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Healthy Darkness

Imagine picking up a prescription, but instead of a list of medications, you get a recommendation for: "Darkness – to be taken for about eight hours each night." This is no joke, as our health depends greatly on the conditions in which we sleep, with darkness playing a critical role.

A. KOTARBA, BASED ON OBSERVATIONS FROM THE SNPP SATELLITE

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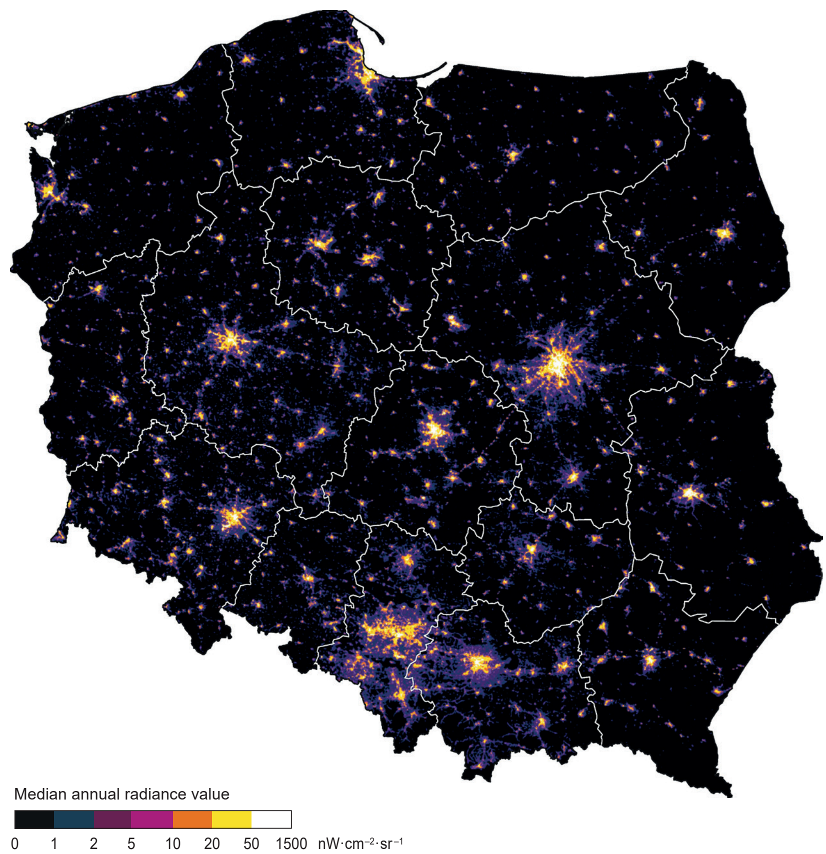
The day-and-night cycle has always been a fundamental part of our natural environment. Life on Earth evolved in its presence, adapting through natural selection to either nocturnal (resting by day) or diurnal (resting by night) activity patterns. The rhythm of day and night is deeply embedded in our genes. It's so integral to our biology that, even if we were completely isolated from the outside world – deep in a cave or a mine, for instance – we would still wake and sleep according to a set rhythm.

Our internal biological clock manages the regularity of our physiological processes and must continuously synchronize with the external environment to support healthy body function. Light is essential in this process. Its presence signals to the brain to stop producing melatonin, the "darkness hormone." The body then enters a state of alertness and activity. In the evening, as darkness falls, melatonin production resumes, marking the time for rest and renewal.



A. KOTARBA, BASED ON VIIRS OBSERVATIONS FROM THE SNPP SATELLITE CONDUCTED IN 2022

Radiance of light emitted into the sky from the area of Poland

Inappropriate lighting

But what happens when we replace natural sunlight with artificial light after dark? To our bodies, light is light, and its presence signals that the day is evidently still underway. This forces the body into an unnaturally prolonged state of alertness. Over time, this can lead to difficulties falling asleep, insomnia, poor sleep quality, difficulty concentrating low mood, and even depression. It also disrupts our metabolic cycle, increasing the risk of obesity, insulin resistance, diabetes, and heart disease. Studies increasingly show a link between exposure to excess artificial light at night and certain cancers.

Artificial light at night also significantly impacts plants and animals. Their reproduction, feeding, and migration cycles are disrupted, with effects varying by species. Delicate relationships between plants and animals degrade as well; for example, artificial light reduces the effectiveness of pollination by both day and night insects.

