A Novel Method to Monitor Electricity Restoration in Orissa Affected by Cyclone Fani using Image Processing with VIIRS DNB Data

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Abstract*: Due to advances in space technology, certain satellite sensors have unique power of capturing data and also generate special kind of observations. The Day and Night Visible Bands (DNB) of VIIRS Sensor mounted on Suomi NPP Satellite provide useful information in real-time monitoring of restoration of electrification after the trigger of a tropical cyclone. Since the destruction ca used by a tropical cyclone is severe, therefore, both restoration and its monitoring play a vital role for law enforcement agencies. This paper presents a novel method to monitor electricity restoration spatially using image processing with VIIRS DNB data. The proposed method is experimented with the cyclone Fani hit Orissa coast during April-May 2019. To conclude, the work accurately determines the spatial analysis of electrification restoration after a tropical cyclone landfall is occurred

***Keywords*: Spatial Analysis, Electricity Restoration, Remote Sensing, Image processing, DNB VIIRS.**

I. INTRODUCTION

Modern satellite imaging systems in the most part record the electromagnetic radiation reflected from the Earth or emit a beam of microwave radiation and record its reflection from objects located on Earth. Some systems recording the satellite imaging are equipped with a more sensitive sensor and they record the light emitted from the surface of Earth. Night imaging provides accurate, cost-effective and straightforward method of the detection of populated areas and any other symptoms of human activity, as well as they allow tracking their changes over time. The accumulation of electricity lighting differs according to the geographical conditions and also majorly depends on the level of country development which may constitute an additional starting point for further researches.

Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB) [1] possess the two specialties namely greater sensitivity and accurate latest onboard calibration. These two features results in getting best measurements even in low light conditions. This advantage leads to enhance, redesign and implement night time applications and thus can have a monitoring of several geographical parameters like snow, dust, fog, urban electricity, volcanic eruption etc. VIIRS DNB is quite superior to its previously commissioned sensors with an improved spatial resolution of 750m. The spatial analysis of the restoration of electrification process can be accomplished using satellite image processing with DNB channels of VIIRS sensor. The algorithm consists of measuring the brightness pixels temporally gives the exact direction of the proposed work. The method is tested and validated with the cyclone Fani hit Orissa coast during April-May 2019. To conclude, the work accurately determines the spatial analysis of electrification restoration after a tropical cyclone landfall is occurred.

A. Visible Infrared Radiometer Suite (VIIRS) Day and Night Band (DNB)

VIIRS DNB captures earth's reflectance within a range of wavelength between 500 to 900nm. VIIRS DNB has the ability to capture certain environment data parameters like snow cover, fog, thick cloud, smoke, ash, during the presence of moonlight. Figure 1A depicts the data products which VIIRS DNB can sense during the presence of moon light. However, VIIRS can sense certain parameters like fire, city lightening, gas flares, eruption of lava, aurora, dim lights, fishing boats with or without presence of moonlight. Figure 1B depicts the parameters which can VIIRS can sense with or without moonlight. Figure 2 presents the reflectance image produced by VIIRS during night time.

Fig. 1. Reflections detected by VIIRS sensor

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Fig. 2. Day-Night Band Image reflectance image produced by VIIRS during night time

B. Tropical Cyclone Fani

Fani is categorized as the severe tropical cyclone majorly effected to the state of Odisha. This cyclone originated in Indian Ocean on 26th April 2019, intensified rapidly and progressed towards the east coast of India. Fani created a massive destruction during its landfall on 3rd May 2019 resulting loss of US $ 8.1 billion (Refer Figure 3).

