



The Ecological Economics of Light Pollution: Impacts on Ecosystem Service Value

Dr. Sharolyn Anderson and Professor Paul Sutton

Valuing Darkness

Light Pollution

2014

Overview

- ◆ Light Pollution
 - Natural Night Skies
 - Upward Radiance vs Skyglow
- ◆ Effects of Light Pollution on Ecosystems
- ◆ Ecosystem Services
- ◆ Ecological Economics
- ◆ Ecological Economics of Light Pollution

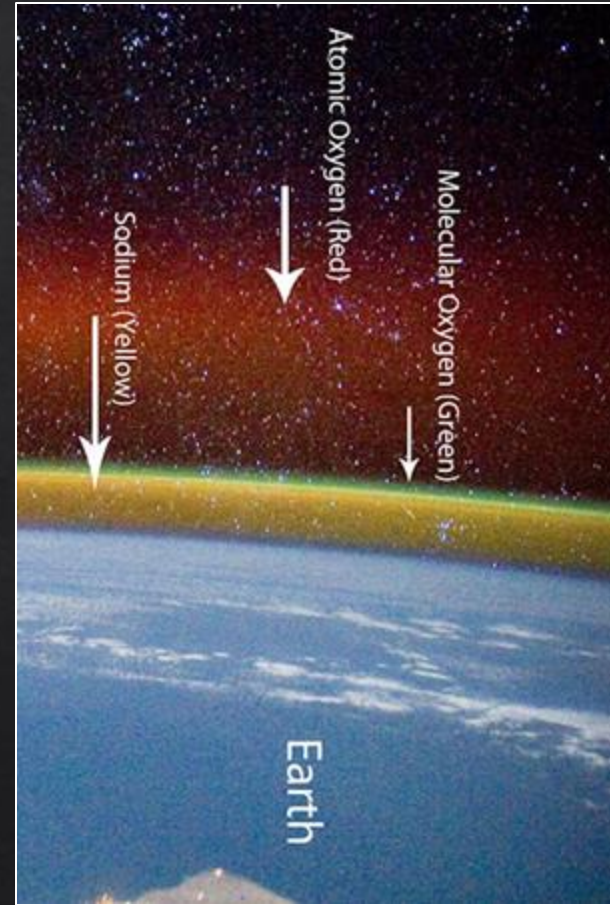
Natural Sources of Light



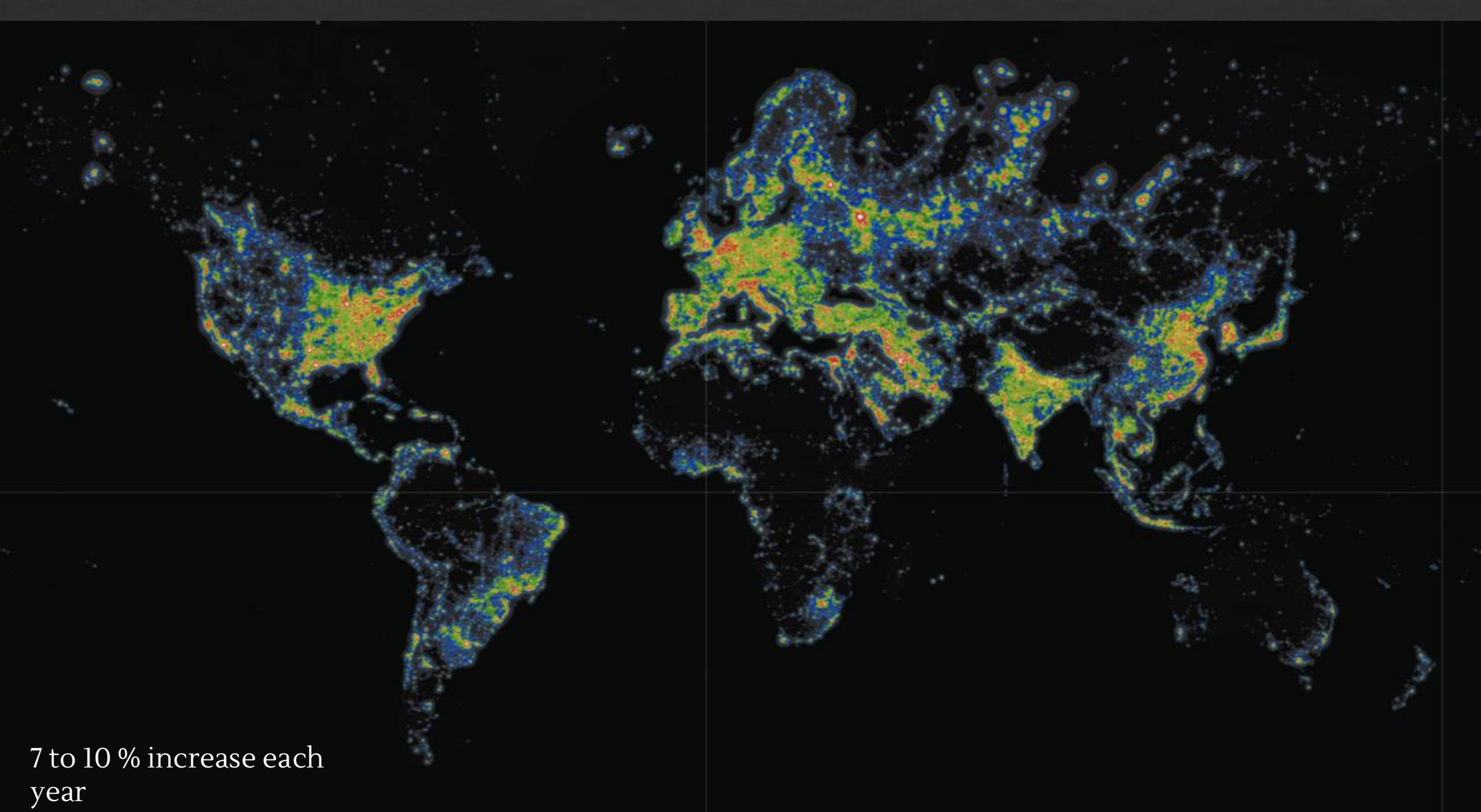
Starlight and Galactic
Light



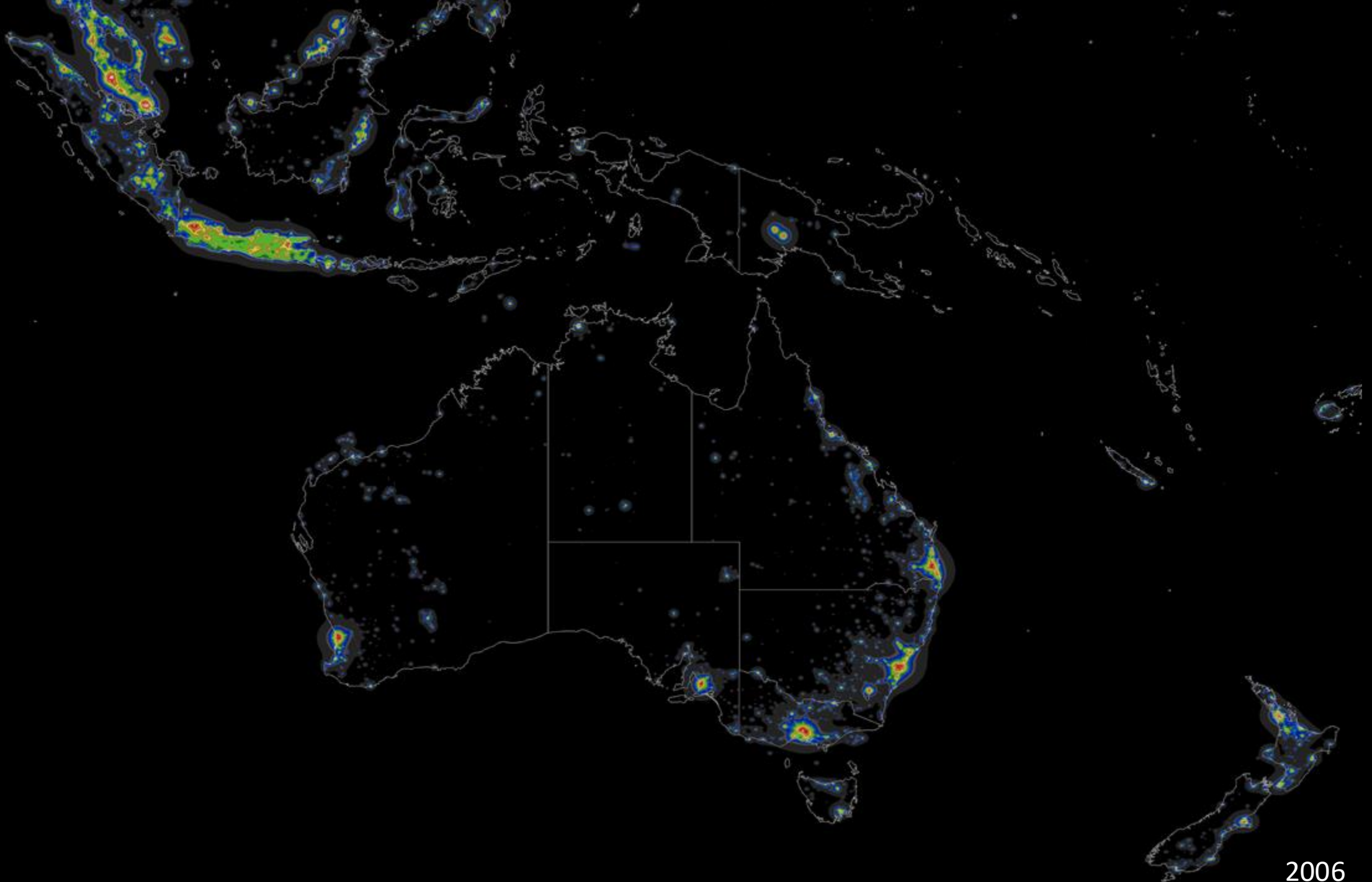
Zodiacal
Light



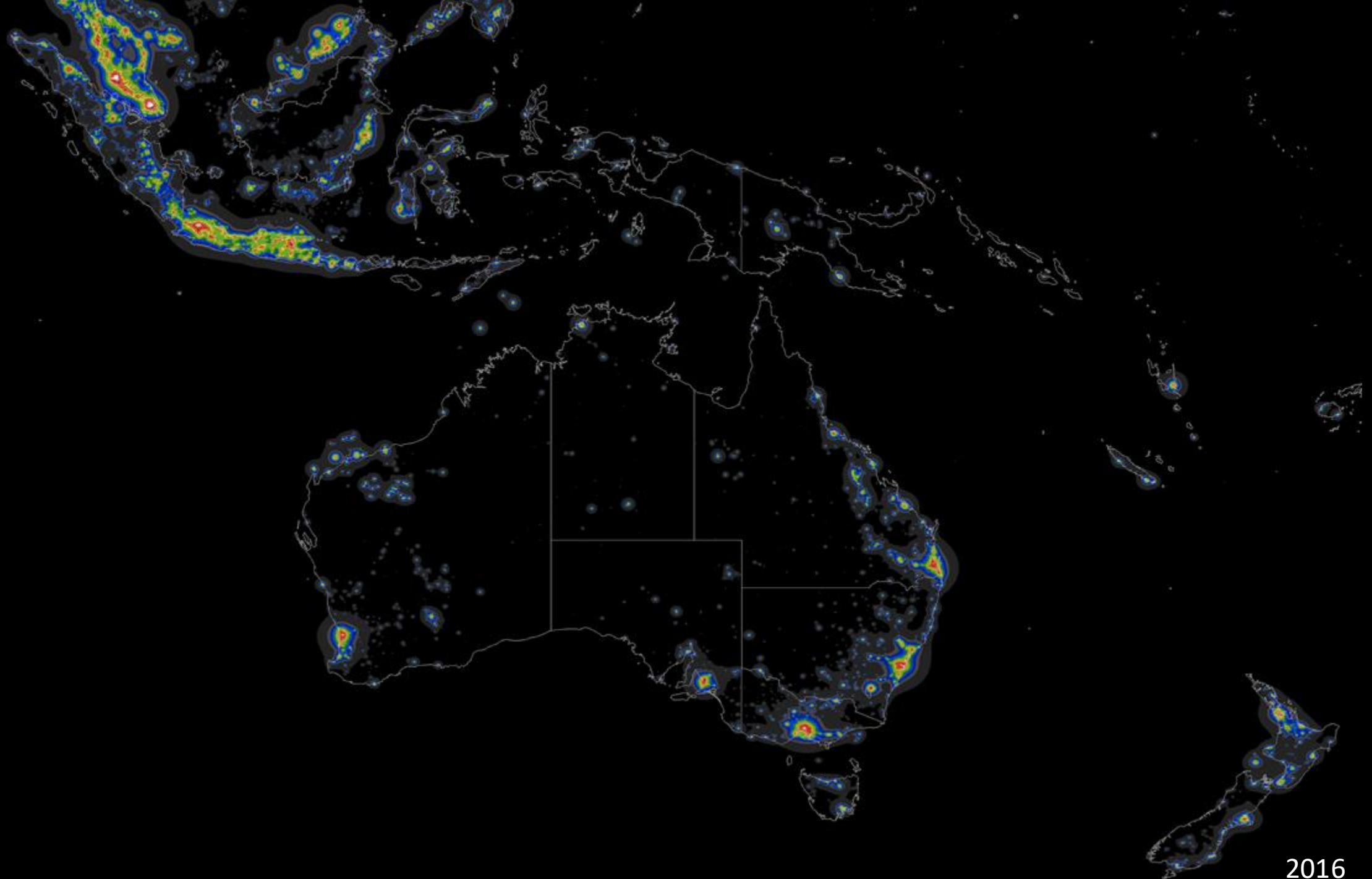
Airglow

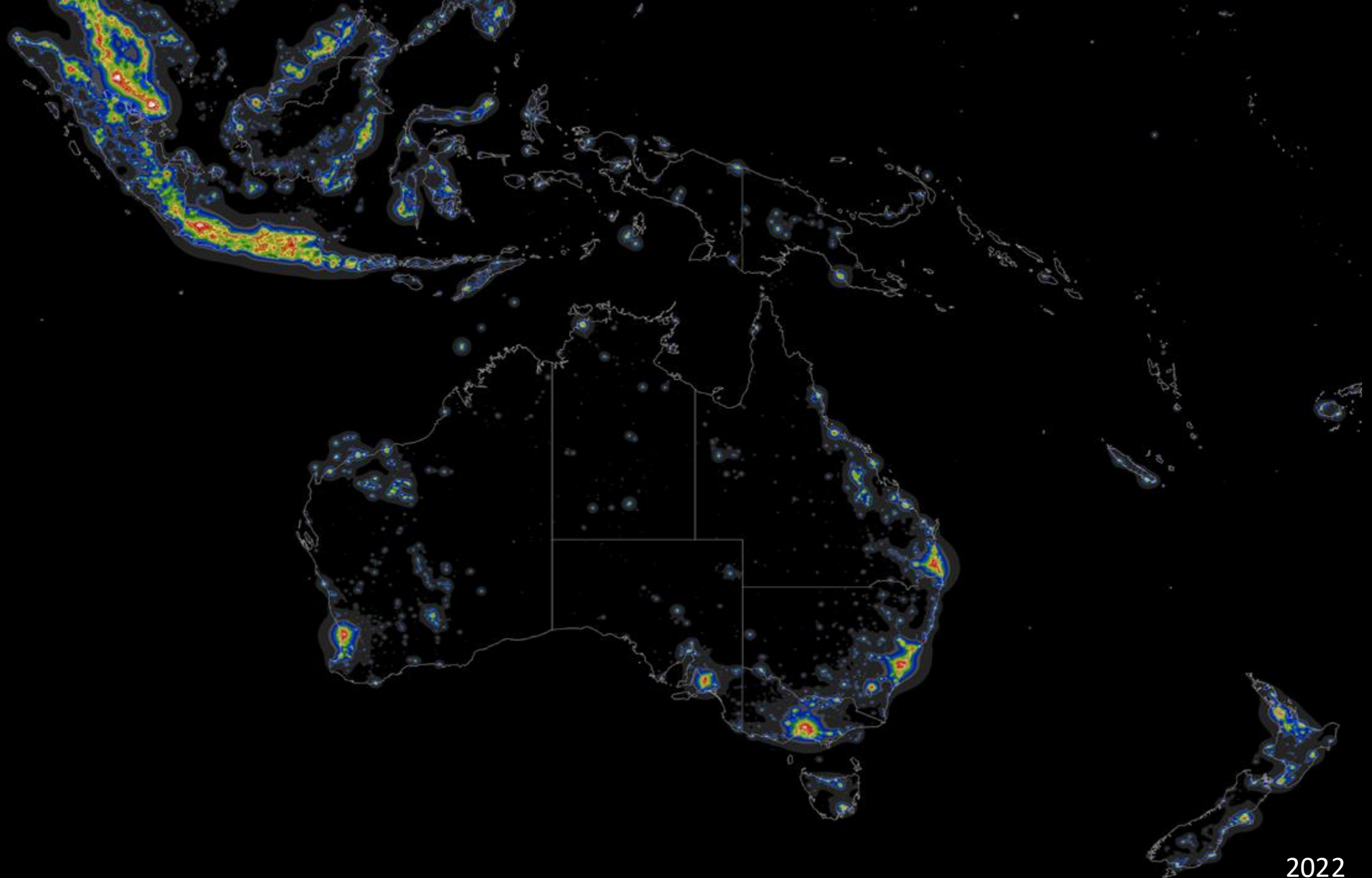


7 to 10 % increase each
