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

Dr. Sharolyn Anderson and Professor Paul Sutton

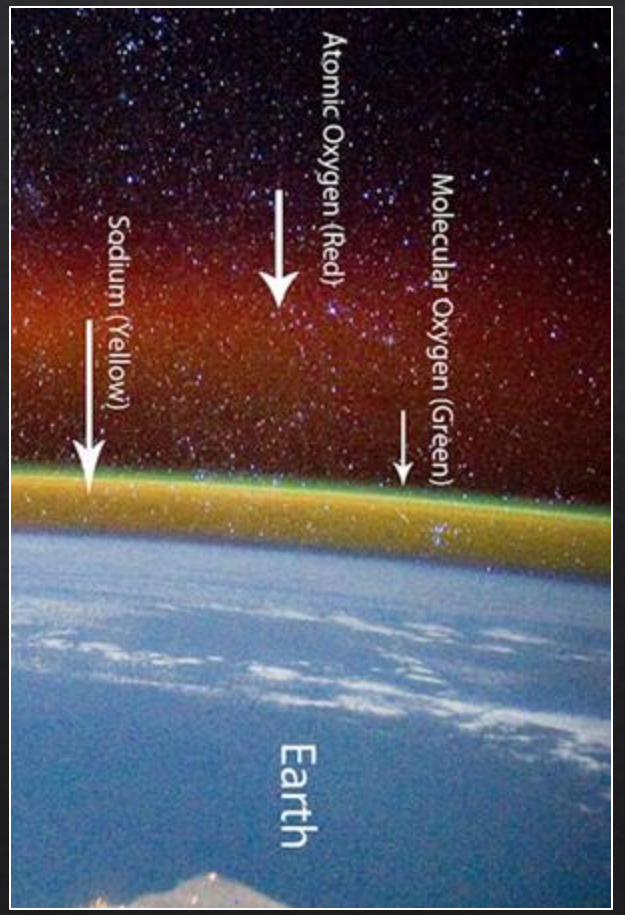
Overview

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

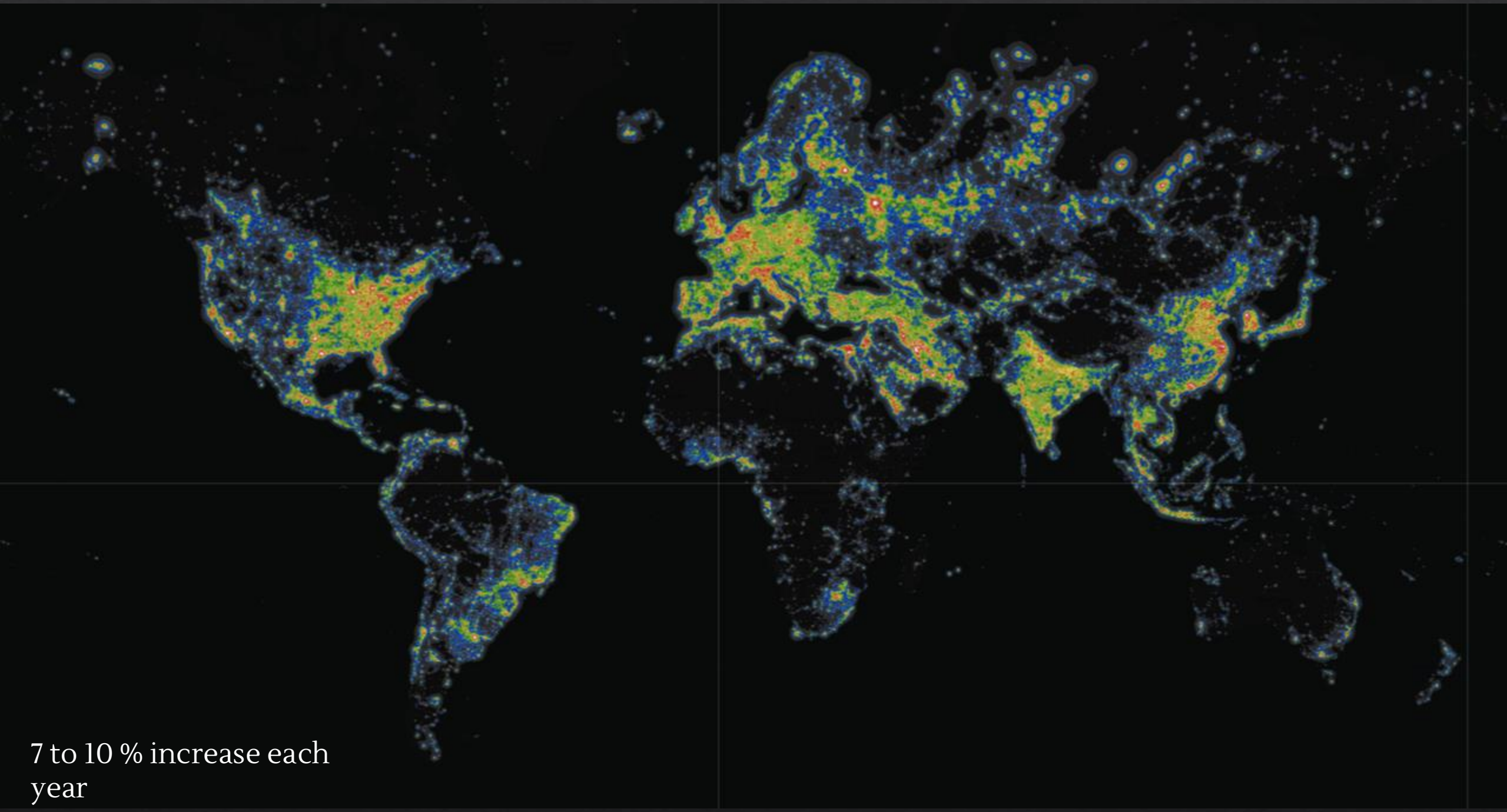
Natural Sources of Light

Starlight and Galactic Light

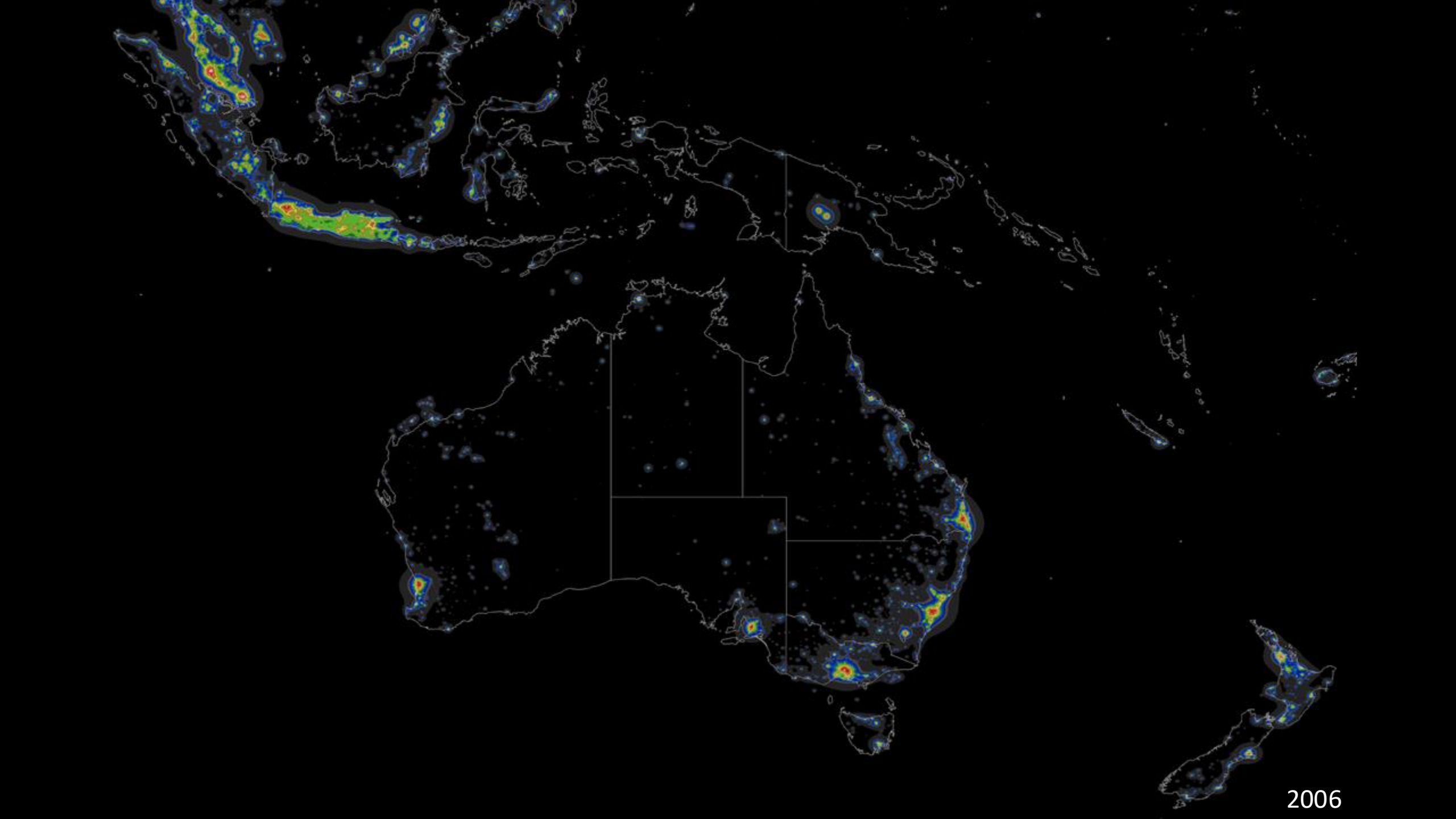
Zodiacal Light

