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Development of Green Zone Energy Mapping for Community-based Low Carbon Emissions

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***Abstract*—The world is heading to digital industrial 4.0; this means everything must be connected. In another-word, energy consumption demand will elevate exponentially scale. Smart-green sources are being substantial to save the sustainability of energy and the environment. The development of green energy alternatives, with low-zero emission sources, becomes potential. However, the urban-city initiative's monitoring and active-management energy pattern are more effective than investing in a new renewable energy source. This paper proposes a new method to build a regulation-system that monitors excessive energy used from the radiance threshold of night-time satellite data. This research dataset consists of light-meter surveys, DMSP-OLS and NPP-VIIRS night-time satellite datasets, and other supporting data. The outcome is a class-criteria zone energy map with three criteria class, ambient, moderate, and excessive. The radiance threshold class determined from cross-analysis of night-time satellite data with light-meter surveys through regression analysis. The histogram of radiance distribution reveals the profiling of the class-criteria. Results show moderate-class becomes a key to attention and can be used to disclose any aspect of spatial-temporal dynamical of urban-cycle. By using this method provides an effective way of assessing energy uses with space-technology.**

***Keywords*—radiance; threshold; energy mapping; carbon emissions; night-time.**

I. INTRODUCTION

The world becomes globally; thousands of people do tours to any place in the world and consume colossal energy. Destination country set up tens of new hotels; commercial, residential buildings had completed and operated. All are equipped with various mechanical and electrical equipment that continuously draw electricity in 24h a day. Over the past century, continuously increasing population and economic development directly induced a high-rise of CO_2 emissions worldwide, especially in rapidly developing countries [1]. The human socio-economic activities closely related to these emissions cause an enormous threat to the natural environment and human society in the world [2], [3]. This treat initiates global warming and climate change and is the most important environmental problem in the last two decades [4], [5].

The Bali tourism industry's original concept inspires by traditional-art, religion, culture, and respectfully to the environment. Unfortunately, developments lead to precious modern concepts that draw huge electricity and become supplying issues. Bali electricity demand is set to grow with a customer's rate of 8.5 percent per year. Customers dominated by business followed by household, industrial type only two percent of total customers. Customers' locations are mostly concentrated in southern Bali, Denpasar city, and Badung regency [6]. Bali population has 1.62 percent of total national (about 258.7 million) and the tourism growth rate of 23.1 percent (about 11.5 million) [7].

The efficiency of energy on the tourism and hospitality sector is not just the result of investment in sophisticated technology but also modified by monitoring and active energy consumption [8]. The role of the community in reducing carbon emission and saving energy is essential [9]. Community initiatives can be carried out by increasing efficiency using energy-saving technologies and behaviors in the commercial and residential sectors.

To maintain the sustainability of electricity due to the rapid development of Bali's tourism industry. Excessive lighting energy overlaps and accumulates into a source of light energy pollution that is monitored up to remote sensing satellites [10]. However, research that has been carried still limited, more comprehensive, and holistic analyses needed. Research and regulations that relate to the role of community or stakeholders in reducing carbon emissions and saving electricity in Indonesia have not been regulated well and limited. It is urgent to carry out fundamental research to build low-carbon emission societies, generally in Indonesia. It must especially use over the top technology to solve the fundamental problem, such as satellite remote sensing technology [11].

This paper has a theme of low-carbon emissions, community-based initiative, and energy savings using night-time satellite data. This paper aims to present the analysis results of light source aspects from surveys and implement an index of radiance threshold class from a long-term dataset of night-time satellite data. First, this paper provides the methods in implementation. A brief introduction to the night-time satellite program shows results and discusses maps of index threshold class from night-time satellite data. Then, this paper concludes results to promote a low carbon emission and energy-saving concept for Bali. Also, propose the best recommendation for stakeholders in law enforcement of light threshold limitation regulation.

