		2014-2017	
	Official	Optimal Linear Measure	Official	Optimal Linear Measure	Official	Optimal Linear Measure
China	10.4	8.5	9.0	5.6	6.9	5.4
India	6.6	5.9	7.4	6.6	7.3	6.4
Brazil	3.3	3.5	3.2	3.1	-1.6	-0.8
South Africa	3.4	3.5	1.9	2.1	1.0	2.0

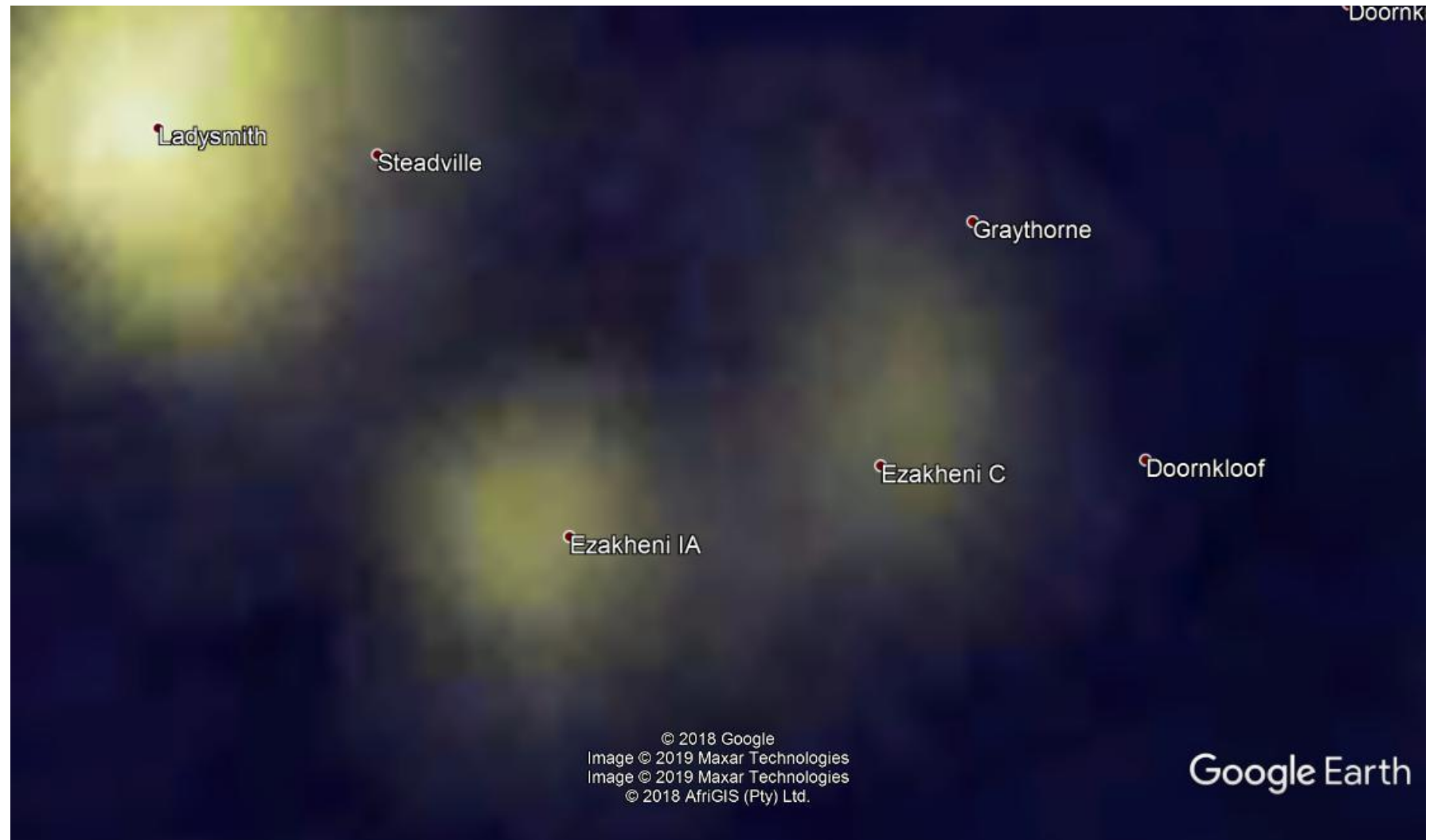
Notes. 1992-2013 results are based on DMSP/OLS data and 2013-2017 based on VIIRS. Growth rates are geometric average.

Ezakheni Industrial Estate

- 640 hectares consisting of 100 Ithala and privately owned factories ranging in size between 200 square metres and 30,000 square meters



Ezakheni Industrial Estate



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Image © 2019 Maxar Technologies
Image © 2019 Maxar Technologies
© 2018 AfriGIS (Pty) Ltd.

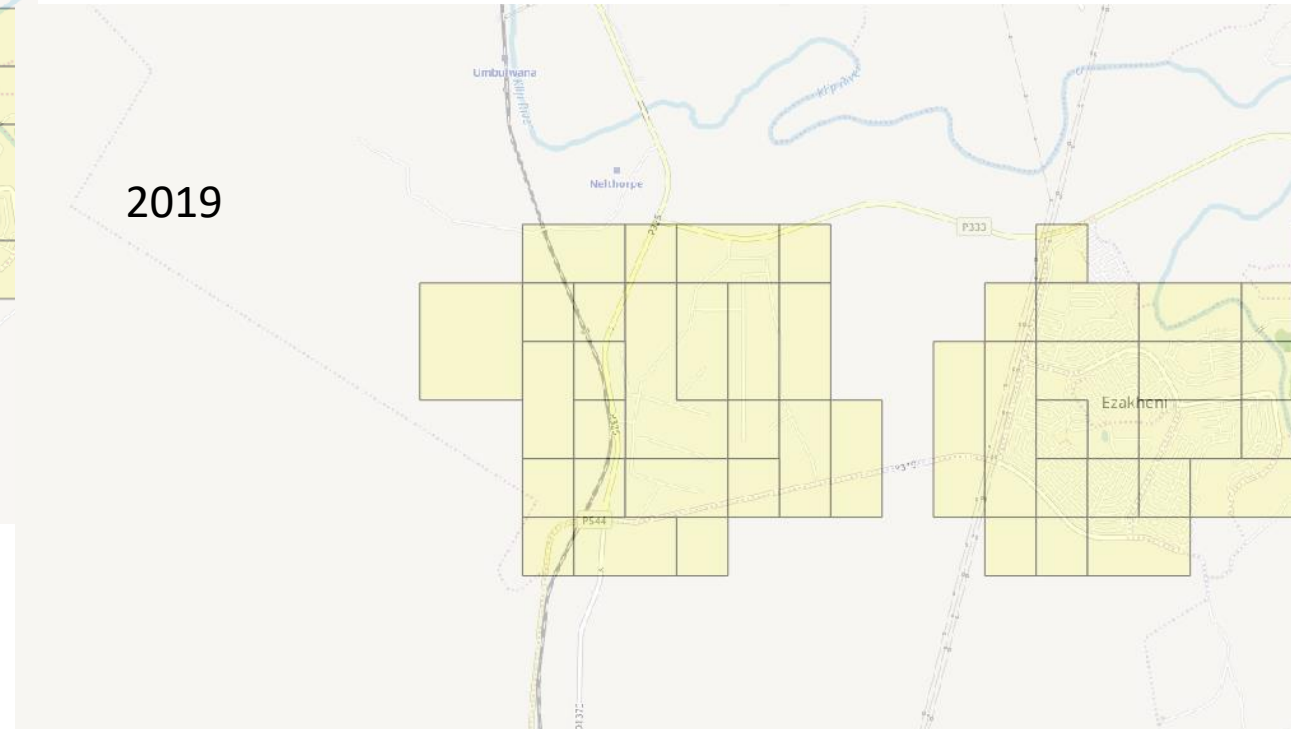
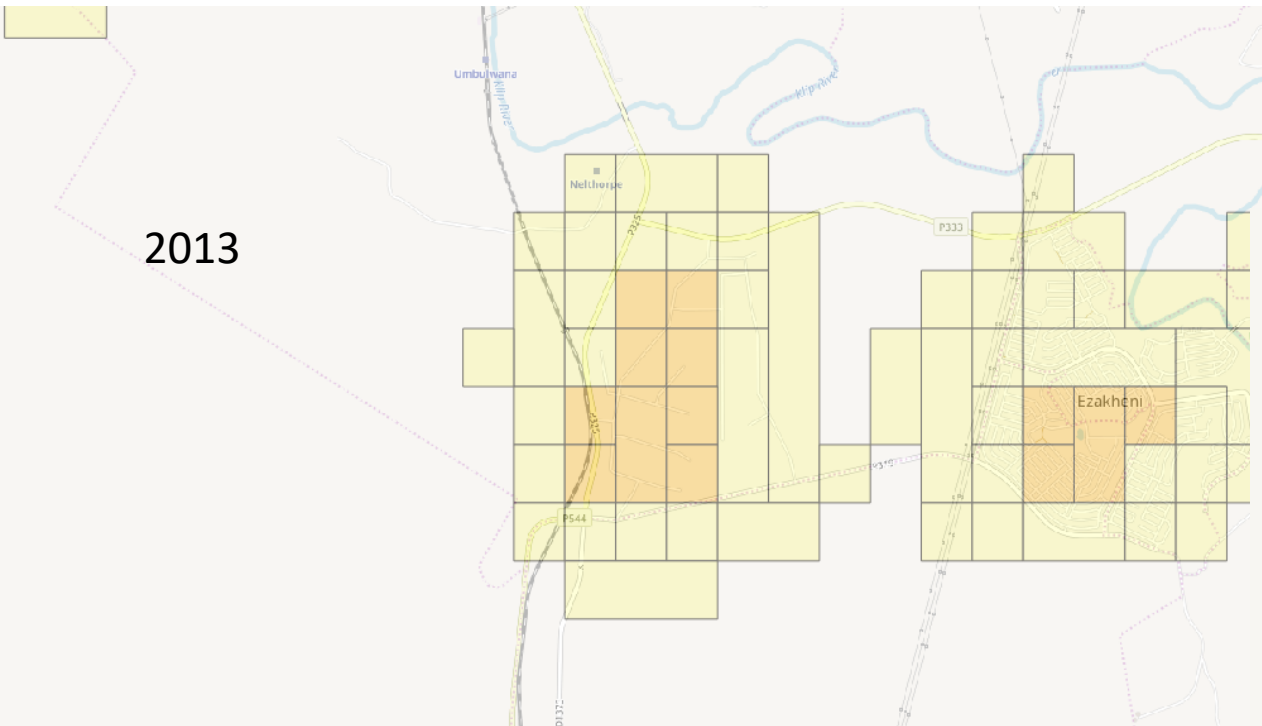
Google Earth

Ezakheni Industrial Estate



Ezakheni Industrial Estate

Year	average	count	max	median	sum
1992	28.43	28	40	27	796
2013	25.00	15	31	25	375
2013	8.21	34	20	8	279
2019	4.96	24	12	4	119