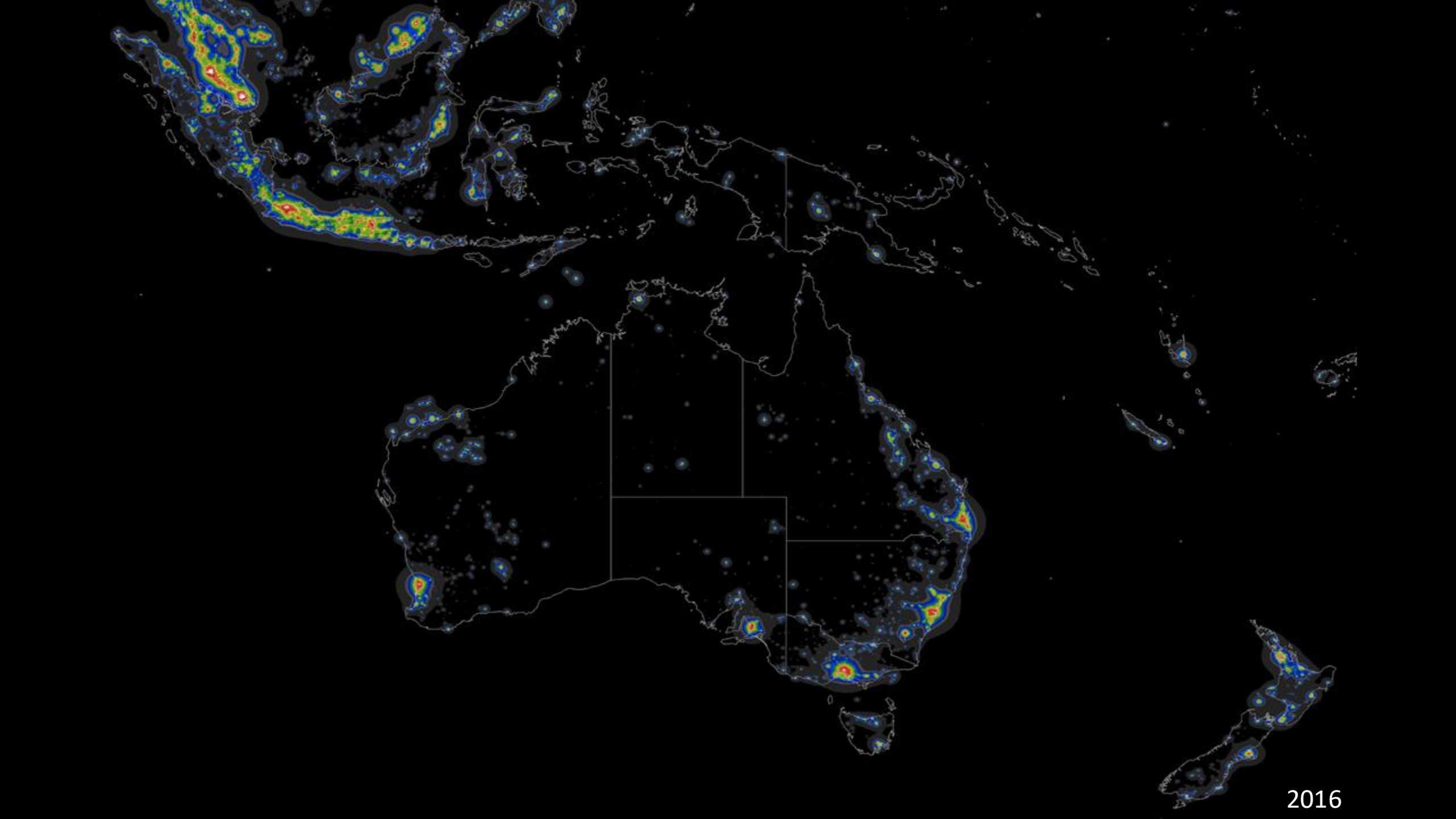


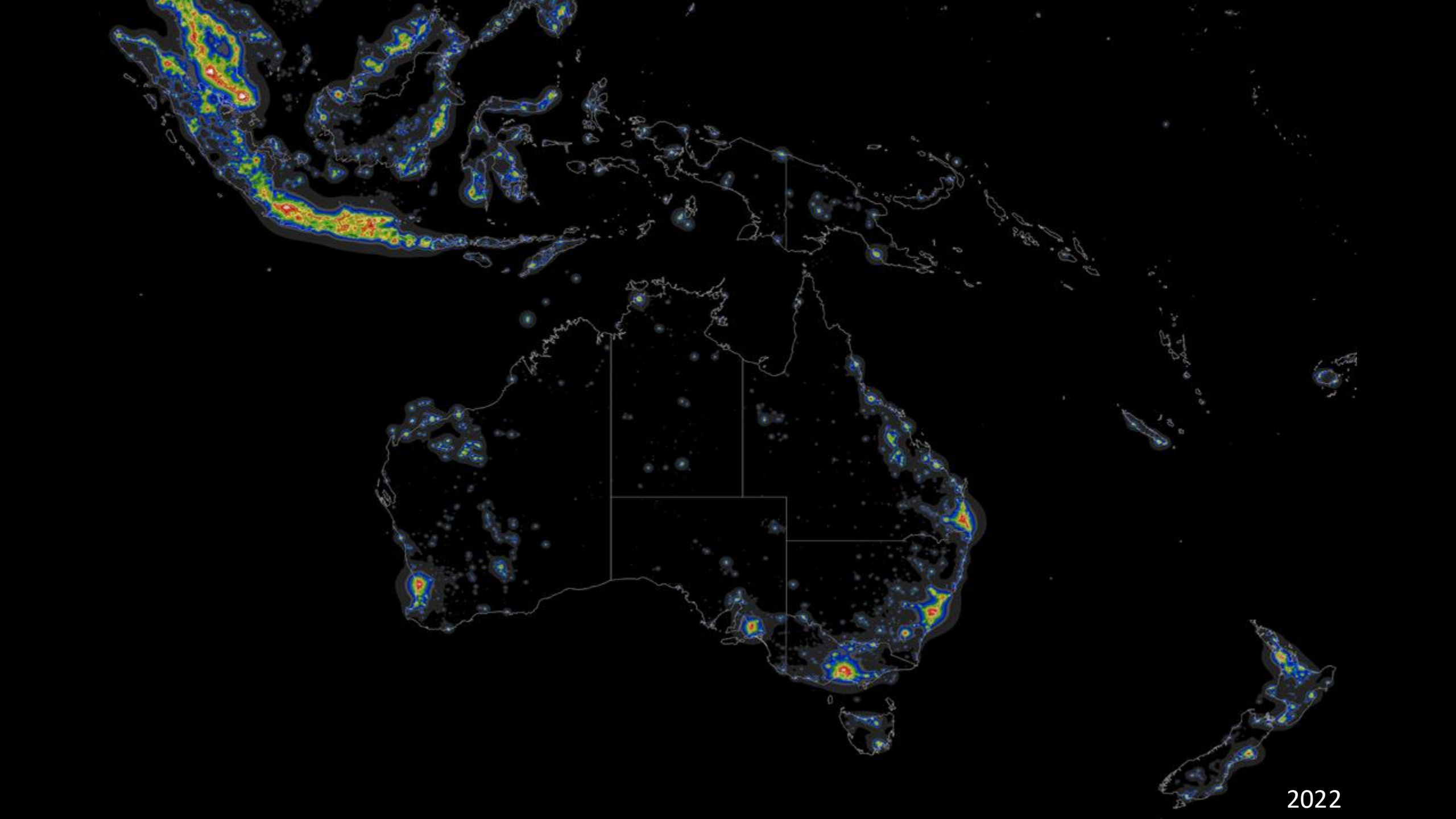
Airglow



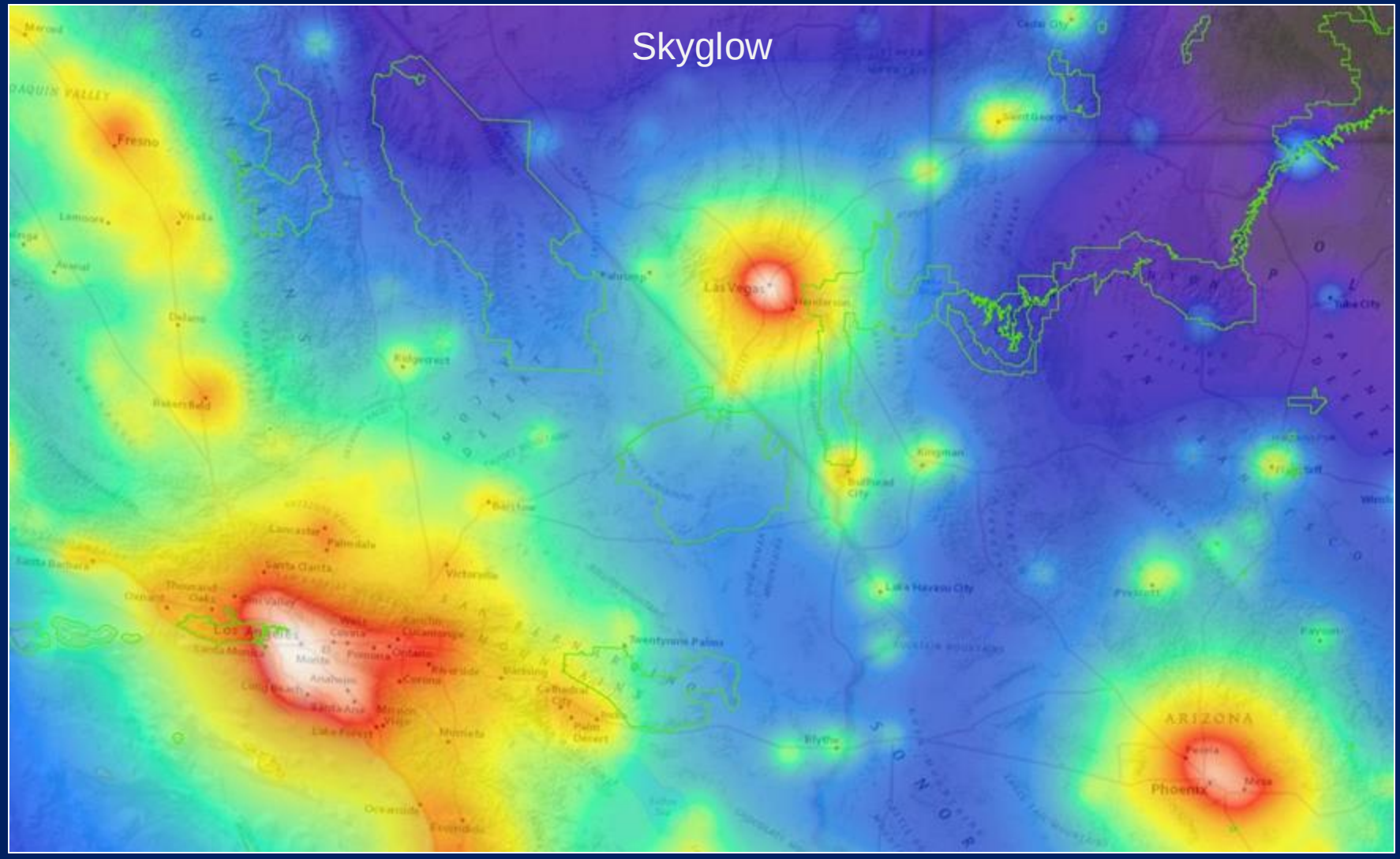
7 to 10 % increase each year


2006


2016


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.

STREET LIGHTS

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

Infographic by Pineapples and Whales

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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