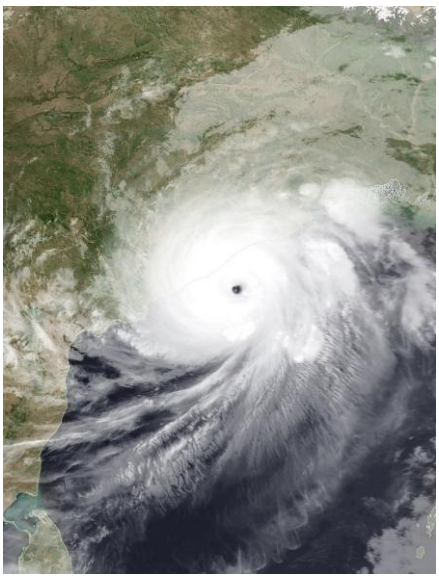


Fig. 3. Extremely Severe Cyclonic Storm Fani approaching India at peak intensity captured on May 2, 2019.

II. LITERATURE REPORTED WORKS USING VIIRS DNB DATA

Christopher Elvidge et al. [2] are the initial researchers who have brought the advantages of VIIRS DNB over its predecessors. Authors have opined that the DNB could be a great helpful to researchers working on land-use, ecology, country's economy and demography dynamics. Authors have revealed substantial inferences of future use of VIIRS DNB data. They have strongly pointed the prime advantage of DNB Band for generating radiance maps over a time-series pertaining to spatially monitor electric lighting over the areas of urban human habitat. Deren Lia et al. [3] opined that the applications of nighttime remote sensing can be extended to several broad fields like estimating dynamics of urbanization, trigger of sudden events (eg: volcanic eruption), forest fires and gas flares etc. Such night remote sensing can also be used to observe man-made disasters like war explosions. In this paper, authors have listed various case studies involved in night time light applications. Light pollution is a major hurdle for sustainable habitation during nighttime. Gas flares, forest fires, sky glares, light clutters are some prominent factors results in light pollution. Nurbandi et al. [4] attempted to estimate the light pollution using VIIRS DNB data. Authors using VIIRS imagery experimented on Yogyakarta province and its surrounding areas namely Yogyakarta City, Depok Beach, and Gajah Mungkur reservoir to determine the light pollution applied over the Bortle Dark-Sky Scale with a value range of 1-9. The work has successfully proved to use VIIRS imagery in estimating light pollution. Wei Shi and Menghua Wang [5] presented three case studies to understand the dynamics ocean and its environment. Authors have presented an approach of assessing ocean diurnal dynamics using VIIRS DNB data. Authors carried their experiments to monitor algal bloom developed in La Plata River Estuary observed during 24th to 26th March 2016. They have also extended their work for a similar kind of experimentation in Hangzhou Bay region (China's east coast) during the period from 12th to 14th April 2017. Authors finally inferred that VIIRS DNB has beneficial scope of capturing ocean observations especially during the nighttime.

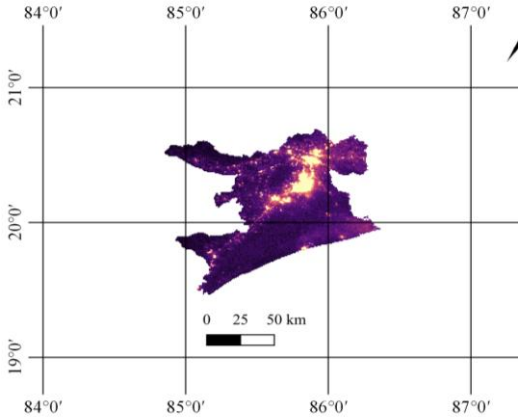


Fig. 4. Study area comprised of Puri, Cuttack and Khordha districts in Orissa State

III. STUDY AREA

Cyclone Fani progressed with a speed of 200 kmph during its landfall on 3rd May 2019. The cyclone made a massive devastation resulting in washout of electricity for 3.5 million households. Puri, Cuttack and Khodhra districts of Odhisa state are the major areas affected by Cyclone Fani [7]. Figure 4 presents the study area of the proposed work which has been massively affected by the cyclone Fani.

IV. METHODOLOGY

Indian National Center for Ocean Information Services (INCOIS) captures real-time VIIRS data and made it public available through its website. The proposed work takes corrected reflectance imagery VIIRS DNB Netcdf (NC) data [6] from INCOIS website. Algorithm for the proposed work is as follows:

Step 1: Import the dataset.

Step 2: Extract the required DNB band data values onto a matrix grid.