year



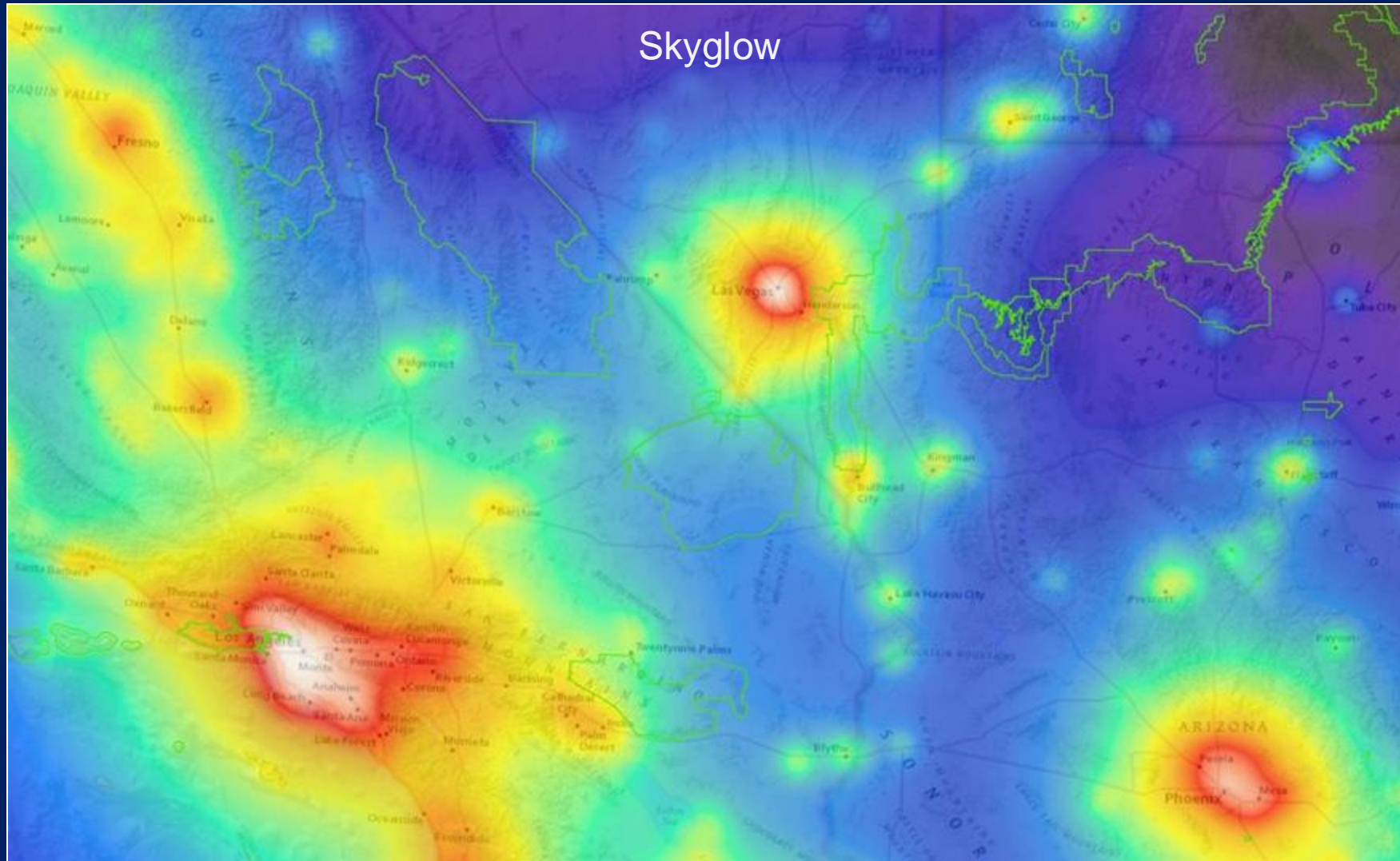
2006





2022

Skyglow Across the Landscape



Blinded by the light: how light pollution affects our environment

What is light pollution?

Daily light and dark cycles create a natural rhythm that is important for many organisms. Some species are only active at night, some migrate by night, most set their internal clocks to the changing length of days and seasons.

Sources of pollution

Light pollution disrupts these natural cycles. **Artificial light at night** comes from human sources such as transportation (cars & planes), electric lighting in buildings, houses, and signs.

DISPLAYS & ADVERTISEMENTS

Sky glow is when the night sky is brightened by diffuse light. Sky glow from artificial light in cities outshines natural sources like the moon.

Not all artificial light is the same.

Human light sources differ in intensity, brightness, spectral composition, and timing (street lights, seasonal lights)—all of which change how much different species are affected.

BUILDINGS

LED LIGHT

Effects across the tree of life

Not only nocturnal animals are affected.

By perceiving light pollution as daylight, the physiology and behavior of many organisms can change.



AMPHIBIANS



BIRDS



FISH



INVERTEBRATES



MAMMALS



REPTILES

PLANTS

HUMANS

Biological consequences

Light pollution influences many levels.

For example, it alters:

MOLECULAR RESPONSES & GENE EXPRESSION

Biological clock expression timing

HORMONES & PHYSIOLOGY

Hormone production, metabolism, cardiovascular systems

BEHAVIOR

Sleep/wake time, resource discovery, reproduction, communication

POPULATIONS

Density, gene flow, home range size, intraspecific competition

COMMUNITIES

Predator-prey interactions, food web processes

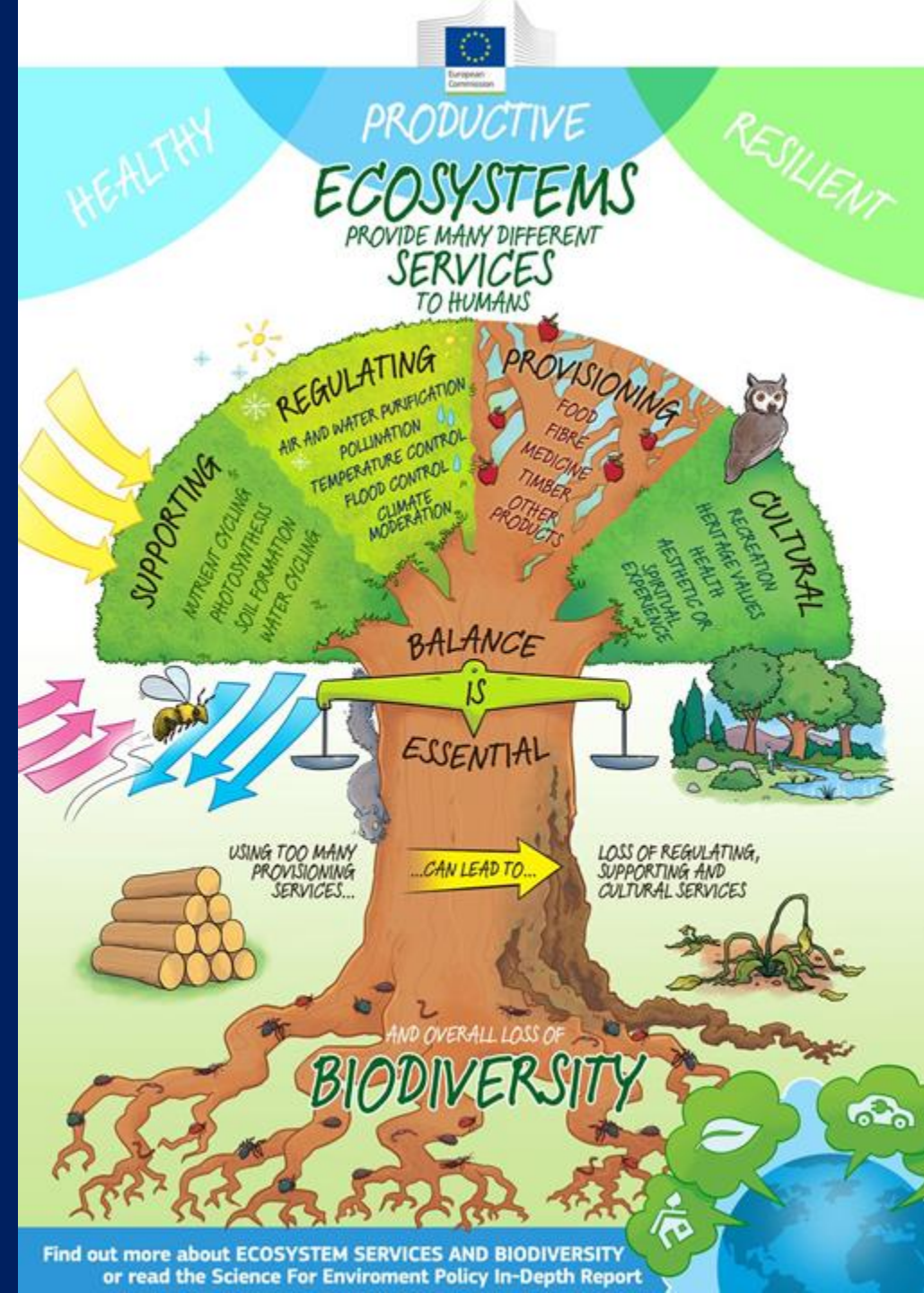
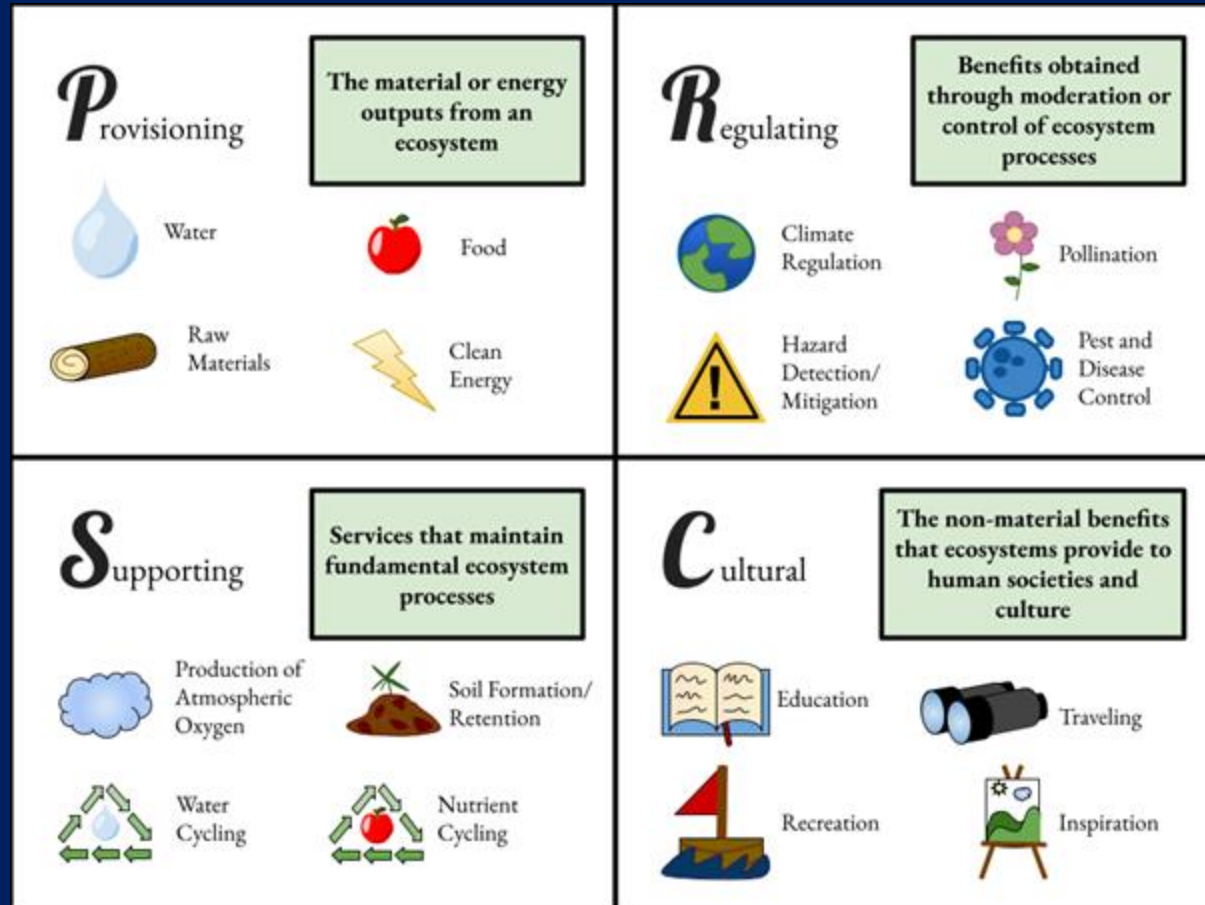
ECOSYSTEM FUNCTION

Species interaction networks, trophic cascades, nutrient cycling

The value of ecosystem services:
putting the issues in
perspective

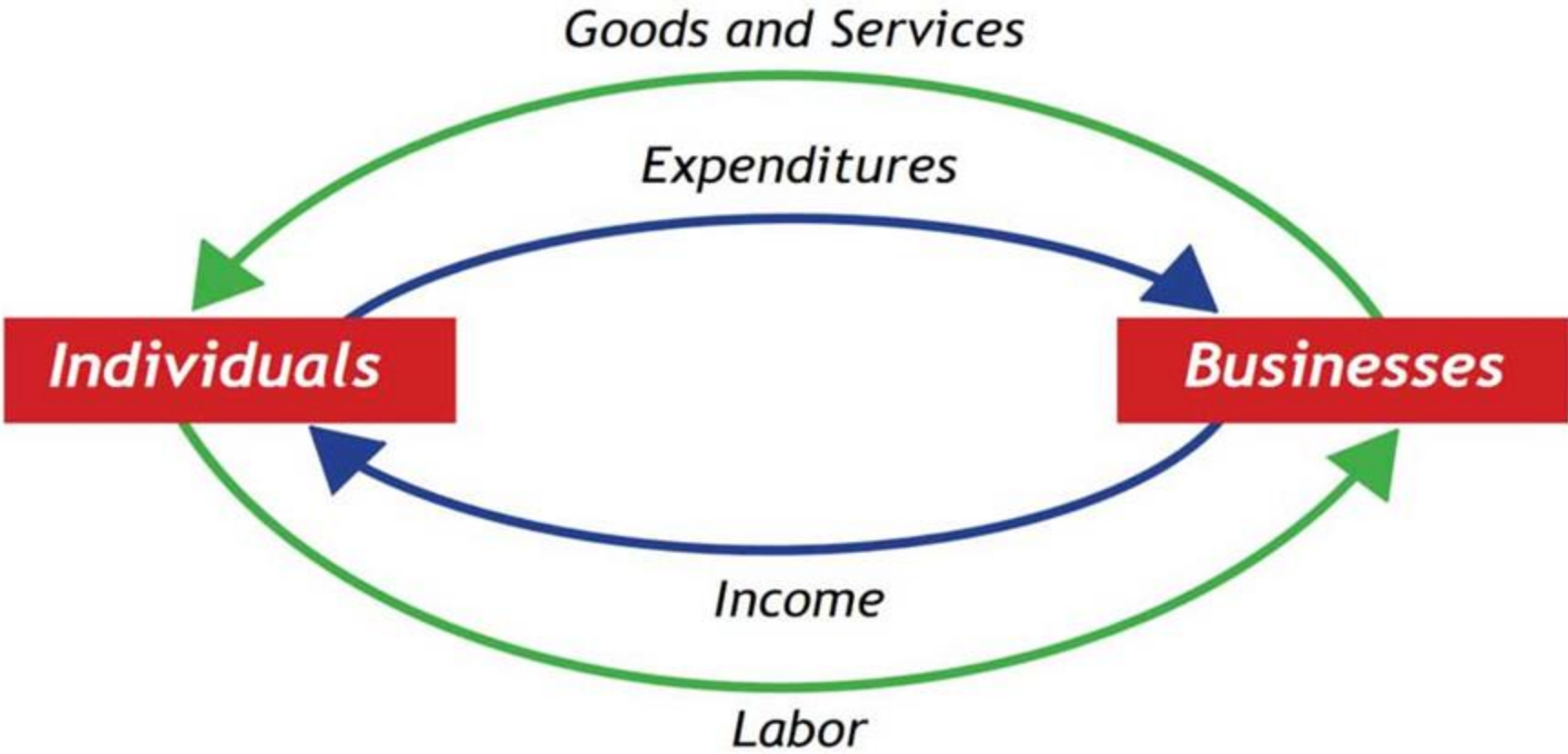
It is a well-accepted method in science to make an initial 'first-approximation' to a complex problem and allow the results to determine whether it is worth investing the effort to do more elaborate studies.

