Lights in the Dark: Tracking Urban Light Pollution in Music City

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Introduction

Remote sensing of nighttime light (NTL) emissions provides valuable insights into human activities, such as urban expansion, power outages from natural disasters, and the ecological effects of artificial light. Unlike daytime remote sensing, which relies on sunlight, nighttime illumination comes from various sources, including moonlight, streetlights, buildings, ships, and surface reflections (albedo). Snow reflects a high percentage of light, while water bodies and forests reflect far less.

NASA's primary source for nighttime light imagery is the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi NPP, NOAA-20, and NOAA-21 satellites. These platforms provide global daily measurements of nocturnal visible and near-infrared (NIR) light for Earth system studies. VIIRS Day/Night Band (DNB) data are used to estimate populations, track electrification, monitor disasters, and study light pollution's biological impacts.

The recently released NASA's atmospheric and Lunar-BRDF-corrected Black Marble NTL product (VNP46A2) offers new opportunities for analyzing NTL dynamics by providing daily VIIRS DNB data at 15-arc-second spatial resolution with operational correction for surface reflected lunar radiance.

Methods

We analyzed nighttime light (NTL) emissions using NASA's Black Marble VNP46A2 product, which provides daily radiance measurements in $nW \cdot cm^{-2} \cdot sr^{-1}$ at a 15-arc-second spatial resolution. Using the `BlackMarbleR` package in R, we defined a polygonal region of interest (ROI) centered around Nashville, TN, representing an approximate 1.5-hour commute radius. Radiance values for towns within this ROI were extracted and exported for further analysis.

In Python, we filtered noise using a minimum threshold of **3 $nW \cdot cm^{-2} \cdot sr^{-1}$**, as recommended in prior studies. For all valid pixels exceeding this threshold, we calculated **light pollution** using the conversion:

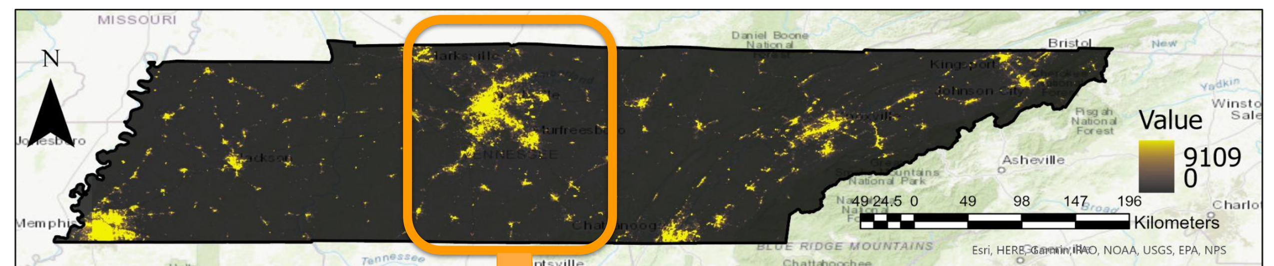
Luminance (cd/m²) = Radiance (nW/cm²/sr) × 10^{-5} × 683

