Calculation and Variation of Light Pollution in Indian State-UP

Sanjana Bhatia, Kanishk

Department of Physics, Panjab University, www.kanishq14@gmail.com

Abstract

Light pollution in India is one of the greatest concerns. It went unchecked and unnoticed for a large amount of time, and slowly and steadily it has crept into the most uninhabited of the places. Now the night skies are full of the artificial light and devoid of the natural starlight. The growing light pollution heavily affects the observational aspects of astronomy, the growth pattern of flora and fauna, and perceivably the health issues in humans. This study highlights some of the perceived causes of LP in India and describes a method of calculating Light Pollution Index (LPI), a quantitative parameter to measure the light pollution of a city or town. As an instance LPI for ten major cities of Uttar Pradesh has been documented, and analysis can be carried in a similar way for all the cities/towns. The light pollution maps have been taken from Google.
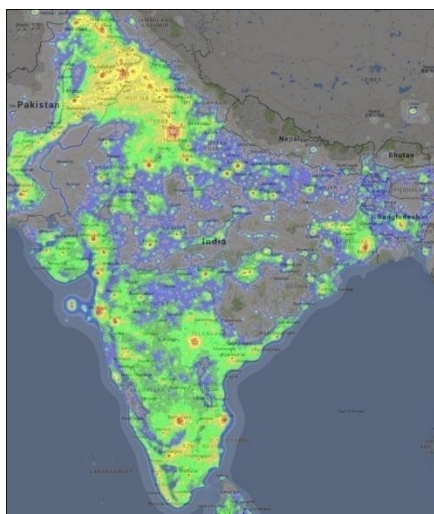
1. Introduction

Light Pollution refers to the unwanted, misplaced, unshielded and excessive artificial light which floods the night skies of the places that they were not intended to. Earlier it was not taken into consideration as human beings tend to take natural things for granted but the unchecked rates of LP has grown over the decades and now the result is that they have started to affect human life directly and indirectly. Studies illustrate that LP leads to sleeping disorders, behavioral changes and hormonal imbalances in humans. Not only humans, but the flora and fauna are also paying adversely for the human neglect, especially the nocturnal species.

Broadly, there are three major types of light pollution- glare, light trespass and sky glow, in addition to over illumination. Although this issue is gaining much attention in the overseas countries, still there is not much awareness over this issue in India, and a large scale quantitative assessment is required for a full damage analysis and to develop methods to prevent and cure it. This paper illustrates a small step in this journey by illustrating a method to calculate LPI for ten major cities in Uttar Pradesh – Lucknow, Kanpur, Gorakhpur, Varanasi, Jhansi, Meerut, Agra, Allahabad, Bareilly and Aligarh.
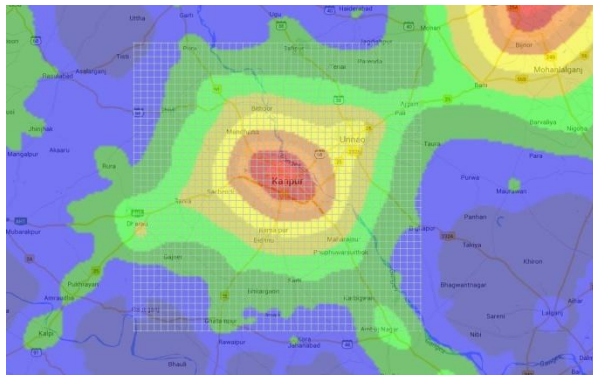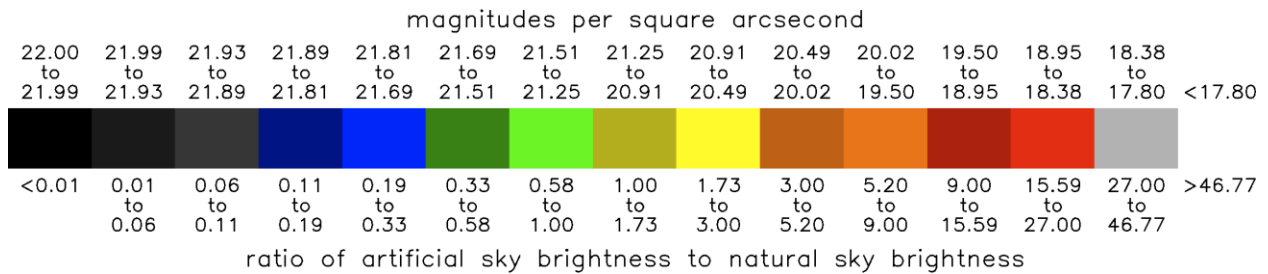
2. Methodology

