EasyChair Preprint

№ 6742

# Utilization of VIIRS Imagery in Analyzing Light Pollution as the Threat Towards Bird Sleep Performance in the Regional of Medan, North Sumatra, Indonesia

Rizki Atthoriq Hidayat, Muhammad Hanif, Giant Amor and H Hafizuurahman



October 3, 2021

# Utilization of VIIRS Imagery in Analyzing Light Pollution as The Threat Towards Bird Sleep Performance In The Regional of Medan, North Sumatra, Indonesia

Rizki Atthoriq Hidayat [0000-0002-7267-8756], Muhammad Hanif [0000-1111-2222-3333], Giant Amor [0000-0003-3379-7303], Hafizurahman H

Department of Geography, State University of Padang, Padang, 25171, Indonesia

rizkiatthoriq99@gmail.com

**Abstract.** The decline in biodiversity is strongly influenced by anthropogenic activities, especially land-use changes and urbanization that cause ecosystem imbalances, even causing ecological disasters. Population growth causes more massive human activities, both during the day and at night. This study will focus on human activities at night in excessive use of artificial light which causes light pollution which results in the disruption to the bird's sleep performance around densely populated areas of human activity. Excessive light causes disturbances in the balance of the surrounding ecosystem, especially the disturbance to the bird performance and behavior change so that this causes habitat stress. The focal area in this study is the region of Medan, North Sumatra Province with the consideration that this province is one of the most populated in Sumatra Island and the region of Medan is the densest in population because situated around the metropolitan area, which surely has massive human activities. This study aims to calculate the magnitude of the threat to the bird performance due to light pollution by utilizing the VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1 satellite image which was analyzed with GIS and Remote Sensing devices combined with infrastructure parameters to support the emergence of artificial light. This study found that 43,9 % of the area in The Region of Medan has light pollution with the highest threat in residential areas and is highly concentrated in Medan City. In the medium zone of bird occupation, the high polluted at the number of 91.2%, in the high zone of bird occupation the high polluted at the number of 0.54%. This threat has begun to penetrate the vegetated area (the forest edge) which is the natural habitat of various wild animals. The area that is less disturbed by the threat of light pollution is found in the northwestern part.

**Keywords:** light pollution, bird sleep performance, ecosystem, population

## 1 Introduction

Today, more than 68% of the world's population is projected to live in urban areas by 2050 [1]. It means that there will be alteration in many places such as land conversion

to become urban areas, also environmental issues related to higher consumption of artificial lights. Although artificial light has vital roles in many aspects of human activities, introduced lights become the pollution of the natural condition of dark night [2]. Light pollution is caused by several factors such as illumination source intensity, population growth, and aerosols and molecular absorption [3]. Urban growth is increasing and more people live in urban areas, it contributed to light pollution during the study period. The increase of artificial light on a global scale touches the rate of 2.2%. The increase of artificial light benefits the activities of humans at night, but this is an imbalance as the effect to other living creatures or the nature around the highly light polluted areas. Bird is one of affected objects of the light pollution that disturb the sleep cycle of bird, especially nesting on trees around the urban. Similar case with human can be highly disturbed by the light when sleeping, but human can avoid that by turning off the lamp or changing the lamp with more sleep-friendly while birds can not do so. Many bird species are in danger of extinction. The first reason that birds are going extinct is habitat destruction during a bird's migration, light attraction (or more aptly called entrapment) causes disorientation, which can lead to the bird to colliding with a lit building or with other birds. Once a bird flies into a light source, they are reluctant to leave the lit area and return to the dark [4].

From the other sides, the conditions in urban areas and urbanization zones have ecological consequences of light pollution. It is not limited to the downtown and suburban zones. This light pollution extends along highways and around protected areas. While there is clearly no single cause of insect decline due to light pollution, every identifiable threat variable is a point for better management plans. In addition, artificial light at night or ALAN is relatively easy to manage, and it can greatly reduce the loss of insects that are a source of bird food [5]. The effects could change the bird movement, settlement and habitat selection, and even transform distribution of bird in a large spatial scales [6].