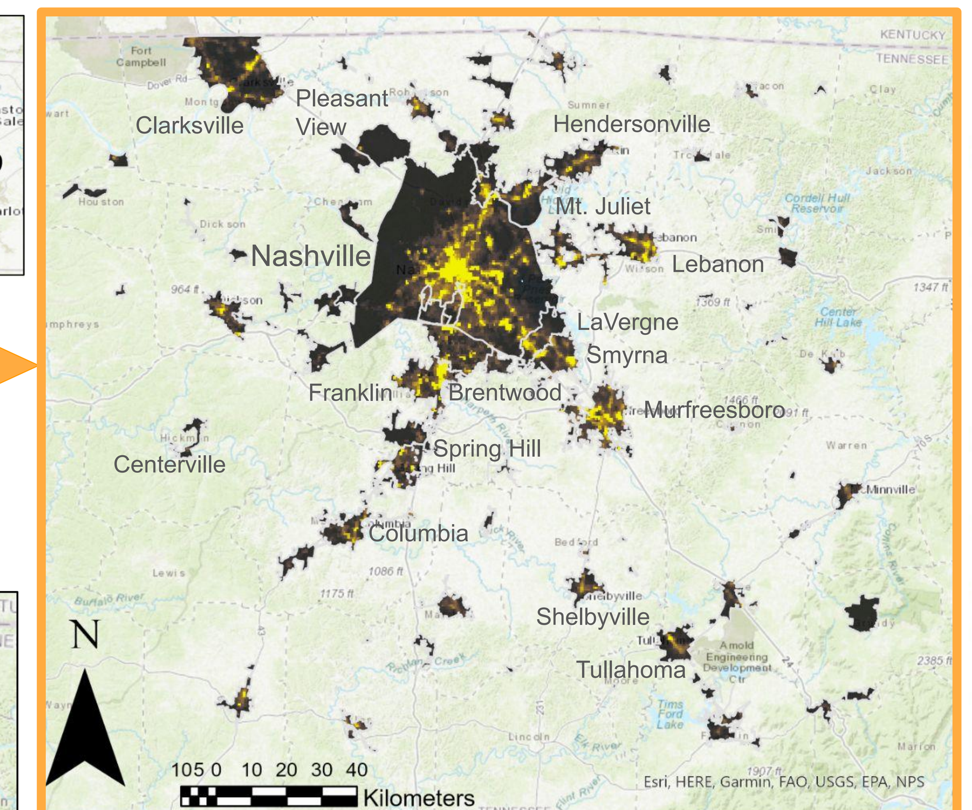
This formula converts radiance from nanowatts to watts per square meter per steradian, then multiplies by the photopic luminous efficacy constant (683 lm/W) to obtain luminance in candela per square meter (cd/m²).

These values were aggregated for each town and normalized by population to evaluate per-capita exposure. We used `pandas`, `numpy`, `plotly`, and ArcGIS Pro software to conduct calculations, map results, and generate interactive visualizations for regional light pollution patterns across Middle Tennessee.