II. MATERIALS AND METHOD

A. Night-time Satellite Data

Satellite remote sensing data has been widely used in various mapping regions that solved problems within wide area coverage, even global. Moreover, satellite remote sensing has capability on temporal or re-visiting time, multi-spectral, multi-polarization, and carried many types of sensors. Satellite remote-sensing of low-light night-time imagery carries sensors that observe low-light at night-time on the earth's surface from human-made light and natural lightings, such as flames from volcanoes, forest fires, and gas combustion in oil fields. The night-time light can be used as an indicator of human activity that measures satellites in space and is very suitable for mapping various settlement problems [12]. Applications of low-light night-time satellite data open on various applications such as socio-economic problems as in [13], [14]. It uses spatial distribution and growth of the human population as in [15], [16]. Estimation of overall energy and energy consumption as in [17], [18], computation of economic growth rates [19], [20], tracing gas emissions from anthropogenic [21], [22] and other estimation of indices.

There are only two operational satellites with NASA's low-light night-time imagery mission, namely the Defense Meteorological Satellite Program (DMSP) Operational Line-Scan System (OLS) and the National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS).

1) DMSP OLS data: The OLS instrument onboard on the DMSP satellite is a passive panchromatic low-light imaging operates at 0.47 to 0.95 μm channel. OLS sensor uses a photomultiplier tube (PMT) to collect radiance ($Wcm^{-2}\mu m^{-1}sr^{-1}$). The instrument is an oscillating scan device with visible and thermal-infrared bands designed to map clouds in both day and night with a swath wide of 3000 km. DMSP satellite is a sun-synchronized polar orbit, with local overpass times at descending and ascending node at 08:30 and 20:30, respectively. OLS data delivered to the end-user within 6-bit quantization of digital numbers (DN) ranging from 0–63 format [23]. The OLS has no onboard calibrator. Sensor will saturate over bright city areas. The calibration steps are needed to correct saturation and inconsistent data sensor in several years of the mission [24-26]. The DPMS OLS starts operational in year 1992 and ends in 2013.

2) NPP VIIRS data: The VIIRS instrument onboard on the NPP Satellite with 827 km altitude polar orbit and night-time overpass at 01:30 AM. The VIIRS sensors have 3000 km swath width, 0.742 km spatial resolution. The low-light sensor is panchromatic imaging band-pass 0.5 to 0.9 μm, 14-bit data quantization without saturation. The sensor has a detection limit to 2e-11 $Wcm^{-2}\mu m^{-1}sr^{-1}$ and uses onboard solar diffuser to calibrate day-night band (DNB) data. The VIIRS has mission objectives to imaging night-time on visible band of moonlight clouds in NOAA Technical Report (2013) [27]. The VIIRS starts operational in year 1992 until present.

B. Light Meter Surveys Data

The measurement of light meter aims to enforce stakeholder decisions. The location of sampling point initially obtains from the threshold criteria map of DMSP-OLS VIIR data. Surveys carried out with GPS and GIS utilities. Measuring instruments used are a highly sensitive radiance lux meter (MS6612 model) and meteorology meter i.e. temperature scanner, anemometer, humidity, and GPS. Measurement points determined where the light strongest occurs, in a 1 Km square area that same as spatial resolution of DMSP-OLS VIIR data. A highly sensitive lux meter provides 0.01 illuminance resolution (lux). Approximately, 1 lux at 1-meter square divides by their luminous efficacy (lumens per watt) give energy in Watt. The typical luminous efficacy of an LED lamp is about 80-100 lm/W [28], [29].

The purpose of survey is to obtain the characteristics of existing lighting sources, such as it is important light (essential or decorative), how much energy is used, and others. Survey data collected and analyzed with descriptive statistics to get their characteristics. Nocturnal light consists of many sources. On-field surveys, features, or an aspect that links into the sources also collected. It will provide clarification of source's light distribution. Features will be analyzed using cross-comparison between them.

C. Research Method

The VIIRS night-time satellite data provide to end-user a Day-Night Band (DNB) product in daily coverage to averaged annual terms. It can be used as a base dataset for assessment of nocturnal light. The VIIRS scientific data are available free for download as long for research. Field surveys cost a lot of expending. Field surveys can be conducted several times to strengthen the results of the assessment.