The Google map overlaid on the light pollution map of India that was used to calibrate the different LP levels the color coding in the map that refers to different levels of light pollution as shown:
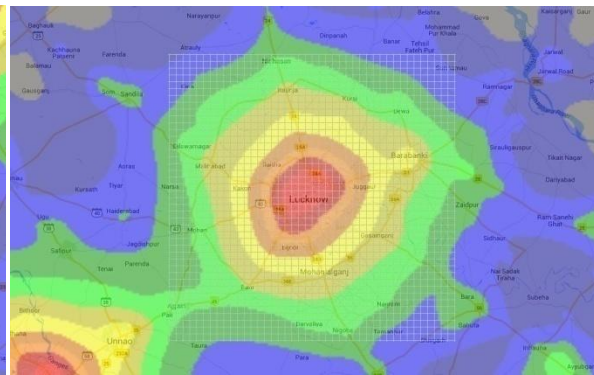
On the map from http://djlorenz.github.io/astronomy/lp2006/overlay/dark.html   [1] keeping a uniform zoom level, uniform segments around the cities and towns of Uttar Pradesh, India were taken out as screen shots
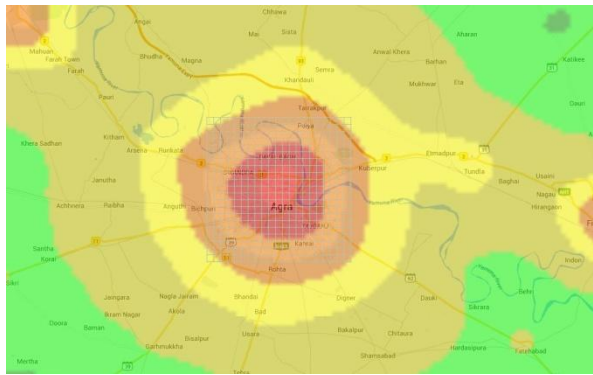
and then a thin digital graph mesh was overlaid as depicted below :

magnitudes per square arcsecond

| 22.00 to 21.99 | 21.99 to 21.93 | 21.93 to 21.89 | 21.89 to 21.81 | 21.81 to 21.69 | 21.69 to 21.51 | 21.51 to 21.25 | 21.25 to 20.91 | 20.91 to 20.49 | 20.49 to 20.02 | 20.02 to 19.50 | 19.50 to 18.95 | 18.95 to 18.38 | 18.38 to 17.80 | <17.80 |

| <0.01 | 0.01 to 0.06 | 0.06 to 0.11 | 0.11 to 0.19 | 0.19 to 0.33 | 0.33 to 0.58 | 0.58 to 1.00 | 1.00 to 1.73 | 1.73 to 3.00 | 3.00 to 5.20 | 5.20 to 9.00 | 9.00 to 15.59 | 15.59 to 27.00 | 27.00 to 46.77 | >46.77 |

ratio of artificial sky brightness to natural sky brightness

Grid overlay on the LP map of Kanpur

Grid overlay on the LP map of Lucknow

Grid overlay on the LP map of Agra
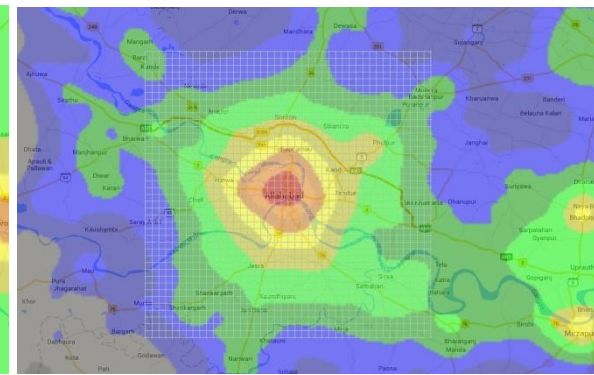
Grid overlay on the LP map of Allahabad

The formula used for calculating Light Pollution Index (LPI) is:

$$LPI = \frac{\sum x_i \, n_i}{\sum n_i}$$, where x_i is the weightage factor written at the column heading and n_i is the number of boxes in the grid of that weightage.

A database was also prepared for ten cities and the basic information related to the places that were taken into account were: Population Density (2011 census)[2],[3] and Literacy rate (2011 census)[4] etc

After analyzing the data reported by the LP maps, tables were made and graphs were plotted between these factors to draw conclusion as to the most prominent cause for Light Pollution.

3. Observation

The inferred Light Pollution Index for the ten prominent cities of Uttar Pradesh, India has been calculated below. The top row indicates the weightage factors. The column indicates number of blocks of that color code in the grid overlaid map.The weightage factors [5] are taken as: **Grey-11, Dark red-10, Light red-9, Orange-8, Mustard-7, Yellow-6, Pale yellow-5, Green-4, Dark green-3, Blue-2, Indigo-1**

Table 1: Calculation of LPI

| City	11	10	9	8	7	6	5	4	3	2	1	sum	LPI	Rank
Lucknow	0	36	40	62	81	176	305	451	416	137	4	1708	**4.5**	6
Kanpur	0	13	39	48	57	145	210	356	566	244	33	1711	**3.99**	7
Gorakhpur	0	0	4	22	26	52	114	290	747	427	8	1690	**3.28**	9
Varanasi	0	0	12	31	45	80	126	244	531	473	159	1701	**3.21**	10
Jhansi	0	0	0	13	74	127	200	17	0	0	0	431	**5.69**	5
Meerut	0	10	63	122	175	54	0	0	0	0	0	424	**7.53**	1
Agra	0	7	23	27	79	190	0	0	0	0	0	326	**6.71**	2
Allahabad	0	0	24	37	56	104	208	459	560	259	41	1748	**3.8**	8
Bareilly	0	0	0	83	105	180	37	0	0	0	0	405	**6.58**	3
Aligarh	0	9	9	64	83	160	95	0	0	0	0	420	**6.43**	4

4. Results

Meerut ranks 1 being the most light polluted city of Uttar Pradesh. Other results are:

a) **Variation of Light Pollution with Population Density**

The bar chart shows blue legend as the population density and the red legend as LPI. It can be concluded that in general, Light pollution index does not vary significantly with population density.