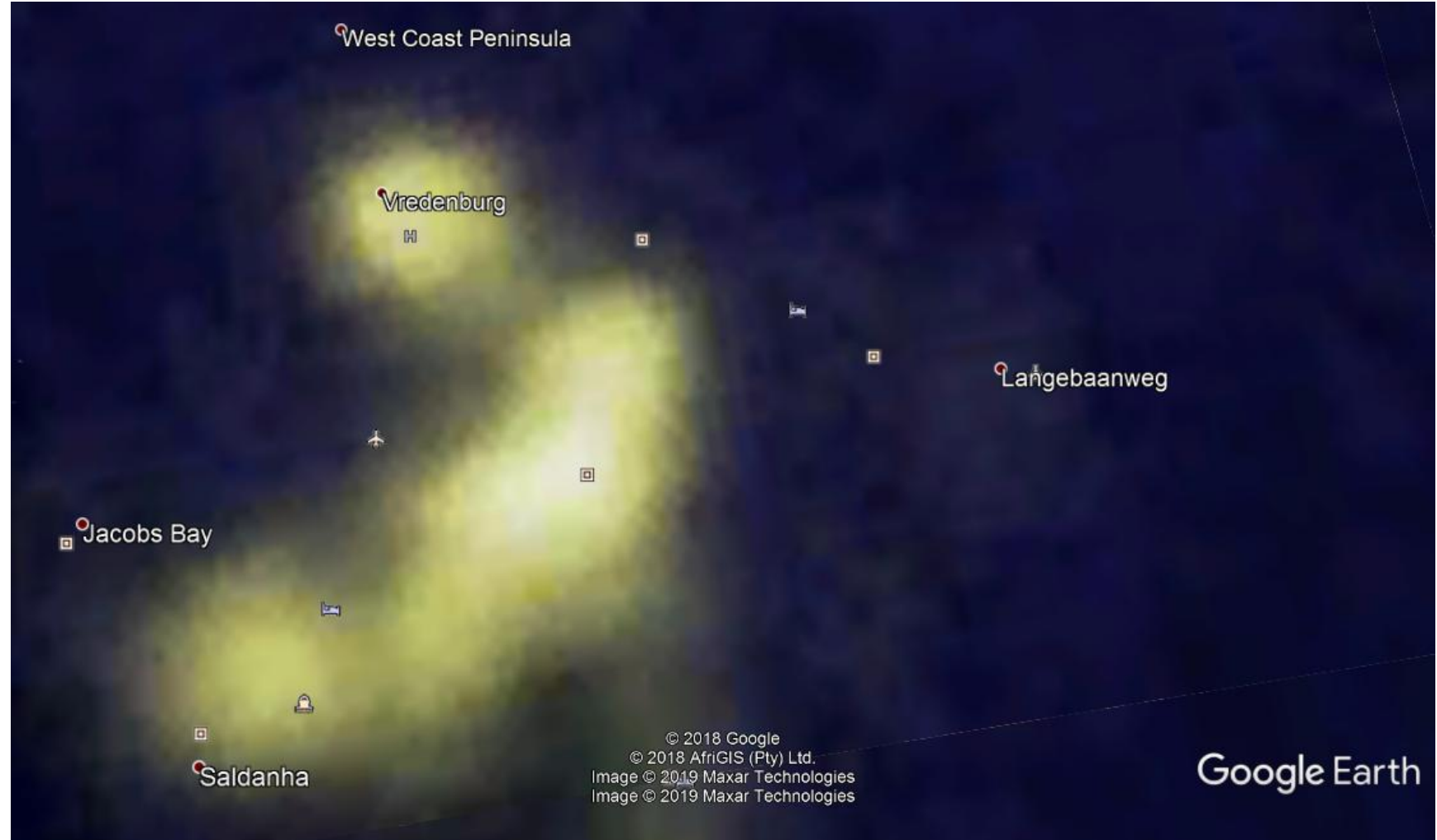


Saldanha Steel

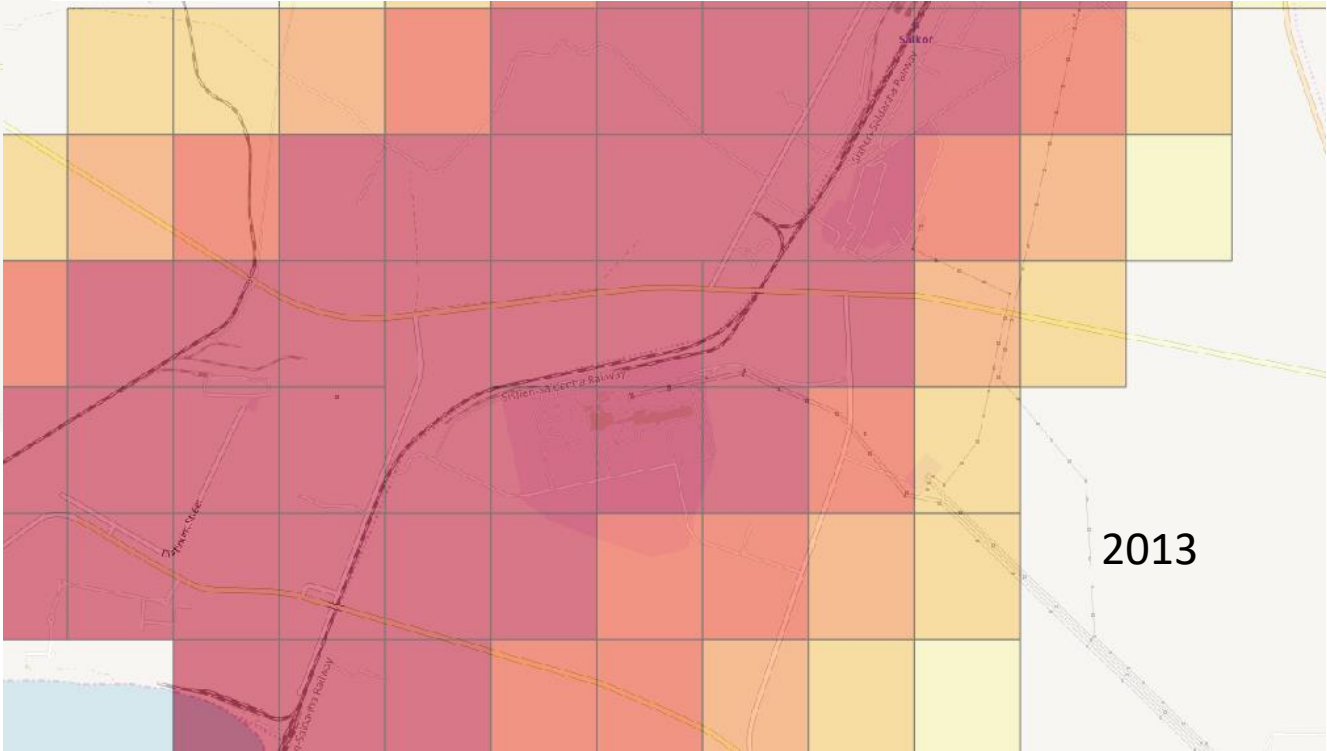
- The R6,8bn **Saldanha Steel** facilities, situated on the Cape west coast, has been designed to produce 1.25 million tons of hot-rolled carbon steel coil per year. The mill was commissioned in 1998.



Saldanha Steel



Saldanha Steel



South Africa Sum of Lights – GTIFF Format (pixels) - 1992

US Air Force
Defense
Meteorological
Satellite Program
(DMSP)
Operational
Linescan System
(OLS)



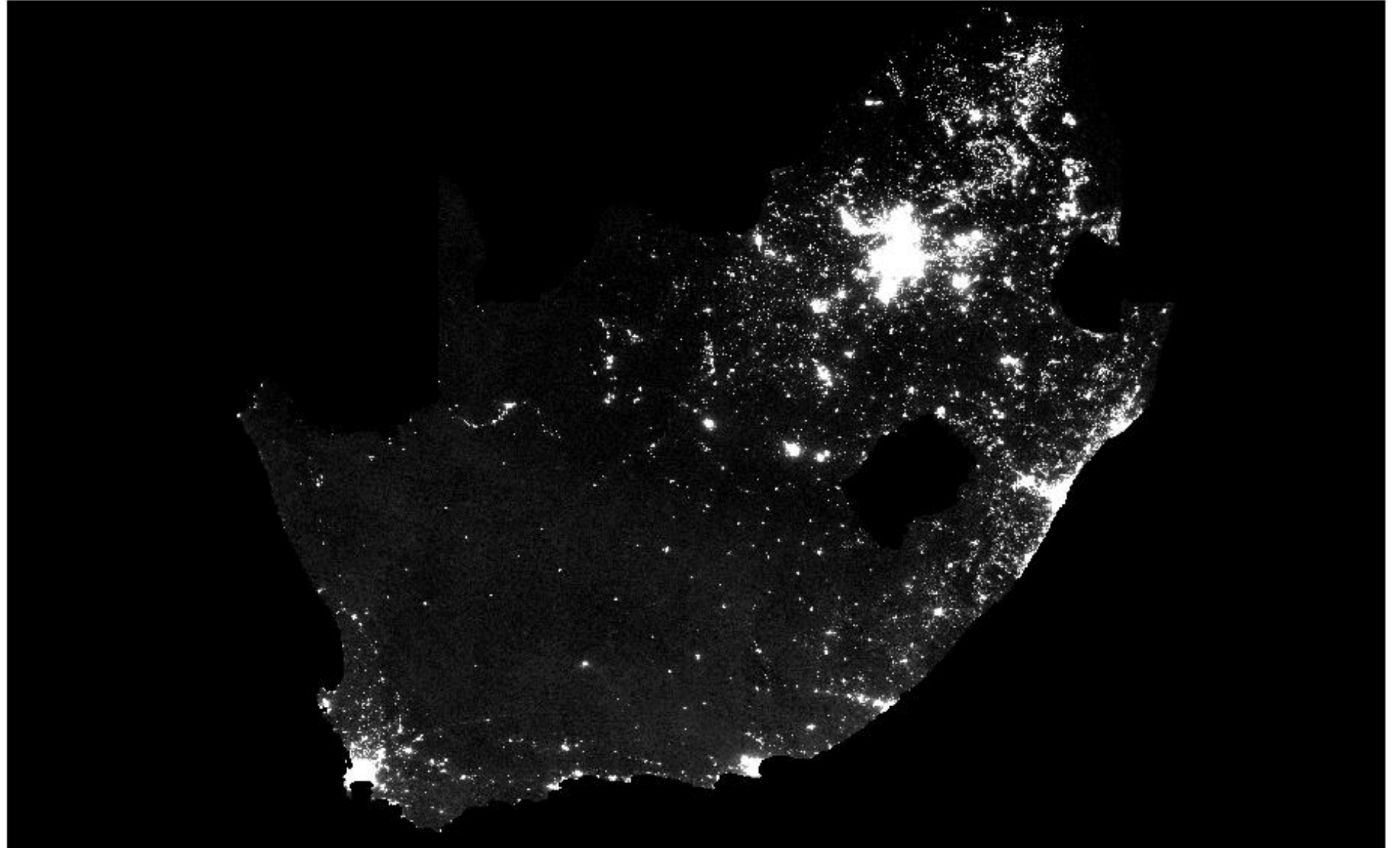
South Africa Sum of Lights – GTIFF Format (pixels) - 2013

Meteorological
Satellite Program
(DMSP)
Operational
Linescan System
(OLS)



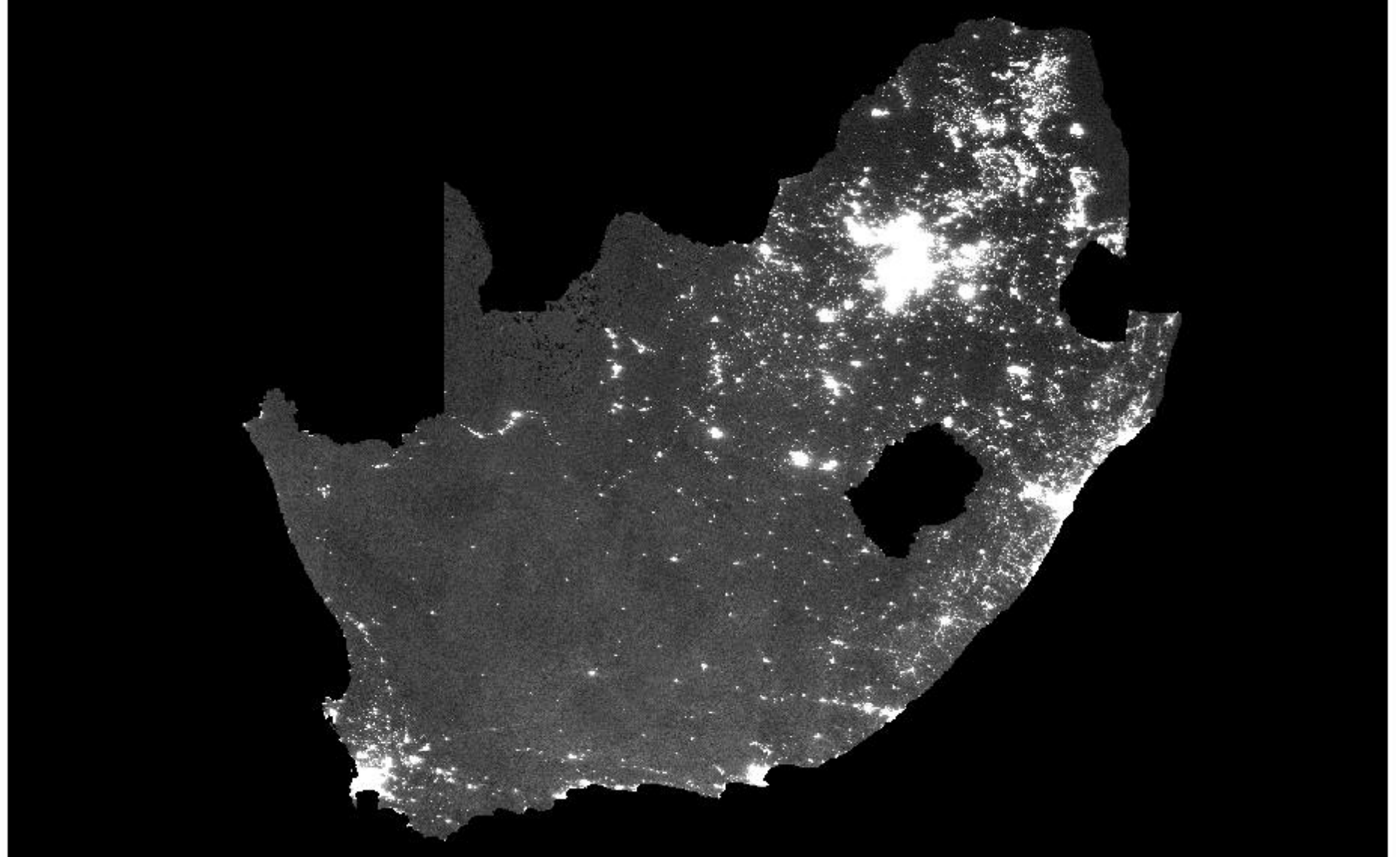
South Africa Sum of Lights – GTIFF Format (pixels) - 2013