Artificial light at night is now so prevalent that ecologists consider it a form of environmental pollution. Light is typically deemed to constitute *light pollution* if it shines in the wrong direction, is of inappropriate intensity or color, or is simply unnecessary (serving no useful purpose).

What does "inappropriate" mean here? In terms of direction, it refers to light spilling beyond the object intended to be illuminated (often a road or pathway). This includes light directed towards lawns, rivers, forests, building façades, and even into building interiors, such as bedrooms. The worst-designed lamps even shine upward, into space, lighting up the air and clouds!

Inappropriate light color, in turn, relates to *color temperature*, which is measured in kelvins (K). The higher the color temperature, the more it suppresses melatonin production. The recommended range is 2000–3000 K, which resembles the warm, orange light of sunset. However, in many places, cold light exceeding 4000 K is used (with 7000 K almost equating to daylight conditions).

Helpful satellites

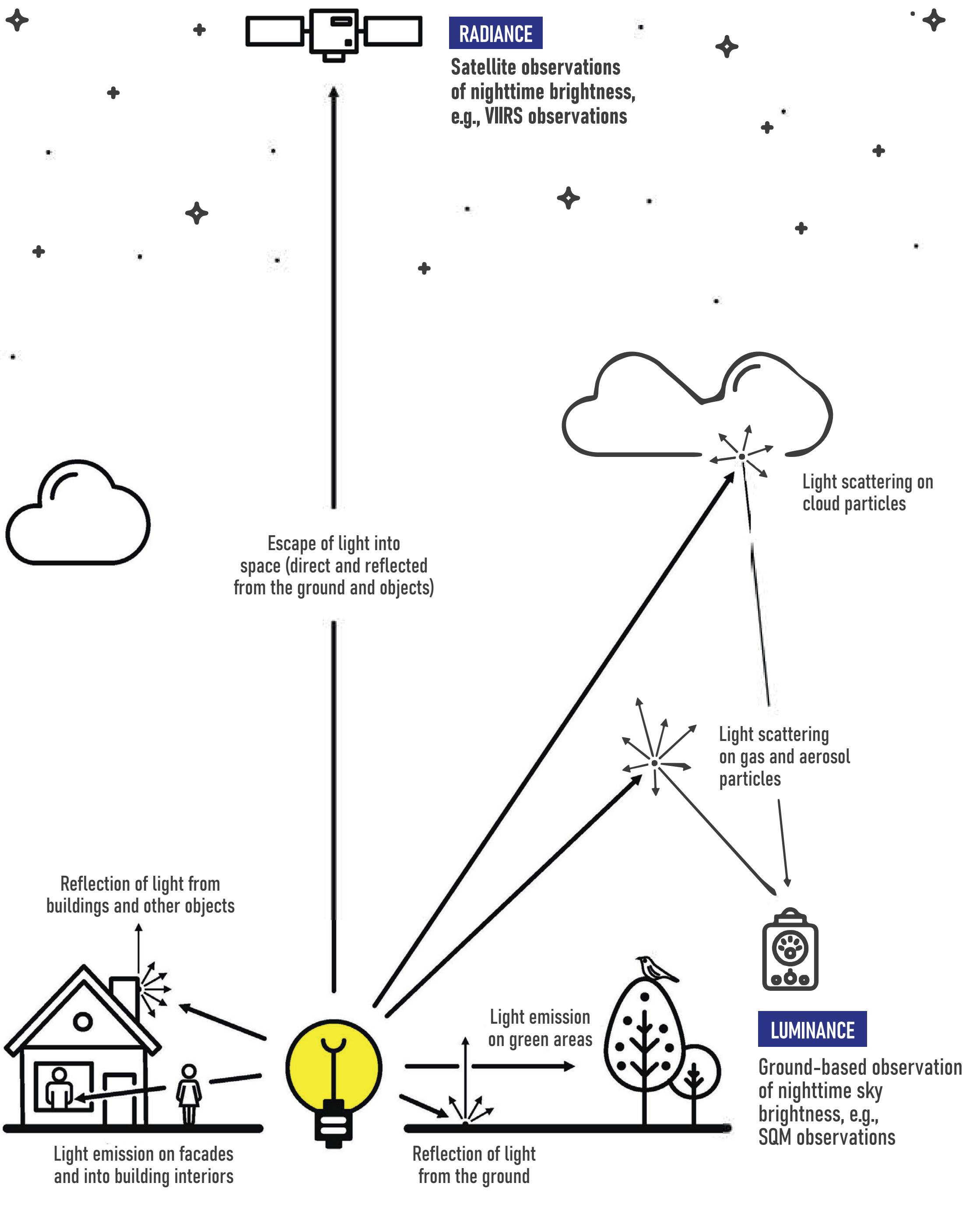
This brings up the question: how much inappropriate light actually surrounds us? More broadly, what is the extent of light pollution in urban areas and in the (relatively) natural environment?