Ecosystem Services



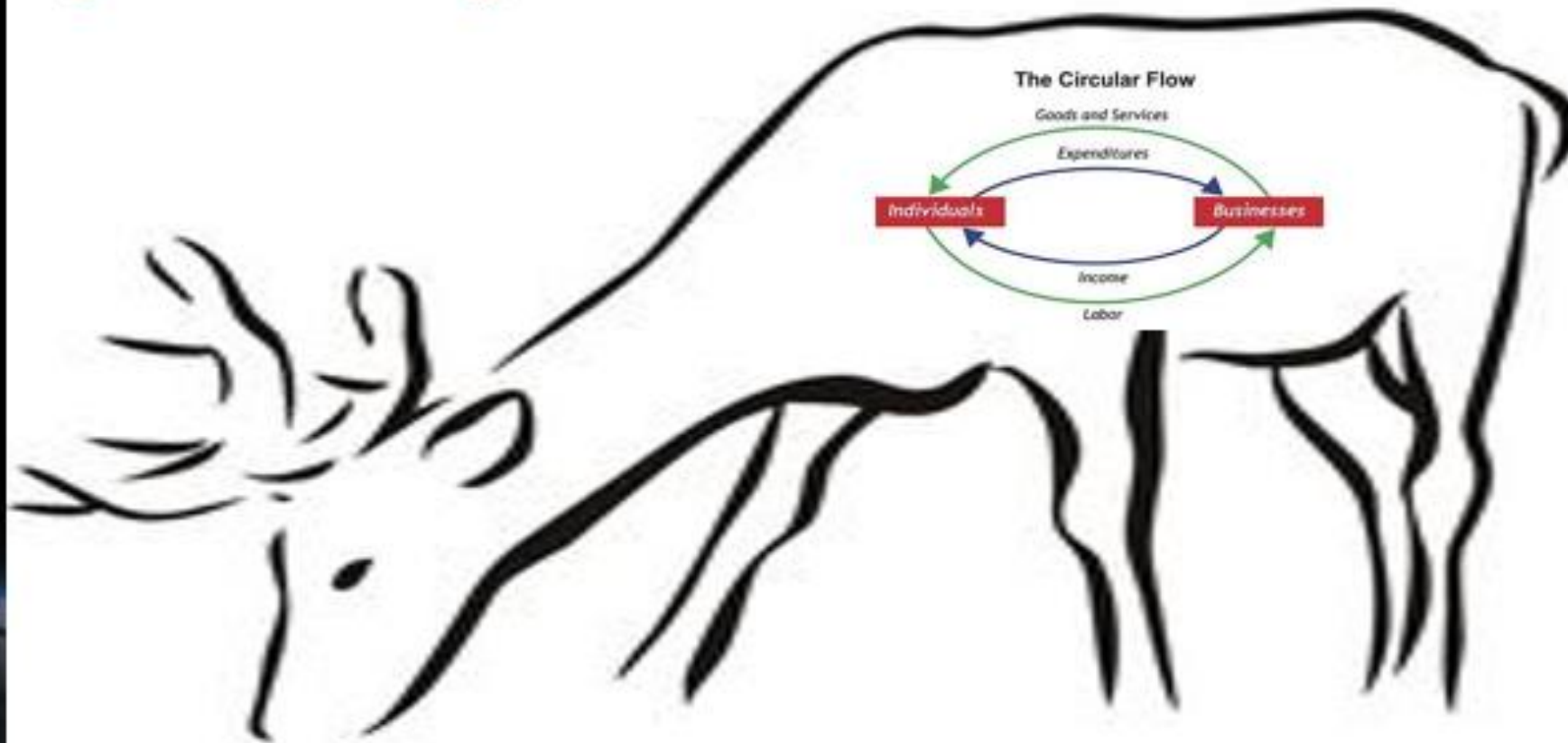
Find out more about ECOSYSTEM SERVICES AND BIODIVERSITY or read the Science For Environment Policy In-Depth Report

The Circular Flow

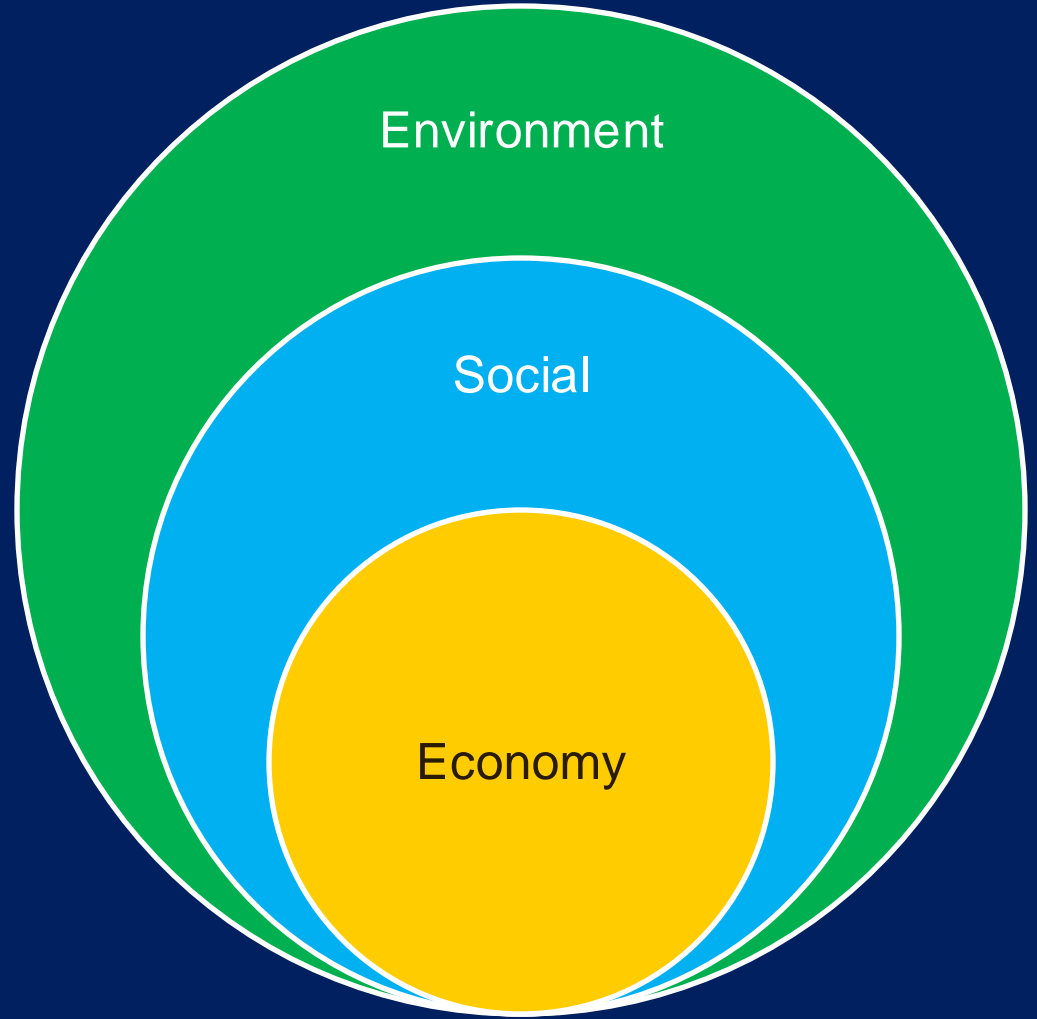
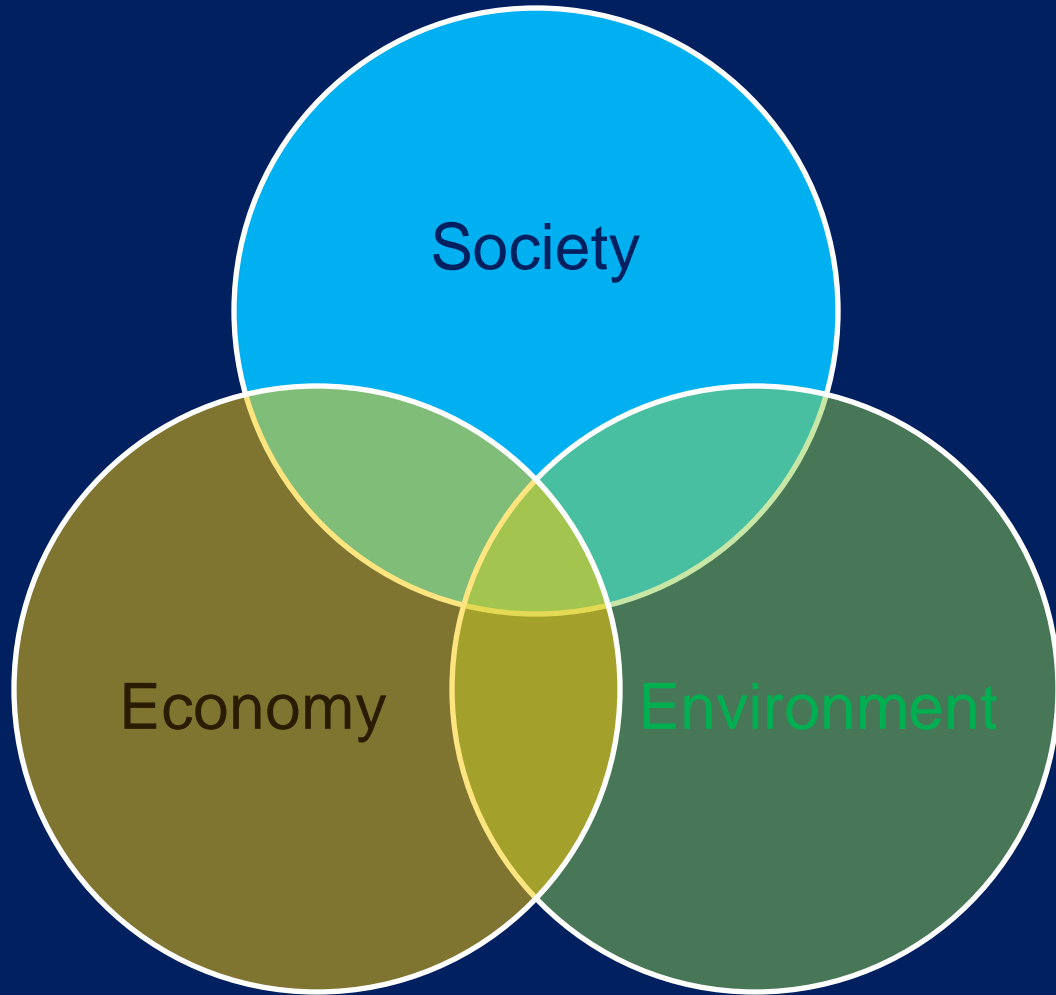