Visible Infrared Imaging
Radiometer Suite
(VIIRS) Day/Night Band
(DNB),



South Africa Sum of Lights – GTIFF Format (pixels) - 2019

Visible Infrared Imaging
Radiometer Suite
(VIIRS) Day/Night Band
(DNB),



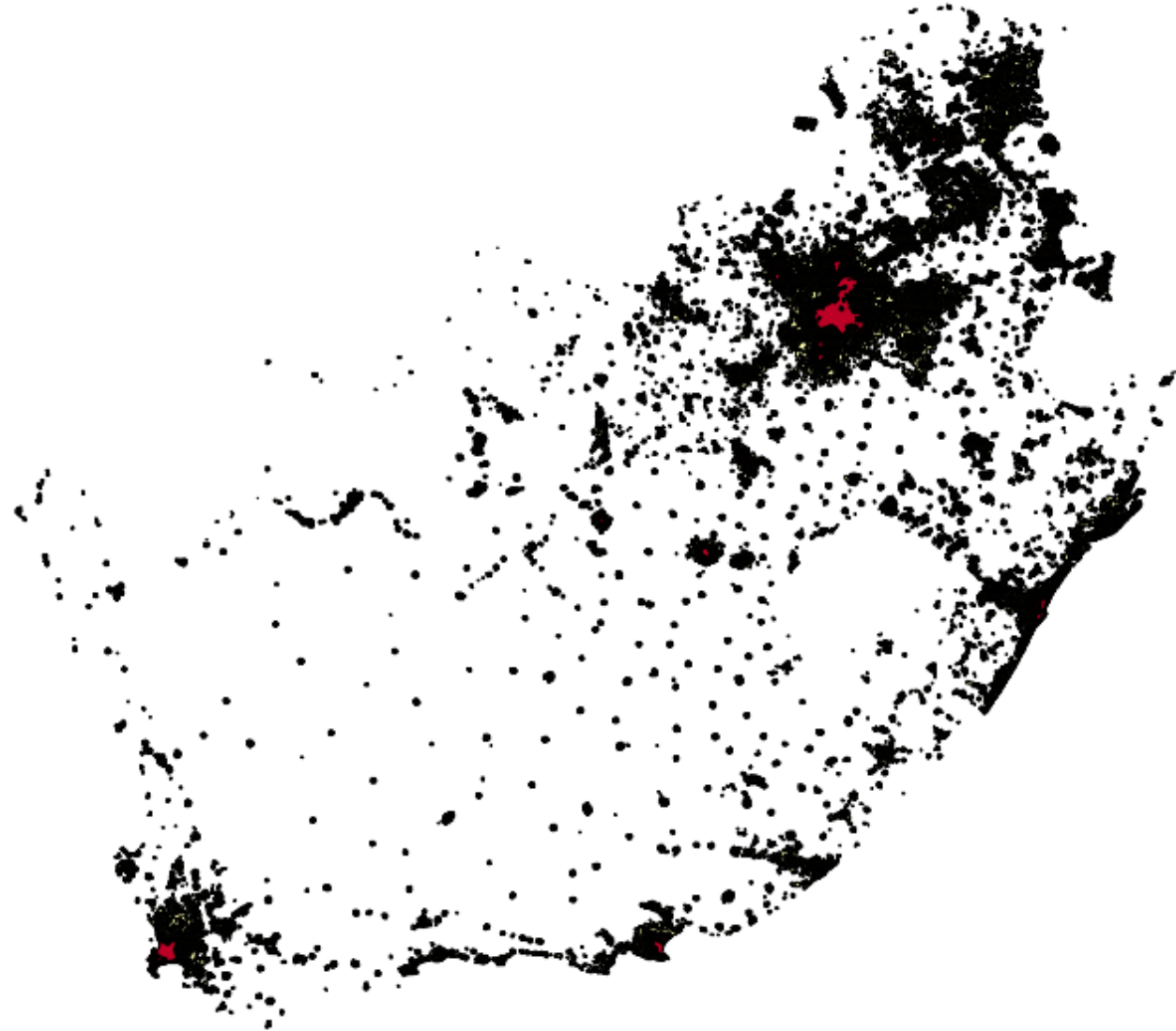
South Africa Sum of Lights – Shape Format (vector) - 1992

US Air Force
Defense
Meteorological
Satellite Program
(DMSP)
Operational
Linescan System
(OLS)



South Africa Sum of Lights – Shape Format (vector) - 2013

US Air Force
Defense
Meteorological
Satellite Program
(DMSP)
Operational
Linescan System
(OLS)