Table 2: Variation of LPI with Population density

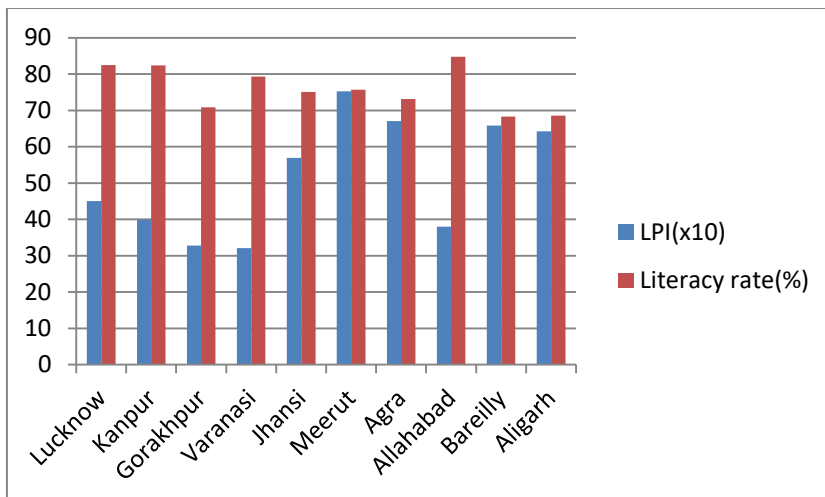| City	LPI	Population density
Lucknow	4.5	1815
Kanpur	3.99	1449
Gorakhpur	3.28	1337
Varanasi	3.21	2399
Jhansi	5.69	398
Meerut	7.53	1346
Agra	6.71	1093
Allahabad	3.8	1087
Bareilly	6.58	1080
Aligarh	6.43	1007
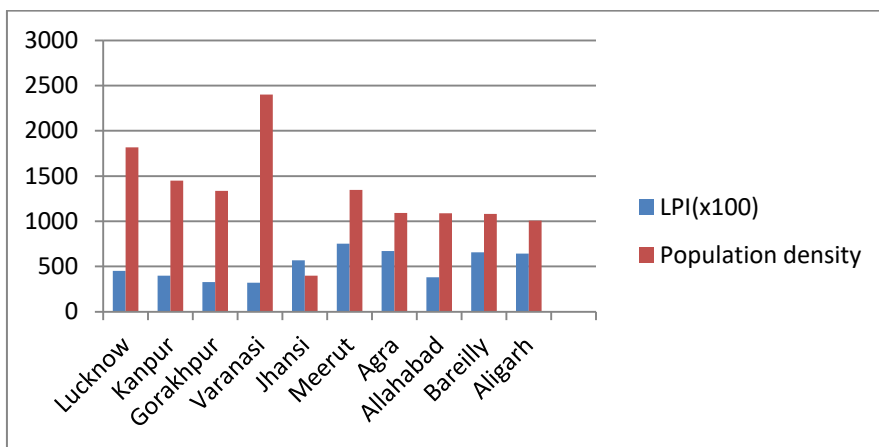
(b) Variation of Light Pollution with Literacy Rate
Below are shown the LP trends with respect to the literacy rates. The Bar charts reveal that the cities with higher literacy rates are the ones with lower amounts of light pollution.

Table 3. Variation of LPI with literacy rate

City	LPI	Literacy rate (%)
Lucknow	4.5	82.5
Kanpur	3.99	82.42
Gorakhpur	3.28	70.83
Varanasi	3.21	79.27
Jhansi	5.69	75.05
Meerut	7.53	75.66
Agra	6.71	73.11
Allahabad	3.8	84.76
Bareilly	6.58	68.25
Aligarh	6.43	68.52

Conclusions
The light pollution maps and bar charts reveal many important aspects of development and inhabitance in destroying the natural pattern, two important factors being Literacy rate and population density. Many more factors can be taken into consideration for a better understanding of the causes and effects of the LP. This study was a step towards awareness.

References
1. http://djlorenz.github.io/astronomy/lp2006/overlay/dark.html
2. **https://www.census2011.co.in/census/state/districtlist/uttar+pradesh.html**
3. **https://www.citypopulation.de/php/india-uttarpradesh.php**
4. **http://up.gov.in/upstateglance.aspx**
5. **http://djlorenz.github.io/astronomy/lp2006/colors.html**