Provisioning — The material or energy outputs from an ecosystem

- Water
- Food
- Raw Materials
- Clean Energy

Regulating — Benefits obtained through moderation or control of ecosystem processes

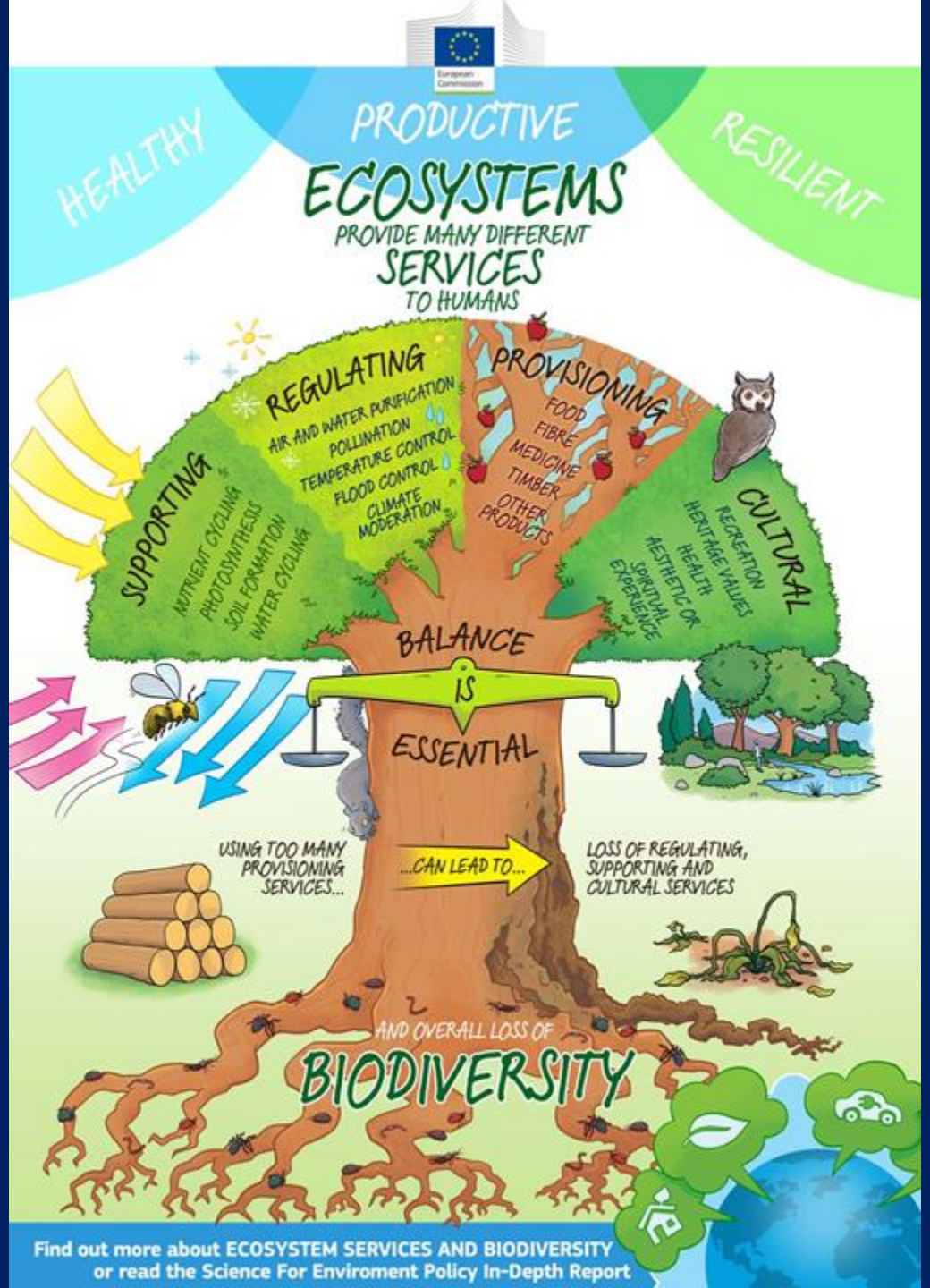
- Climate Regulation
- Pollination
- Hazard Detection/ Mitigation
- Pest and Disease Control