South Africa Sum of Lights – Shape Format (vector) - 2013

Visible Infrared Imaging
Radiometer Suite
(VIIRS) Day/Night Band
(DNB),

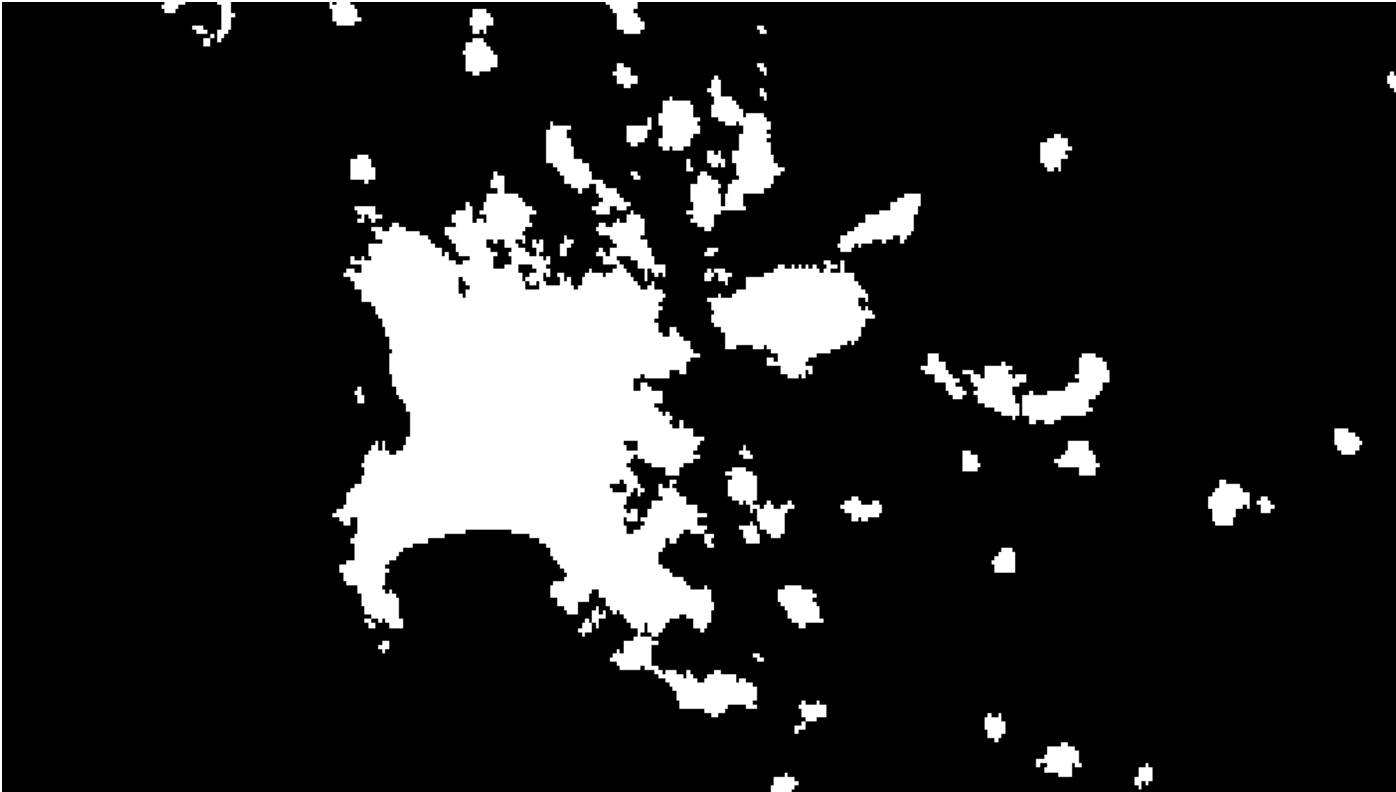


South Africa Sum of Lights – Shape Format (vector) - 2019

Visible Infrared Imaging
Radiometer Suite
(VIIRS) Day/Night Band
(DNB),

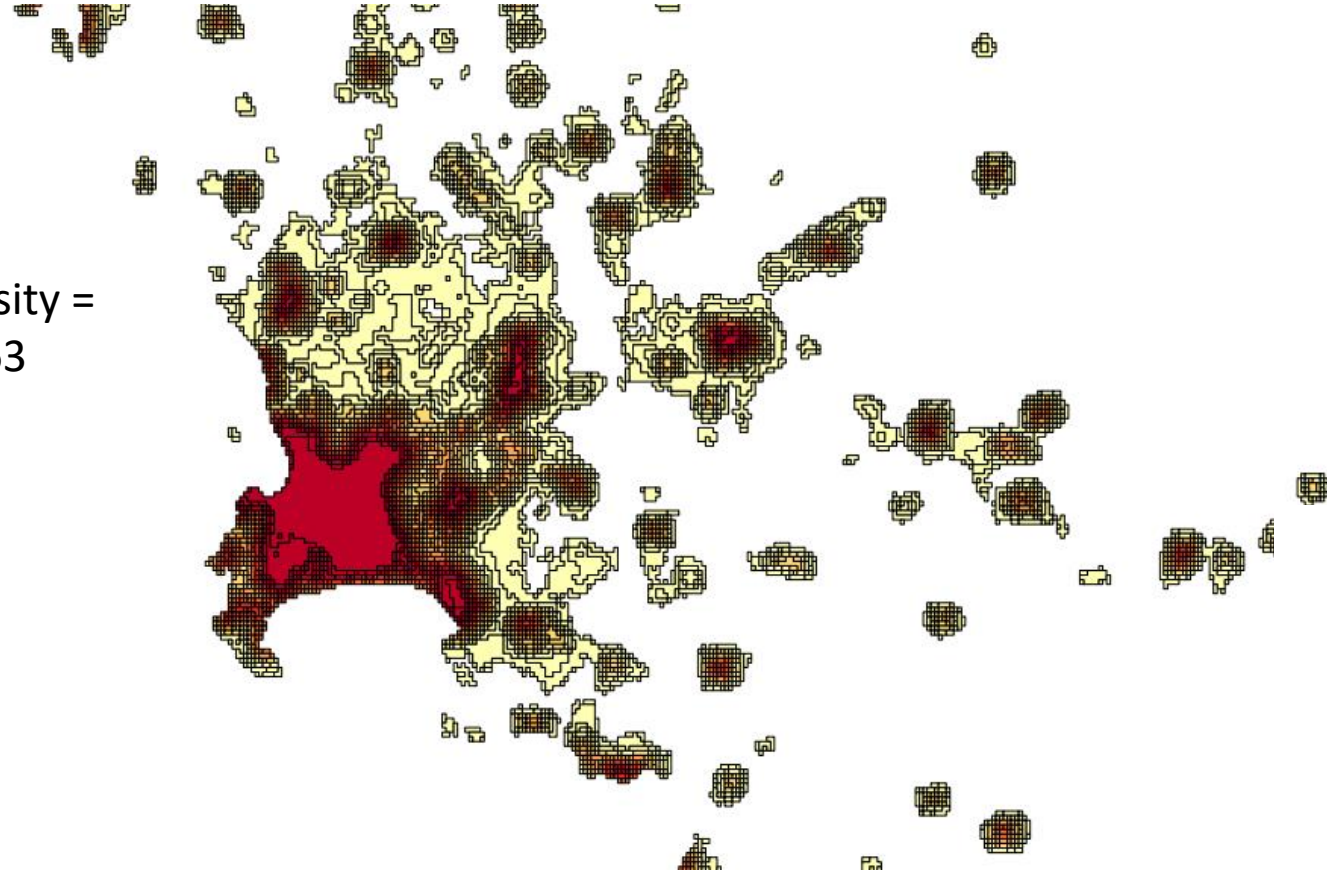


Raster vs Vector Cape Town 1992

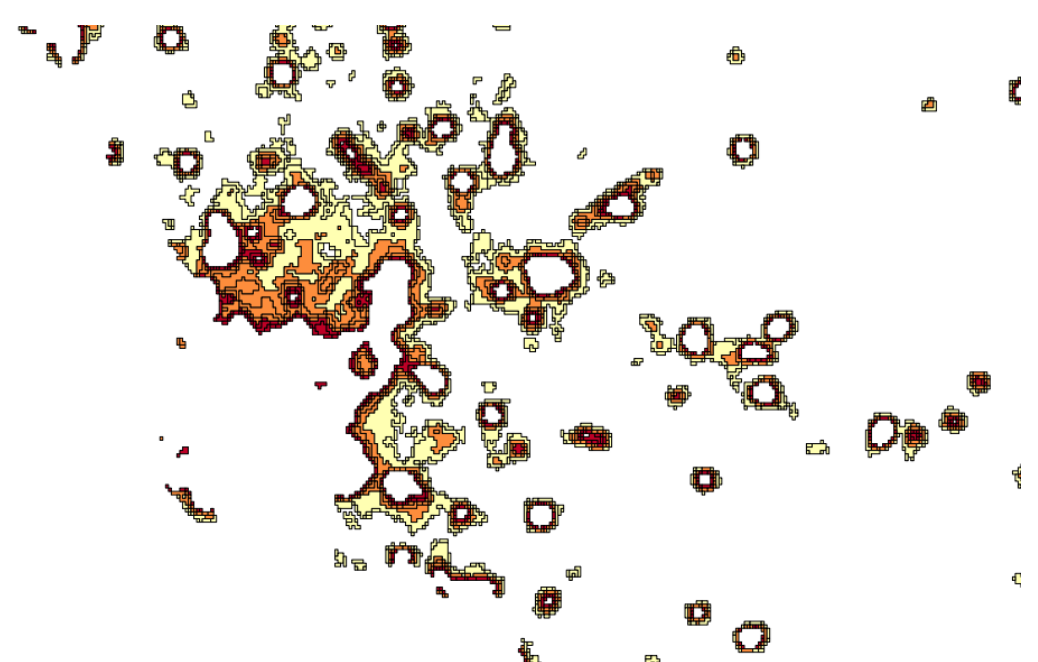


Cape Town 2013

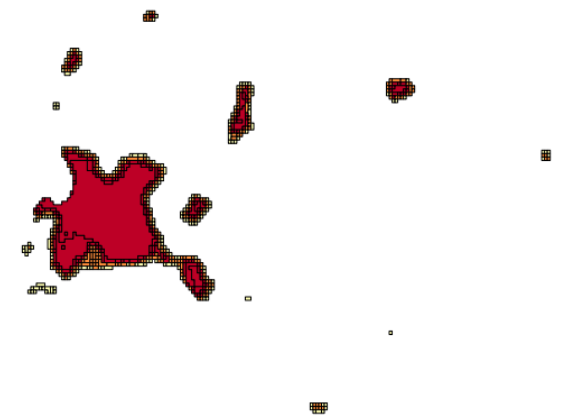
Intensity =
3 to 63



Intensity =
2 to 15



Intensity =
45 to 63

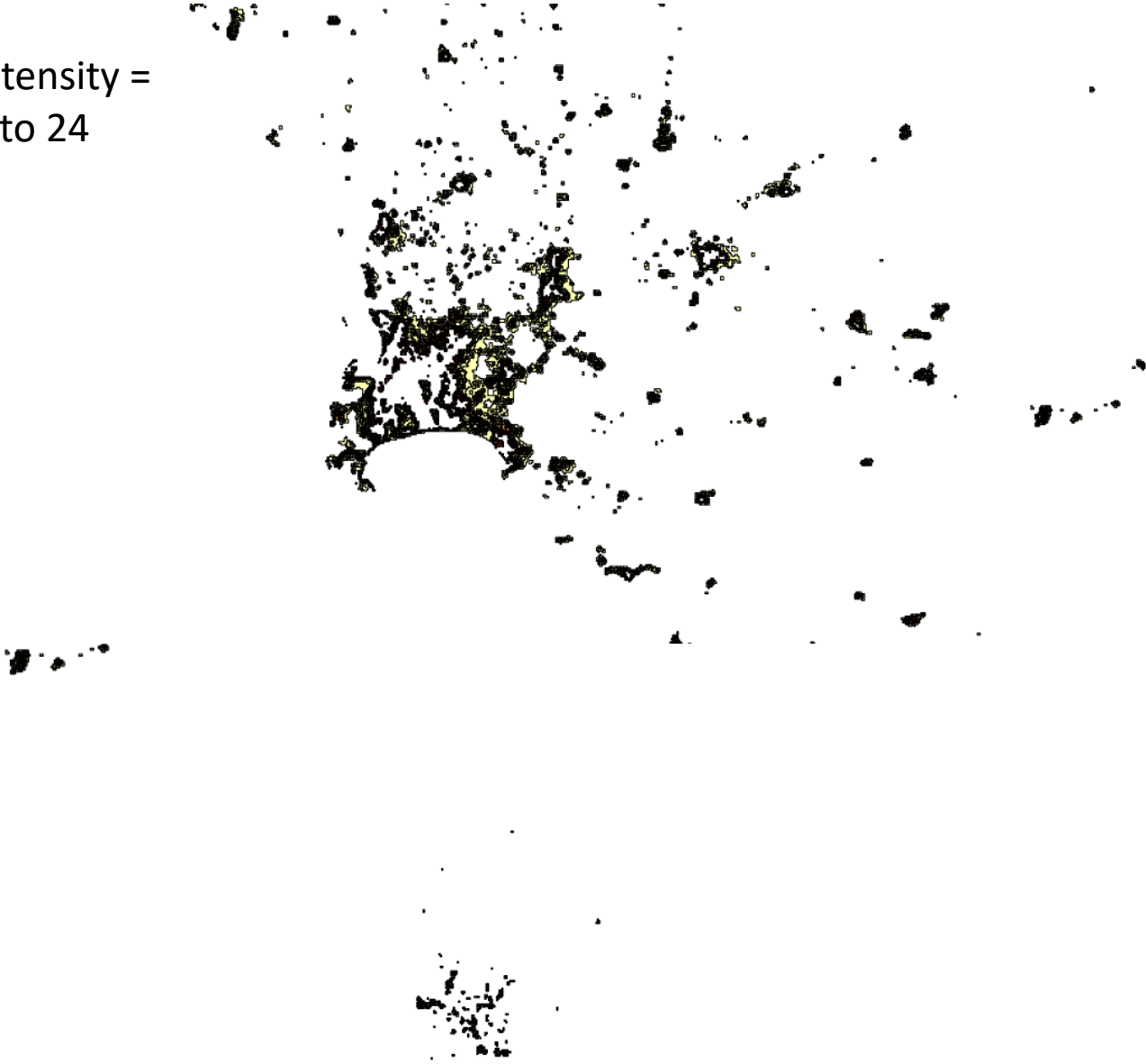


Cape Town 2019

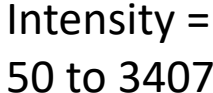
Intensity =
2 to 3407



Intensity =
2 to 24



Intensity =
50 to 3407



West Coast Example

Figure 1 shows the night lights for the West Coast (Langebaan, Saldanha, Vredenburg, Hopefield, Langebaanweg, Paternoster, St Helena Bay, Velddrif and Dwarskersbos) at two different points 1992 (top left) and 2013 (top right). Figure 2 shows the night lights in 2012 (bottom left) and 2019 (bottom right).

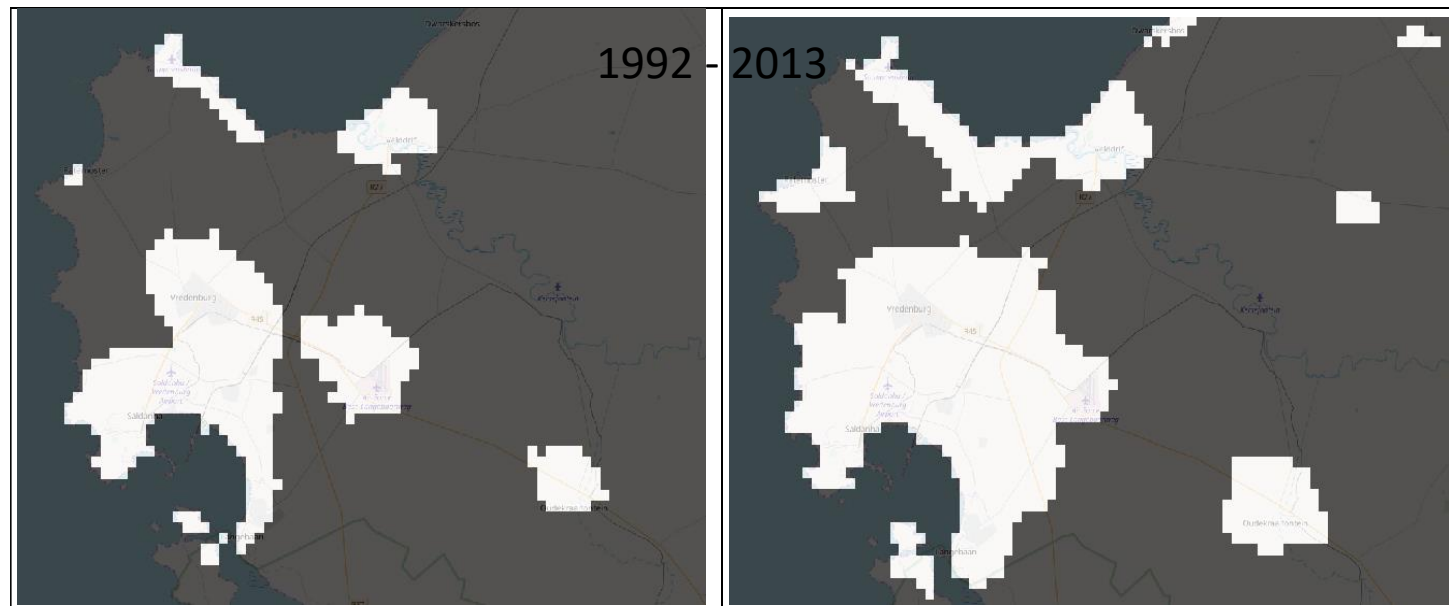


Figure 1

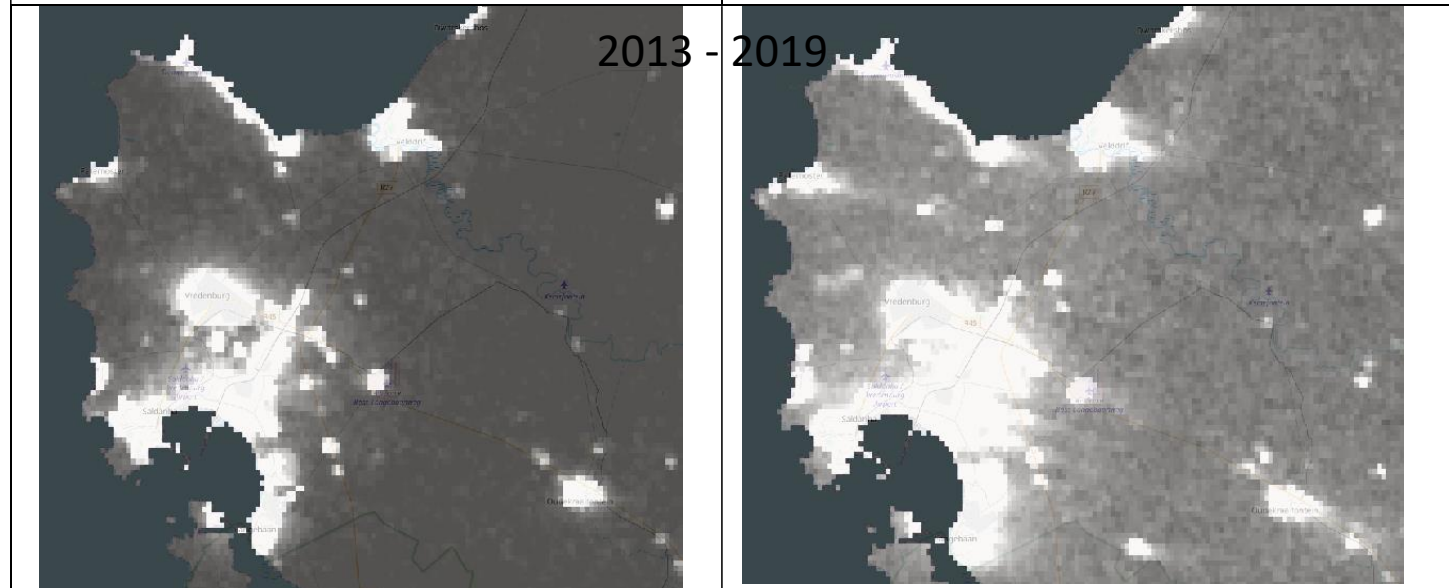
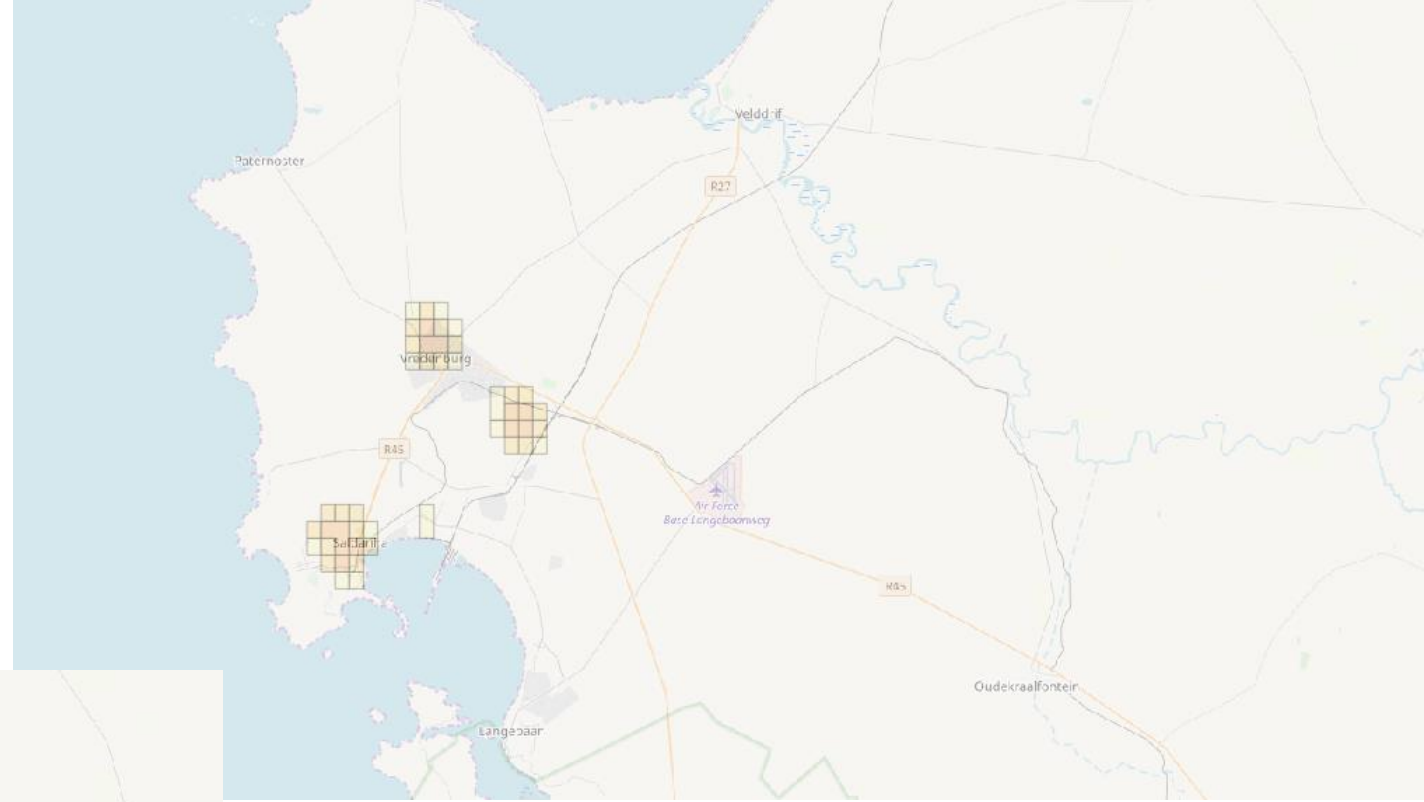