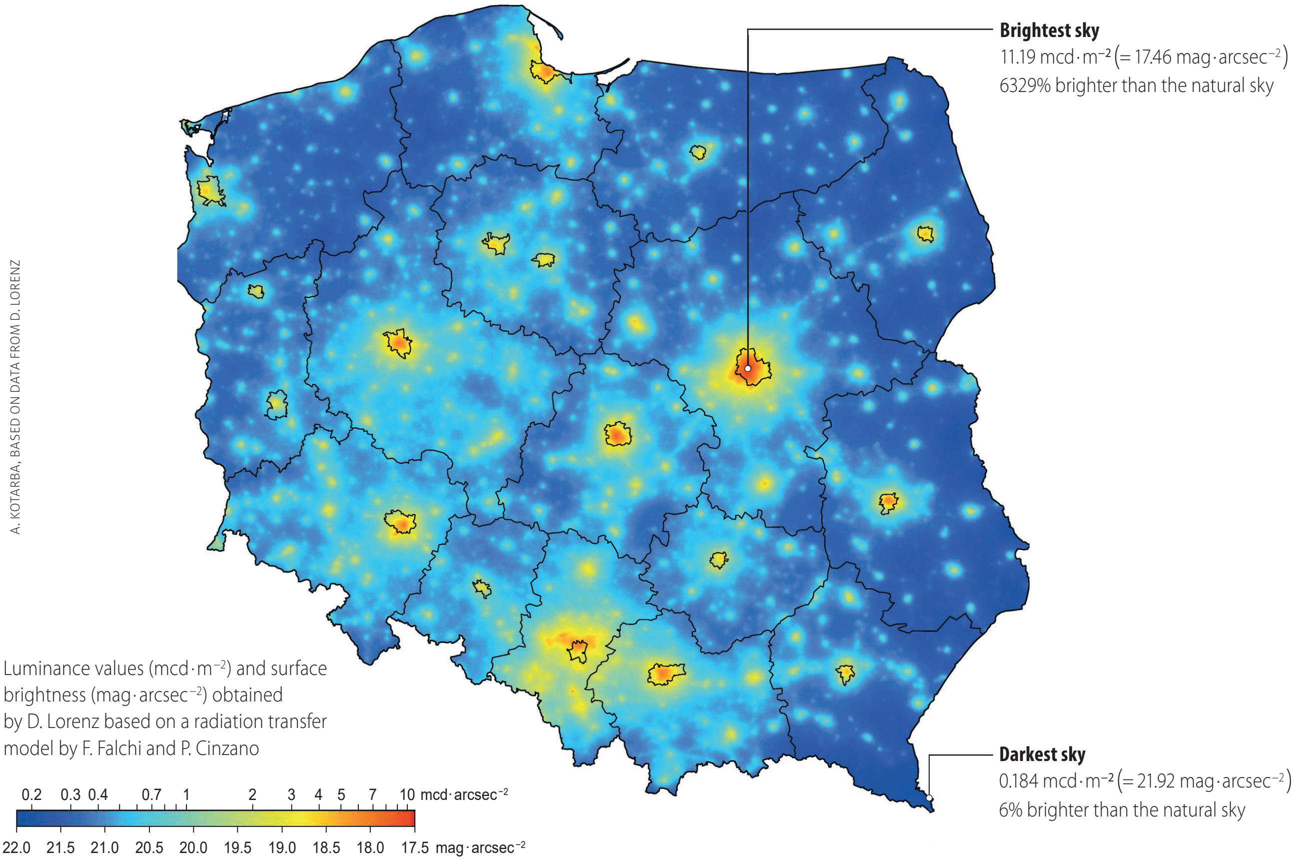
On a national or global scale, we can assess this using satellite observations from orbit. The SNPP and NOAA meteorological satellites are particularly useful, equipped with the VIIRS (Visible Infrared Imaging

Radiometer Suite) instrument. VIIRS focuses on capturing the portion of nighttime light that escapes into space. Physically, it measures *radiance* – the intensity of light flow. The higher the radiance, the more nighttime light is escaping, indicating a greater degree of light pollution.