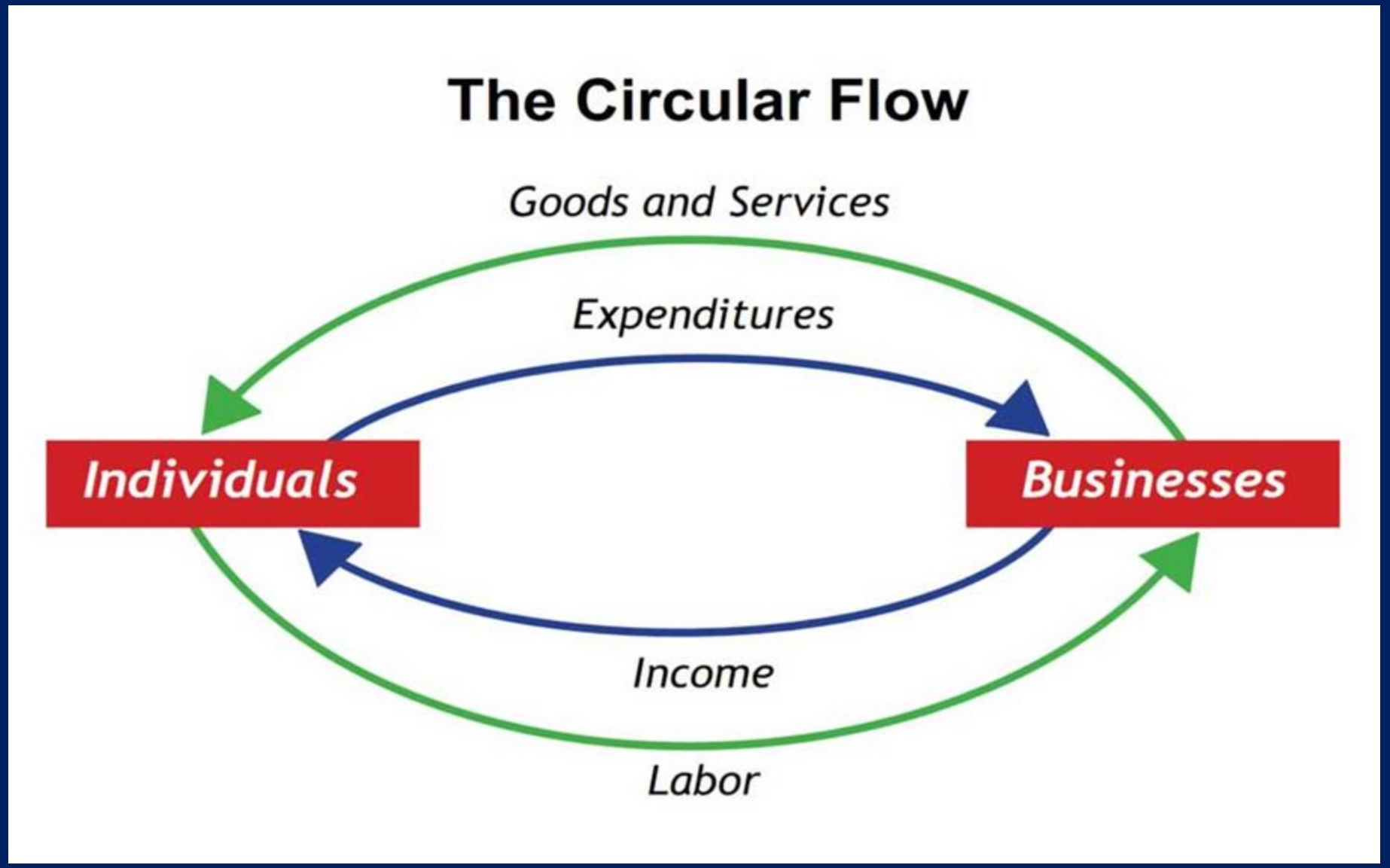
Supporting — Services that maintain fundamental ecosystem processes

- Production of Atmospheric Oxygen
- Soil Formation/ Retention
- Water Cycling
- Nutrient Cycling

Cultural — The non-material benefits that ecosystems provide to human societies and culture

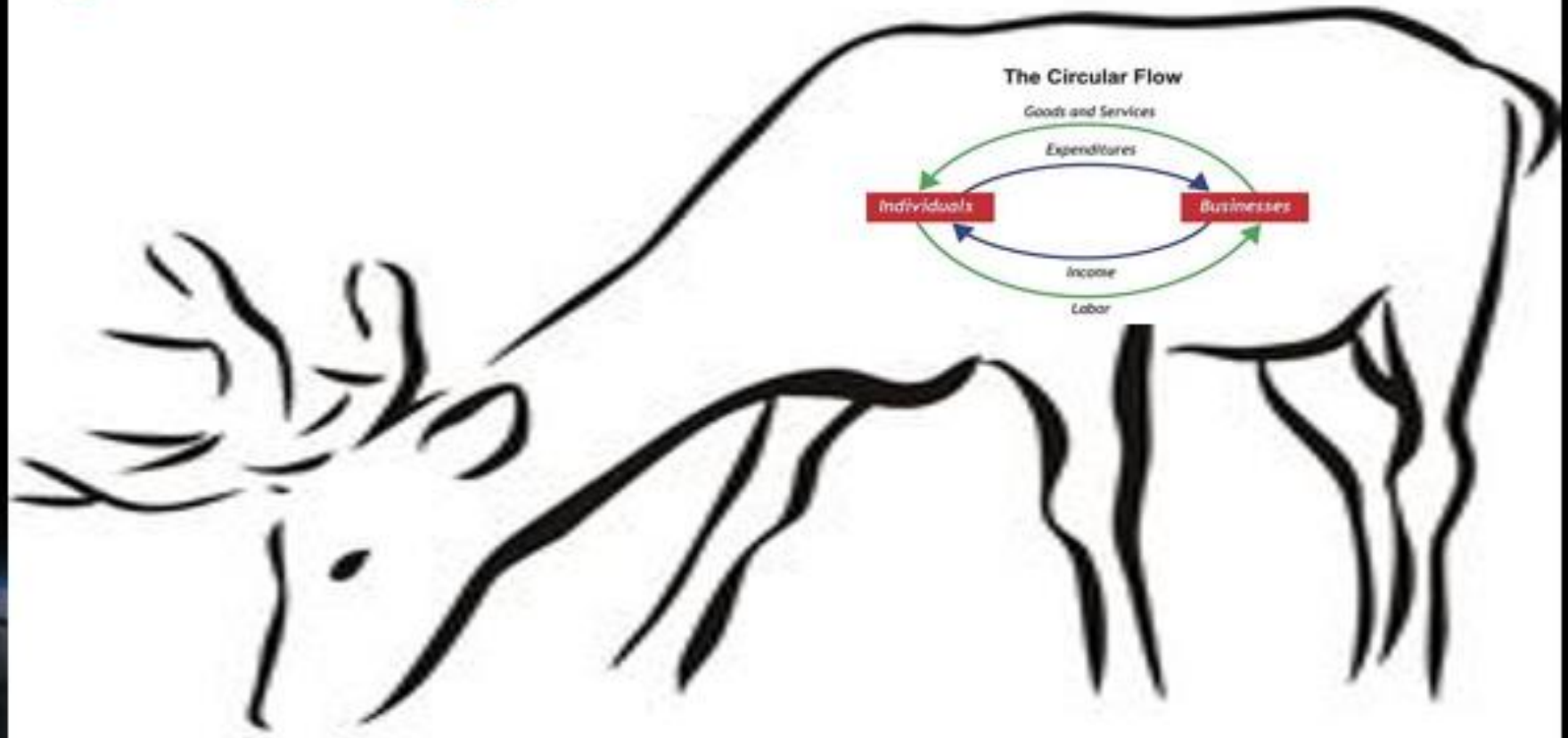
- Education
- Traveling
- Recreation
- Inspiration