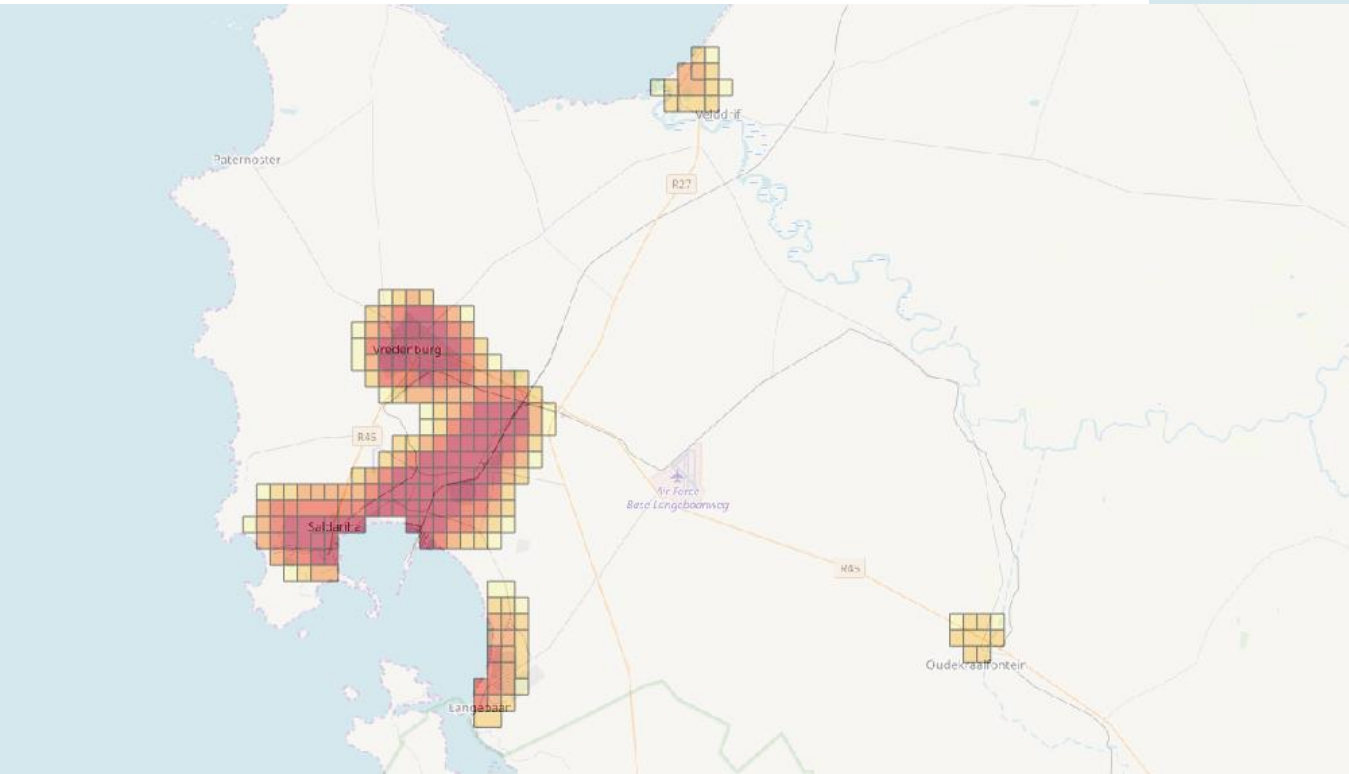
Figure 2

West Coast Example

1992

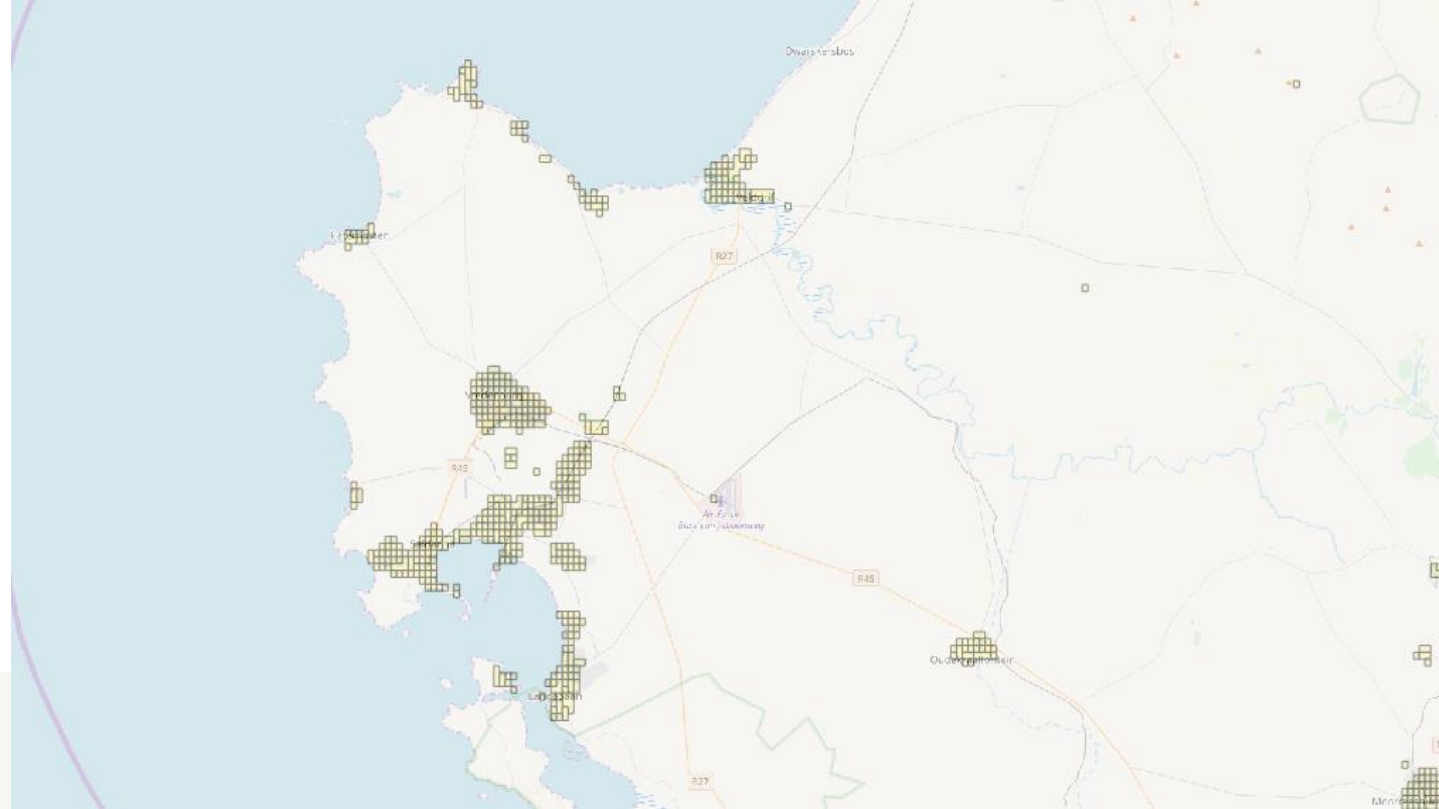


2013

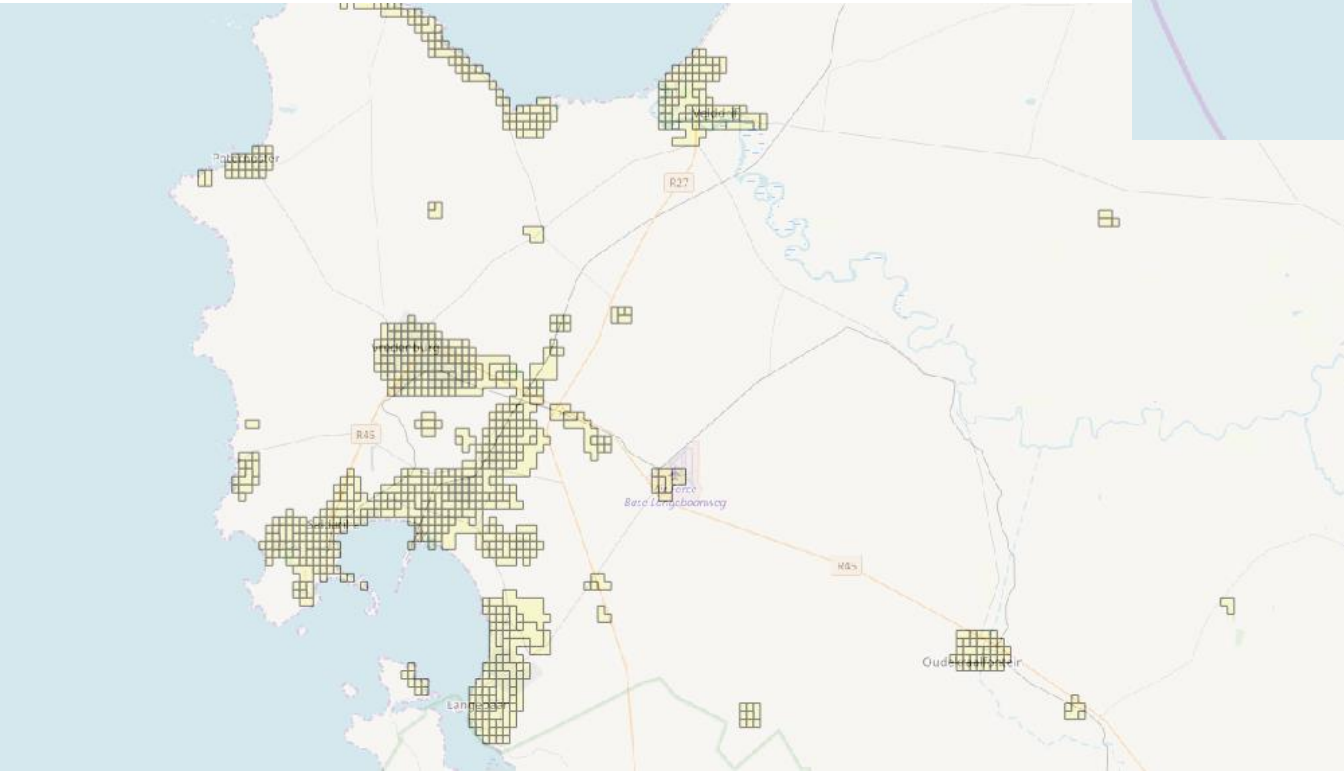


West Coast Example

2013



2019



Function	average	count	max	median	sum
2013	11.25	467	67	8	5275

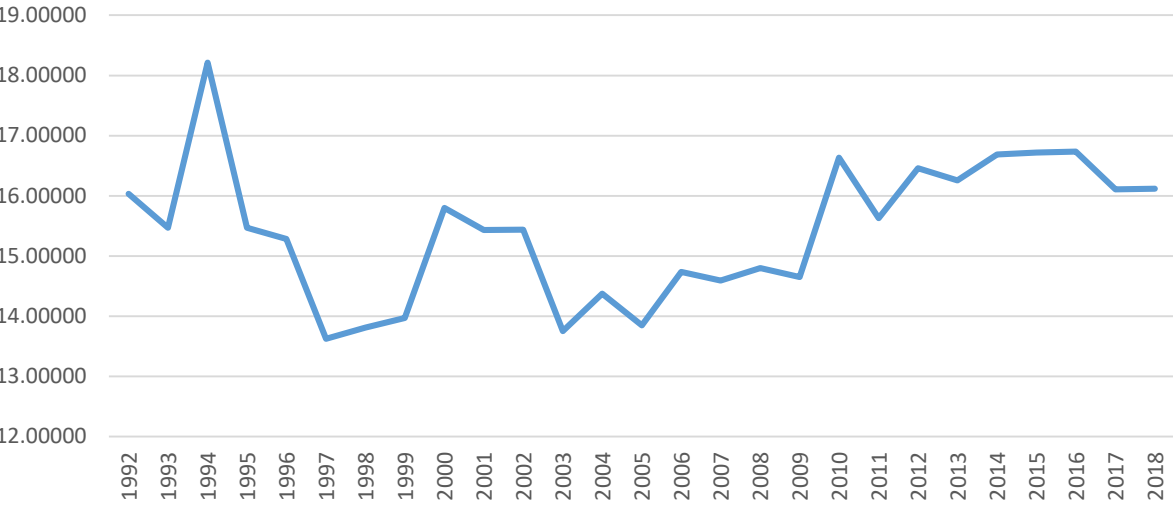
Function	average	count	max	median	sum
2019	10.25524	764	154	6	7835

