Estimation of Vegetation Index over the State of Sikkim

IJIMSR, Vol.1, No.1, (2023) 23.1.1.009

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Received 29th August 2023; Accepted 11th September 2023
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ABSTRACT

Processing and evaluating remote sensing data from available satellite images are software dependent and space consuming tasks. This work represents a recent widely used method for processing of satellite data at an online platform named Google Earth Engine (GEE). In this platform the task can be done individually as well as a team can work in collaboration mode. GGE platform allows the various remote sensing data processing and plotting without downloading remote sensing data to the user's system (which are mainly space constraints). Motivation of this work is to perform remote sensing time series data analysis to study the vegetation index over Sikkim state in north east part of India in the GGE platform as a case study. In this work the normalized difference vegetation index (NDVI) is estimated at regional scale using the Landsat-8 data. The index generally detect the plant canopies green pigmentation in the remote sensing data of multi-spectral nature. This is also helped in quantifying the photosynthetic strength of green vegetation. The time span is selected from 2015 to 2020 according to the availability of Landsat8 data having 30m of spatial resolution to process the NDVI. For NDVI calculation, May month period of each year has been selected because of minimum cloud cover in the data for Sikkim region and the spatial distribution of the index is generated which clearly indicates the year to year variability because of the weather variations like rainfall, humidity, temperature etc.

Keywords: NDVI, GEE, Vegetation Index, Remote Sensing, Landsat, Sikkim

1. INTRODUCTION

A widely used method for processing of satellite data at an online platform named Google Earth Engine (GEE) has been used for processing Landsat 8 data over the Sikkim region to estimate vegetation cover in the area. GGE segregates various satellite images and geospatial datasets at global scale. This is available for scientists, researchers, and developers to which has been making analysis and processing of large datasets very easy (Schmid 2017; Mutanga and Kumar 2019). Vegetation Cover is a highly sensitive and dynamic part of the ecosystem . Normalized difference vegetation index (NDVI) is one of the well-established vegetation index that has been widely used for understanding the vegetation dynamics over a region (Tucker et al. 1985; Goetz and Prince 1999). Vegetation cover can be estimated using the NDVI analysis using the state of art remote sensing data and act as a simple graphical indicator to assess the target to observe for live green vegetation using space technology. NDVI is the one of the most useful and successful methods to identify vegetated areas and vegetation phenology. Temporal variation of the (NDVI) is also closely related with the climatic factors . The impact of climate change also affects the growing season of the plat and it is directly linked with the greenness of the plant canopies representing vegetation (Chen and Pan 2002; Scherler et al. 2011). NDVI for vegetation dynamic and land cover land use changes at regional/local scale are being presented in few earlier studies (Wang et al. 2015; Piao et al. 2003). On successful detection of feasibility for demonstration of vegetation, NDVI also can be used to assess the capacity of photosynthesis of the green plant canopies. The phonological data can be also derived from the modelling of NDVI values .

