An Assessment of Economic Disparity Using Night Light Satellite Data and Population Density in District Shahjahanpur

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Abstract

The study sought to investigate the economic disparity using Night Light satellite data and population density in district Shahjahanpur during 2015. The monthly average night light radiance and UN-Adjusted Population Density data were used. Spatial Autocorrelation (Morans I) technique was used to identify the pattern of the night light radiance and population density. Statistically significant hot spots, cold spots, and spatial outliers of night light radiance were found using the Anselin Local Moran's I statistic. Grouping Analysis tool was used to better comprehend nightlight data in relation with population density. The results show the spatial pattern of night light radiance (z-score 53.11) and population density (z-score 93.37) is highly clustered. Eight places were identified having low night light radiance but surrounded with high night light radiance (z-score ≤-1.67), however six places were identified having high night light radiance but surrounded with low night light radiance (z-score ◊-0.99142 &-0.661341). Under grouping analysis, group two (477 places) was identified having less night light radiance compare to population density. These places should be given more attention for the development of power to reduce the night light imbalance. This study may help the policy makers and planners to take the measures for the sustainable and balanced development of the Shahjahanpur district.

KYWOREDS: Night Light Radiance, Population Density, Autocorrelation, Grouping Analysis.

1 Introduction

The history of Night time Light map produced by EOG can trace back early as 1994, with the Operational Linescan Sensor (OLS) onboard Defense Meteorological Satellite Program (DMSP) satellites("VIIRS Nighttime Light," 2017).Night lights collected by the VIIRS instrument of NPP satellite delivers batter spatial resolution than DMSP-OLS night light data(Small et al., 2013). NOAA has developed a satellite data derived "Night Light Development Index" (NLDI) as a simple, objective, spatially explicit and globally available empirical measurement of human development derived solely from nighttime satellite imagery and population density(NCEI, 2012).

Nighttime radiance is more importantspecially in underdeveloped areas, where data are not easily available or of poor quality(Weidmann & Schutte, 2017).

Many researchers have developed the developmental indexes as "Night Light Development Index" (NLDI) is a simple, and globally available scientificmeasurement of human development derived solely from population density

and nighttime satellite imagery(Elvidge et al., 2012). Nighttime lights (NTL) can categorize different kinds of urbanization progressions(Zhang & Seto, 2013)
Urbanization is complexphenomena involving imbalanced transformation processes(Fan et al., 2014).
It is possible to investigatethe association between night lights and GDP (Bhandari & Roychowdhury, 2011), So far, night light data has received less attention to study human activities at local level (Xu et al., 2014).
The India Lights platform shows light output at night for 20 years for 600,000 villages across India. The Defense Meteorological Satellite Program (DMSP) has taken pictures of the Earth every night from 1993 to 2013. Researchers at the University of Michigan, in collaboration with the World Bank, used the DMSP images to extract the data you see on the India Lights platform("India Night Lights - ENERGYDATA.INFO," 2013).
The specific objectives of this work were set as;first, to find the night light radiance at village level, second to find the population density at village level,third to find the spatial pattern of night light radiance and population density, forth to identify theclusters of night light radiance and finally fifth to the groups of night light radiance in relation with population density.

2 Material and Methods

2.1 Study Area

This study was conducted at the village level in district Shahjahanpur (Fig. 01).Shahjahanpur lies 28° 15 39.37 N to 27° 28 21.28 N and 79° 21 22.98 E to 80° 20 40.38 E with the total area of about 4266 km2 and mean elevation of 160 m above sea level("Shajahanpur," 2016).