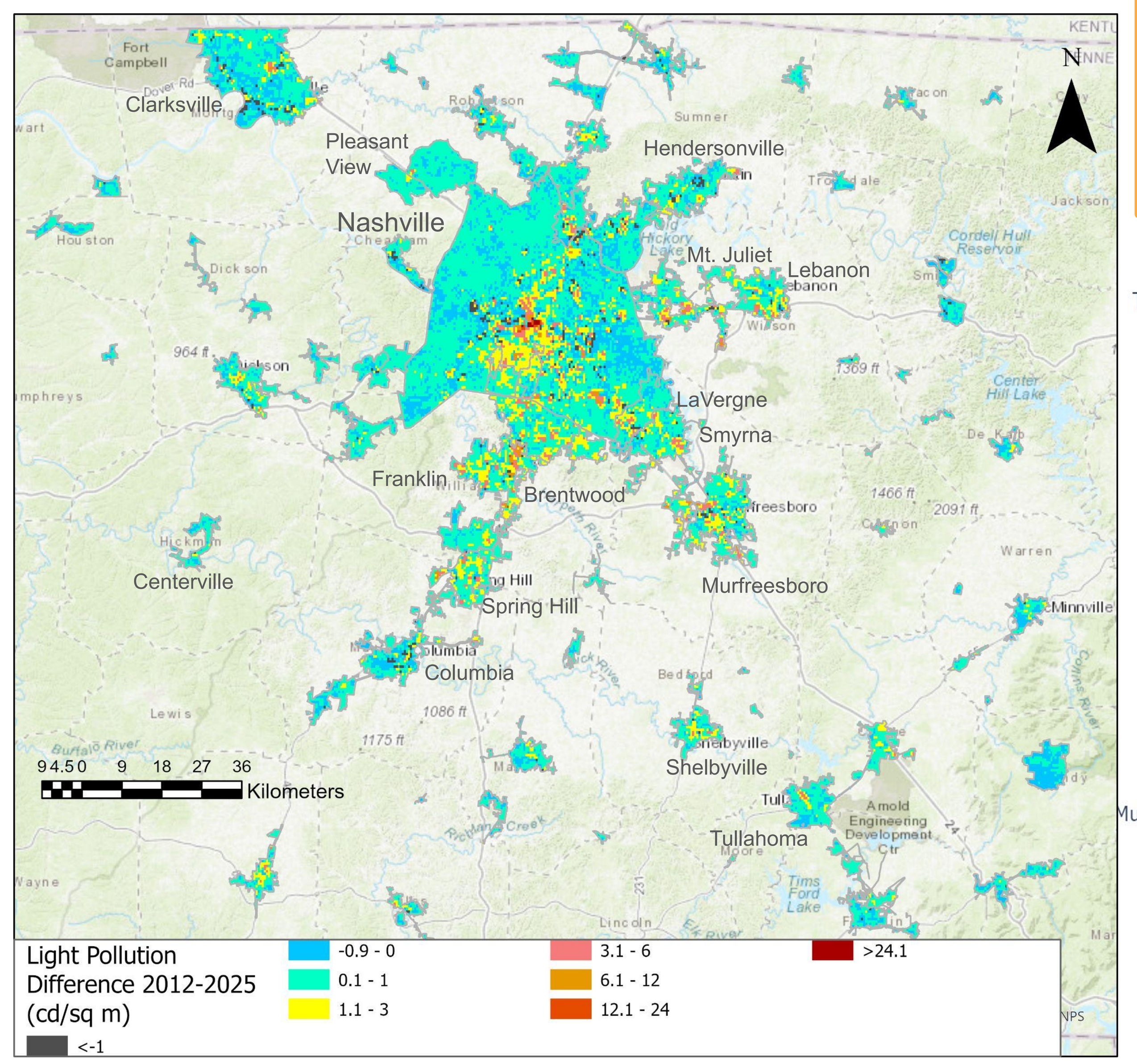
Results

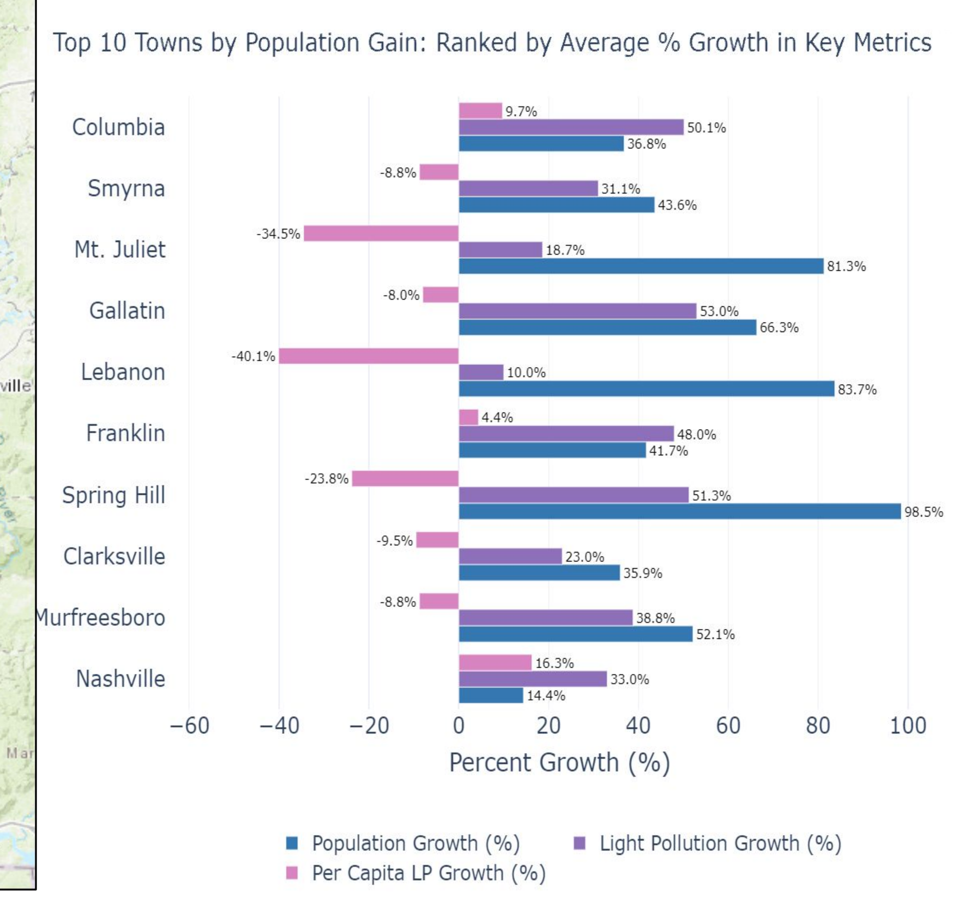
Night time lights (NTL), January 2025

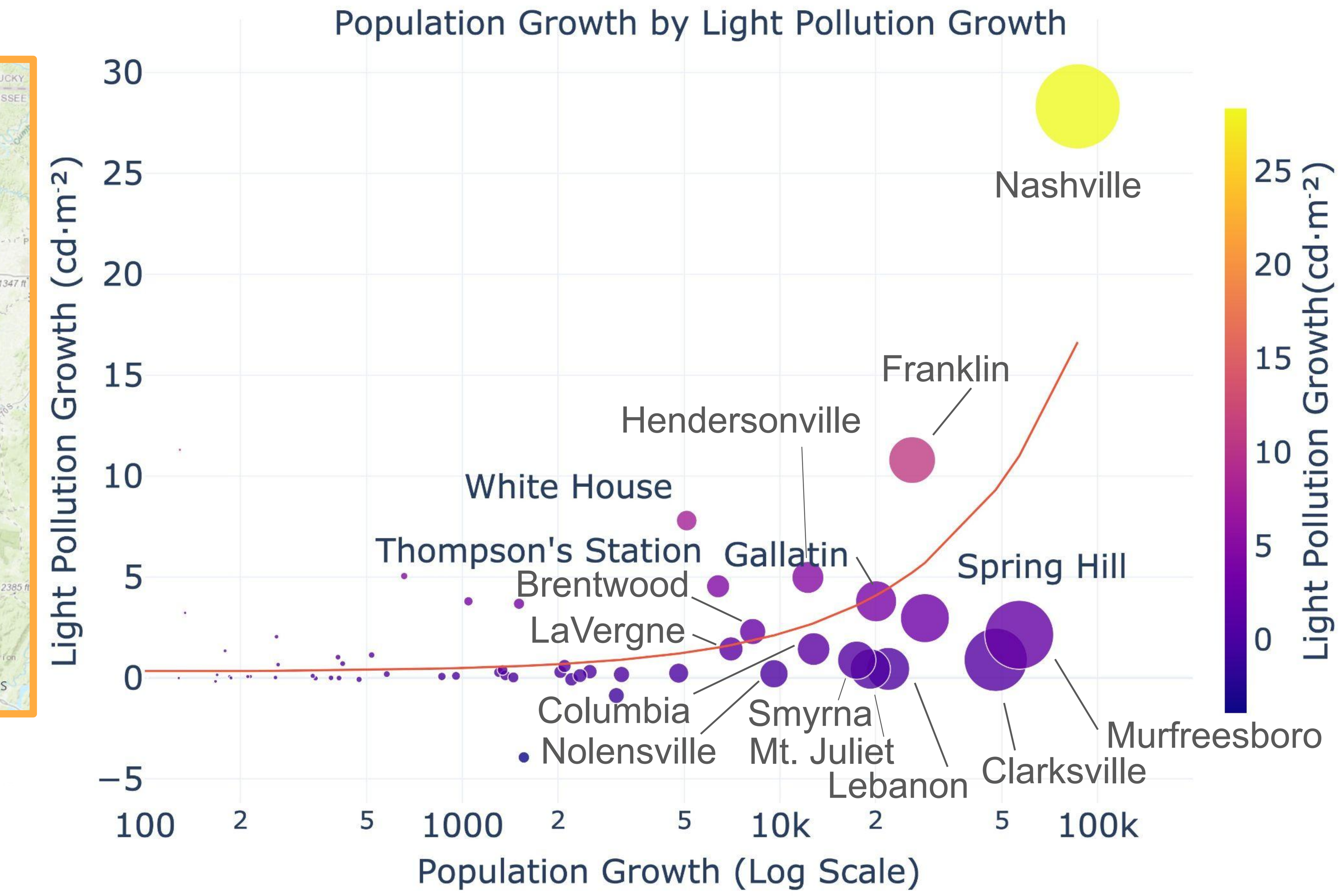


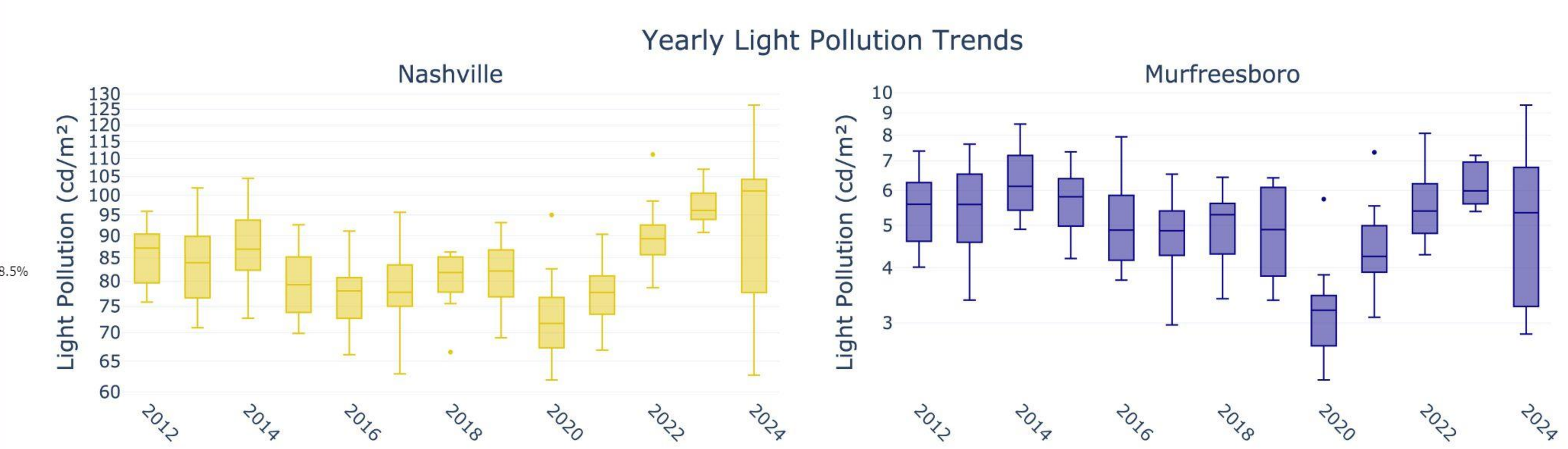


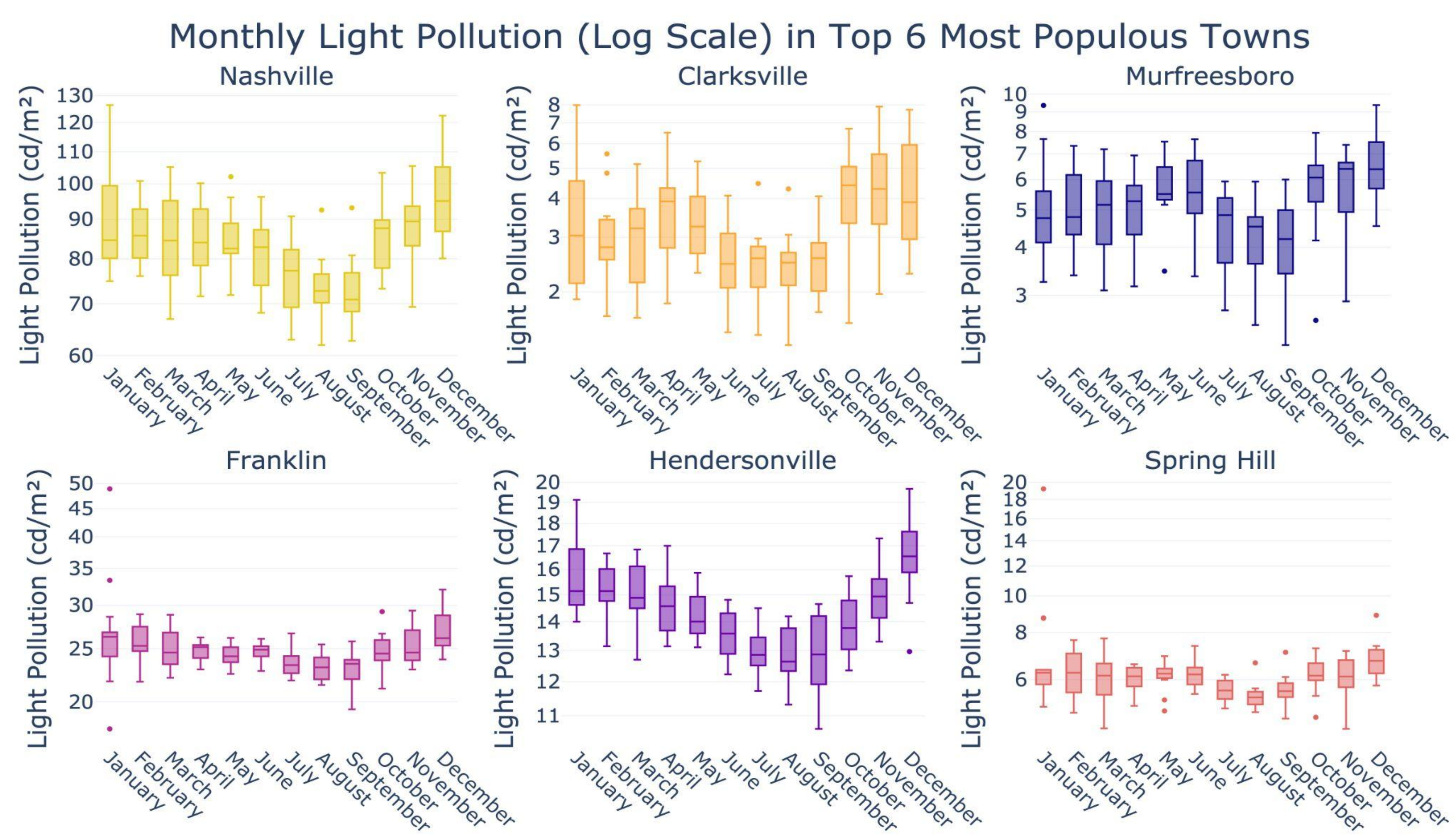
Changes In Light Pollution (cd/m²), January 2012 - January 2025











From 2012 to 2025, the total light pollution across the 89-town study region increased by over **230%**, from **~4,938 cd/m² to over 16,300 cd/m²**. Towns such as **Spring Hill (+98.5% population)** and **Lebanon (+83.7%)** experienced significant urban growth. However, **Nashville** stood out with the highest absolute light pollution increase (**+29.4 cd/m²**).

Several towns (e.g., **Franklin**, **Gallatin**, **Columbia**) showed high light pollution growth despite modest population gains, indicating a rise in **per capita or commercial lighting**.

Regression analysis showed a positive but nonlinear relationship between population growth and light pollution increase, with some outliers deviating due to local development patterns.

Conclusions

Nighttime light emissions are rapidly rising across central Tennessee. Notably, light pollution and population are growing at different rates. The impact of population growth on light pollution varies across the region - it's more noticeable in smaller, initially darker towns, while in already well-lit cities like Nashville, further population growth has a smaller effect on total light pollution levels. VIIRS Black Marble data clearly captured these trends, linking light pollution to population growth, land use, and infrastructure.

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