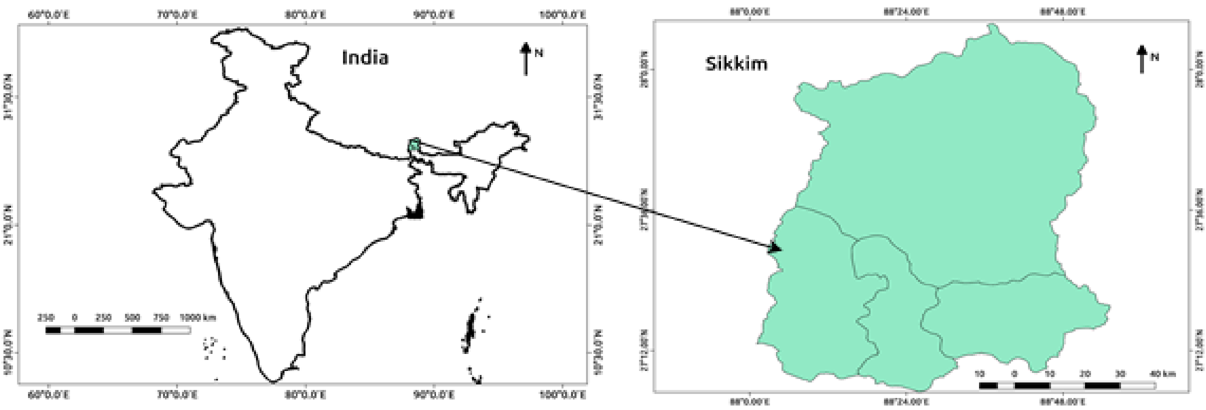

Fig 1. Study area showing the location of the Sikkim State of India

Sikkim, is one of the mountainous states of India in the North-Eastern Himalaya which extends about 114 km latitudinally and 64 km longitudinally (Fig 1). Sikkim state lies between 27.0130 to 27.130N latitude and 88.016oto 88.923oE longitude and altitude ranges from 300 to 8585 m MSL. Sikkim has an area of 7096 sq. km. covering only 0.2% of the total geographical area of India, and having abount 26% of the India's total biodiversity. Thus it is famous for its biological diversity also and the total forest cover of Sikkim area is around 82% of its total geographical area

DATA AND METHODOLOGY

In this work Landsat 8 data has been used to calculate NDVI. On February 11, 2013, Landsat-8 was launched in a collaboration between NASA and the U.S. Geological Survey (USGS) and the data are consistent with other mission in terms of temporal and special characteristics (Irons et al., 2012) . It is having two sensors i.e. Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Landsat consists of a total eleven bands. Band 1, 2, 3, and 4 has visible ranges from 0.43 to 0.45 µm, from 0.450 to 0.51 µm, 0.53 to 0.59 µm, and from 0.64 to 0.67 µm, called ultra-blue, blue, green, and red respectively. Band from 0.85 to 0.88 µm, band 6 from 1.57 to 1.65 µm, and 7 from 2.11 to 2.29 µm called near Infrared (NIR), short wave infrared (SWIR 1) and SWIR 2 respectively. Band 1-7 has a spatial resolution of 30 meter. Band 8 is Panchromatic (PAN) ranges from 0.50 to 0.68 µm has spatial resolution of 15 meter, and band 9 is Cirrus band ranges from 1.36 to 1.38 µm having spatial resolution of 30 meter. Band 10 and 11 are thermal band ranges from 10.6 to 11.19 µm and from 11.5 to 12.51 µm which has 100m spatial resolution .

To work is accomplished by following methodology as described in Fig. 2. Landsat8 data has been taken as an input for NDVI calculation. The Earth Engine team has been working with collaboration with Google Cloud. Google cloud contains plenty of remote sensing data as well as GIS data also. In this work the boundary data of Sikkim state is also collected from Google cloud only to mask the Landsat 8 data (Google cloud; sikenvis.nic.in). Yearly Landsat data are collected from 2015 to 2020 of the month of May to avoid the cloud cover. NDVI is computed and assessed using the Landsat 8; red (band 4) and NIR (band 5) bands. NDVI data for 5 continuous years from 2015 to 2020 is calculated as output. The output NDVI image ranges from -1 to +1. On the basis of this output, spatio-temporal variation of vegetation cover over the Sikkim region is analysed.

The following equations are used for the computation

$\boldsymbol{NDVI} = \frac{NIR-R}{NIR+R}$ and for Landsat 8 $\boldsymbol{NDVI} = \frac{Band\ 5-Band\ 4}{Band\ 5+Band\ 4}$

The outcome of NDVI lies between -1 to +1 where, -1 to 0 indicate basically the dead vegetation or objects such as built up areas, barren lands etc.. Values lying between zero to one indicate organic objects such as live plants. NDVI values for the healthiest plant go towards the positive means 1 and towards the 0 or -1 indicated the dead plants. By the analysis NDVI values, images could be created to provide an accurate measurement of the vegetation type, intensity or quantity, and the condition like healthy or not. And, the value of every pixel can be assigned different colours representing the different ranges of NDVI values. As a result, a false-colour (FC) map would be created to depict the spatial variability of the NDVI in the study region.