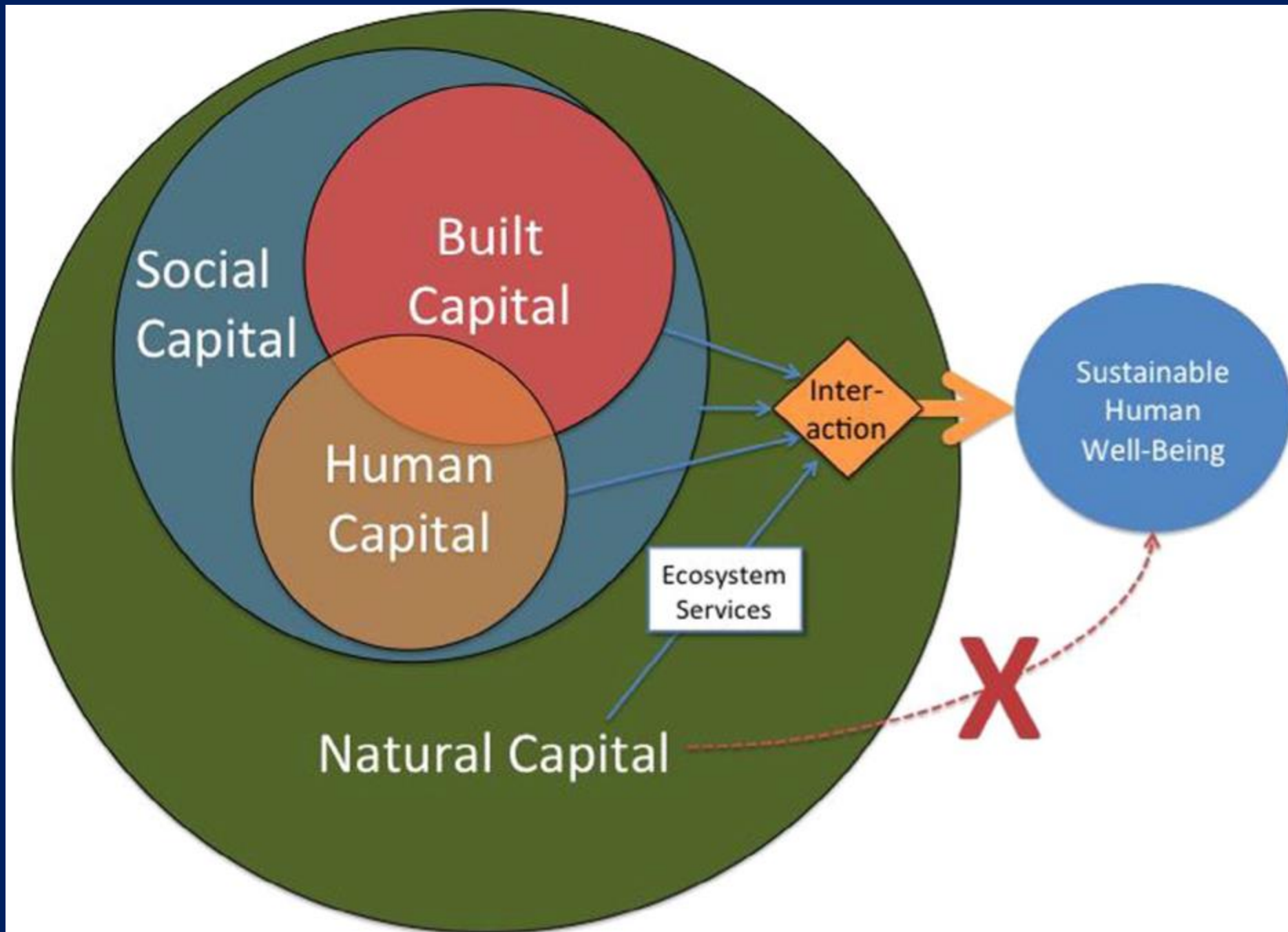
The Circular Flow Model of the Economy

This conceptualization of the economy is analogous to Observing a deer and concluding that its entire functioning resulted from its circulatory system while ignoring that it Ingested matter and energy and excreted waste.



Is it time for a NEW conceptual model of the Economy?