Indirectly, light affect the shifting of circadian clock [7] like the illustration besides. This shifting could be lowering performance at the day and make birds are vulnerable to the attack of predators, so this case potentially impacts the imbalance within particular ecosystem.

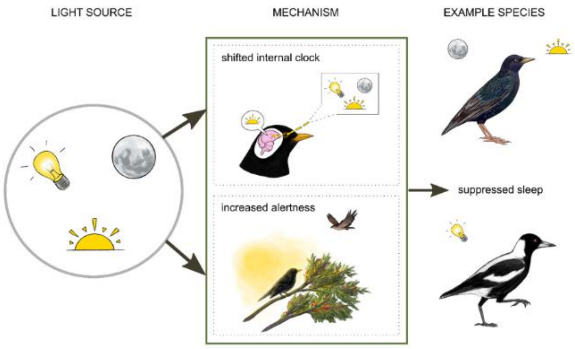


**Fig 1.** Exposure to light can suppress sleep in birds [8].

Much evidence has been collected that natural and artificial light radiation ALAN interferes with the time needed for sleep in diurnal birds. Sleep is needed by the living body for the restoration of cognitive performance in birds, including during early development. More light leads to reduced natural sleep time for birds [8]. This light pollution condition causes behavioral changes. It is believed that there may be physiological variations in bird responses to light, perhaps driven by differences in evolutionary history. Sleep deprivation that occurs in the wild, such as through exposure to light pollution, affects bird learning and memory. Impairments in cognitive performance are important for survival and reproduction [7. 8].
In this research, we want to demonstrate and analyze how the artificial lights impact the bird sleep performance in the spatial perspective as the aim in this study, so we can discover the locations of light pollution towards bird sleep performance in multiple levels using remote sensing data (satellite imagery) and Geographic Information System (GIS) analysis as the development and the extension of the hand of previous researches.

# 2 Data and Methodology

### 2.1 Data

In the process of carrying out this research, several types of materials or data were used, all of which we obtained free of charge from cloud computing data providers. The data used is Sentinel 2A satellite imagery which is a product of the European Union for environmental observation, the satellite image used has a spatial resolution of 10m. These satellite image used to map the land cover classes. Then this sentinel satellite image is also used to obtain information of vegetation density or vegetation index. We use Night VIIRS imagery which is a satellite image recording the earth's surface at night. This data has the capability to detect faint sources of visible near-infrared (VNIR) emissions on the Earth's surface [9]. Both of these data, Sentinel 2A and Night VIIRS satellite imagery, were obtained and processed in Google Earth Engine cloud computing technology. The supporting data used is the administrative boundary at the research location to facilitate regional orientation and description, the administrative boundary data is obtained free of charge from the website http://tanahairindonesia.go.id. Remotely sensed data processed using Google Earth Engine Platform then analyzed using QGIS application as the further spatial data processing.

### 2.2 Analysis Data

The integrated spatial analysis use cloud data for identifying the threat of environment to biodiversity using GIS are able to represent the distribution on the existing conditions of land cover [10]. The technological context of the proposed approach includes GIS and SRS techniques [5. 9].

### 2.2.1 Random Forest Classification

To obtain the land cover on the research area can also by interpreting the Imagery using image classification [11]. Image classification is a computation process to classify pixels by statistical model to group pixels for land cover identification. This image classification works by calculating the pixel values from each sample of the training area, then other areas which have the same cluster pixel value with marked location will be in the same class [12]. The Random Forest ensemble method is a processing technique in data classification to improve data accuracy [13]. In this research we use random forest classification. Random Forest is a data mining technique with the principle of decision tree. A random forest consists of a structured data set where each data or cell will push a vote for the most popular group on input (x) [14].