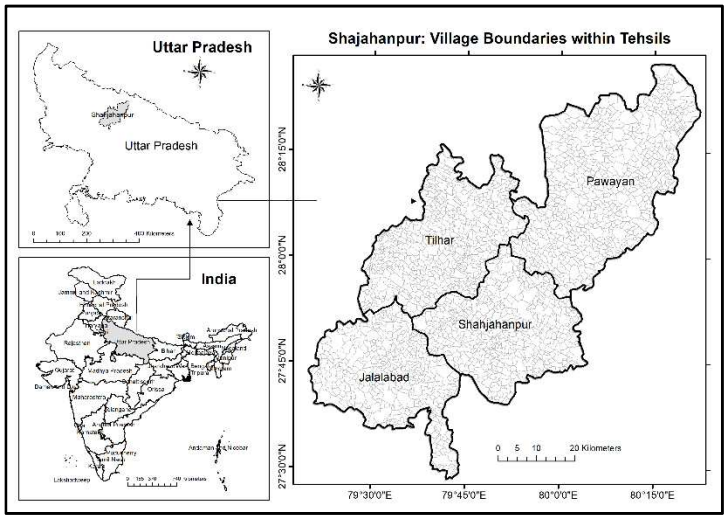

Figure 1 Study Area Map

2.2 Work Flow

The workflow is given in Fig. 02.

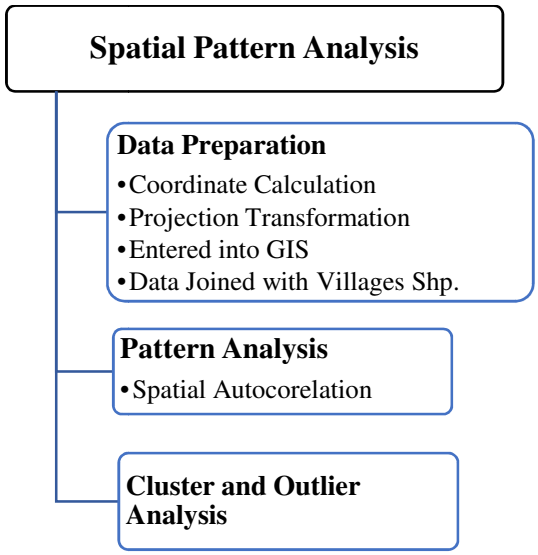

Figure 2 Work Flow

2.3 Data Used

The source and type of data used are given in table 01.

Table 01 Data Types and sources

Dataset	Format	Data Source
Night Light	tif	https://eogdata.mines.edu/products/vnl/
Population Density	tif	https://developers.google.com/earth-engine/datasets
Admin boundaries	Vector	https://www.diva-gis.org/gdata
Village level boundaries	Vector	https://sedac.ciesin.columbia.edu

2.4 Data Processing

- To find the pattern of radiance and population densitythe Spatial Autocorrelation (Global Moran's I) tool was used. This tool calculates spatial autocorrelation on the basis of both location and values of the features simultaneously. The pattern may be dispersed, clustered, or random, it depends on the location and the attribute values of the features.

The Moran's I statistic for spatial autocorrelation is given eq.1 to 5:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \quad \sum_{j=1}^{n} \quad w_{i,j} z_i z_j}{\sum_{i=1}^{n} \quad z_i^2} \qquad (01)$$

Where zi denotes the feature's attribute deviation from its average, is the spatial weightage in between feature j and i, n is the all number of features, and S0 is the combined of all the spatial weights:

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} \quad (02)$$

The z_i-score for the statistic is computed as:

$$z_I = \frac{I - E[I]}{\sqrt{V[I]}} \quad (03)$$

Where:

$$E[I] = -1/(n-1) \quad (04)$$

$$V[I] = E[I^2] - E[I]^2 \quad (05)$$

- To identify statistically significant hot spots, cold spots, and spatial outliers Anselin Local Moran's I statistic was used Eq. 06 to 10.:

$$I_e = \frac{\mathrm{x}_i - \bar{X}}{S_i^2} \sum_{J=i, j \neq i}^{n} w_{i,j} = \mathrm{X}_j - \bar{X} \quad (06)$$