Figure 1 shows procedural flow to obtain the VIIRS radiance threshold class, denoting an Ambient, Moderate, and Excessive class. Ambient class indicates the surface receives light as natural, adequate, and does not lead vision visibility and ability matter. The middle class indicates surfaces accept ambient light and light that reason for the specific purpose. Excessive-class defines the highest level of exposure to sunlight.

First, the procedural flow begins with lux light meter surveys that collect light sources' data and characterization. It is necessary to obtain the statistical mean of light sources. However, to use night-time satellite data, the statistical standard must be calibrated into radiance mean using an approved regression model.

Second, procedural flow begins with analyzed the VIIRS radiance histogram. As scene VIIRS dataset consists of the whole area of Bali Island, include ocean, forest, and mountain area dataset will dominate by background lights. Then, the radiance histogram profile carefully analyzed the trend, transformation of its frequency distribution. The result of frequency distribution confirms with radiance mean from lux light meter surveys. From that statistical base mean, criteria of the radiance threshold class can be decided.

Third, the implementation processes begin with the preparation of global VIIRS scenes data. Daily to annual averages of the VIIRS day-night band available globally. The subject area is Bali island, representative of an excellent tourism resort. Datasets are subset into the Bali area, included background, i.e., the ocean. Data do not subset with associate coastline because light can spread into the seas. It applied to Bali dataset as density slices. Thus, thematic maps of radiance threshold class were obtained with zones i.e. blue as moderate and red zones as an excessive zone. Finally, stakeholder uses these maps for field's assessment.

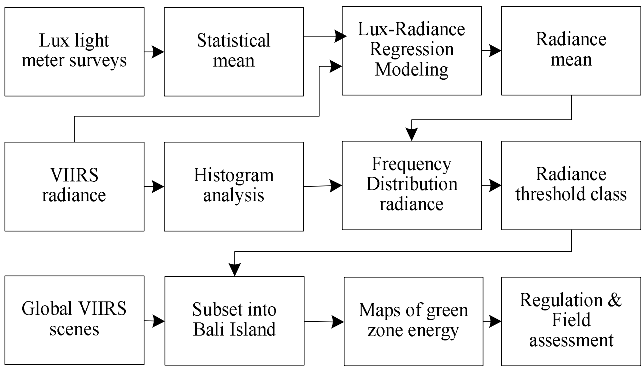

Fig. 1 The procedural flows to obtain radiance threshold class.

III. Results and Discussion

A. Feature of Light Sources

In infield surveys, the surveyor also collects features or aspects of light sources, i.e., the light source of ownership, nature of the light source, etc. Results showed an un-scaled one-single pie-chart Figure 2 below. As per-part of aspects, data, for instance, the type of location of light source gave result: for ambient type (about 37%), Excessive dominance type (about 63%), and total become 100 percent.

From the designated area aspect, light mostly from the business area (42%), then from tourism area (39%) some percent of the public area (14%) few from the settlement (4%). Measly of light condition aspect has low-visibility (objects recognition from a distance) and low-ability (for reading) mostly (77%) has an adequate amount of light. As light mostly for business area, lights come from any sources, i.e., streetlight, neon advertising, signboard, etc. denote as composite sources (about 78%). From the source of ownership, light sources are dominated by private ownership (69%), i.e., such as malls, outlet stores, restaurants, hotels, etc. Hence, the nature of the source is dominated by decorative (79%).

The chart below clarifies that sources of aspects that cause excessive and redundant energy (lights)—as the most tourism destination, surrounding resort growth up many tourism businesses managed privately, such as 24-hour shops, restaurants, art markets, and others. Many use decorative lighting to attract visitors' attention at night; even there is adequate exiting light. This happens because of no guarantee that services (the government, if for the public) will be sustainable. Mutual agreement among stakeholders to regulates overlapping of lighting urgency to realize.

