Effectiveness of PNL technique in disaster damage assessment: evidence from selective case studies

P Dave¹ and S Pasari¹
¹ Mathematics Department, Birla Institute of Technology and Science, Pilani, Jhunjhunu – 333031, Rajasthan, India

Abstract. Natural disasters often cause large scale infrastructural damage and disruption of services. In such cases, a rapid damage assessment technique might prove beneficial to assist the disaster management efforts. Percent of normal light (PNL) can be one such technique. In this study, we test the effectiveness of PNL technique in rapid damage assessment from four selected case studies, namely the 2014 cyclone Hudhud, 2015 Gorkha (Nepal) earthquake, 2016 Central Italy earthquake, and the 2018 flood in Kerala. The dataset used has been taken from the Visible Infrared Imaging Radiometer Suite–Day/Night Band (VIIRS-DNB) scan data from the Joint Polar Satellite System (JPSS-1). The change in radiance values from the VIIRS-DNB dataset enables PNL computation to map the disaster affected regions. The results depict that PNL can be a viable alternative for rapid damage assessment.

1. Introduction
Remote sensing has been widely used in studying various features of the Earth surface (Chuvieco, 2016). Night-light time imagery, based on night-time capture, forms a useful data set in remote sensing. It is suitable to study human activities on Earth and their implications. The associated dataset primarily includes illumination due to various sources, such as city lights, fires, volcanoes, and gas flares. Night-time visible imaging was first initiated by the Defense Meteorological Satellite Program–Operational Linescan System (DMSP-OLS) in the 1960s, which was the only source of visible nighttime images until the launch of the Suomi National Polar-orbiting Partnership–Visible Infrared Imaging Radiometer Suite (SNPP-VIIRS). The nighttime light data set is available through various sources in the form of different data products. They vary in terms of the pre-processing step and associated information channels. A few major sources of night-time light data products are the NASA’s Black Marble and the Earth Observations Group (EOG) at NOAA/NCEI. A detailed summary on the generation and usage of VIIRS-DNB satellite data is available in Doll (2008) and Elvidge et al. (2017).

2. Literature review
Several studies have explored the applicability of nighttime light data in disaster management. For instance, Gillespie et al. (2014) utilized nighttime light data from the DMSP-OLS to study the effect of the 2004 Indian Ocean tsunami in Indonesia. Extensive field surveys were carried out to validate the results and to establish a relationship between the aftermath economic expenditure and the night-time light data. Zhao et al. (2018) used the night-time PNL method from the National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite Day/Night Band (NPP-VIIRS DNB) to assess damages from three selected case studies related to earthquakes, storms, and floods. One month before and ten days after a disaster was averaged to obtain pre-disaster and post-disaster values. A longer time-period for pre-disaster was chosen so as to account for the variations of the light intensity due to
clouds and other effects. A larger period averaged out fluctuations of normal time and reflected the true light in a normal scenario. A shorter aftermath period was considered based on the assumption that it represents a critical period where post-disaster work is underway. Seasonal changes were not considered as the time periods were relatively small. The non-parametric Mann-Whitney U-test was employed to carry out significance test of the emanated results. In 2018, Wang et al. studied the power outages in USA as an aftermath effect of the 2012 Hurricane Sandy and the 2017 Hurricane Maria. Their study used the NASA Black Marble Product data that eliminates cloud-affected pixels and accounts for several disturbances due to atmospheric effects, terrain changes, vegetation cover, snow reflection, lunar effects, and stray light properties on the VIIRS-DNB radiances. The PNL technique was used to assess the damage. As a part of the study, the authors estimated power recovery metrics, comprising date of initiation, period, and proportion of recovery. The results were compared for different levels of urbanization, providing new insights to the disaster management efforts.

3. Methodology
In the present study, we have selected four natural disasters that occurred during 2013-2019, when the VIIRS-DNB data by NOAA/NCEI was available. A cyclone namely the 2014 cyclone Hudhud, two earthquakes namely the 2015 Gorkha (Nepal) earthquake and the 2016 Central Italy earthquake, and the recent 2018 flood in Kerala (India) have been considered here.

3.1. Dataset
The VIIRS-DNB sensor data has been used for this study. The data is available in monthly and annual packets for different regions of the world. It is divided into six tiles according to the geographical coordinates. The data-product is a processed version of the radiance data collected by the VIIRS instrument on the NOAA-20 satellite. The processing has been carried out to remove disturbances due to clouds and artifacts of stray lights. There are three types of data, such as steady lights, calibrated radiance, and mean digital number based on different parameters of detection frequency, radiance, and digital number, respectively. Such differences in data characteristics make the datasets usable in a number of applications such as economic activity, urbanization, light pollution, population growth, greenhouse gas emissions, and moreover disaster management.

3.2. Percent of normal light
The percent of normal light (PNL) is a technique used to estimate the affected areas after a disaster. It is based on the principle that an affected area will have structural damage thus affecting the urban lights from the area. As the nighttime light data captures these lights, they are used for applying the PNL method. The radiance values before and after the disaster are compared by taking their ratio to detect the change. The PNL method is susceptible to various sources of errors, such as erroneous data, insignificant change in radiance values, and other aspects of damage. Thus, it is necessary to test the efficacy of the PNL method prior to its implementation on practical applications such as discussed here.

3.3. Procedure
The VIIRS-DNB data for a month preceding and succeeding the disaster along with the month of the occurrence of the disaster is collected. As these datasets are for a whole tile, the data for the region of interest is extracted. The radiance values are threshold by 0.3 nWcm⁻²sr⁻¹ to remove the effect of background noise and other disturbances. The disaster-affected months are assigned weights on the basis of the number of days affected by the disaster. The monthly dataset is then averaged to generate pre-disaster and post-disaster radiance values for the region. Using these values, the PNL image is generated by taking the ratio of pre-disaster radiance values (Rad_pre) and post-disaster radiance values (Rad_post). A PNL value less than 1 represents a drop in the radiance values and thus areas with PNL<1 are classified as affected. A summary of the entire methodology is shown in figure 1 below.
4. Results and conclusions

In this study, disaster affected areas were identified (figure 2) for the four selected case studies using the PNL technique. The figure provides a colour coded map to depict the areas affected by the natural disaster. For example, the blue and yellow regions in figure 2(a) highlight the areas that had more devastation due to the 2014 Cyclone Hudhud, whereas the regions in blue in figure 2(b) show the most affected epicentral region of Kathmandu. In figure 2(c), the blue regions depict the regions that were most severely affected by the earthquake in Italy as identified by the PNL method. Similarly, the districts highlighted in blue in figure 2(d) are the worst affected ones by the 2018 Kerala flood, and it matches with the official reports of the state administration.

In conclusion, the present study implemented PNL technique for rapid damage assessment and found the results corroborating to the effectiveness of the technique. The PNL technique proves to be a promising alternative to traditional disaster damage assessment methods.

Figure 1. Flowchart of the proposed methodology.
Figure 2. The PNL-based assessment of affected areas; (a) effect of the 2014 Cyclone Hudhud in eastern states of India such as Andhra Pradesh and Odisha, in which the yellow and blue lines highlight the areas of worst hit; (b) affected areas of the 2015 Gorkha (Nepal) earthquake; (c) affected areas of the 2016 Central Italy earthquake; and (d) the affected areas of the 2018 Kerala flood, in which the areas in blue represent the most devastated regions.

5. References

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