Where x_i is the attribute value for feature i. X bar is the mean of the corresponding attribute, w_{ij} is the spatial weight between feature I and j, and:

$$S_i^2 = \frac{\sum_{J=i, j \neq i}^{n} w_{i,j} \, (\mathrm{X}_j - \bar{X})^2}{n-1} \quad (07)$$

With n equating to the total number of the features.
The z_{Ii} score for the statistics are computed as:

$$z_{Ii} = \frac{I_i - E[I_i]}{\sqrt{V[I_i]}} \quad (08)$$

Where

$$E[I_i] = -\frac{\sum_{J=i, j \neq i}^{n} w_{i,j}}{n-1} \quad (09)$$

$$V[I_i] = E[I_i^2] - E[I_i]^2 \quad (10)$$

1. To better understand radiance distribution in relation with population density grouping analysis was performed (Eq. 11to 14).

$$\text{Calinski} - \text{Harabasz pseudo F} - \text{statistic} = (R^2/n_c - 1)/(1 - R^2/n - n_c) \quad (1)$$

Where:

$$R^2 = \frac{SST - SSE}{\text{SST}} \quad (2)$$

and SST is a reflection of between-group differences and SSE reflects within-group similarity:

$$\text{SST} = \sum_{I=1}^{nc}\sum_{k=1}^{ni}\sum_{j=1}^{nv}(V_{ij}^{k} - \overline{V^k})^2 \quad (3)$$

$$\text{SST} = \sum_{I=1}^{nc}\sum_{k=1}^{ni}\sum_{j=1}^{nv}(V_{ij}^{k} - \overline{V_i^k})^2 \quad (14)$$

Where

n = the number of features

n_i= the number of features in group t

n_c= the number of classes (groups)

n_v= the number of variables used to group features

V_{ij}^{k}= the value of the k^{th} variable of the j^{th} feature in the t^{th} group

$\overline{V^k}$ = the mean value of the k^{th} variable

$\overline{V_i^k}$ = the mean value of the kth variable in group i

3 Results

3.1Night Light

The annual average of mean monthly radiance during the year 2015 is given in Fig. 02. The min. and max. radiance recorded 0.14 and 44.252nanoWatts/cm2/sr respectively. The mean annual radiancewas0.62nanoWatts/cm2/srwith a standard deviation of 1.63 nanoWatts/cm2/sr.