### 2.2.2 Normalized Difference Vegetation Index (NDVI)

The vegetation indicated the common character for occupancy of birds. Different vegetation facilitates different bird occupancy based on its density or canopy cover. NDVI is an approach we utilize to extract the information of bird occupation probability. NDVI is often used to evaluate the relationship between species distributions and the productivity of vegetation in broad both spatial and temporal scales [15]. NDVI used as the measurement the greenness and the difference between NDVI form the season of leaf-on and leaf-off to measure the deciduousness [16]. So, in this study is also effective in evaluating bird distribution estimation. NDVI value then classified become three classes (low, moderate, high) which the higher the NDVI value represents the higher bird occupancy. NDVI Value can be computed by transforming Sentinel 2A remotely sensed data using both Near Infrared (Band 8) and Red (Band 4) band [17].as this following equation

$$NDVI = \frac{Nir - R}{Nir + R}$$

Where:
NIR = Near-Infrared Band
R = Red Band

### 2.2.3 Overlay Data

The next stage in this research is an analysis area that was impacted by light pollution. It was carried out in the overlay technique for determining the dominant spot of the threat zoning [10]. After the information about bird occupancy potential and light intensity derived, both information then overlaid using intersection geo-processing tools in QGIS to observe the area of light pollution impact towards bird sleep performance.

## 3 Result and Discussion

In the first stage, we designed data on environmental variables that became the basis for assessing indicators such as habitats for bird species. We need to emphasize that the potential zones where bird species live are a regional approach that is common to all bird species, we do not discuss specific bird species with specific bird species characteristics or characteristics. In this study, there are two main approaches that we use as the basis for assessing the potential of bird occupancy, namely land cover and vegetation density, because in general, mainland birds will only make daily movements to find food and return to their nests or landscapes of trees and shrubs to occupancy. Landscape assessment by determining the type of land cover is based on the fact that in general bird species will have occupancy in forest landscape and vegetation types. We also approached the vegetation density approach, because from the literature study the majority of small to medium-sized bird species in herbivorous and omnivorous groups favor dense leafy vegetation for occupancy and hiding strategies from predators. The natural landscape of vegetation with dense vegetation conditions is a source of diversity of insect species which is also a source of food for bird species. In this study, random forest and NDVI algorithms have been applied for making the land cover and vegetation density maps from the extraction of Sentinel 2A satellite imagery, which many previous researchers did research that this algorithm is more established for making the land cover and vegetation density maps. Natural ecosystems belonging to vegetation in high density are habitat for many species. It is the key variable to measure the potential area for bird's occupancy and migration [10. 11].

From the diagram in general, it has been revealed that the landscape at the location of this study is covered by a landscape that has vegetation. From the calculation of spatial geometry, we find that in the first group there are plantation landscape stands at the number of 40.21%, in the second position is forest landscape at the number of 15.38%, in the third position is a mixed farm at several 11.23%. Vegetation density conditions have variations, in this study, we grouped vegetation density into three classes, low density stood at the number of 33.54 vegetation high density at the number of 33.33%, the last is the vegetation moderate density at the number of 33.13%.