What does VIIRS tell us about Poland's nighttime lights? The first study of this kind in Poland was conducted at the Earth Observation Department of the Space Research Centre, Polish Academy of Sciences. The analysis included over 4,000 nighttime images taken between 2012 and 2022, providing statistics at the province, municipal, and individual location levels, covering 2.4 million sites.

The findings reveal that Poland's nighttime brightness is on the rise. In 2022, the radiance of light emitted from Polish territory was 6% higher than the average from 2012–2021. The year 2022 was the brightest on record, though only slightly brighter than 2017 and 2019. Notably, there was a significant darkening in 2020, linked to the COVID-19 pandemic, as municipalities turned off unnecessary lighting during lock-





Luminance values (mcd·m⁻²) and surface brightness (mag·arcsec⁻²) obtained by D. Lorenz based on a radiation transfer model by F. Falchi and P. Cinzano

A. KOTARBA, BASED ON DATA FROM D. LORENZ

Night sky brightness over Poland in 2022

downs. As a result, 2020 was as much as 20% darker than 2022.

The brightest areas on the map of Poland are its major metropolitan regions. Interestingly, five cities – Warsaw, Łódź, Kraków, Gdańsk, and Poznań – accounted for 10% of Poland's total brightness. Each emitted over 100 times more light than the average municipality in Poland and over 1500 times more than the darkest municipalities. Looking at individual infrastructure objects rather than entire municipalities, large-scale greenhouses emitted the most skyward light in 2022, with the greenhouse in Goczałkowice-Zdrój standing out as being 600% brighter than the area around Warsaw's landmark building, the Palace of Culture and Science (Poland's brightest urban location).

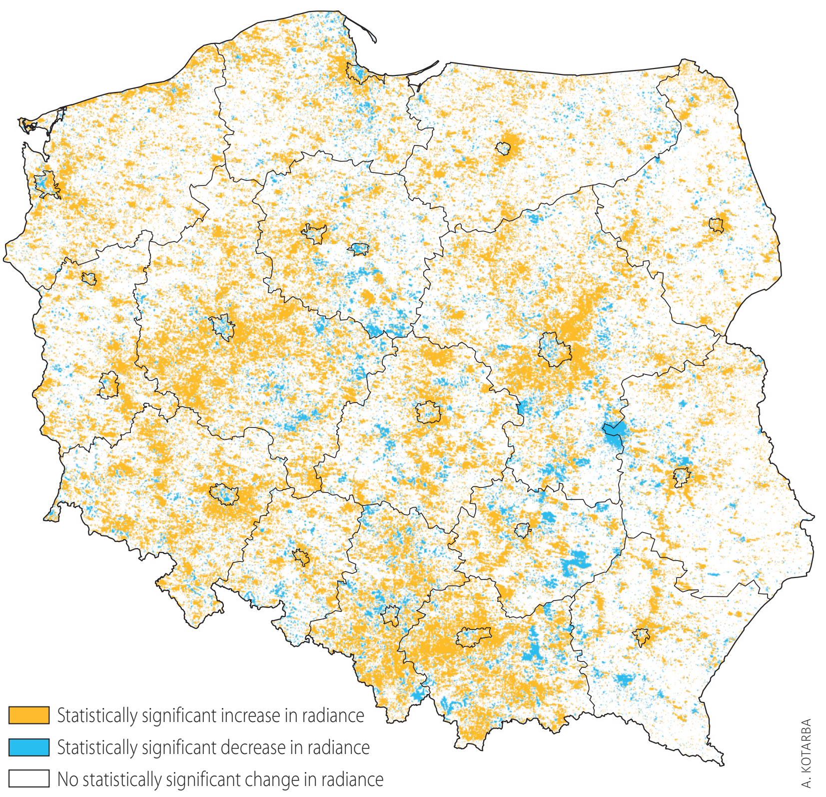
Tracking trends in light pollution based on VIIRS-measured radiance is challenging, as these changes are nonlinear. When comparing 2022's brightness to the 2012–2021 average, a statistically significant brightening was observed over nearly a quarter of Poland's surface area (23.3%), while a reduction was noted over 5.2% of the country.

The Małopolskie region experienced the greatest brightening (radiance increased over 40% of the region's area and decreased over 8%), while Podkarpackie experienced the least (brightening over 13% and dimming over 4% of the area). In every province, brightening areas were 2 to 9 times more common than dimming areas. At the municipal level, radiance increases dominated in 1,927 municipalities (78% of the total).