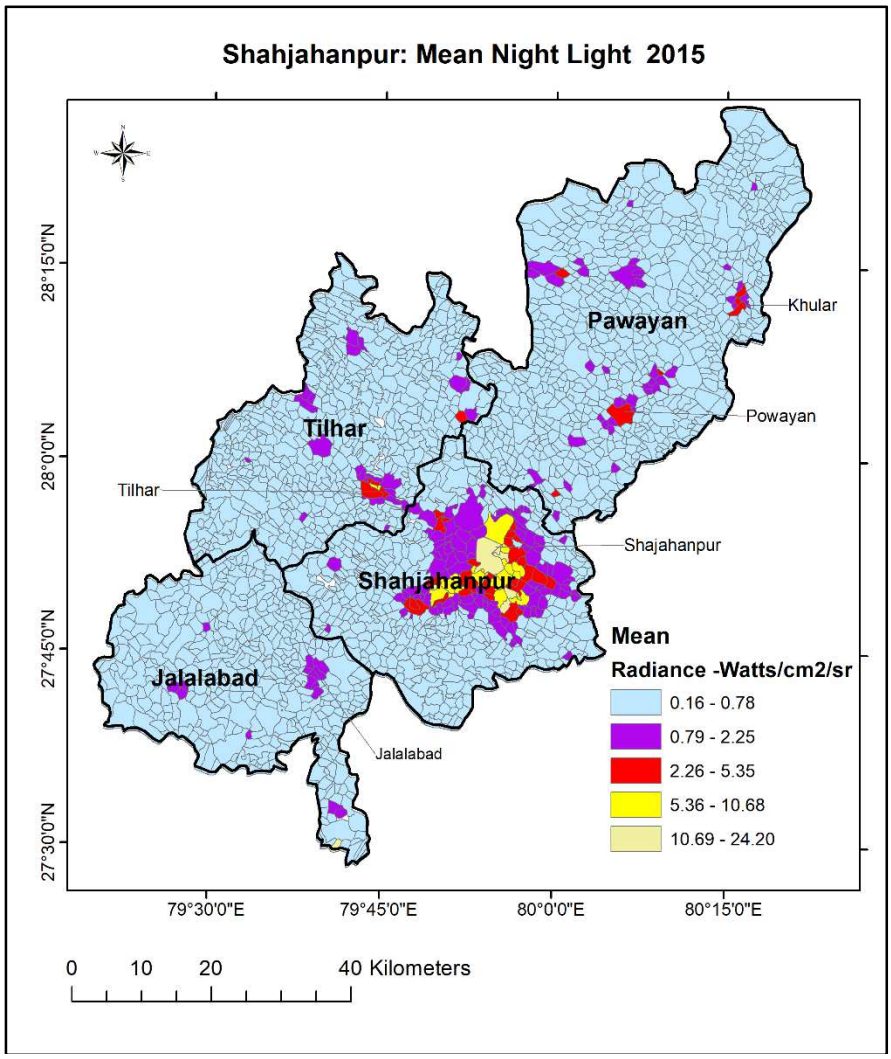

Figure 3 Mean night light

3.2 Population Density

The Population Density during the year 2015 is given in Fig. 04. The min. and max. radiance recorded121and1811 persons/km^{2}respectively. The mean Population Density was597persons/km2 with a standard deviation of 293persons/km2.