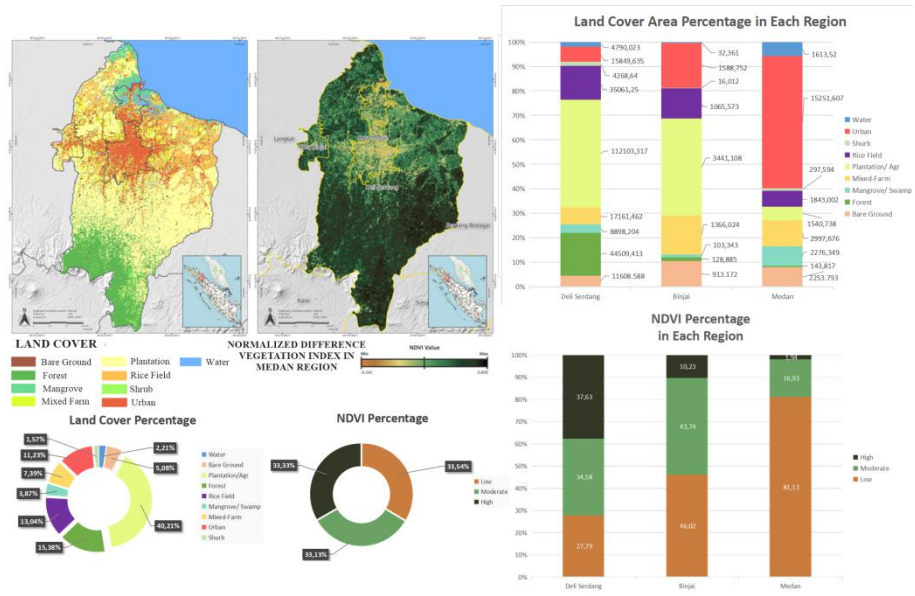


**Fig. 2.** Land cover classification and NDVI map

This study has involved three administrations which are namely Medan, Binjai, and Derli Serdang. We calculate the land cover area based on this administration to make it easier to describe and explain the narrative of any information we find. The Medan city area is dominated by built-up areas or settlements, and Binjai stands in the second position with a large built-up area, and the last area has a small size of the built-up area is Deli Serdang. Ecosystem land cover with natural vegetation in the form of the forest is the widest in the Deli Serdang area, and is in second place is Binai. The majority of the area in the Deli Serdang and Binjai sub-districts are plantations, if we look at satellite imagery, the real image of this land cover is in the form of oil palm plantations.

In the next stage, we did an overlay of land cover and NDVI maps to create a potential area for the bird occupation. From this calculation, we determine the zones most favored by birds for shelter into several groups. It aims to facilitate the identification and qualitative representation of the area. We provide an assessment of each type of land cover and vegetation density. By considering the results of the literature study, we conclude that the condition of vegetation or natural ecosystems is more attractive to various types of birds to settle down than being in the human environment. Nevertheless, high-density vegetation is also more in demand by various bird species than sites with little or no vegetation.

The DMSP satellites have the capacity to object on the earth using visible near-infrared (VNIR) it reveals emissions on the Earth's surface. This technology was also developed for investigation and mapping of the nighttime emission [18. 23]. The artificial light at night or ALAN is represented by VIIRS Imagery.