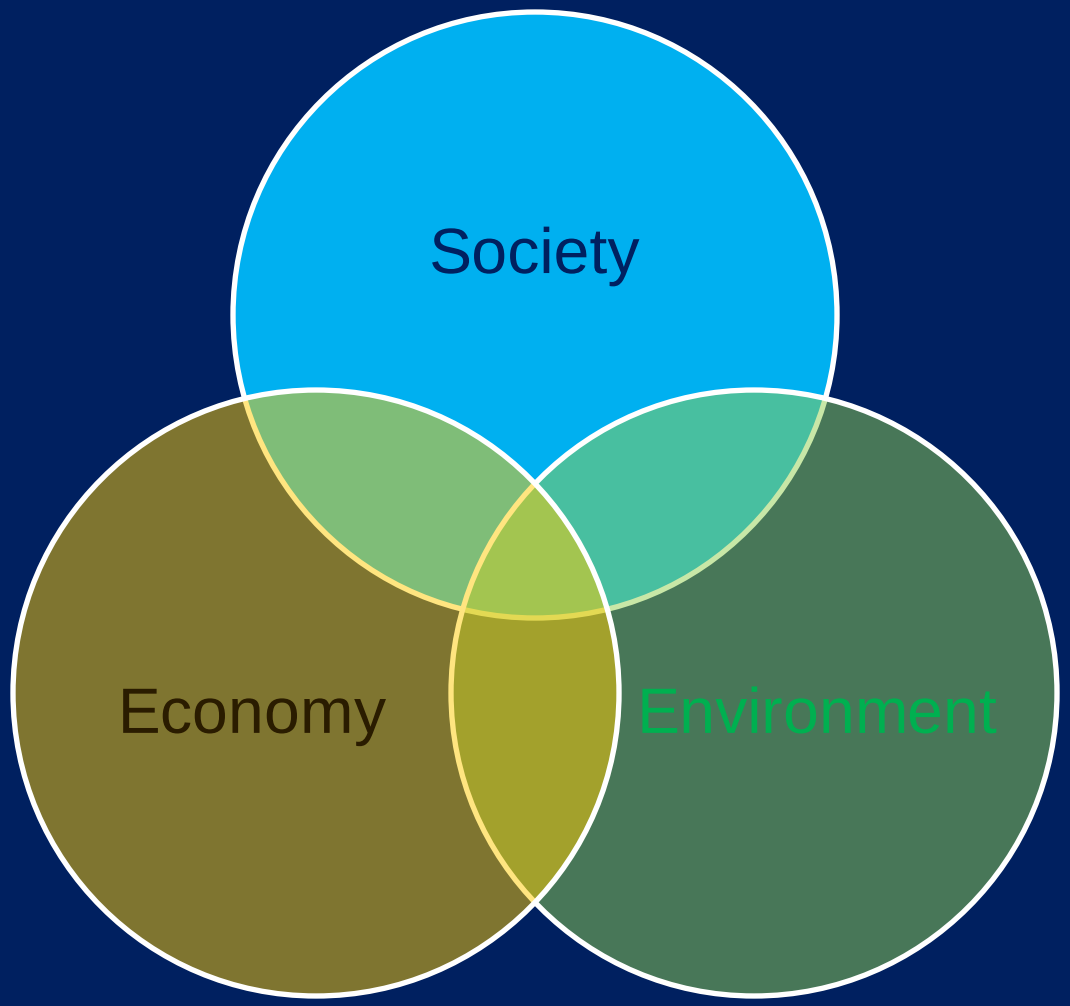

The Circular Flow
Goods and Services
Expenditures
Individuals
Businesses
Income
Labor