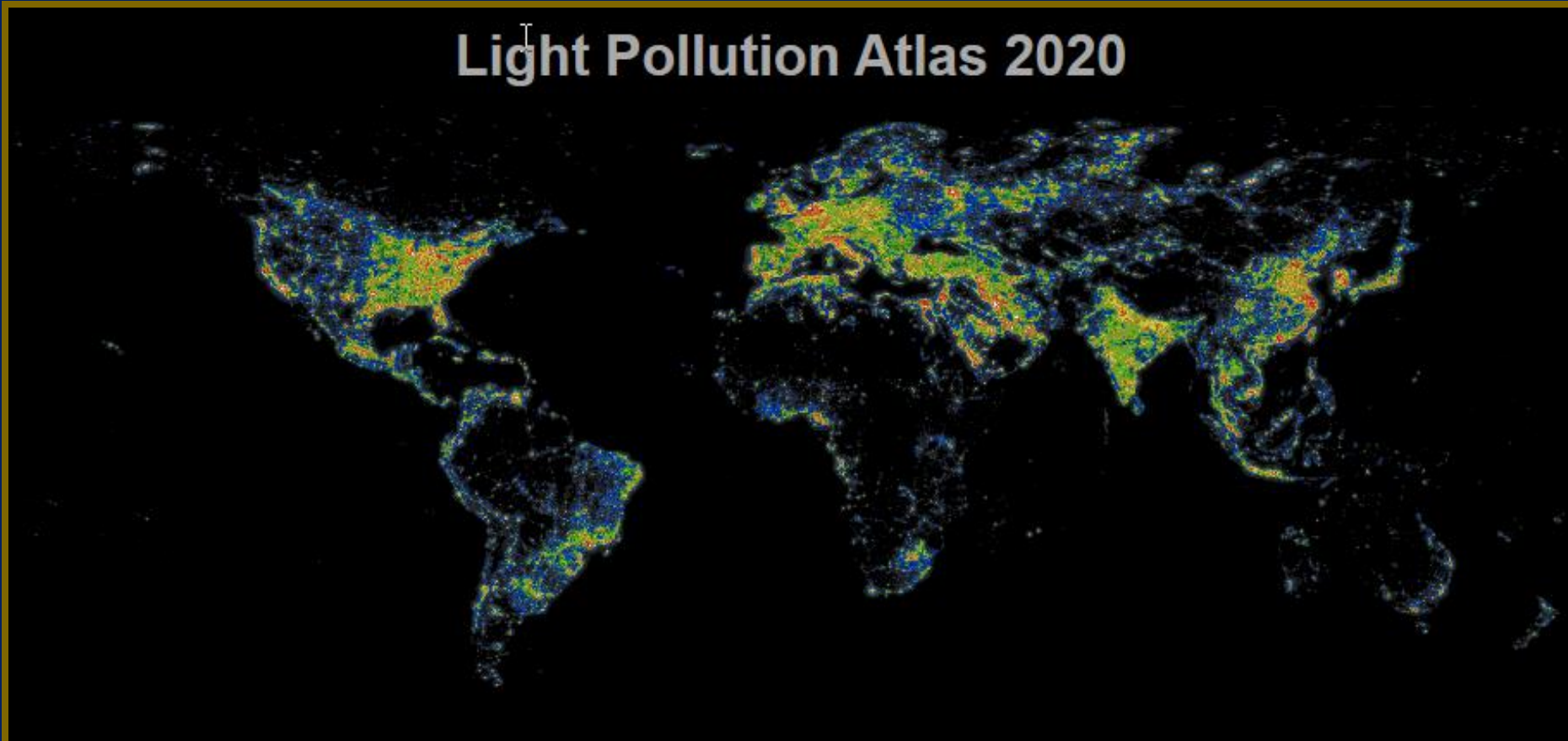




The Ecological Economics of Light Pollution: Impacts on Ecosystem Service Value

by Sharolyn J. Anderson ^{1,2,*} ✉, Ida Kubiszewski ^{1,3}  and Paul C. Sutton ^{2,4} ✉ 

Light Pollution Atlas 2020



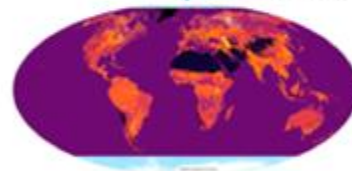
Land cover – Biomes



Reclass

OBJECTID *	InCode *	ESV/ha	Reclass
1	0	0	0/NoData
2	20	4268	Grasslands/Range
3	30	4268	Grasslands/Range
4	40	3567	Cropland
5	50	6863	Urban
6	60	388	Bare/Sparse Vegetation
7	70	0	Snow/Ice
8	80	12512	Lakes/Rivers
9	90	3463.74	Wetlands
10	100	648	Moss/Turf
11	111	1137	Temperate/Boreal
12	112	3.962	Tropical
13	113	1137	Temperate/Boreal
14	114	1137	Temperate/Boreal
15	115	3800	Forest
16	116	3800	Forest
17	117	1137	Temperate/Boreal
18	118	3.962	Tropical
19	119	1137	Temperate/Boreal
20	124	1137	Temperate/Boreal
21	125	3800	Forest
22	126	3800	Forest
23	200	0	0/Ocean

Code Values



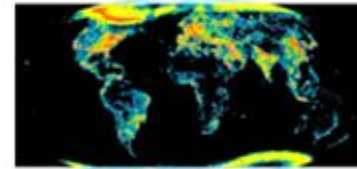
Country	ESV (10^12 USD)
USA	1000000000000
China	800000000000
India	600000000000
...	...

ESV per Land Cover

VIIRS DNB Annual Composite

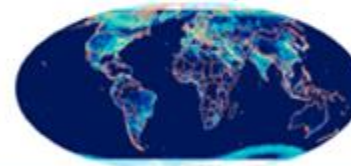


Light Pollution Model (sALR)



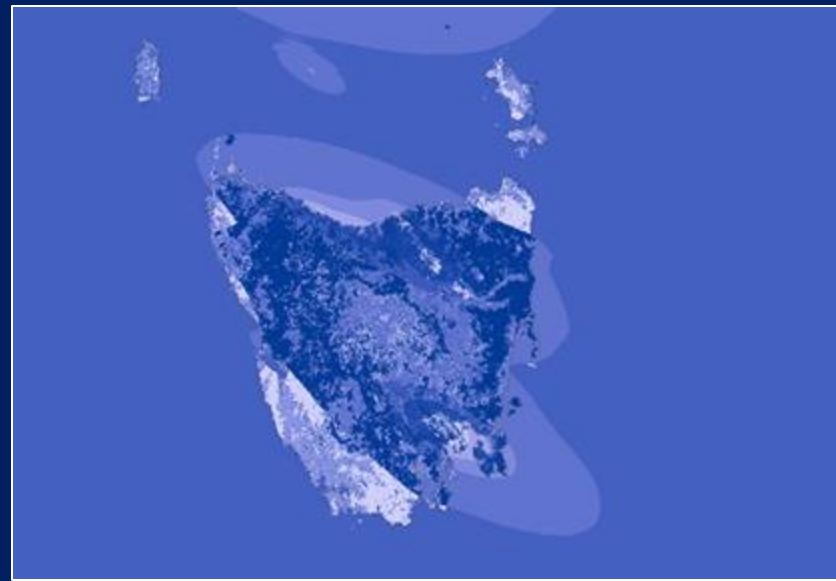
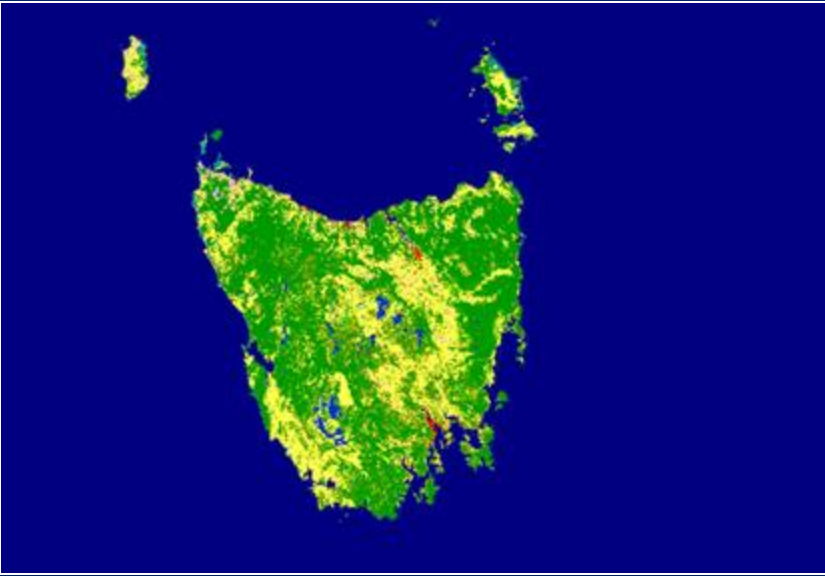
$$ESV_{deg} = ESV_{base} * (0.6 + (0.4 * (1 - ALR/10)))$$

Degradation Ratio Formula



Country	ESV (10^12 USD)
USA	1000000000000
China	800000000000
India	600000000000
...	...