West Coast Example

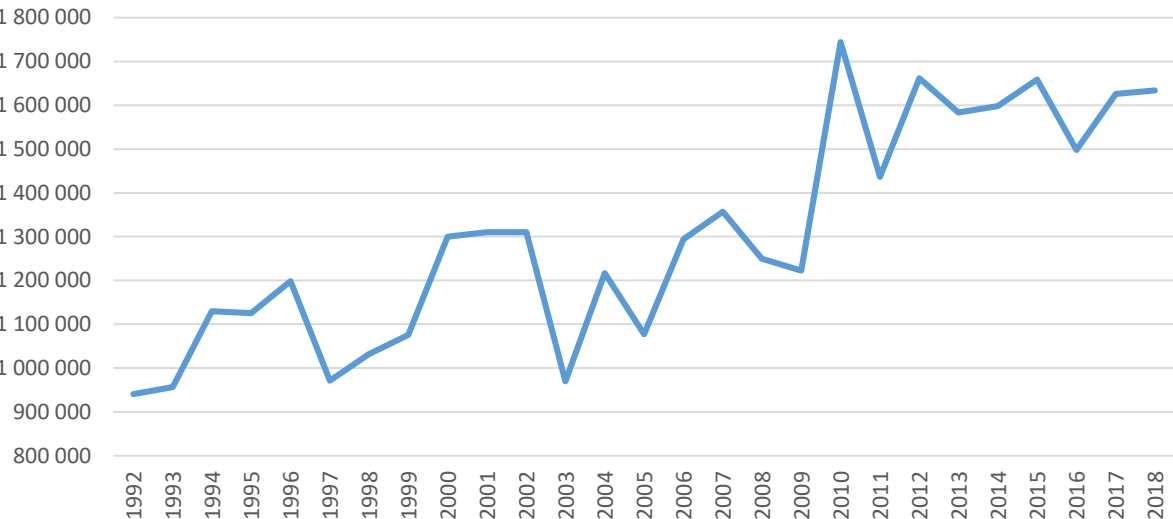
Period	Number of Years	Average Light Intensity	Count of Light Areas	Maximum Light Intensity	Median Light Intensity	Minimum Light Intensity	Sum of all Light Intensity
1992		10.52	390	31	8	3	4 102
2013		18.97	658	61	12	15.88	12 482
2012		8.28	676	67	5	1	5 598
2019		8.99	885	154	5	1	7 958
Percentage Change (%)							
1992 - 2013	21	80.35	68.72	96.77	50.00	429.41	204.29
2012 - 2019	7	8.59	30.92	129.85	0.00	0.00	42.16