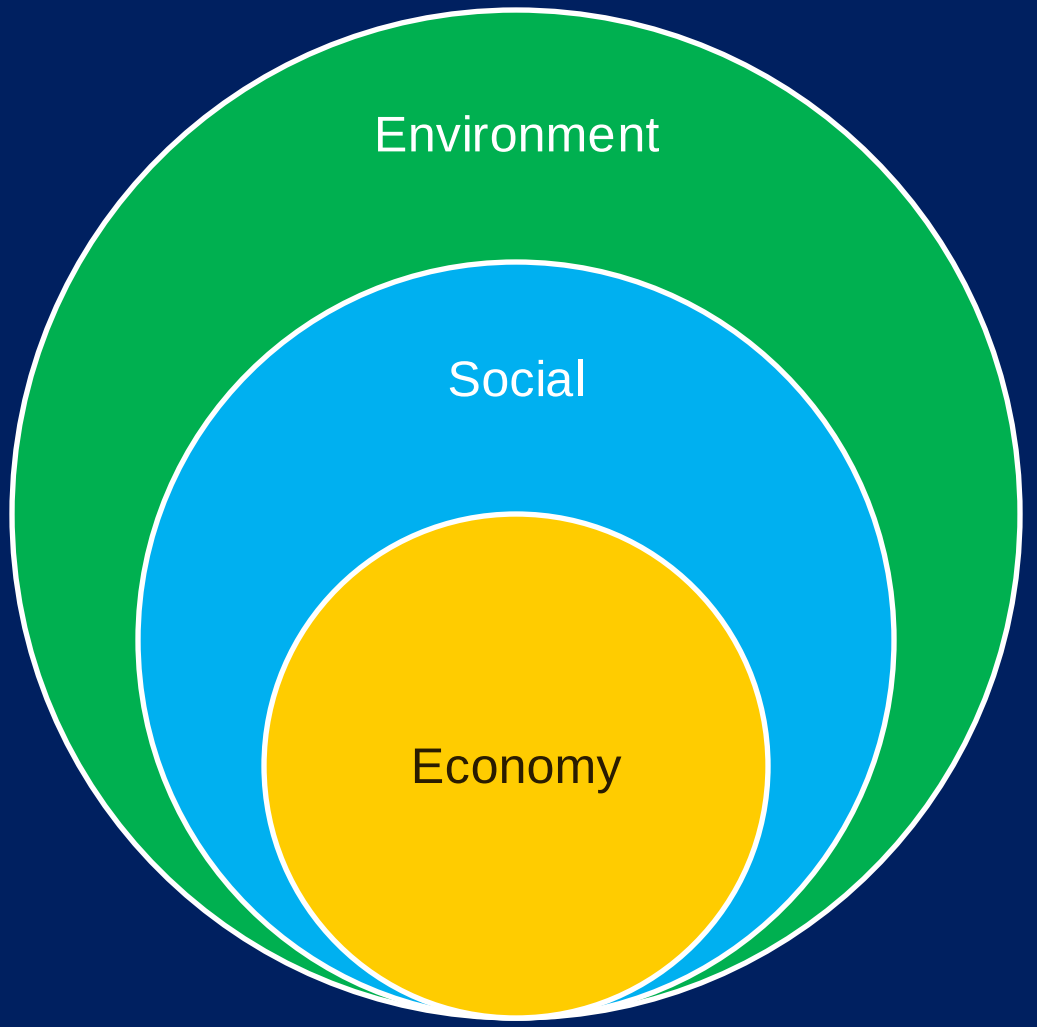
The Circular Flow Model of the Economy

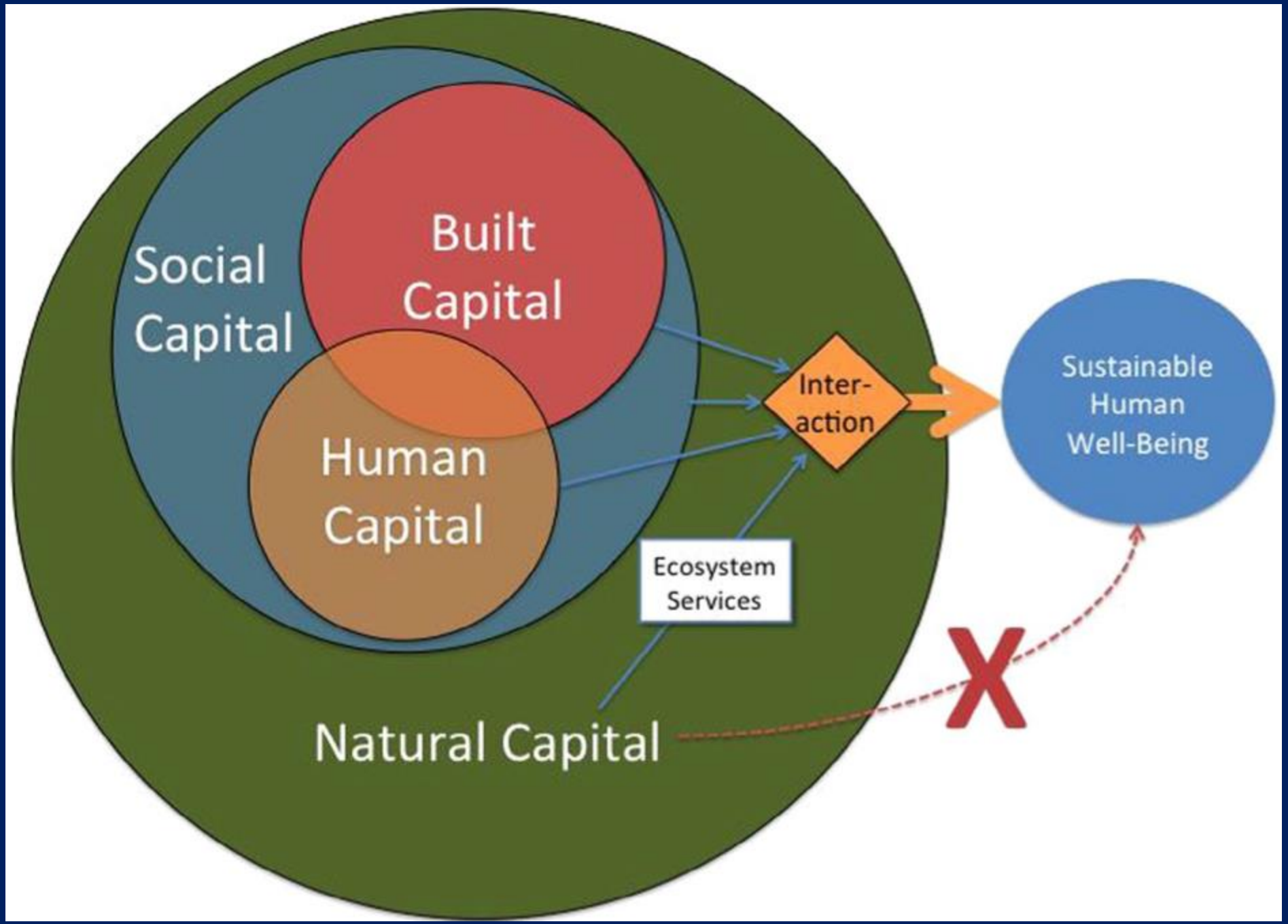
This conceptualization of the economy is analogous to Observing a deer and concluding that its entire functioning resulted from its circulatory system while ignoring that it Ingested matter and energy and excreted waste.



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


Society
Economy
Environment


Environment
Social
Economy


Social Capital
Built Capital
Human Capital
Inter-action
Sustainable Human Well-Being
Ecosystem Services
X
Natural Capital