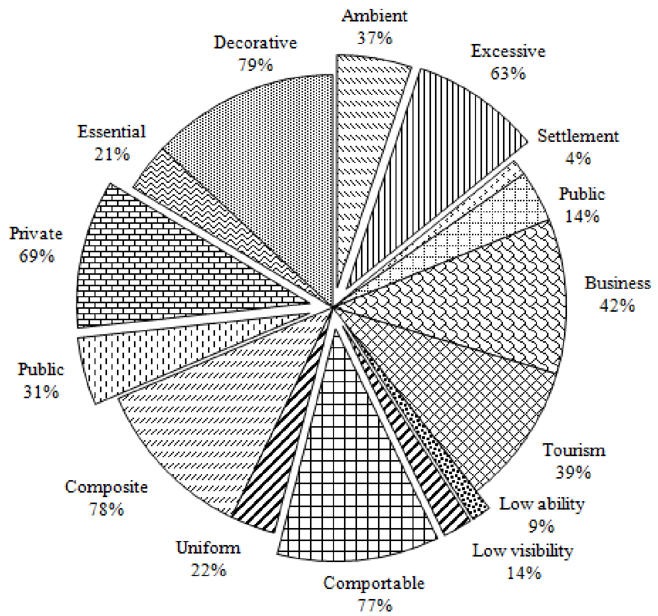

Fig. 2 Pie chart of light sources aspects surveys.

B. Class-Index of Radiance Threshold

Figure 3 below shows the class-index of the radiance threshold result. This class-index is obtained by cross-analysis of histogram radiance of night-time satellite dataset with the light meter survey results. The histogram was dominated by low energy radiance (about 94 percent), the radiance that ≤ 0.05 nWcm^{-2}µm^{-1}sr^{-1} and hereafter denoted as background radiances. Few percent of radiance distributed as non-background radiance or essential radiance for analysis (Table 1).

TABLE I
DISTRIBUTED RADIANCE FREQUENCY AND CLASS.

Radiances threshold (nWcm^{-2}µm^{-1}sr^{-1})	Frequency	Percent	Class*
≤ 0.05	39313	94.31	A
1.07	1634	3.92	A
2.09	500	1.19	A
5.16	108	0.25	A
7.54*	54	0.12	M
12.99	10	0.02	M
13.33	15	0.03	M
20.83*-86.60	47	0.11	E

*Ambient (A), Moderate (M), and Excessive (E).

From Table 1, shows radiances within range 7-8 nWcm^{-2}µm^{-1}sr^{-1}, the frequency numbers become dozens. The radiance that begins within 20 $nWcm^{-2}\mu m^{-1}sr^{-1}$ and greater, the frequency numbers become unit. In general, light that potentially a source of uses of excessive energy very few. According to the light meter of field survey results, the mean of lux meter surveys within range 23-28 lux. These results corresponded with 11-16 $nWcm^{-2}\mu m^{-1}sr^{-1}$ of the radiance of night-time satellite dataset and denoted as base-line radiance. From here, criteria or class of radiance threshold can be decided (Ambient, Moderate, Excessive). For generally, class-criteria of radiances of ≤ 15 $nWcm^{-2}\mu m^{-1}sr^{-1}$ denote as ambient (A), start from 20 $nWcm^{-2}\mu m^{-1}sr^{-1}$ denote as excessive class (E). In between, denote as moderate (M). In detail, distribute the radiance class presents in Table 1.

Using this index class criterion, maps can be produced as a base for a stakeholder to setup regulation. The stakeholder can use monthly to annual scale maps to assessing blue to red zone that need attention. This index defines which areas or pixels on satellite data must be monitored in case of energy use. It is interesting to watch the economic aspect's development and growth, which will imply a moderate class of nocturnal light growth. The development of a middle class of nocturnal light can be essential to understand the spatial-temporal of many dynamical aspects of urban cycles such as urbanization, food distribution, etc.

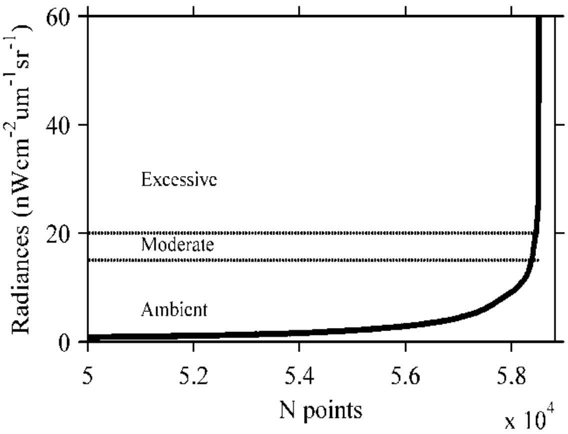

Fig. 3 Class-index of radiance threshold histogram.