Step 3: Count the number of grid locations which have greater than 0 reflectance values.

Step 4: Multiply the obtained count value with 750m resulting the spatial extent of city electric lightening.

Step 5: Repeat step 1 through step 4 for all the datasets captured over the period of study.

For instance, if the count value is 10 i.e. number of bright pixels are 10 then overall spatial extent comprised is of 10*750m = 7.5Kms.

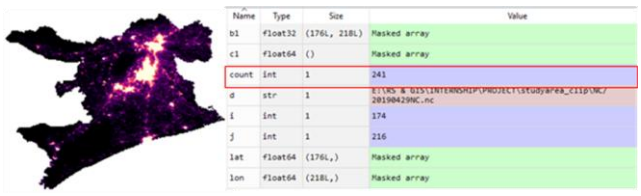
The key idea behind is purely location specific. Since, the proposed work deals with the city limits therefore it is quite evident that the reflectance imagery is comprised of city lighting. A similar kind of analogy could be implied in identifying spatial extent of snow, gas flares, dust, forest fires etc depending on their geographical parameters and the trigger of recent events.

V. RESULTS AND DISCUSSION

Fani track has been plotted in figure 5 using the latitude and longitude details obtained from India Meteorological Department (IMD). Red dotted line in figure 5 depicts the exact tract of the cyclone Fani.

Fig. 5. Cyclone Fani Track

On 29th April 2019, the proposed work has estimated 241 bright pixels indicating 180.750Sq. Kms of spatial extent covered with regular city lighting. This observation deals with the pre-cyclonic status (Refer figure 6).



Name	Type	Size	Value
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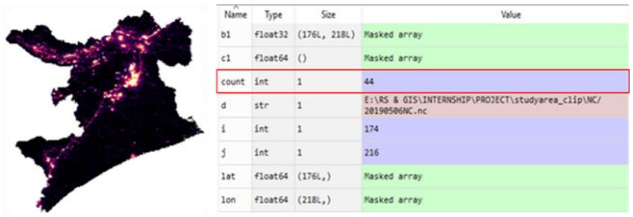
c1	float64	()	Masked array
count	int	1	241
d	str	1	E:\RS & GIS\INTERNSHIP\PROJECT\studyarea_clip\NC/20190429NC.nc
i	int	1	174
j	int	1	216
lat	float64	(176L,)	Masked array
lon	float64	(218L,)	Masked array

Fig. 6. Estimation of brightness pixels on 29th April 2019

Figure 7 illustrates a massive washout of electrical network over certain areas in Orissa and the proposed work estimated 44 bright pixels indicating 33 Kms of electrical lighting during 6th May 2019. The Government of Orissa has taken rapid initiation to restore electricity after Fani hit. Since, the process of electricity restoration is a time taking job, the proposed work gives the spatial extent improvement temporally.



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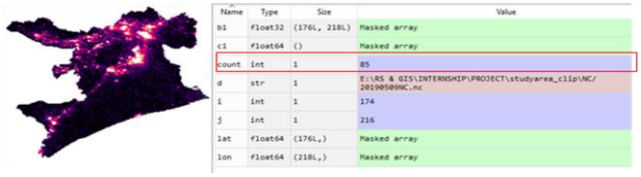
i	int	1	174
j	int	1	216
lat	float64	(176L,)	Masked array
lon	float64	(218L,)	Masked array

Fig. 7. Estimation of brightness pixels on 6th May 2019

On 9th of May 2019, the work estimated 85 pixels covering an area of 63.75Kms with an improvement of 30Kms electricity restoration. The overall change in electricity restoration from 29th April to 9th April is 64.73% (Refer figure 8).