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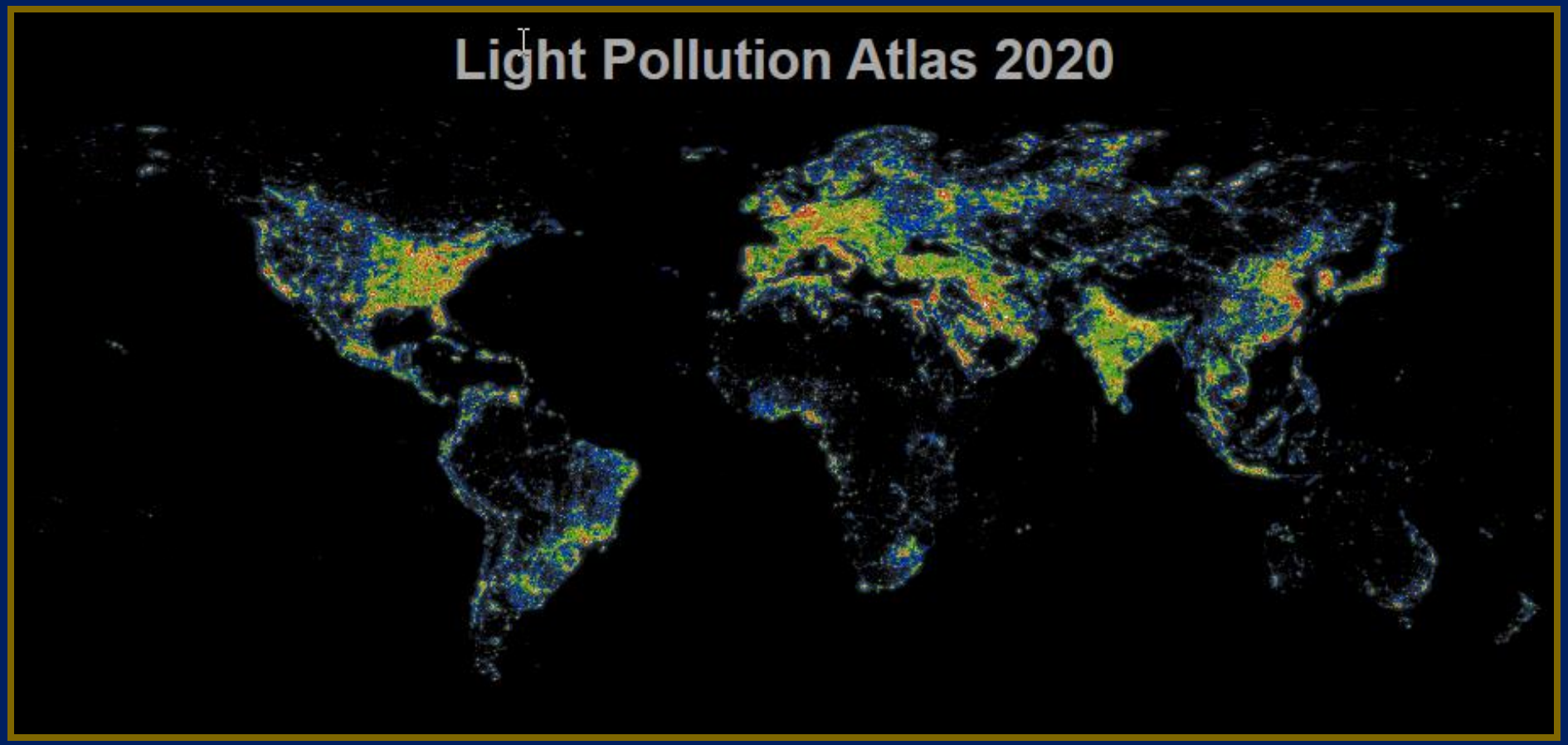
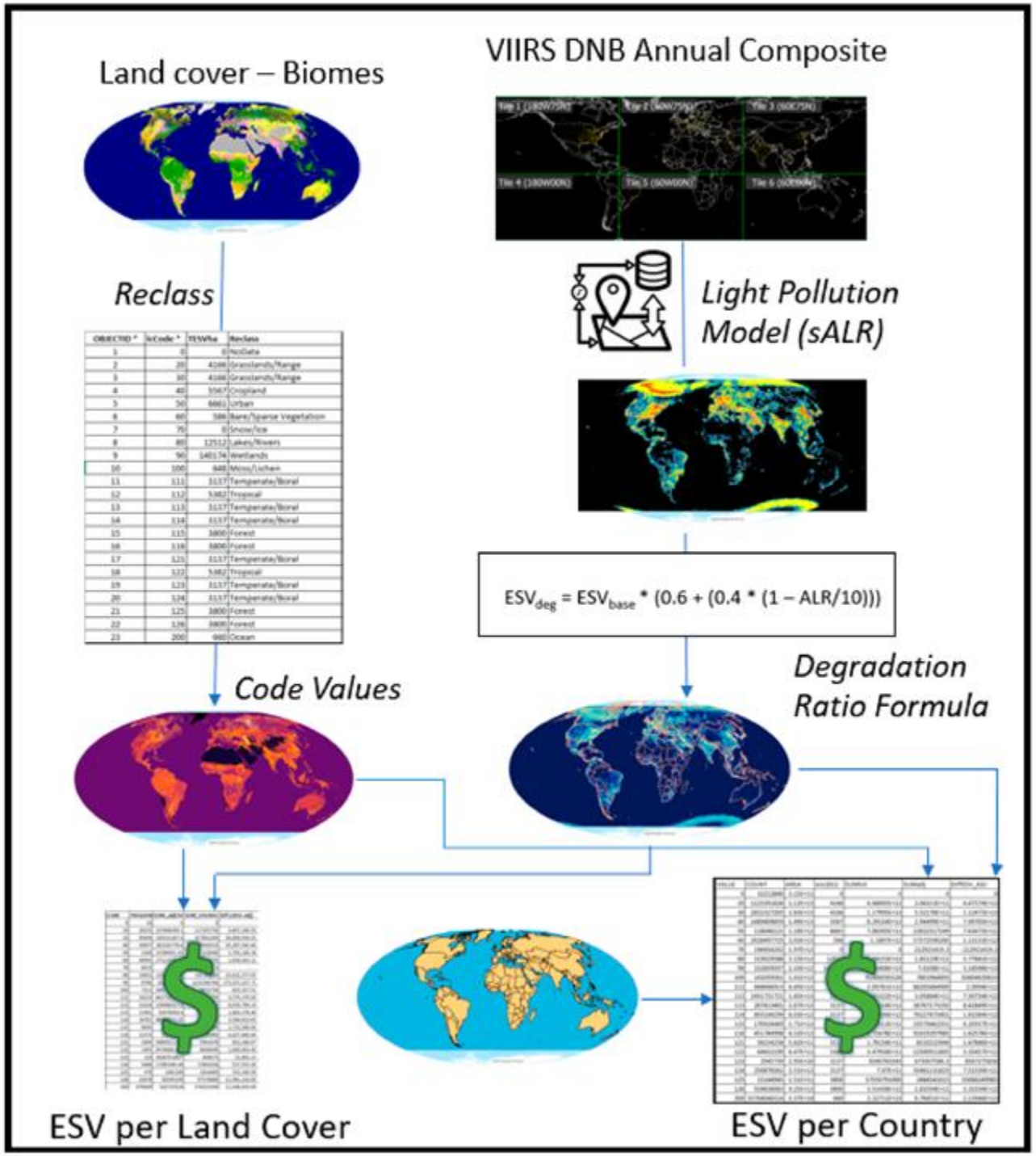
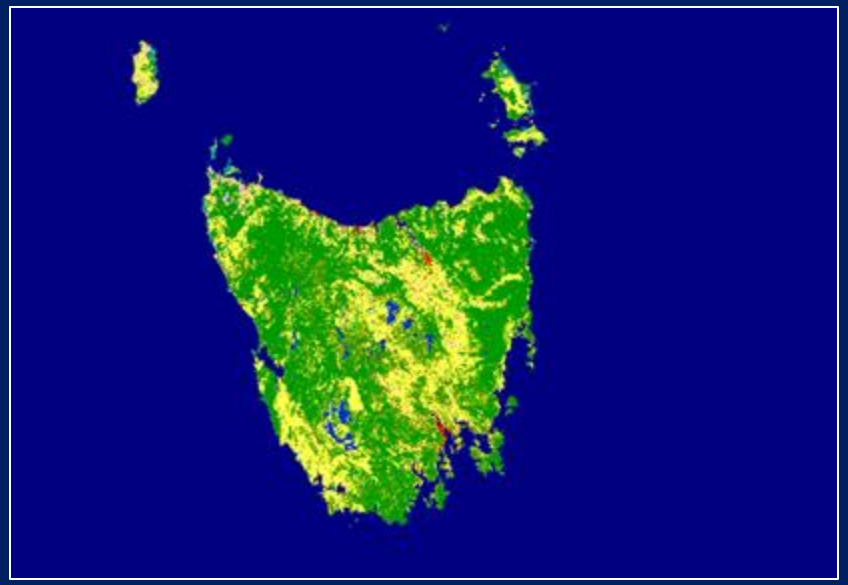
by Sharolyn J. Anderson [1,2,*], Ida Kubiszewski [1,3] and Paul C. Sutton [2,4]



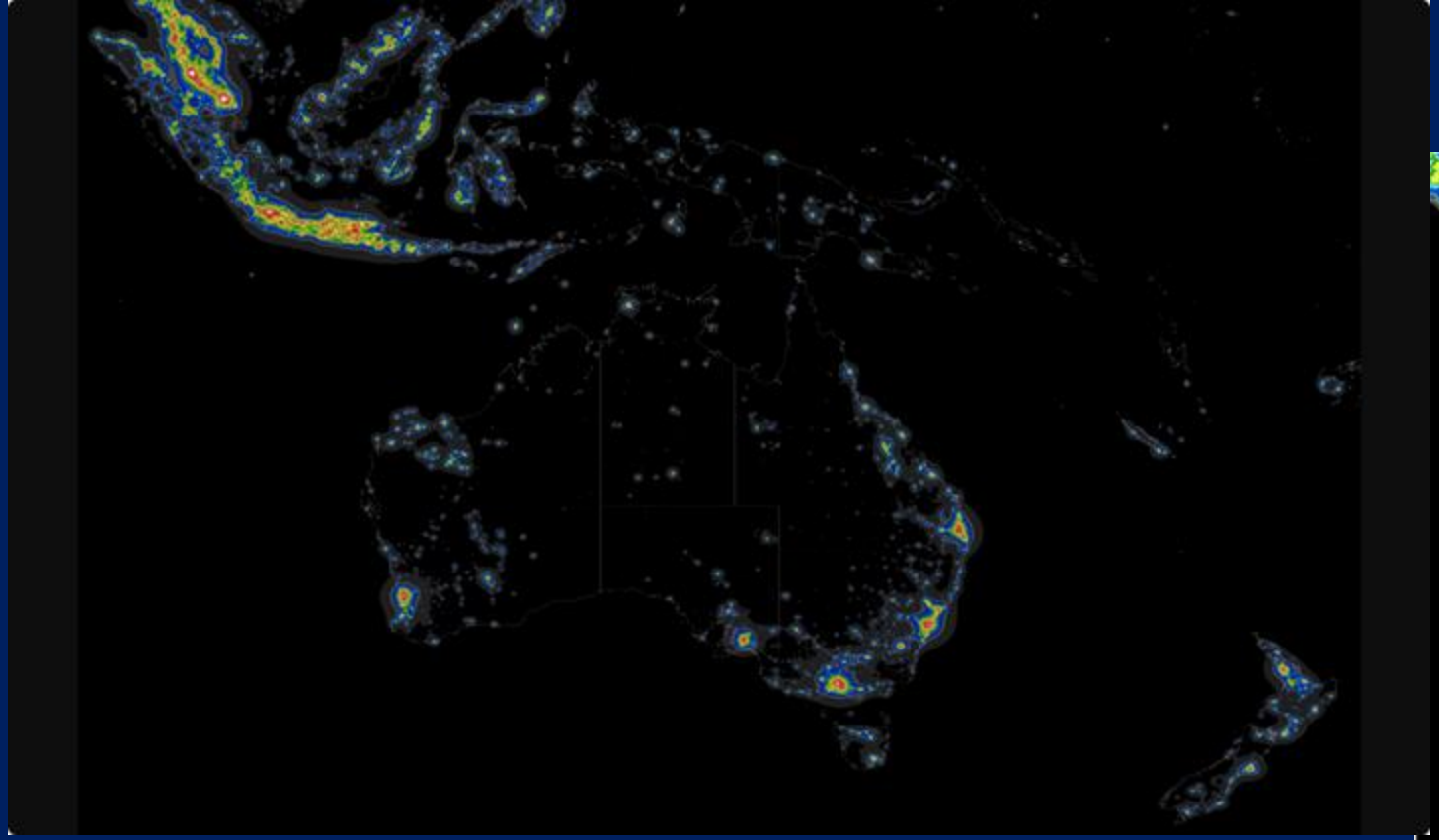

Land cover – Biomes
VIIRS DNB Annual Composite
Reclass
Light Pollution Model (sALR)
Code Values
$ESV_{deg} = ESV_{base} * (0.6 + (0.4 * (1 – ALR/10)))$
Degradation Ratio Formula
ESV per Land Cover
ESV per Country