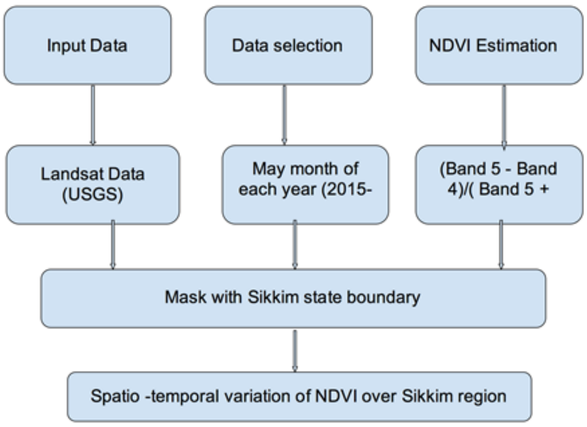

Fig 2. flowchart of the methodology

TRADITIONAL METHOD VS. GOOGLE EARTH ENGINE

Traditional method of estimating NDVI is to 1st download the data which contains lots of space in the system and time in data processing. Such as selecting cloud free data, atmospheric correction of the data and applying NDVI formula. These all steps take much time and space compared to the processing the data on the online platform that is Google Earth Engine. At this platform library of the data like Landsat series, MODIS, Sentinel etc. and Python, JAVA API functions are available to process and plot the data.

RESULTS AND DISCUSSION

The main significance of the present work is to perform a case study to assess the NDVI over Sikkim region. Google has created an infrastructure named Google Earth Engine (GGE) which allows the researchers to access the wider range of parameters from the remote sensing observations and enable to apply the innovative methodologies in the cloud platform to obtain the data based on user requirement basis. On the online platform of Google Earth Engine, there is a public data catalog available which includes a variety of the geoscience datasets in raster format. This makes users' task easiest to search and filter the data according to requirement. This work also explored the availability of Landsat 8 data having lowest cloud cover to calculate NDVI [Schmid, 2017]

Result of this work shows that Temporal variation of vegetation cover over Sikkim region has increased in the year of 2017 and 2018. Vegetation cover has started to decrease again in 2019. Normalised vegetation Index of the Sikkim area shows that the vegetation cover is highest in 2017 and lowest in 2016 (Fig 3). Spatial analysis presented in Fig 3 shows that the major changes have occurred in the East and west Sikkim district of Sikkim. From the report of Sikkim 2019, the total forest cover of the country is 21.67 % of total geographical area of India which is slightly from the year 2017 which is 21.54% of total geographical area. The results indicated that, Sikkim region is also following almost the same pattern for variation in vegetation cover. Histogram of vegetation index from 2015 to 2020 (Fig 4.) shows the statistical representation of vegetation cover. It represents that area under the curve of the year 2017 is highest for the positive values NDVI, which represents the denser vegetation. Negative values of NDVI represent the sparser vegetation and zero values for higher soil moisture on the surface. Soil moisture also reflects some positive values of NDVI. This study represents the area under the curve having the values less than zero is very less indicating a larger area in the state is covered with intense vegetation.