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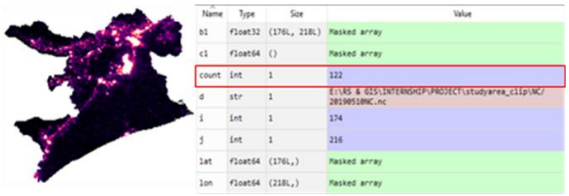
i	int	1	174
j	int	1	216
lat	float64	(176L,)	Masked array
lon	float64	(218L,)	Masked array

Fig. 8. Estimation of brightness pixels on 9th May 2019

On 10th of May 2019, the work estimated 122 pixels covering an area of 91.5Kms with an improvement of 27.75Kms electricity restoration compared to its previous day. The overall change in electricity restoration from 29th April to 10th April is 49.377% (Refer figure 9).



Name	Type	Size	Value
b1	float32	(176L, 218L)	Masked array
c1	float64	()	Masked array
count	int	1	122
d	str	1	E:\RS & GIS\INTERNSHIP\PROJECT\studyarea_clip\NC/20190510NC.nc
i	int	1	174
j	int	1	216
lat	float64	(176L,)	Masked array
lon	float64	(218L,)	Masked array

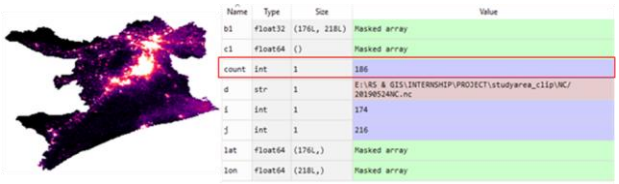
Fig. 9. Estimation of brightness pixels on 10th May 2019

On 14th of May 2019, the work estimated 157 pixels covering an area of 117.75Kms with an improvement of 26.25Kms electricity restoration compared to previous observation took on 10th May. The overall change in electricity restoration from 29th April to 14th April is 34.855% (Refer figure 10)

Name	Type	Size	Value
b1	float32	(176L, 218L)	Masked array
c1	float64	()	Masked array
count	int	1	157
d	str	1	E:\RS & GIS\INTERNSHIP\PROJECT\studyarea_clip\NC/20190514NC.nc
i	int	1	174
j	int	1	216
lat	float64	(176L,)	Masked array
lon	float64	(218L,)	Masked array

Fig. 10. Estimation of brightness pixels on 14th May 2019

On 24th of May 2019, the work estimated 186 pixels covering an area of 139.5Kms with an improvement of 21.75Kms electricity restoration compared to previous observation took on 14th May. The overall change in electricity restoration from 29th April to 24th April is 22.821% (Refer figure 11).



Name	Type	Size	Value
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c1	float64	()	Masked array
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i	int	1	174
j	int	1	216
lat	float64	(176L,)	Masked array
lon	float64	(218L,)	Masked array

Fig. 11. Estimation of brightness pixels on 24th May 2019

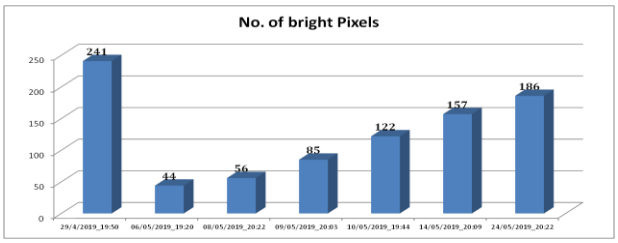

Fig. 12. Day-wise Pixel Count

Figure 12 presents the day-wise pixel count tabulation along with its time-series in a bar graph. The graph depicts monotonic improvement in electricity restoration after the cyclone Fani hit.

Table 1 presents the percentage of improvement between recorded observations on various days before and after cyclone Fani hit.

Table- 1: Percentage of change or improvement in electricity restoration from 29th April to 24th May 2019

Day	Percentage Change
29th April to 6th May	81.743
29th April to 8th May	76.763
29th to 9th May	64.73
29th to 10th May	49.377
29th April to 14th May	34.855
29th April to 24th May	22.821

VI. CONCLUSION AND FUTURE SCOPE

The proposed work accurately determines the spatial extent of electrification restoration after a tropical cyclone landfall is occurred. The work could lead towards a promising direction using VIIRS DNB data combined with digital image processing. The present work can further be extended to spatially monitor volcanic eruption, forest fire, gas flares and other parameters obtained from night reflected imagery observations.

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