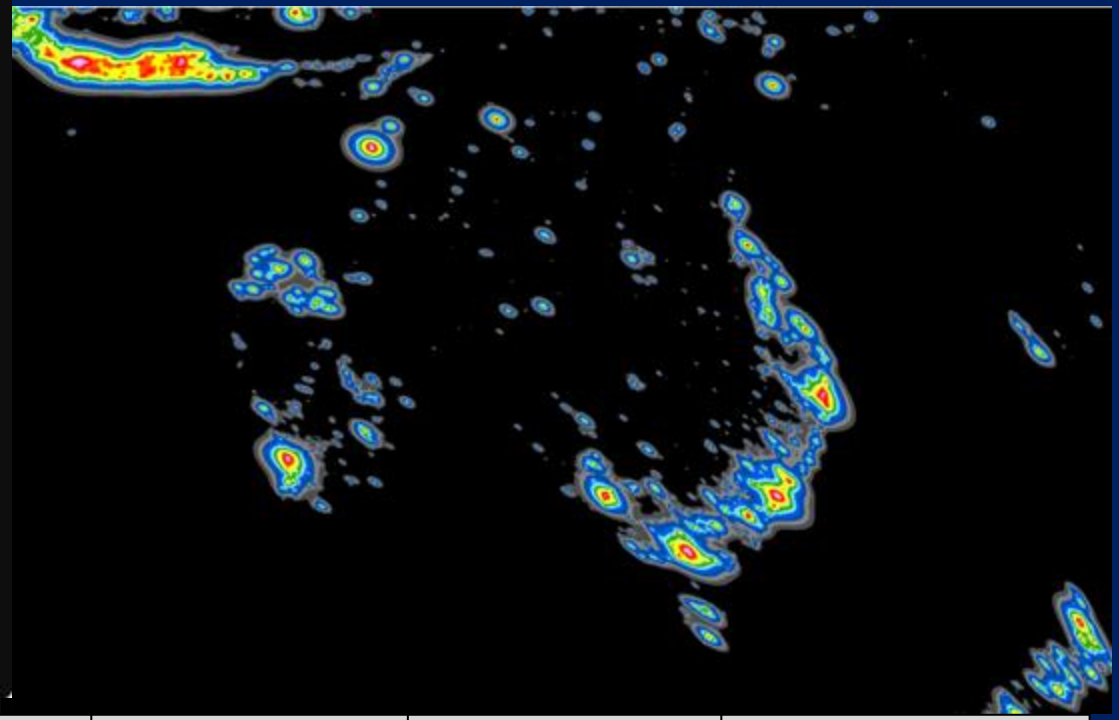


Landcover / Biomes

Ecosystem Service Value
US$ 2011

Ecosystem Service Value
Degraded by Light Pollution





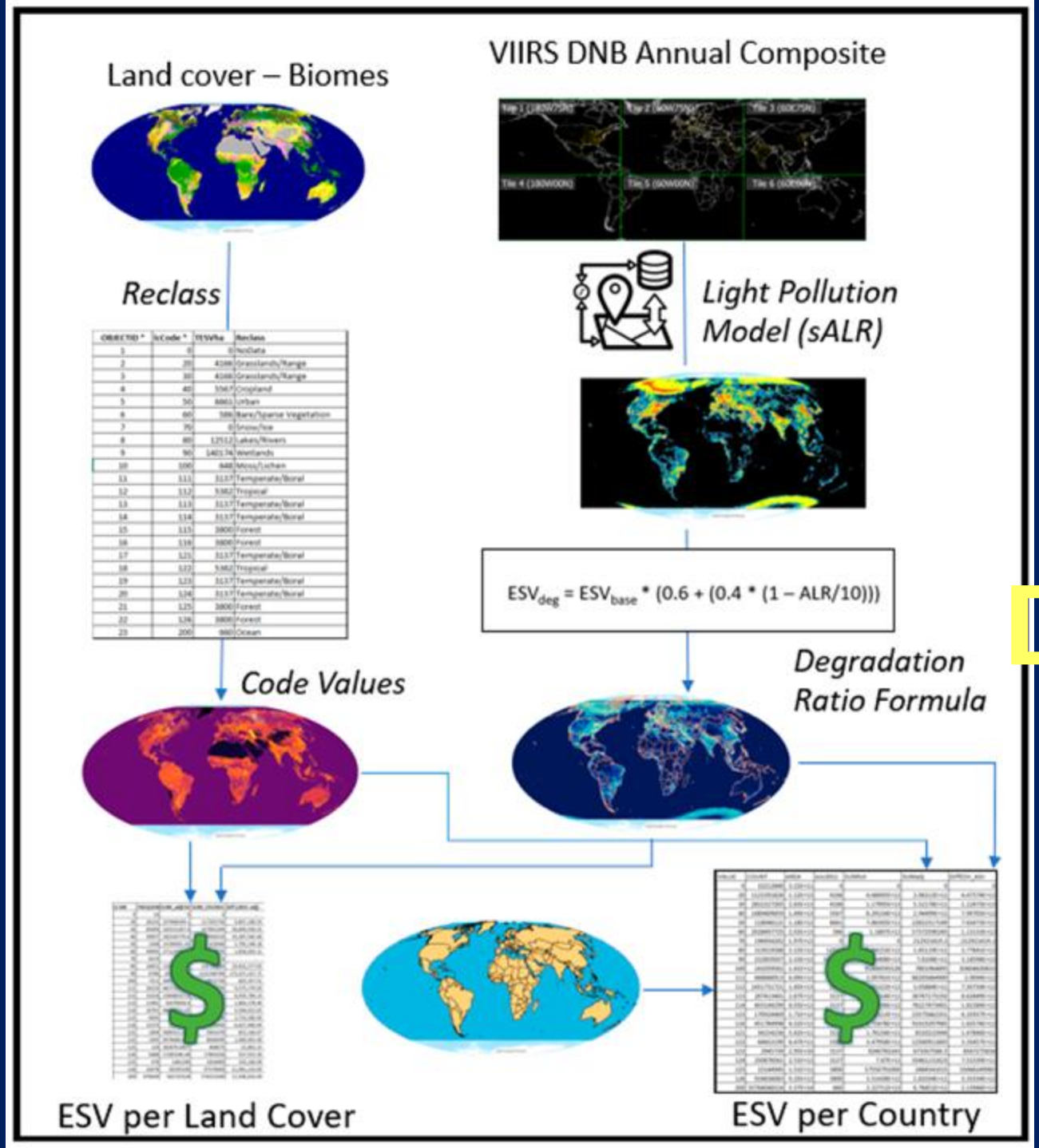
Country	Poputaltion	BaseESV	DegradedESV	TotalLossESV	PcentLossESV	PerCapitaLossESV
Australia	**24,756,403**	**3,438,966,391,285**	**3,429,792,769,129**	**9,173,622,156**	**0.3**	**371**
Russian Federation	145,428,954	21,983,656,122,536	21,229,344,088,388	754,312,034,148	3.4	5,187
United States of America	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**.

Dollar Values



LP Model

Degraded Eq.

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*’.