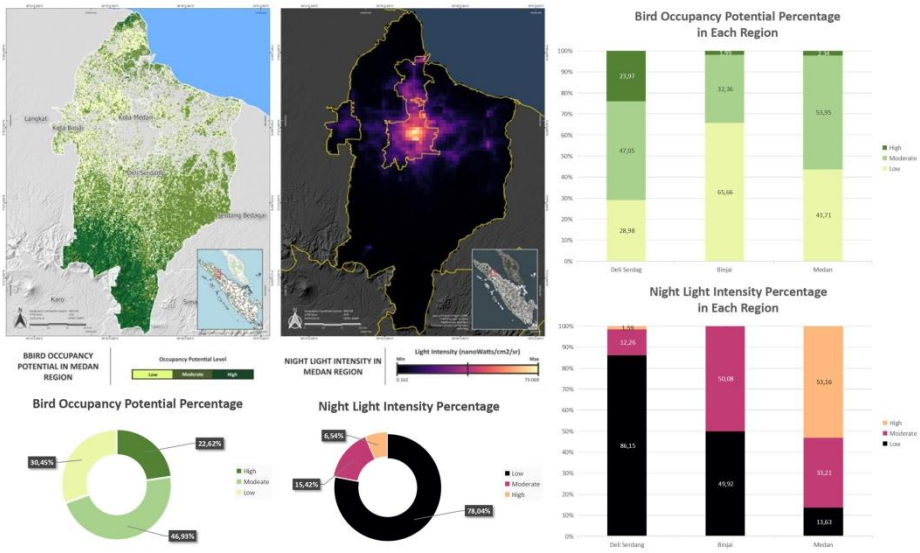


**Fig. 3.** Bird occupancy potential and night light intensity map and analysis

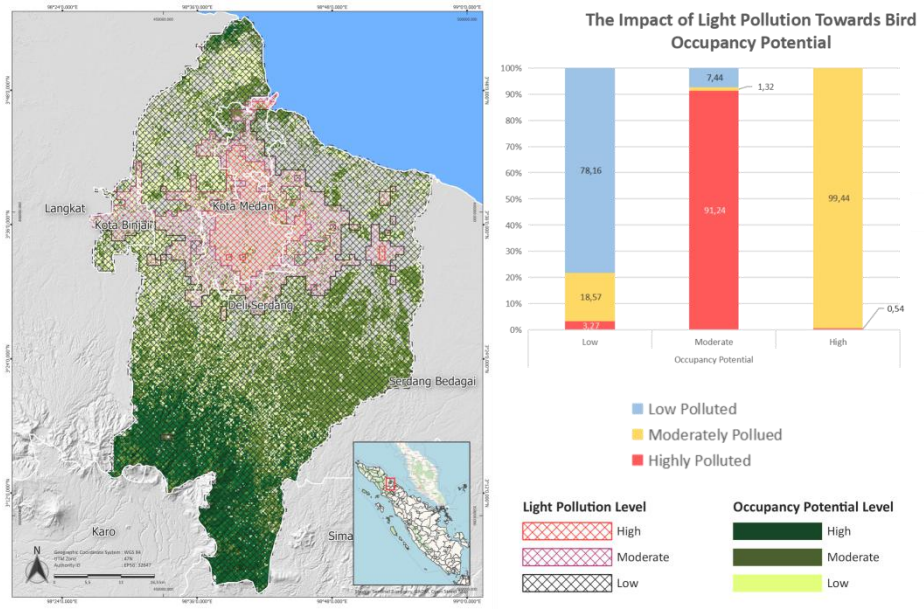


**Fig. 4.** The Impact of light pollution towards the bird occupancy potential.

Overall from the map image above, we can observe the Impact of Light Pollution on Bird occupancy. The main spot with the brightness level of the pixel value in this

satellite image covers an area or location with land cover conditions in the form of settlements. In the VIIRS satellite image coverage, object information on the earth's surface is recorded in the form of pixel values then this value are grouped into three classes of light pollution levels at night. The pollution zone is centered on the city of Medan which is the capital of North Sumatra Province. This city has a large population density and settlements as well as active urban activities, so the consumption of electrical energy for lighting equipment in the form of lamps with a fairly large light spectral is evident from the results of the Night VIIRS satellite image recording.

With this spatial analysis approach, we assess that bird species experience disturbances in their natural life cycles in locations that have high and moderate potential for bird occupancy. Locations polluted by radiation from light pollution on bird occupancy are in low and moderate classes. Zones with high bird occupancy potential experienced the threat of light pollution in the moderate polluted group. We can see that the location of the high and moderate bird occupancy zone is believed to have a large population of birds. This pollution condition is very disturbing the natural cycle of life. This wild bird has distortion problems adapting to bright artificial light at night. It further threatens the stability of the physiology of birds and the environment. The disturbance effect of light pollution on the environment for bird occupancy is not a single effect, because disturbance in one species will disrupt other living systems in a natural ecosystem. The location of this research with physiographic conditions that are on the coast, will involve many bird species, not only bird species with nocturnal nature but also diurnal species. The level of light pollution will disrupt the habits and lifestyle of birds, which will not only affect the number of hours of sleep but also the migration pattern.

Form literature, the effects of artificial light on moths at different stages of their lifecycle. They note that it is not fully understood why moths exhibit phototaxis (flight-to-light) or why they exhibit a diversity of behaviours at light sources including spiralling around it, crashing into it, settling at a distance or ignoring it [19]. Increasing day length on the light intensity has a strong effect on some bird production and, therefore, indirectly, on reproduction; chronically low light intensity at night can dramatically affect the reproductive system [6. 20]. has been much preliminary evidence that sleep needs affect spatial learning abilities in birds. This spatial learning ability is very important for wild birds, considering the location, understanding the orientation of different positions such as home ranges and the location of sources or storage of food is very important for survival, especially in extreme environments. There it was found that the chicks spent more time sleeping after learning the spatial discrimination task. Further research shows a link between closing one eye during sleep and spatial learning [21]. Some nocturnal bird problems experience this form of disorientation often leading to death by exhaustion, which occurs after a dramatic increase in flight time, but also directly by a collision with a light structure [22. 24]. The existence of the distribution of lights in the urban environment and street lights can interfere with sleep at night even in birds that are adaptable and tolerant to urban environments [5. 23. 25]. The problem of light pollution in the urban environment and urbanization has a strong relationship. This

occurs gradually from reduced sleep time, behavioral changes, weakened brain abilities and disruption of the natural ability of spatial navigation for many birds. Spatial distribution of light pollution to the environment with vegetation and land cover conditions which are potential locations for birds to stay scattered around residential areas. This spatial distribution condition is able to become the basis for affirming more effective spatial management to maintain the natural balance of living things with normal needs.