C. *Mapping of green zone energy*

It is necessary to maps the distribution of radiance threshold class. Figure 4 shows the radiance threshold class after applying the VIIRS dataset of Bali Island and displaying two last present year (2012-2019). Those Figures indicate that potential sources of light as moderate (Blue pixel color) to excessive (Red pixel color) in common denotes as light pollution sources mainly at Kuta, Nusa Dua, and few at Benoa and Denpasar city. Summary of class amount and percent contributions present in Table 2. An interesting result shows some points that emerge at the North of Bali Island (Buleleng regency).

In general, light trends spread up from southern to northern parts of island. This is common because the Badung regency has territory spreads from south to central-north of island. Settlement expands into the north side of island. Notice for stakeholder to attention diminishes of green space.

Application of index threshold class to the whole of island, not urban cities, only aims to encourage stakeholder so that one island one management becomes actual. As a result, few areas or pixels become an object of matters. Remain dominates by nature of nocturnal light and adequate for visibility and ability of lighting. For the short term within eight years, expect to reveal the transformation class of nocturnal light. Dynamical condition, up-down of sum of class's pixels along year's term is nature. That shows many aspects i.e. socio-economic, political, etc. can be linked with nocturnal light [13-14].

More clear maps show in Figure 5 by zooming at dense urban cities. Figure 5 at the above side is for year 2012, and at below side for year 2019. If just looks at the radiance data (grey level color), it cannot spot the changes. In year 2012, it had some pixels identified as moderate and excessive, mainly at Kuta, Nusadua Denpasar, and Benoa areas. At Denpasar area denser of bright-lit pixels, but lower pixels that match criteria. In year 2019, pixels that identified in class criteria spread wider.

On the north side of Island, some pixels identified as class criteria starting in year 2018. That is, a steam power plant locates at "Celukan Bawang," Buleleng regency. Table 2 shows a summary of the amount of pixel's class and percent of total 58520 pixels. It showed progress in numbers of class pixels from 2012 until 2019. Development can be analyzed that on year 2014-2016, moderate and excessive class going up and then down next. It might be correlated with a socio-economic or national electric bill [15-16].

TABLE II
PROGRESS NUMBER OF CLASS PIXEL POINTS FROM 2012-2019.

Years	Class*	n points	Percent
	A	58415	99.82
2012	M	55	0.09
	E	50	0.08
	A	58420	99.82
2013	M	60	0.10
	E	40	0.06
	A	58359	99.72
2014	M	87	0.14
	E	74	0.12
	A	58334	99.68
2015	M	92	0.15
	E	94	0.16
	A	58342	99.69
2016	M	87	0.14
	E	91	0.15
	A	58383	99.76
2017	M	83	0.14
	E	54	0.09
	A	58381	99.76
2018	M	78	0.13
	E	61	0.10
	A	58333	99.68
2019	M	90	0.15
	E	95	0.16

*Ambient (A), Moderate (M) and Excessive (E), Dimension of Full Scene (58,520 points)

For clear data in Table 2, again presents on hectare area. With projection changes to UTM zone 50 south, one pixel approximately has 211646 m^2 (21 hectares) area. Figure 6 shows detection changes of wide-area in hectare.