SA Lights Statistics

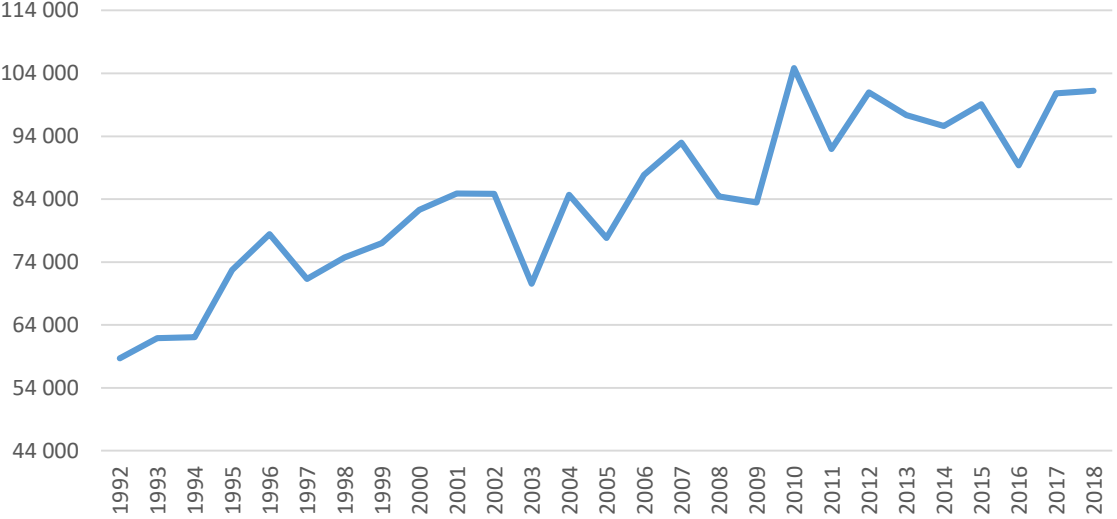
Average Light Intensity



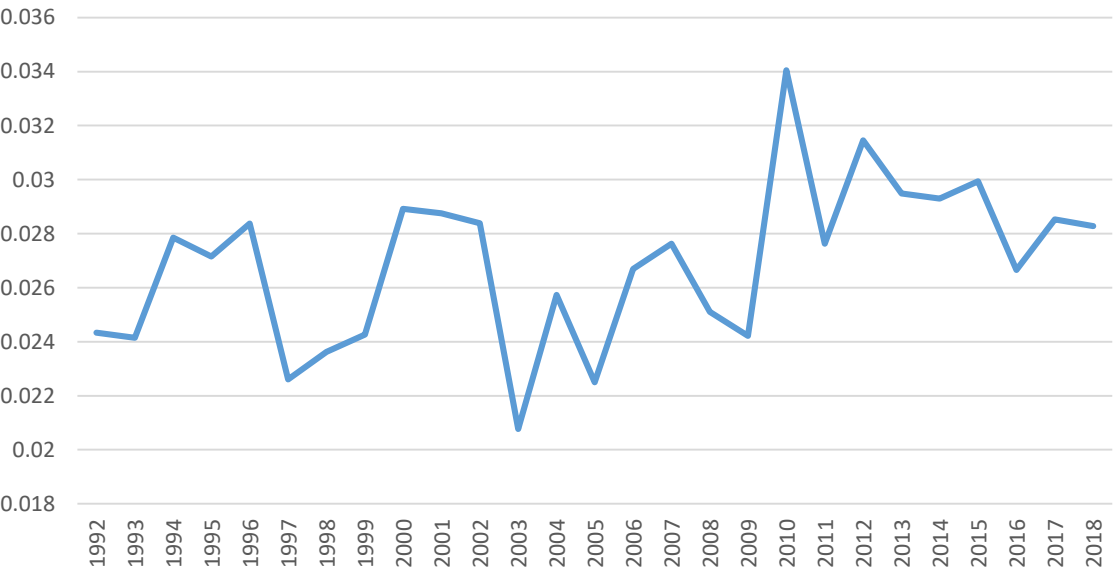
Sum of Lights



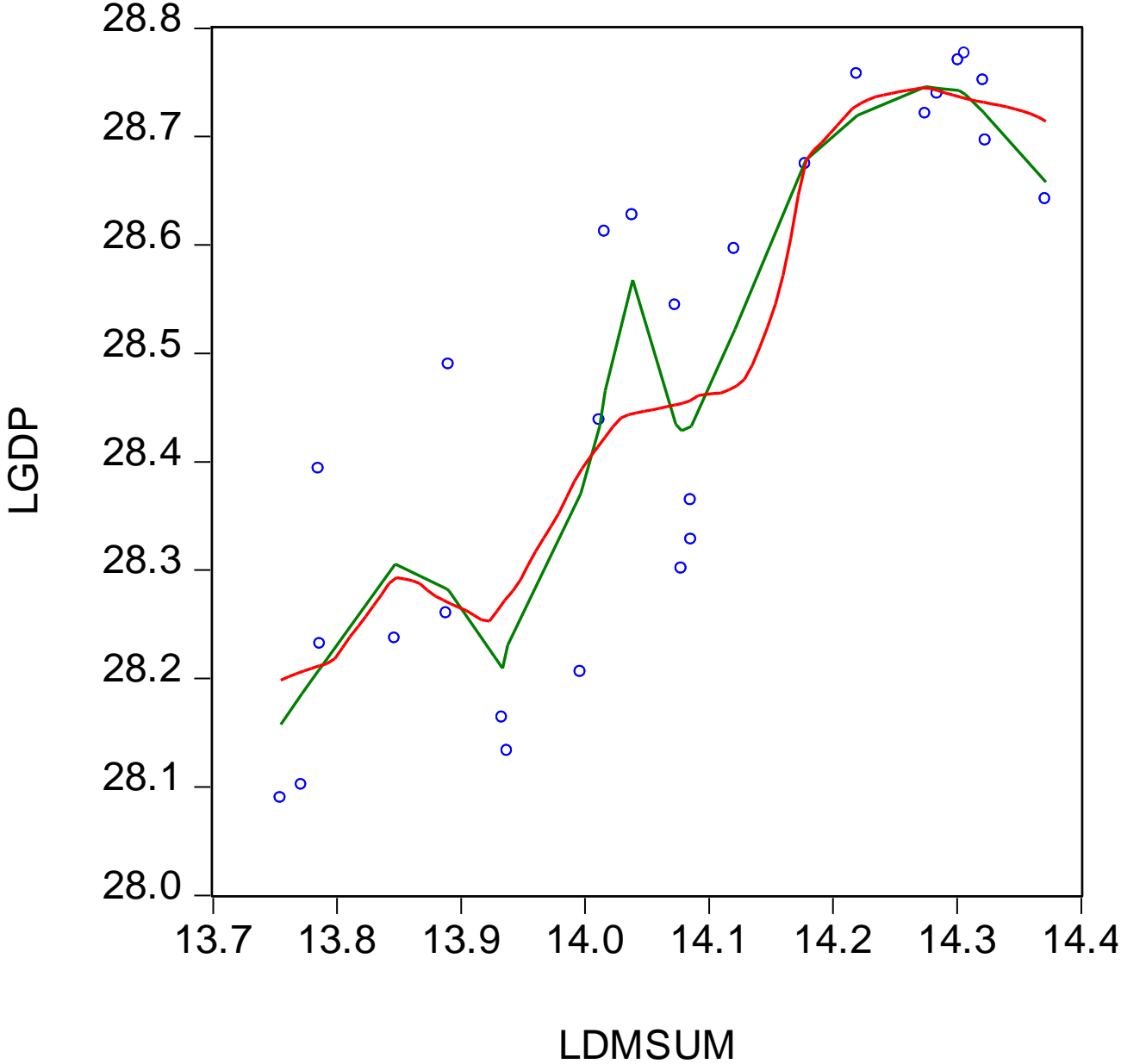
Count of Lights



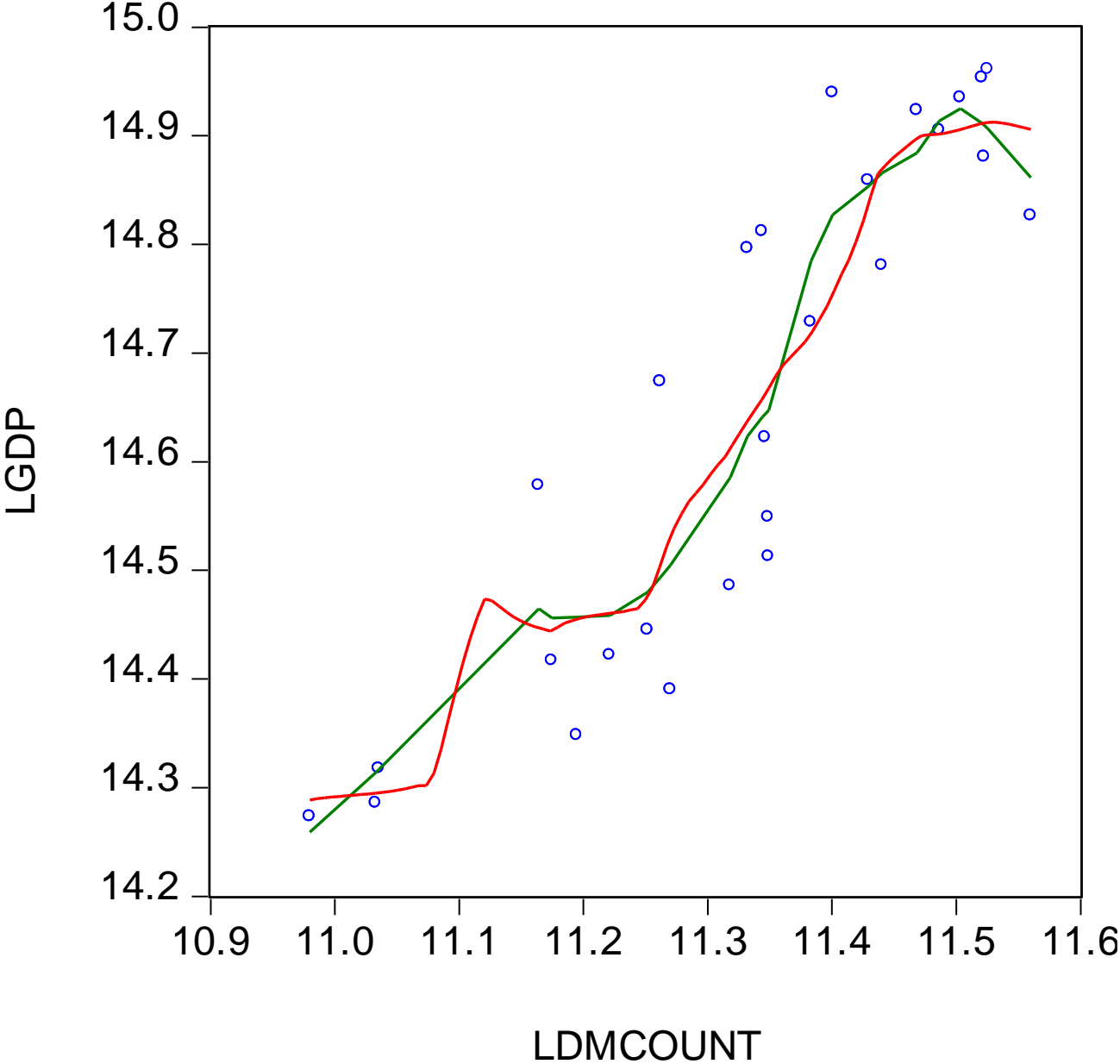
Sum of Lights Per Capita



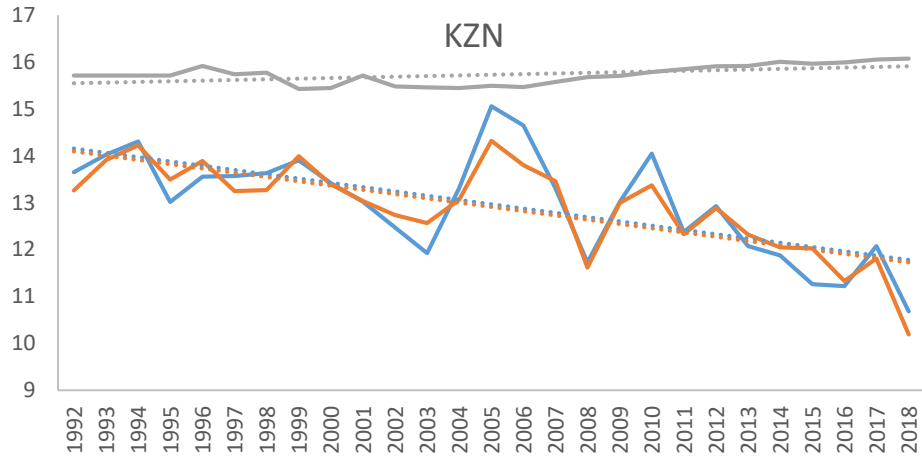
SA Lights Statistics



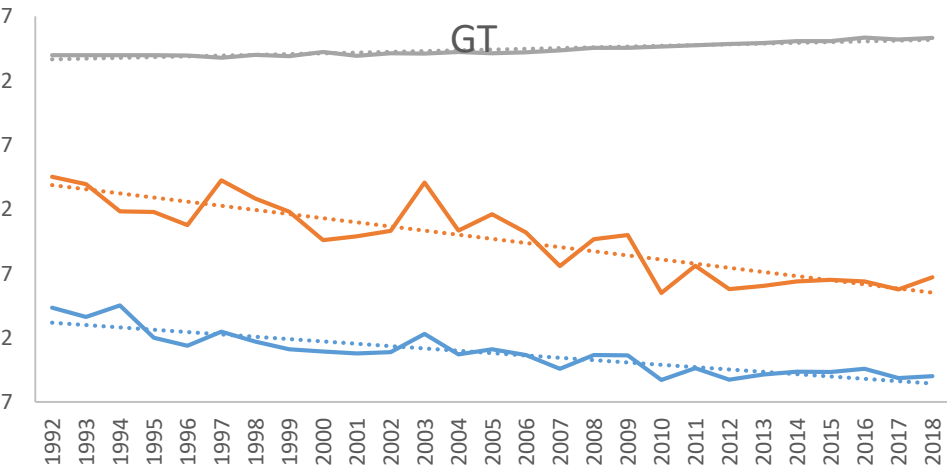
SA Lights Statistics



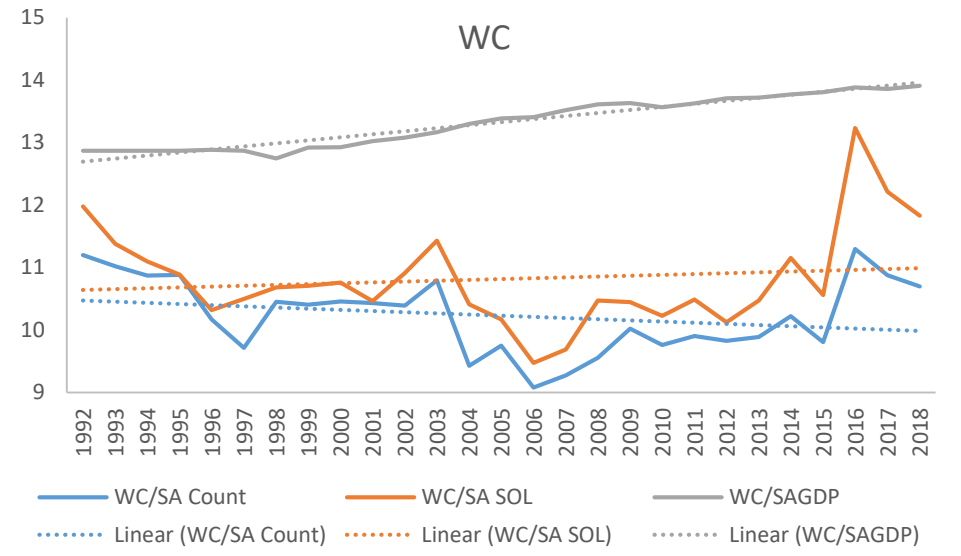
Provincial Dynamics



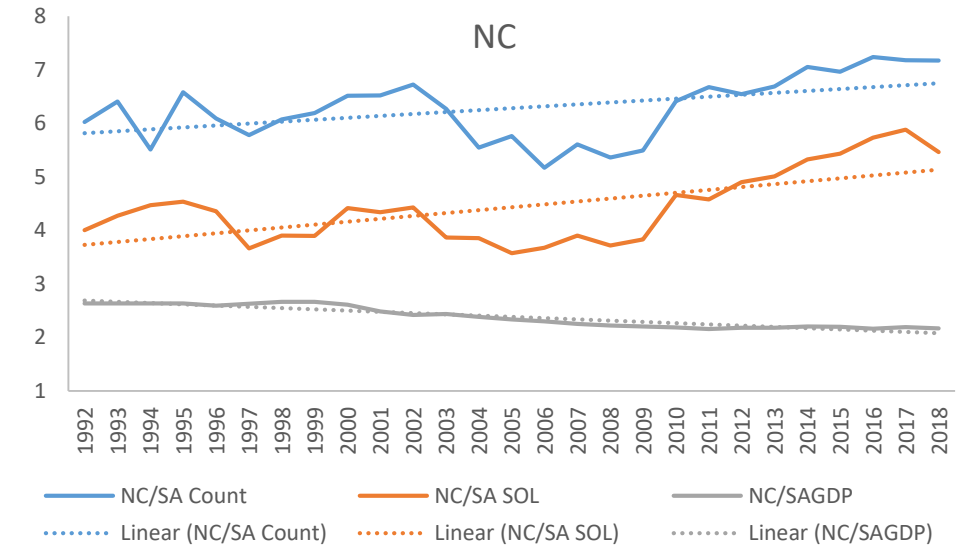
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 Linear (KZN/SA Count) Linear (KZN/SA SOL) Linear (KZN/SAGDP)



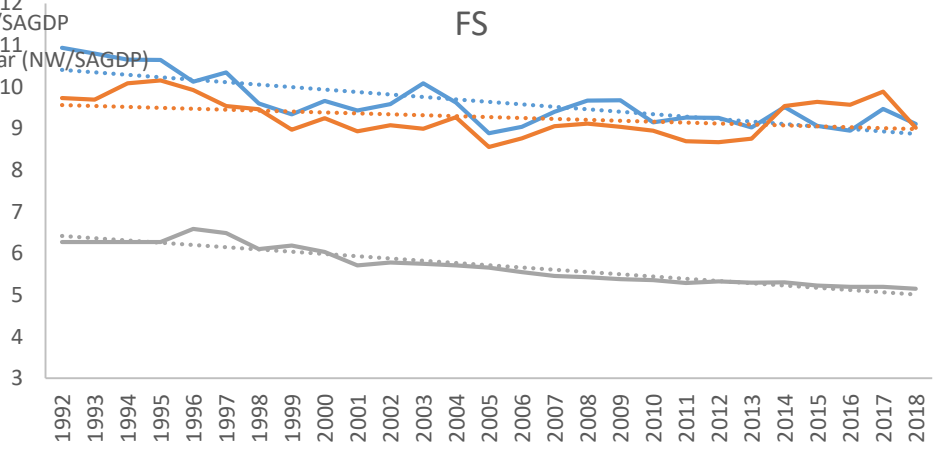
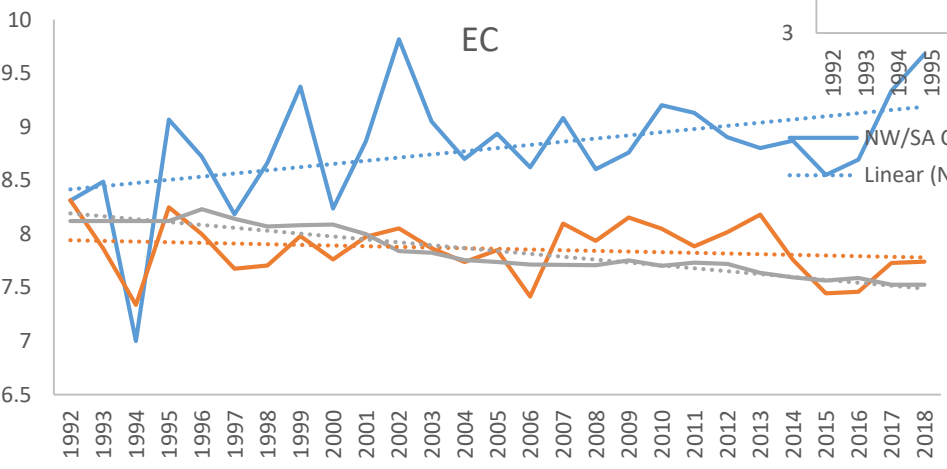
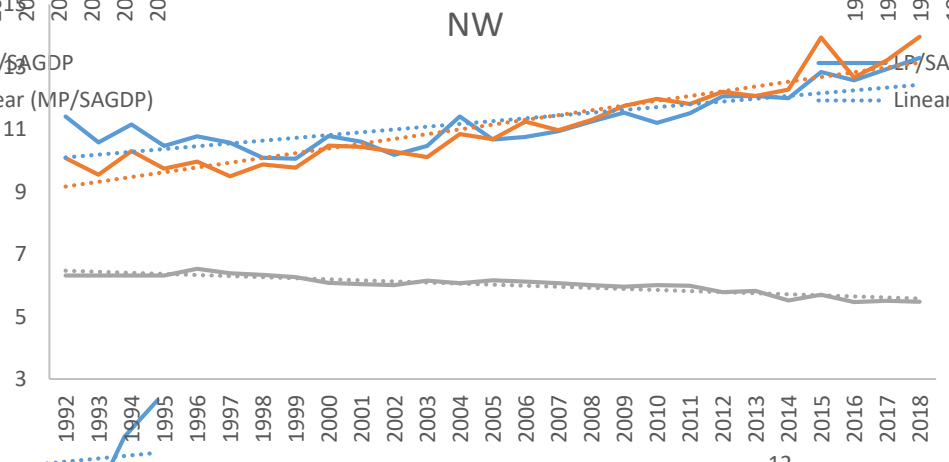
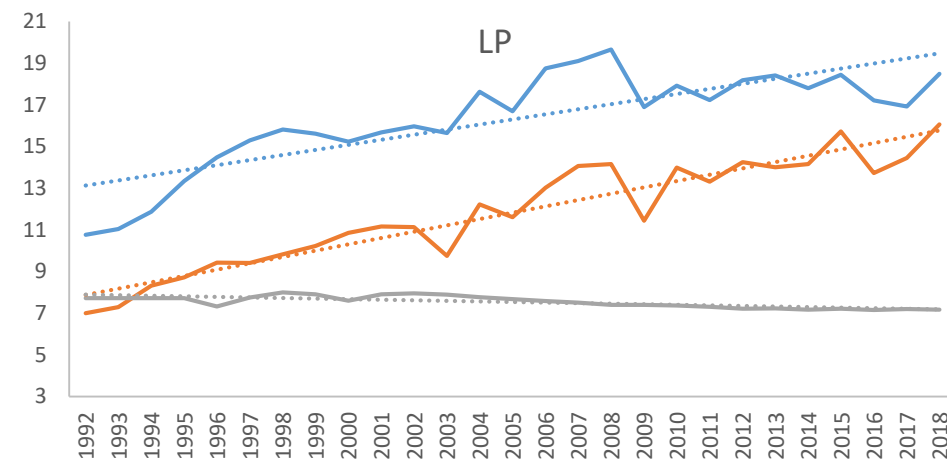
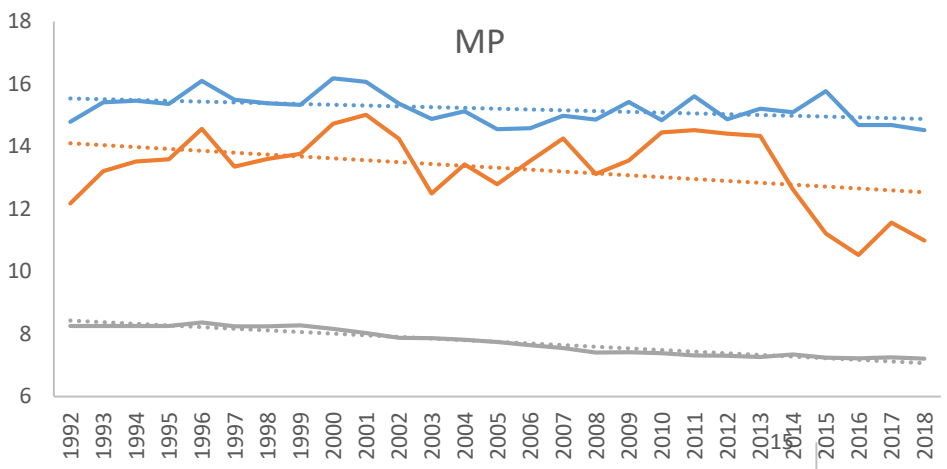
— GT/SA Count — GT/SA SOL — GT/SAGDP
 Linear (GT/SA Count) Linear (GT/SA SOL) Linear (GT/SAGDP)



— WC/SA Count — WC/SA SOL — WC/SAGDP
 Linear (WC/SA Count) Linear (WC/SA SOL) Linear (WC/SAGDP)



— NC/SA Count — NC/SA SOL — NC/SAGDP
 Linear (NC/SA Count) Linear (NC/SA SOL) Linear (NC/SAGDP)



— MP/SA Count — MP/SA SOL — MP/SAGDP
⋯ Linear (MP/SA Count) ⋯ Linear (MP/SA SOL) ⋯ Linear (MP/SAGDP)