## 4 Conclusion

From the Spatial analysis can be used to identify the impact of light pollution on bird sleep performance. According to the result, In the region of interest, problematic points are: Highly polluted areas 6,54% of the total area of research location and mostly in highly urbanized areas) cover moderate occupancy potential of birds over 91,24% and moderately polluted areas (15,42% of the total area of research location) cover high occupancy potential of the bird over 99,4%. While the low polluted areas dominant, 78,04% of the total area of research location) as the highly tolerated site for bird sleep cover 78,16% of low bird occupancy potential. According to this research, we suggest that in urban areas to use sleep-friendly light, it especially streetlights such as amber light, and/ or filtering the scatter of light by covering light surrounding that directs the direction of light exposure straight to the ground. For better validation, we also suggest using real bird occupancy coordinate data, so we can calculate the number of the affected population.

## Acknowledgement

We say thanks to all of member joining in finishing this research. Thanks to committee of INCREASE conference which give an opportunity to presenting this article in this conference and also to and USGS for providing open-source remote sensing data.

## References

[1]. United Nations Department of Economic and Social Affairs, “68% of the world population projected to live in urban areas by 2050, says UN,” UN DESA, 16th May 2018. [Online]. Available: https://www.un.org/development/desa/en/news/ population/2018 -revision-ofworld- urbanization-prospects.html

[2]. Azman, M. I., Dalimin, M. N., Mohamed, M., & Bakar, M. A. (2019, July). A Brief Overview on Light Pollution. In IOP Conference Series: Earth and Environmental Science (Vol. 269, No. 1, p. 012014). IOP Publishing.

[3]. Shirkey R.C. (2006). A Model for Nighttime Urban Illumination. Modeling and Simulation Conference. Dec 11-14, 2006, Las Cruces, NM.

[4]. Pimm, S., Raven, P., Peterson, A., §ekercioglu, Q. H., & Ehrlich, P. R. (2006). Human impacts on the rates of recent, present, and future bird extinctions. Proceedings of the National Academy of Sciences of the United States of America, 103(29), 10941-10946. doi: 10.1073/pnas.0604181103

[5]. Owensa S.C Avalon C.S, Cochardb Précillia, Durrantc Joanna, Farnworthd Bridgette, Elizabeth K. Perkine, Brett Seymouref. 2020. Light pollution is a driver of insect declines. Biological Conservation 241 (2020) 108259. https://doi.org/10.1016/j.biocon.2019.108259

[6]. Adams Ann Carrie, Blumenthal Arden, Esteban Fernández-Juricic, Erin Bayne and Colleen Cassady St. Clai1. 2019. Effect of anthropogenic light on bird movement, habitat selection, and distribution: a systematic map protocol. Journal Environmental Evidence. https://doi.org/10.1186/s13750-019-0155-5

[7]. Aulsebrook AE, Lesku JA, Mulder RA, Goymann W, Vyssotski AL and Jones TM (2020) Streetlights Disrupt Night-Time Sleep in Urban Black Swans. Front. Ecol. Evol. 8:131. doi: 10.3389/fevo.2020.00131.

[8]. Aulsebrook, A.E.; Johnsson, R.D.; Lesku, J.A. Light, 2021. Sleep and Performance in Diurnal Birds. Clocks&Sleep 2021, 3, 115–131. https://doi.org/10.3390/clockssleep3010008.