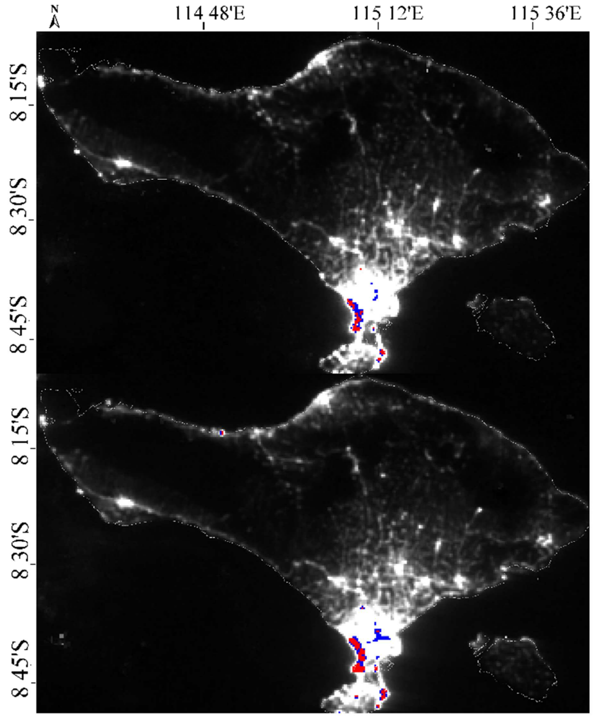

Fig. 4 Maps of threshold class results of Bali Island year of 2012 (above) and 2019 (below).

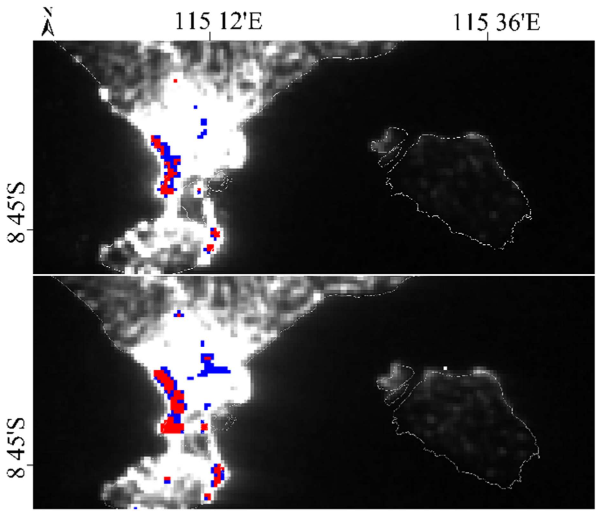

Fig. 5 Zoom maps of threshold class at the southern part of Bali island year of 2012 (above) and 2019 (below).

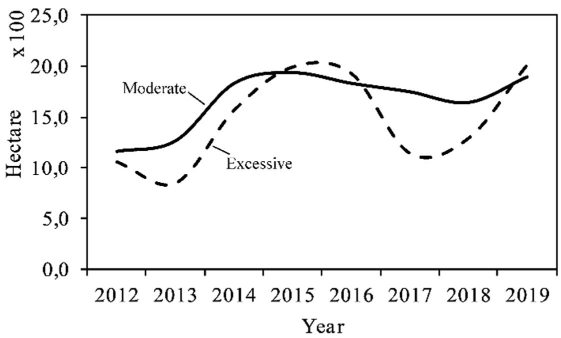

Fig. 6 Development areas of moderate and excessive classes from year 2012-2019.

IV. Conclusion

This paper had defined variability of light sources aspects that relate to excessive use of energy. The development of business support tourism in Bali, which is owned privately, is a key to this case. Public purpose facility should be multiply. For sustainability, a mutual agreement among stakeholders regulates the overlapping of lighting urgency to realize. This paper also presents the procedural to obtain an index of radiance threshold class that can be used to assessing many aspects of an urban cycle from nocturnal light. The radiance threshold class determined from cross-analysis of night-time satellite data with the result of light meter surveys. The energy radiance of night-time satellite data was carefully analyzed to obtain the profile of histogram radiance distribution. The index has three criteria class; the middle class becomes key to attention.

Areas that define as class criteria spread widely. Class criteria found mostly at Kuta and Nusadua city. The development of moderate class light is key to understanding the spatial-temporal of many dynamical aspects related to urban cycles—uncontrolled growth of moderate class drive urban planning disreputable. The nocturnal light trend spread up from the southern to the northern part of island. Settlement expands into the north side of island. Notice for the stakeholder to attention to diminishes green space. This paper's method provides an effective way of assessing the excessive uses of electricity by applying the satellite remote sensing technology.

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