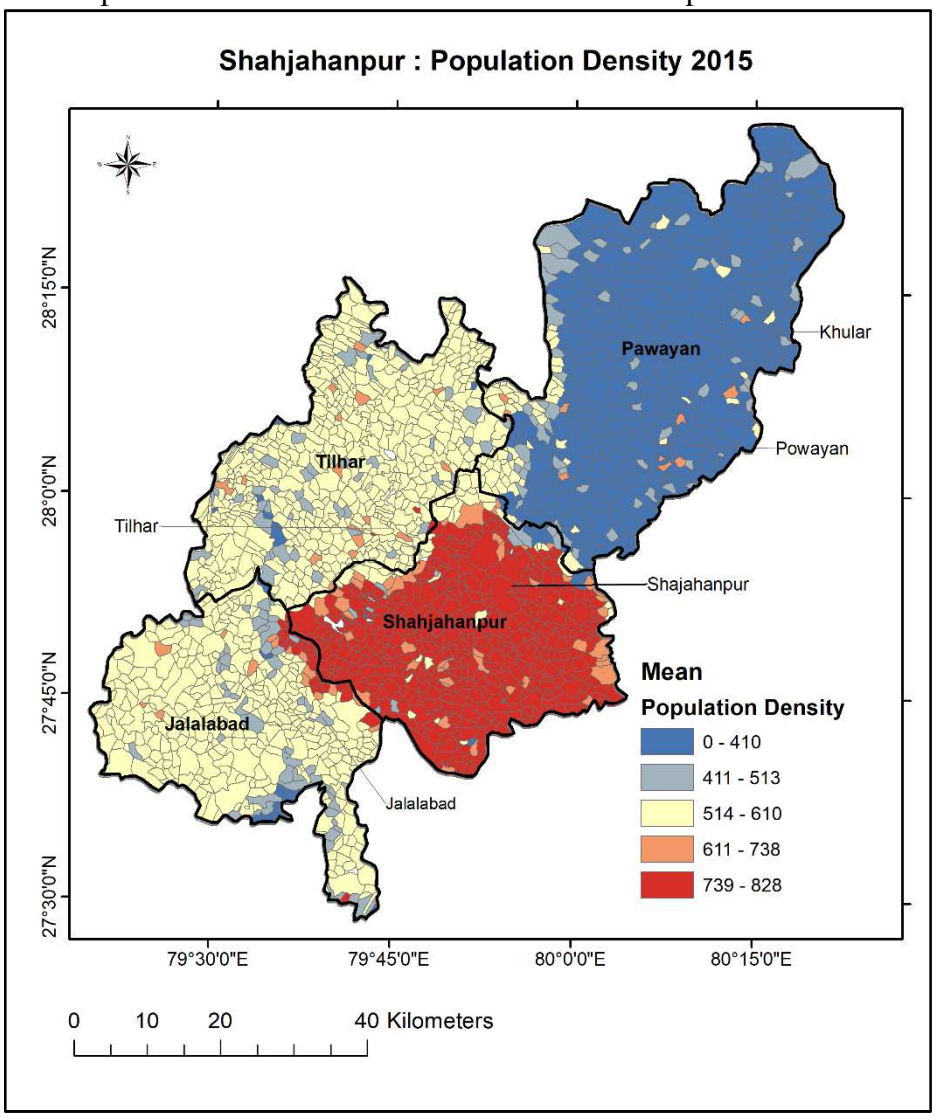

Figure 4 Population Density

3.3 Pattern of Nightlight and Population Density

The result of autocorrelation for pattern analysis given in table 02& Fig. 05 indicatesradiance and population density at the village level is highly clustered. Because the given z-scores of 53.11&93.37validates that there is a less than 1% probability that this clustered pattern may be due to random chance in both the cases.

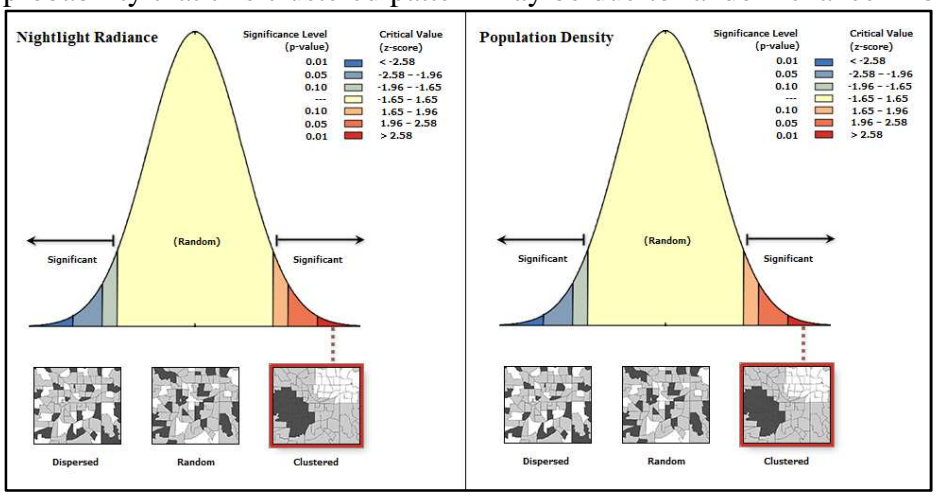

Figure 5 Spatial Autocorrelation

Table 02 Global Moran's I Summary

Item	NL Radiance	Population Density
Moran's Index:	0.481417	0.870117
Expected Index:	-0.000412	-0.000412
Variance:	0.000082	0.000087
z-score:	53.116559	93.375930
p-value:	0.000000	0.000000

3.4 Spatial distribution of Night Light

Statistically significant hot spots, cold spots, and spatial outliers are shown in figure 06.**The map shows Rarua, Rasulpurbujurg, Rampur hira, Madarpurvaiwaha, Jaitipur and Navadiapremraj are the places having higher radiance but surrounded by the places of low radiance, However the places Sunara Khurd, Khera Rath, BiddhalpurPrahaladpur, Baruara, Nagla Hazi, SaijnaMathu, Chandaupur and PuchDeoriya were having low radiance but surrounded by the places of high radiance.**