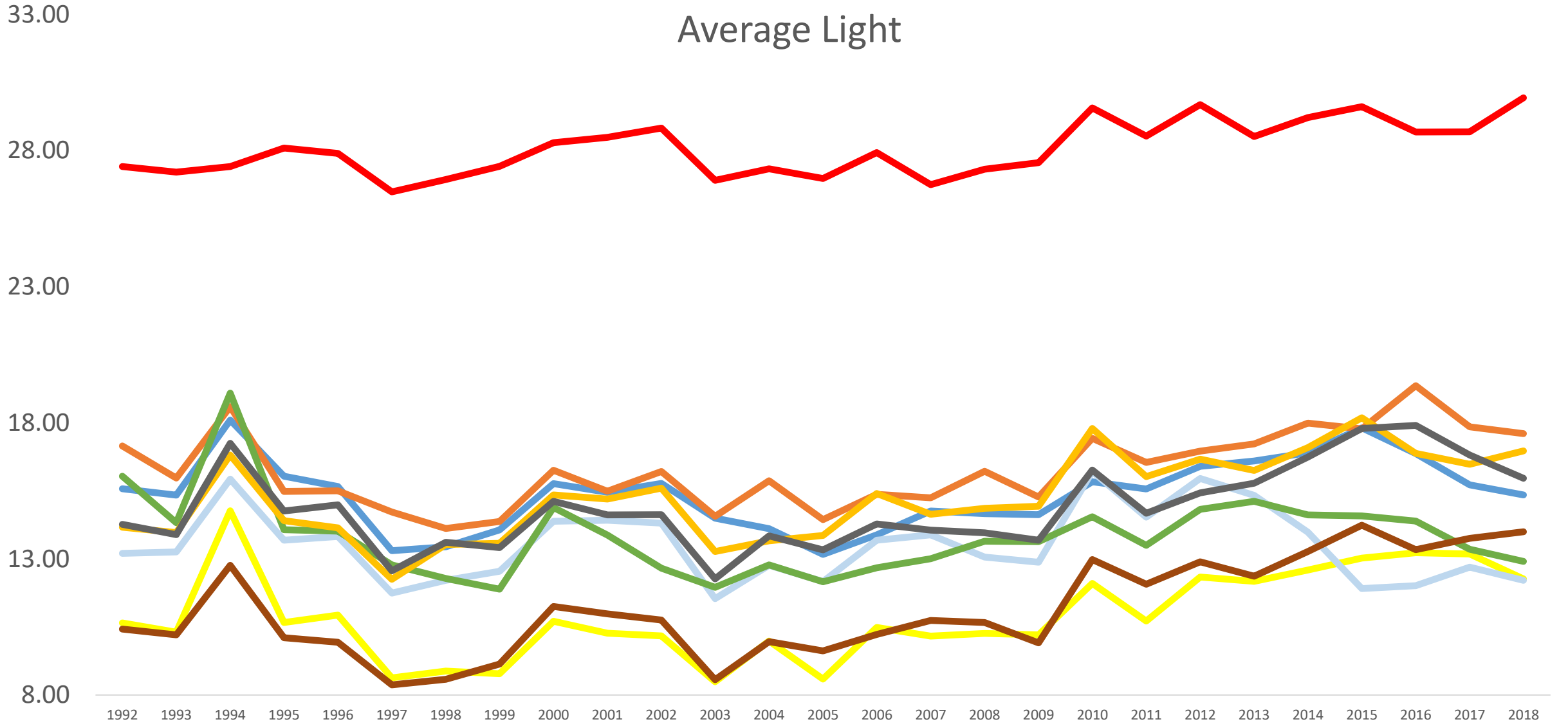
— LP/SA Count — LP/SA SOL — LP/SAGDP
⋯ Linear (LP/SA Count) ⋯ Linear (LP/SA SOL) ⋯ Linear (LP/SAGDP)

— NW/SA Count — NW/SA SOL — NW/SAGDP
⋯ Linear (NW/SA Count) ⋯ Linear (NW/SA SOL) ⋯ Linear (NW/SAGDP)

— EC/SA Count — EC/SA SOL — EC/SAGDP
⋯ Linear (EC/SA Count) ⋯ Linear (EC/SA SOL) ⋯ Linear (EC/SAGDP)

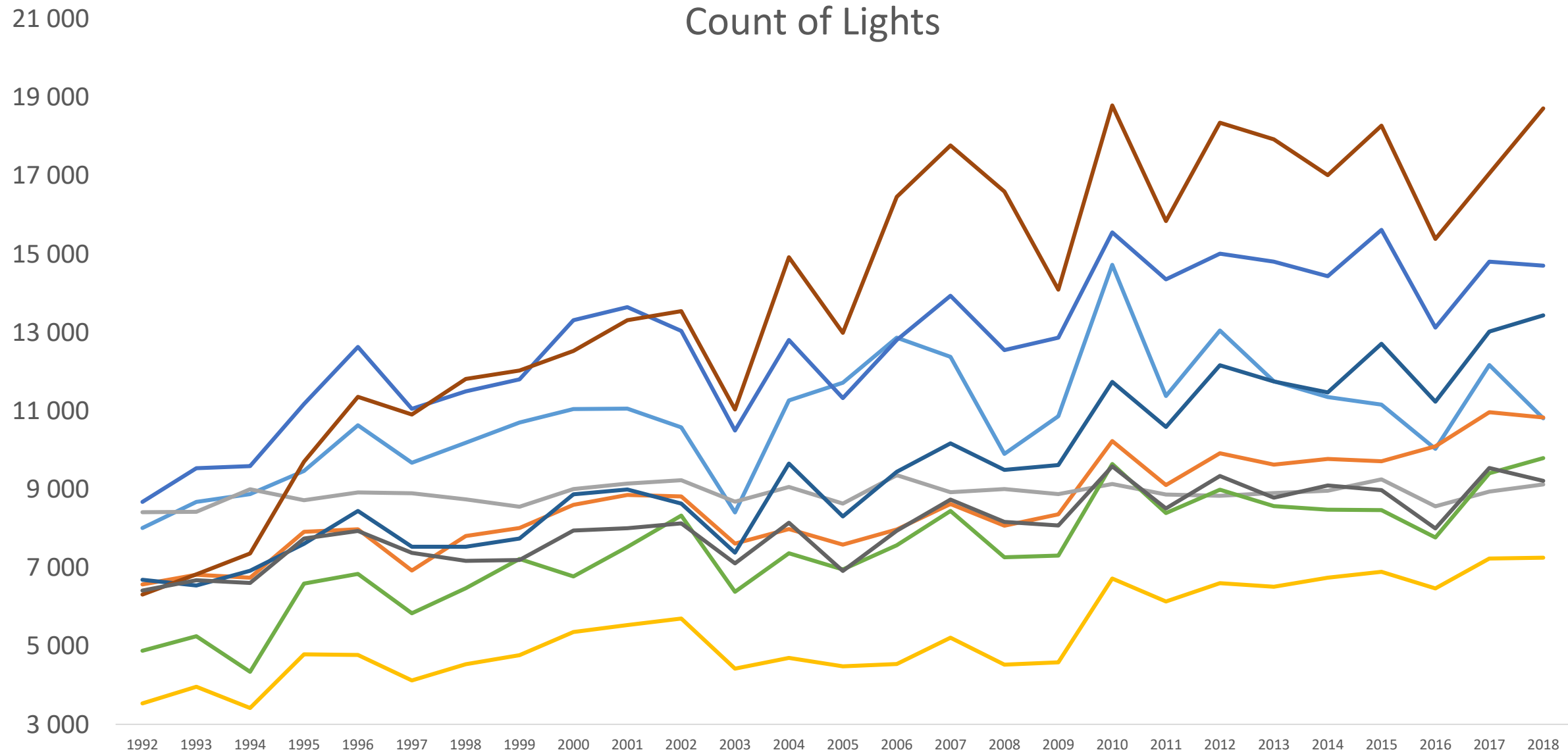
— FS/SA Count — FS/SA SOL — FS/SAGDP
⋯ Linear (FS/SA Count) ⋯ Linear (FS/SA SOL) ⋯ Linear (FS/SAGDP)

Average Light



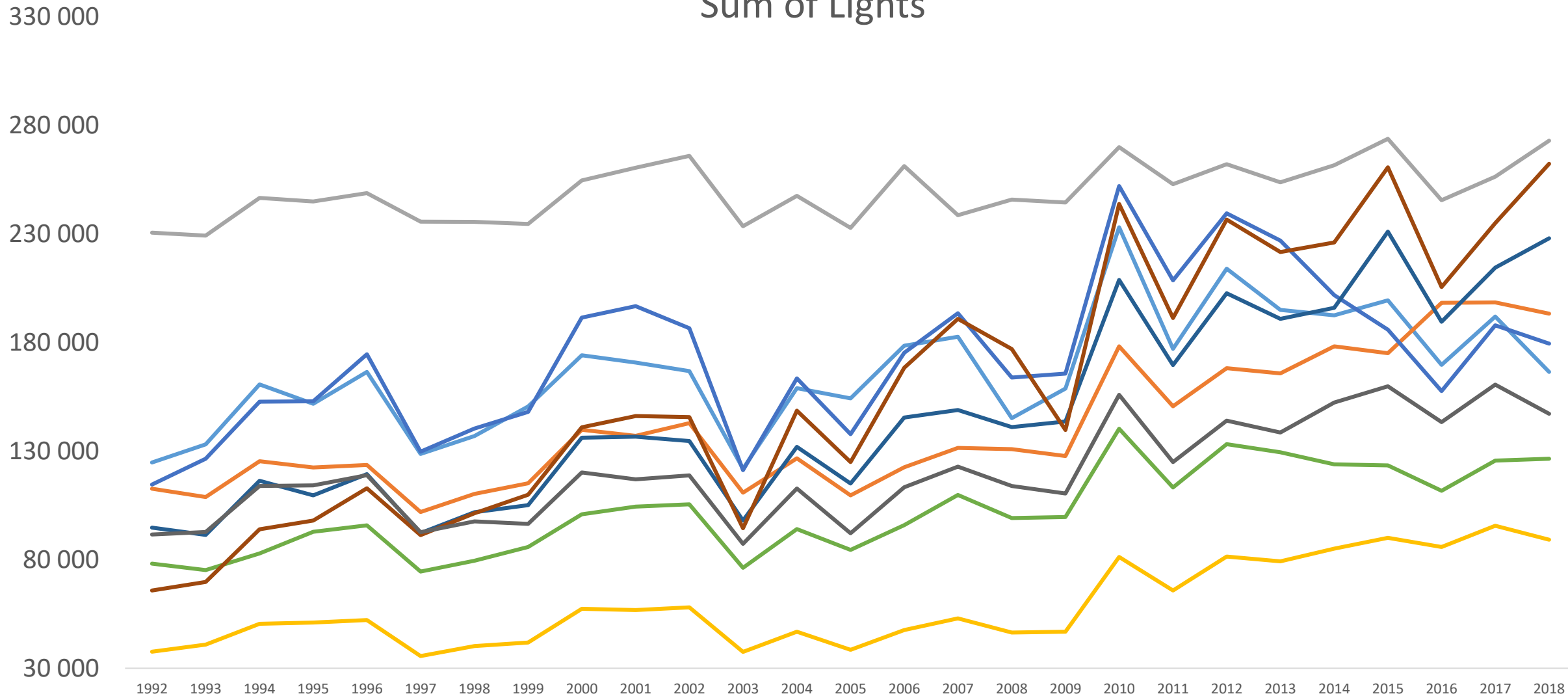
— KZNAvlight — WCAvlight — GTAvlight — NCAvlight — MPAvlight
— ECAvlight — NWAvlight — LPAvlight — FSAvlight

Count of Lights
































— KZNCCount — WCCCount — GTCCount — NCCCount — MPCCount
— ECCCount — NWCCount — LPCCount — FSCount

Sum of Lights



— KZNSOF — WCSOL — GTSOL — NCSOL — MPSOL
— ECSOL — NWSOL — LPSOL — FSSOL

KZN	GDP	GDPCAP	Pop	
AveLight	0.25	0.28	0.19	
Count	0.63	0.61	0.63	
SOL	0.68	0.67	0.65	
WC	GDP	GDPCap	Pop	
AveLight	0.47	0.35	0.51	
Count	0.84	0.71	0.88	
SOL	0.80	0.66	0.85	
GT	GDP	GDPCap	Pop	
AveLight	0.61	0.35	0.65	
Count	0.38	0.41	0.35	
SOL	0.60	0.44	0.61	
NC	GDP	GDPCap	Pop	
AveLight	0.42	0.14	0.52	
Count	0.83	0.54	0.89	
SOL	0.77	0.43	0.86	
MP	GDP	GDPCap	Pop	
AveLight	0.00	0.07	-0.05	
Count	0.84	0.79	0.84	
SOL	0.64	0.64	0.62	

EC	GDP	GDPCap	Pop	
AveLight	-0.10	-0.04	-0.25	
Count	0.84	0.80	0.87	
SOL	0.83	0.82	0.78	
NW	GDP	GDPCap	Pop	
AveLight	0.61	0.38	0.68	
Count	0.91	0.67	0.95	
SOL	0.87	0.62	0.92	
LP	GDP	GDPCap	Pop	
AveLight	0.61	0.61	0.59	
Count	0.91	0.88	0.93	
SOL	0.92	0.90	0.93	
FS	GDP	GDPCap	Pop	
AveLight	0.46	0.49	0.28	
Count	0.83	0.80	0.76	
SOL	0.76	0.75	0.62	
Average	GDP	GDPCap	Pop	
AveLight	0.37	0.29	0.35	
Count	0.78	0.69	0.79	
SOL	0.76	0.66	0.76	