ESV per Country



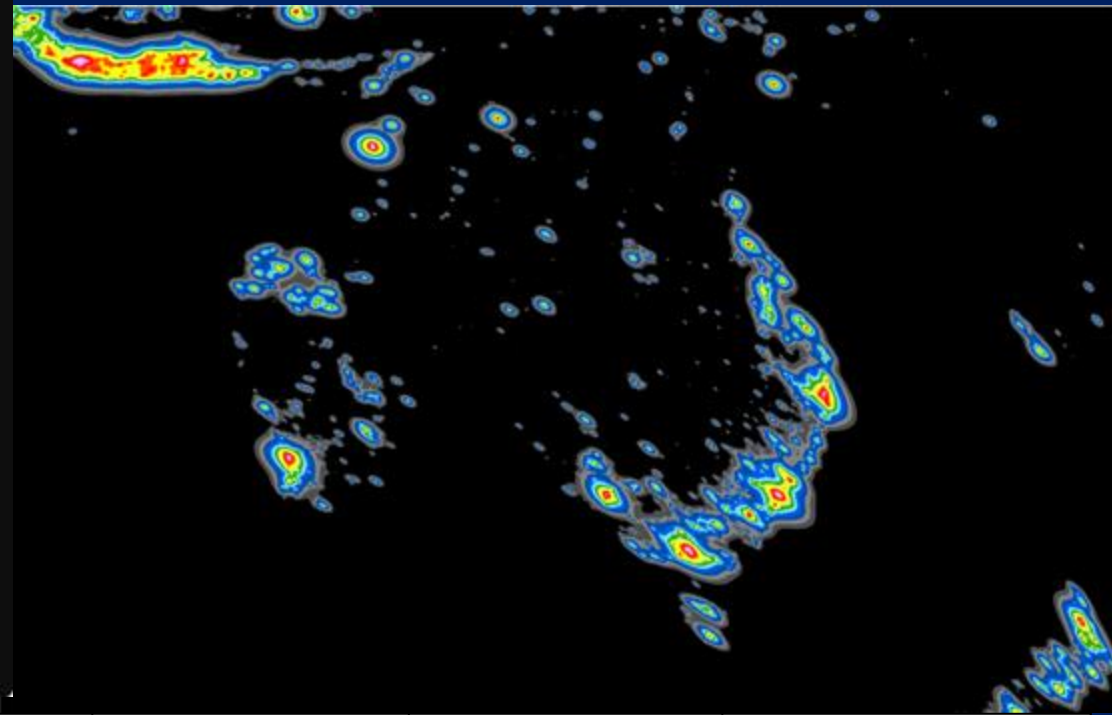
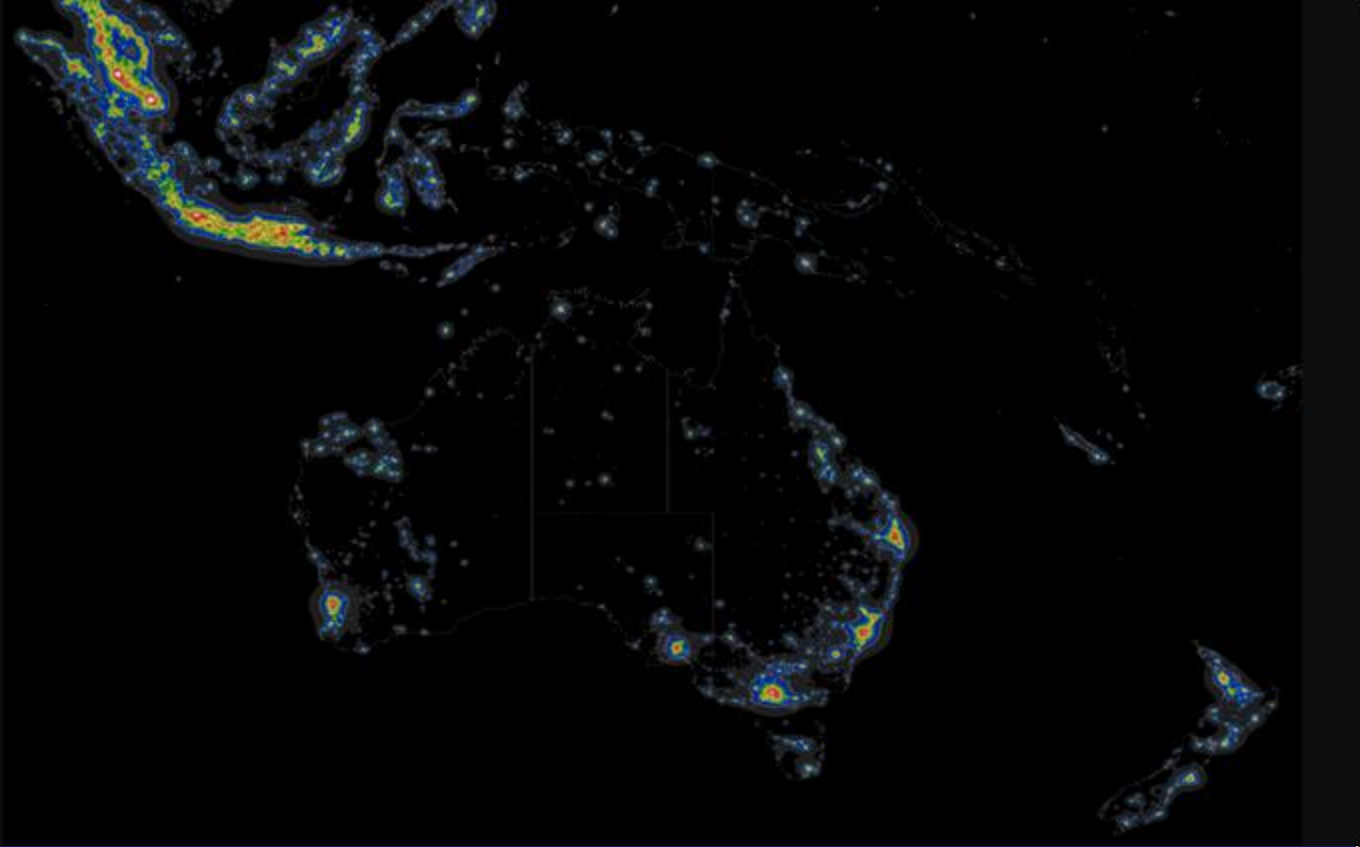
Evergreen needleleaf closed forest	Shrubland
Deciduous needleleaf closed forest	Herbaceous vegetation
Evergreen broadleaf closed forest	Herbaceous Wetland
Deciduous broadleaf closed forest	Moss & lichen
Mixed closed forest type	Bare / sparse vegetation
Unknown closed forest type	Cropland
Evergreen needleleaf open forest	Built-up
Deciduous needleleaf open forest	Snow & ice
Evergreen broadleaf open forest	Permanent Water Bodies
Deciduous broadleaf open forest	Ocean
Mixed open forest type	No input data available
Unknown open forest type	

Ecosystem Service Value US\$ 2011



Ecosystem Service Value Degraded by Light Pollution

Landcover / Biomes



Country	Poputaltion	BaseESV	DegradedESV	TotalLossESV	PcentLossESV	PerCapitaLossESV
Australia	24,756,403	3,438,966,391,285	3,429,792,769,129	9,173,622,156	0.3	371
Russian Federation	145,428,954	21,983,656,122,536	21,229,344,088,388	754,312,034,148	3.4	5,187
United States of America	325,446,306	6,660,740,456,992	6,174,323,476,115	486,416,980,877	7.3	1,495
Canada	37,089,067	5,740,884,713,588	5,428,744,451,378	312,140,262,210	5.4	8,416
China	1,422,468,925	4,147,893,588,321	3,922,615,516,736	225,278,071,585	5.4	158
India	1,359,486,373	1,703,221,284,422	1,593,502,651,031	109,718,633,391	6.4	81

Loss of Ecosystem Services Per State in Australia

StateName	AREA(m2)	Total_2011esv	Total_LPDesv	Loss_Of_ESV	pct
New South Wales	800,797,550,000	373,449,571,712.00	371,146,118,170.22	2,303,453,541.78	0.006
Victoria	227,496,890,000	117,987,756,811.00	115,964,472,715.15	2,023,284,095.85	0.017
Queensland	1,730,171,890,000	825,653,156,305.00	823,600,201,745.01	2,052,954,559.99	0.002
South Australia	984,229,810,000	407,191,819,162.00	406,536,891,040.34	654,928,121.66	0.002
Western Australia	2,526,635,130,000	1,063,202,736,904.00	1,061,666,813,277.40	1,535,923,626.60	0.001
Tasmania	68,017,640,000	50,571,115,484.00	50,432,305,230.20	138,810,253.80	0.003
Northern Territory	1,348,135,980,000	600,753,800,920.00	600,521,893,500.38	231,907,419.62	0.000
Australian Capital Territory	2,358,190,000	1,219,161,035.00	1,115,529,380.97	103,631,654.03	0.085
Other Territories	242,210,000	38,300,195.00	38,635,470.81	(335,275.81)	(0.009)
Australia	7,688,085,290,000	3,440,067,418,528	3,431,022,860,530	9,044,557,998	0.003

This research suggests that the global losses in ecosystem service value associated with light pollution are to the order of **USD 3 trillion/year**.

This work was motivated by the idea expressed by the Florida Department of Fish and Wildlife:

‘Short of a thorough discussion on the ecological place of sea turtles, it is sufficient to say that the world would be a poorer place to live without them. We just don’t know how much poorer’.