[9]. Huang Qingxu, et al. 2014. Application of DMPS/OLS Nighttime Light Images: A Meta-Analysis and a Systematic Literature Review. Journal Remote Sensing MDPI. https://10.3390/rs6086844

[10]. Hidayat R A, Hanif M. 2020 a. Spatial Modeling of the Threat of Damage to the Peatland Ecosystem In the Mainland of Bengkalis Regency, Riau Province. Journal Social Polites. Special Issue Youth Peatland Conference. e-ISSN 2620-4975.

[11]. Hidayat A R, et al. 2020 b. Modeling of Conservation Priority Zone for the Helmeted Hornbill (Rhinoplax Vigil) In Silokek Geopark Area, West Sumatra. Preprints (www.preprints.org). Posted: 27 September 2020. doi:10.20944/preprints202009.0676.v1

[12]. Hanif M, et al. 2019. Multi Spectral Satellite Data to Investigate Land Expansion and Related Micro Climate Change as Threats to the Environment. IOP Conference Series: Earth and Environmental Science. 303. doi:10.1088/1755-1315/303/1/012030

[13]. Han, Jiawei. 2012. Data Mining Concepts and Techniques Third Edition. USA: Elsevier.

[14]. Breiman Leo. 2001. Machine Learning. Berkeley: University of California.

[15]. Vogeler, J. C., Hudak, A. T., Vierling, L. A., Evans, J., Green, P., & Vierling, K. T. (2014). Terrain and vegetation structural influences on local avian species richness in two mixed-conifer forests. Remote Sensing of Environment, 147, 13-22.

[16]. Swatantran, A., Dubayah, R., Goetz, S., Hofton, M., Betts, M. G., Sun, M., ... & Holmes, R. (2012). Mapping migratory bird prevalence using remote sensing data fusion. PloS one, 7(1), e28922.

[17]. Barbosa, H.A., Huete, A.R. and Baethgen, W.E. 2006. A 20-year Study of NDVI Variability over the Northeast Region of Brazil. Arid

Environments 67: 288-307. Shelf Sci. 80: 435 – 471. https://10.1016/j.ecss.2008.09.003

[18]. Elvidge, C. D., Cinzano, P., Pettie, D. R., Arvesen, J., Sutton, P., Nemani, R., Longcore, T., Rich, C., Safran, J., Weeks, J. R., and S. Ebener, 2007, "The Nightsat Mission Concept," International Journal of Remote Sensing, 28:2645–2670.

[19]. Boyes, D.H., Evans, D.M., Fox, R., et al. 2021. Is light pollution driving moth population declines? A review of causal mechanisms across the life cycle. *Insect Conservation and Diversity*. doi: 10.1111/icad.12447.

[20]. Dominoni M David. 2015. The effects of light pollution on biological rhythms of birds: an integrated, mechanistic perspective. Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Glasgow, UK. Springer. http://eproofing.springer.com/journals

[21]. Nelini, C.; Bobbo, D.; Mascetti, G.G. Local sleep: A spatial learning task enhances sleep in the right hemisphere of domestic chicks (Gallus gallus). Exp. Brain Res. 2010, 205, 195–204.

[22]. Gil Diego and Henrik Brumm. 2013. The impact of artificial light on avian ecology. Print ISBN-13: 9780199661572. Published to Oxford Scholarship Online: May 2015. DOI: 10.1093/acprof:osobl/9780199661572.001.0001

[23]. Mohsin Jamil Butt1. 2012. Estimation of Light Pollution Using Satellite Remote Sensing and Geographic Information System Techniques. GIScience & Remote Sensing, 2012, 49, No. 4, p. 609–621. http://dx.doi.org/10.2747/1548-1603.49.4.609

[24]. Foott Bettymaya. 2015. Light Pollution Hazards Within Ecosystems and Mitigation Strategies for the Future. A Senior Honors Thesis Submitted to the Faculty of The University of Utah. In Partial Fulfillment of the Requirements for the. Honors Degree in Bachelor of Science.

[25]. Shirkey, R. C., 2006, A Model for Nighttime Urban Illumination, White Sands Missile Range, NM: U.S. Army Research Laboratory, Computational and Information Sciences Directorate.