In fact, these statistics can be considered an *optimistic* scenario. VIIRS does not capture the full range of visible light, only its low-energy portion. Specifically, VIIRS records radiation in the 500–900 nm range, whereas visible light spans from 380–780 nm. Thus, VIIRS does not detect blue light, found, for example, in increasingly widespread LED lighting. Some areas marked by VIIRS as slightly dimming or with no clear trend are, in reality, likely also brightening.

Poland shines

Let's return to Earth. We can also estimate the extent of light pollution from ground level by simply looking up at the sky. Before light escapes into space, it passes through the atmosphere, where it gets scattered by the air, aerosols, and clouds. This scattering causes the nighttime sky, which should be dark, to glow unnaturally, creating a characteristic halo over cities. By taking photometric measurements, we can assess the intensity of this glow, which indicates the level of light pollution.



Trend in the intensity of light emission into the sky. Expressed by the difference between radiance values in 2022 and the average values from the decade 2012–2021

However, photometric measurements are point-specific, only providing information about the sky brightness directly above each observation site. To obtain a comprehensive view of sky brightness across Poland, we need to rely on sky brightness modeling. One such tool is the *radiation transfer model* developed by Italian astronomers Fabio Falchi and Pierantonio Cinzano. The model incorporates VIIRS satellite data, which shows the intensity and location of light sources, and is calibrated with ground-based photometric data collected worldwide.

Using this method, a map was created showing that in 2022, the typical cloudless night sky over Poland was, on average, 147% brighter than it would be without light pollution. The darkest sky could be observed over the Bieszczady Mountains, one of the least developed areas in the country, though even there, it was still 6–8% brighter than a truly natural sky. This means a natural night sky no longer exists anywhere in Poland. The closer to populated areas, the brighter the night sky becomes. An extreme example is Warsaw, particularly around the city's central point of Defilad Square, where the night sky in 2022 was 6329% brighter than a natural sky.

If we compare the map of artificial sky brightness with Poland's population density map, it turns out that 58% of the country's population lives under a sky so bright that the Milky Way is invisible. The situation is worst in the Śląskie province (where 89% of the population can't see the Milky Way at night) and Mazowieckie (72%) province, while Podkarpackie fares best (28%).

In some areas, covering 0.7% of the country's surface, the sky is even brighter – so much so that the Milky Way, most stars, and even night itself are invisible. The brightness of the night sky in these places is so intense that the human eye cannot enter its typical night (scotopic) vision mode. It's as if night never falls, and with it, the conditions needed for proper rest and recovery for all living organisms, including humans, never occur.

At first glance, 0.7% of the country's area may seem insignificant. However, these are the most densely populated regions, meaning this problem affects 20% of the Polish population, including nearly all residents of Warsaw, Łódź, Poznań, Kraków, Gdańsk, and Lublin.

Just as with VIIRS, this scenario is optimistic. The model estimates only consider the zenith sky (directly overhead) and only for cloudless nights. As one looks away from the zenith, the sky usually becomes brighter, so in reality, we experience a much brighter night sky. The presence of clouds can amplify this brightness several-fold, sometimes even dozens of times. Since cloudless nights are relatively rare in Poland, the actual scale of light pollution is greater than what sky brightness maps suggest.

Studies performed by the Space Research Centre of the Polish Academy of Sciences conclude that light pollution in Poland is both widespread and increasing. This trend is evident in satellite observations and data on artificial sky brightening.

From a public health perspective, light pollution is an issue that cannot be ignored – yet it often is. Unlike toxins, harmful gases, particulates, smog, sewage, or noise, which are all widely recognized as pollutants harmful to health, Polish law does not yet classify excessive light as a form of pollution.

Of course, laws can evolve, but public attitudes need to change first. There is a psychological barrier that needs to be overcome. Culturally, we're taught that light is good and darkness is bad – something to avoid or defeat. In this mindset, night becomes an adversary. Yet research shows the opposite: naturally dark nights are essential for health, providing a sanctuary where our bodies regenerate and gather energy for daytime activity.

So, what's the remedy for this condition known as light pollution? The solution isn't to turn off all lighting at night. Instead, what we need are sustainable lighting policies – lighting that saves energy, provides comfort and safety after sunset, and protects human health and ecosystems. As the old saying goes, "too much of a good thing can be harmful." We now know that this also applies to light. ■

Further reading:

Bogard P., *The End of Night: Searching for Natural Darkness in an Age of Artificial Light*, 2014.

Eklöf J., *The Darkness Manifesto: On Light Pollution, Night Ecology, and the Ancient Rhythms of Life*, 2024.

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