LIGHT POLLUTION-POPULATION CORRELATION BY POWER LAWS

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Pollution is an air, water and ground contamination process, which has over time manifested itself in different manners, contexts and forms, such us waste, toxic gas, electromagnetic and lighting radiation…yes light can pollute!

Measuring the effect of sky glow on a global scale is a complex procedure. The natural atmosphere is not completely dark, even in the absence of terrestrial sources of light. This is caused by two main sources: airglow and scattered light. At high altitudes, primarily above the mesosphere, UV radiation from the sun is so intense that ionization occurs. When these ions collide with electrically neutral particles they recombine and emit photons in the process, causing airglow. The degree of ionization is sufficiently large to allow a constant emission of radiation even during the night when the upper atmosphere is in the earth's shadow. The sky also scatters incoming light, primarily from distant stars and the Milky Way, but also sunlight that is reflected and backscattered from interplanetary dust particles (the so-called Zodiacal light). The amount of airglow and zodiacal light is quite variable but given optimal conditions the darkest possible sky has a brightness of about 22 magnitude/square arcsecond. In densely populated areas a sky brightness of 17 magnitude/sq. arcsecond is not uncommon, or as much as 100 times brighter than is natural. To precisely measure how bright the sky gets, night time satellite imagery of the earth is used as raw input for the number and intensity of light sources. These are put into a physical model of scattering due to air molecules to calculate cumulative sky brightness. Maps that show the enhanced sky brightness have been prepared for the entire world.

A number of people have modeled light pollution in various ways. As an example, Garstang in 1986 has detailed calculations for a number of observatory sites, creating maps showing how the skyglow varies at different altitudes and azimuths from each site. Burton, in 2000, is analyzing satellite data from the Defense Meteorological Satellite Program (DMSP; run by the U.S. Air Force) to estimate skyglow in close to the urban areas. This has the advantage of considering actual satellite data at high resolution, both spatially and in terms of intensity. DMSP data have been linked with a scattering model in Europe by Cinzano et. al. (2000, 2001). When properly calibrated, this provides greater spatial information about the sources of light pollution than population data alone. The model creates a map of expected skyglow at the zenith. For each location in the map, the light pollution contribution from each city is assumed to be related linearly to the population and the inverse 2.5 power of the distance. This is similar to the relation used in Walker's law in 1977, except that we are estimating light pollution at the zenith instead of 45 degrees high in the azimuth of the brightest city. The relation is

$$I = Apr^{-2.5} \tag{1}$$

I is sky glow in nanoLamberts, p is the city population, and r is the distance to the city in meters, and A is a normalization costant.

Inspection of the area surrounding Madrid reveals that the effects of light pollution caused by a single large conglomeration can be felt up to 100 km away from the center. Global effects of light pollution are also made obvious.

We consider an improvement of the previous law. In fact the consideration of linear relationship between intensity and city population can be better modified. In general one can consider an exponent in p that can be real. To obtain the value of this exponent one can perform two procedures. First it is possible to determine it by fitting the experimental data. Otherwise, in the second case it can be related by a computational model of distribution. In this case a good approximation is to use the power law exponent of two dimension distribution of city population, that is two.

Light pollution is excess or obtrusive light created mainly by humans. Among other effects, and like any other form of pollution, it disrupts ecosystems, can cause adverse health effects, obscures the stars for city dwellers, and interferes with astronomical observatories. Light pollution can be construed to fall into two main branches: annoying

light that intrudes on an otherwise natural or low light setting and excessive light, generally indoors, that leads to worker discomfort and adverse health effects. Since the early 1980s, a global dark-sky movement has emerged, with concerned people campaigning to reduce the amount of light pollution.
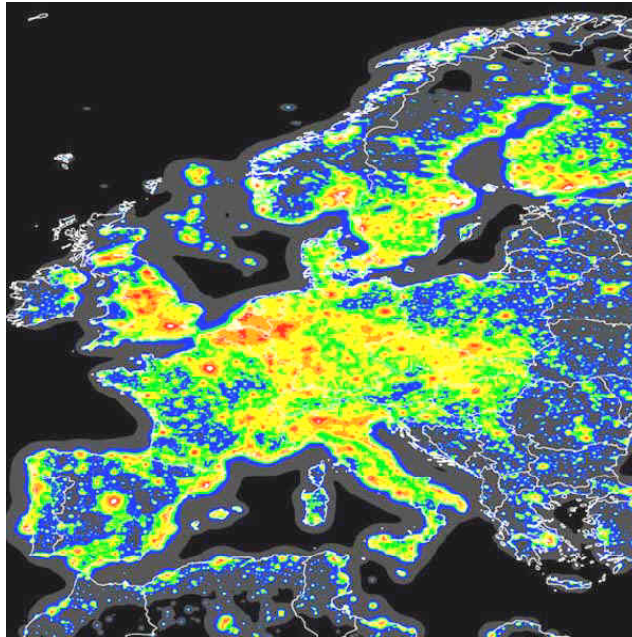

Fig. 1- Light pollution in Europe

Light pollution is an excess of artificial light used where is not useful.

Artificial light diffusion has successfully allowed us to live in our towns with serenity in the night, however, at the same time it obstructs us the view of the starlet sky and alters important biologic balance.

Light pollution is a side effect of industrial civilization. Its sources include building exterior and interior lighting, advertising, commercial properties, offices, factories, streetlights, and illuminated sporting venues. It is most severe in highly industrialized, densely populated areas of North America, Europe, and Japan and in major cities in the Middle East and North Africa like Cairo, but even relatively small amounts of light can be noticed and create problems. Like other forms of pollution, such as air, water and noise pollution, light pollution causes damage to the environment.

There are a significant number of studies and experiments on the effects on the natural world of the artificial life; it affects, for instance, the chlorophyll process, animal reproduction and migration.

Public road illumination has permitted a global growth in terms of safety, development and productivity and is nowadays so important that it must be maintained, albeit in an environment-compatible way.

The case against light pollution is strengthened by a range of studies on health effects, suggesting that excess light may induce loss in visual acuity, hypertension, headaches and increased incidence of carcinoma. Several industry groups also recognize light pollution as an important issue. For example, the Institution of Lighting Engineers in the United Kingdom provides its members information about light pollution, the problems it causes, and how to reduce its impact.

Disputes are still common when deciding appropriate action, and differences in opinion over what light is considered reasonable, and who should be responsible, mean that negotiation must sometimes take place between parties. Where objective measurement is desired, light levels can be quantified by field measurement or mathematical modeling, with results typically displayed as an isophote map or light contour map.

Light pollution is linked to a careless plan about surroundings and energy savings, but this problem can be solved by a new kind of projects with low environmental impact. There are indeed a few and simple rules that one may follow for attaining good lighting system respecting sky and natural balance:

1. Using electrical cabin with lighting flux regulator or dimmer
2. Switching off some part of the system during the night according to the actual needs of the community and traffic
3. Choosing cut-off type of reflectors so as not to waste light and also reduce dazzle instances
4. Reducing angular bend of the road armature
5. Using more, shorter and less powerful street lamps
6. Using High Pressure Sodium lamps (yellow light) for urban centres and low Pressure Sodium lamps for industrial zones
7. Restricting metal halide lamps only for sports arenas where white light is essential

8. For lighting of monuments, positioning floodlights in a top-to-bottom manner, choosing also asymmetric reflectors

9. Using the right light in the right direction

10. According to the technical norms

If a new system can be born according to these simple light projection rules for reducing light pollution and use of energy, the old system can be modified to be efficient and economic.