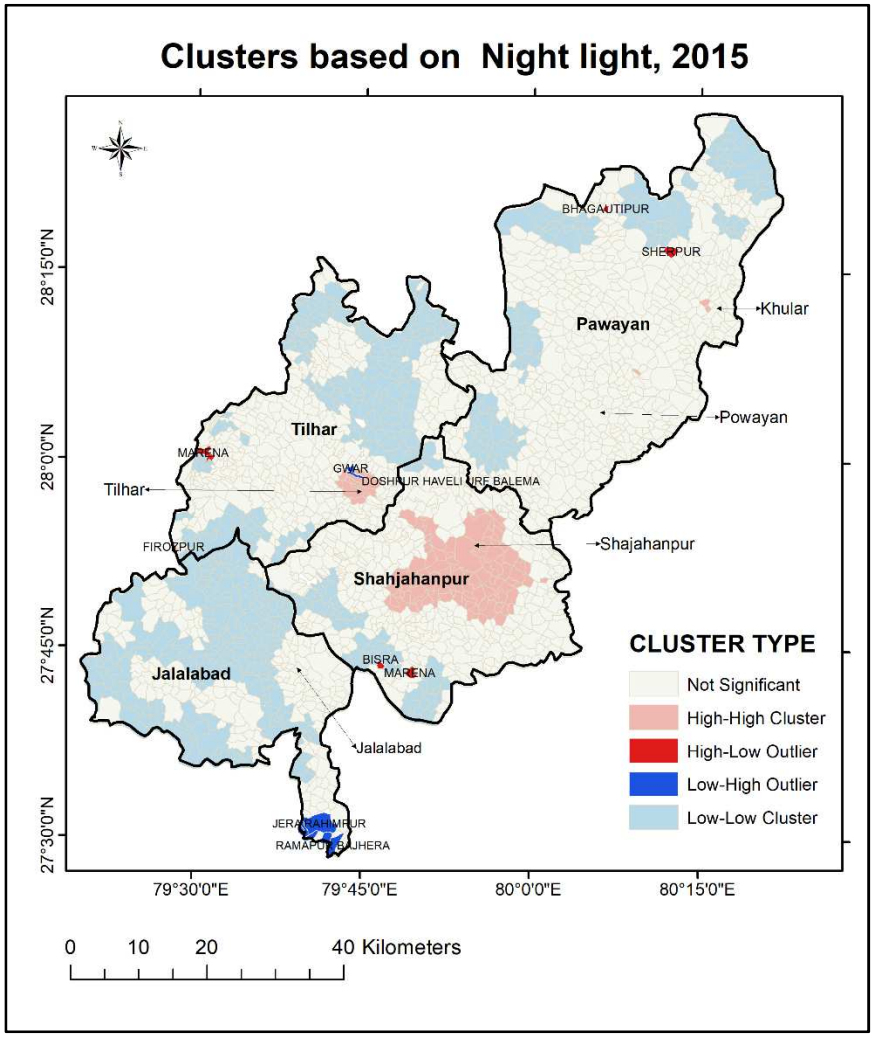

Figure 6 Clusters and Outliers

3.5 Groups of Night light in relation with Population Density

Figure 07& 08 shows the map of the groups of night light radiance& Parallel box plot chart respectively. Group numbers twois of special interest because in in this group night light radiance is less compare to population density as shown in the Parallel box plot chart (Fig.10).

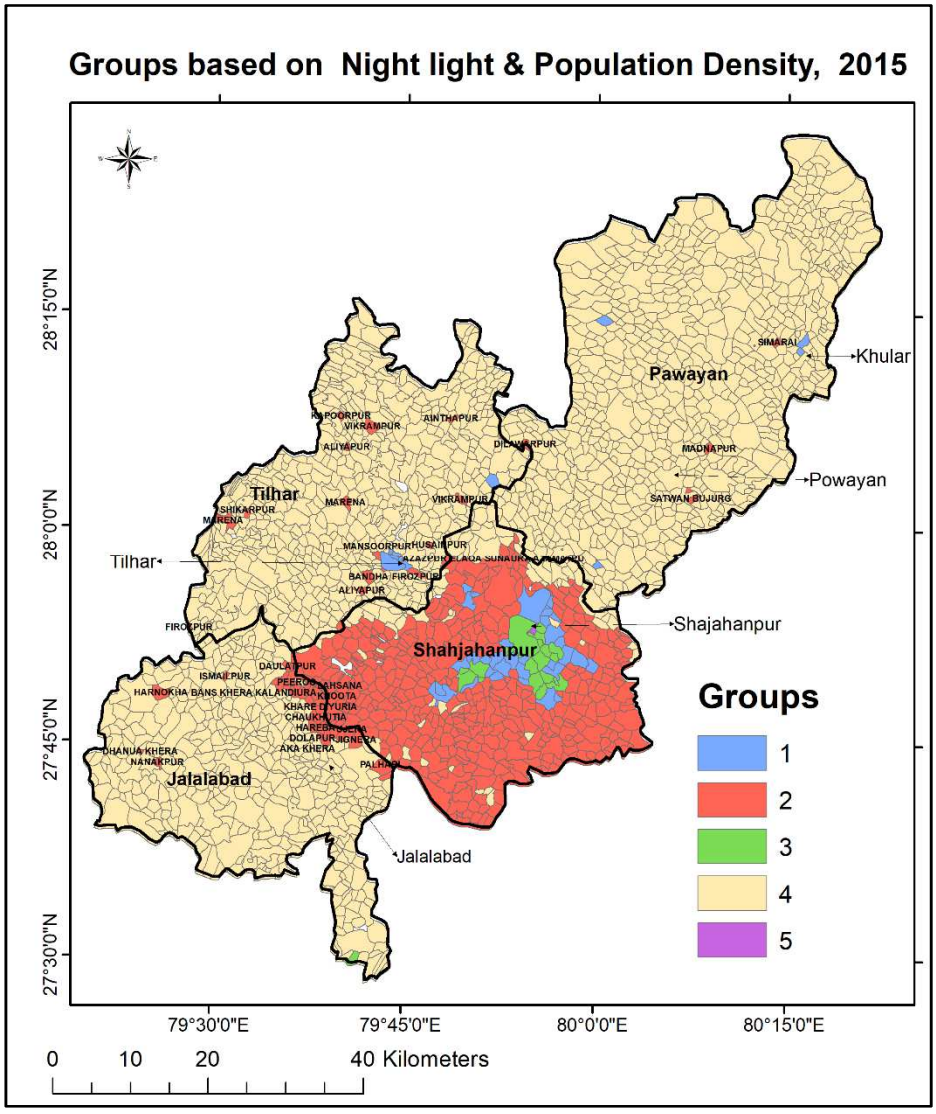

Figure 7 Groups

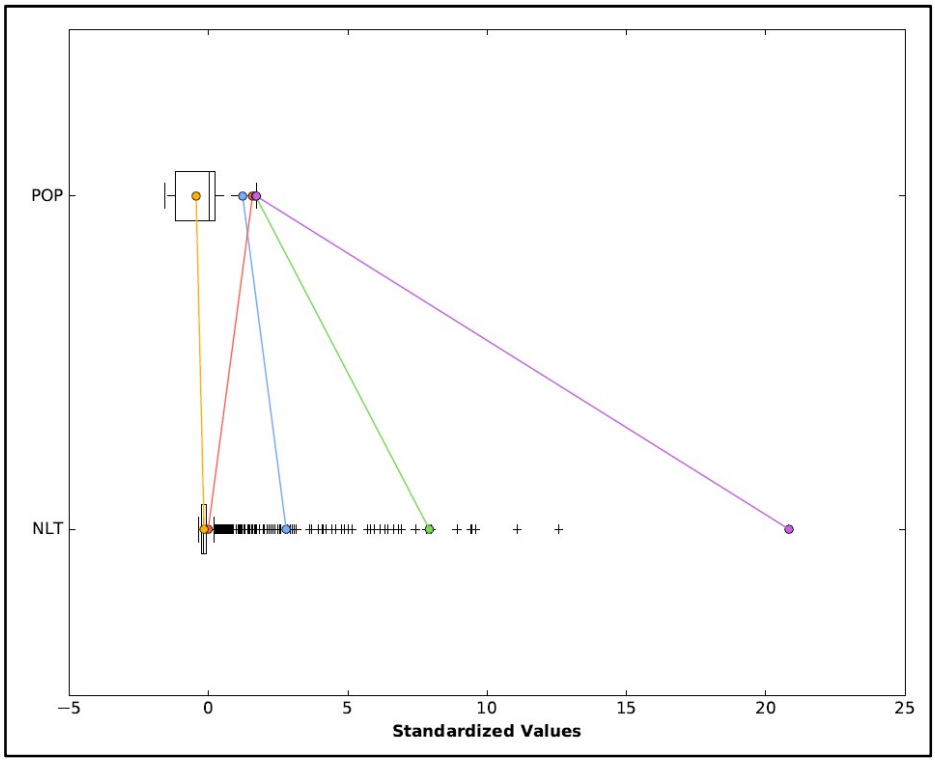

Figure 8 Box Plot

4 Discussion

Human developed lights at night directly observe human activity from space (Levin et al., 2020), so the use of night lights is increasing day by day. There were five objectives addressed, the results related to first objective shows the night light radiance, the top ten places were found around district head quarter Shahjahanpur suchas Durjanpur Kalan, Kishanpur Haripur, NizampurUrf Lah, NarainpurGovindpur, NawadiaMunjapta Kalan, Pazawa, Chatipur, GulalpurKhamaria, Sondha, Bangar, and Bahadurpur.However, the palces where very low night light radiation was found are as Durjanpur Kalan, Kishanpur Haripur, NizampurUrf Lah, NarainpurGovindpur, NawadiaMunjapta Kalan, Pazawa, Chatipur, GulalpurKhamaria, Sondha, Bangar and Bahadurpur. The results of the second objective of population density indicate Shahjahanpur tehsil has highest population density, while Puwayan has lowest population density.The spatial pattern of night light radiance and population density was found highly clustered, which is the direct influence of the road network, distance from the urban centers.The largest clusterof night light radiance was found around Shahjahanpur, second largest around Tilhar, rest small clusters were found in another tehsil, it clearly indicates the spatial distribution of economic development is highly imbalanced. Group number two, where 447 places were identified, is of special interest because this is the only group where night light radiance was found less than population density.In these group 33 places were found in Jalalabad tehsil, 13 places in Tilhar tehsil, 05 places in Pawayan and rest 423 places were found in Shahjahanpur tehsil, as names are given in the map. These places should be given more attention to reduce the inequality.

Conclusion

The analyses presented in this study confirm that night lights are apractically strong indicator of economic activity. It is possible to measure spatial and temporal variability in the level of development. If GDP data is available at micro regional level, it will help to validate the statistical significance of the data. There are certain limitations of using night- light data for economic measurement, as all economic activities are not merely depended on night light such as primary activities as agriculture. Despite its limitations, the findings of this research advocate that night-light information can be a valuable source of understanding for valuable economic analysis and research especially primary data deprived areas. New technology has a great influence on our understanding of human influence. So, it is needed to enhance the research in this fields for better and quick understanding of the man and nature interaction.

Declaration

I wish to confirm that there are no conflicts of interest associated with this publication. The author has no relevant financial or non-financial interests to disclose. The author declares that no funds, grants, or other support were received during the preparation of this manuscript. I further confirm that this manuscript has no ethical issue.

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