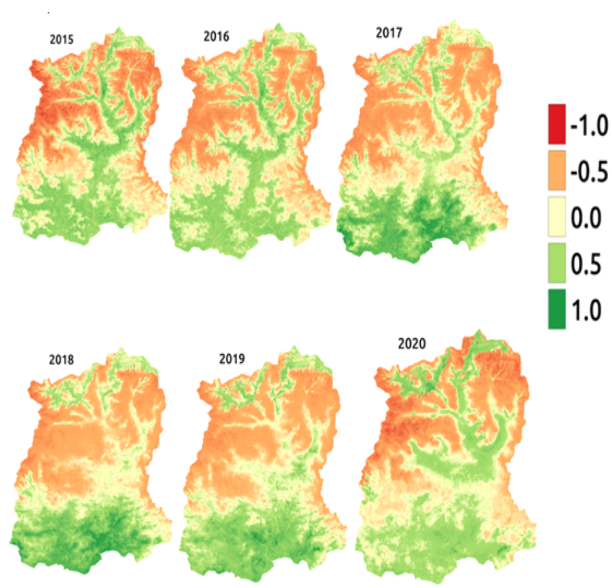

Fig 3. Raster image of vegetation index from 2015 to 2020

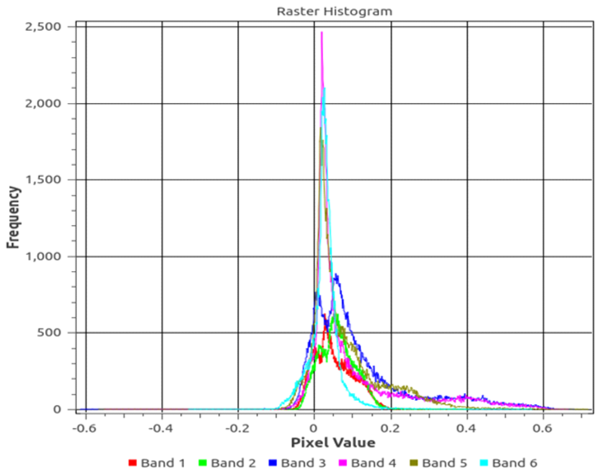

Fig 4. Histogram of vegetation index from 2015 to 2020 (Band 1- 2015, Band- 2 2016, Band 3-2017, Band 4- 2018, Band 5- 2019, Band 6- 2020)

According to the USGS, remote sensing phenology studies indicates that the NDVI values range from +1.0 to -1.0. Areas covered with snow, sands or barren rocks shows NDVI values approximately 0.1 or less. NDVI values for moderate vegetation lie between 0.2 to 0.5 approximately and higher values indicated for very dense vegetation which is greater than 0.5. In this study we are analysing our NDVI data for the moderate dense vegetation. In this work we have done analysis for moderate dense vegetation. For the moderate dense vegetation we have taken the NDVI range from 0.125 to 0.5. The reason to take these ranges is to analyse the NDVI data for moderate dense vegetation to take the reference from a report of the Government of India for forest cover [India state forest report].

Year	Area (km^2)	% of total geographical area of Sikkim
2015	852.30	12.01
2016	804.66	11.34
2017	2123.85	34.15
2018	1877.29	26.45
2019	1792.39	25.25
2020	1149.98	16.20

Table1: Result from NDVI data analysis for the NDVI range i.e. MDF ((Moderate dense forest)

This study is showing the analysis of moderate dense vegetation over the Sikkim region from the year 2015 to 2020 as a sample study using GGE. The study over the Sikkim region are carried out on the basis of variation of area covered with moderated dense vegetation. This study comprises the study done by GOI. In the GOI study LISS 3 (23.5 m resolution) has used for four alternate years from 2013 to 2019 along with ground truth data for validation. But in the present study the Landsat data are considered which are comparable in the spatial resolution (30m) as the target is to study the decadal variability. This is very useful for the large time scale analysis of vegetation area and their impact on decadal climate change which is our next motivation to do for the whole north east region.

Vegetated region of the processed image is validated using online Google earth images. This validation has given support to process the further vegetation index for year 2015 to 2020. Variation of forest cover result of the study is also likely to be the same as the temporal image of Google earth. In the Google earth images it can be seen that the vegetated area has improved in the southwest region of Sikkim from 2016 to 2018 as our study also represents the same shown in fig 3.

From the government of India report for forest cover analysis as shown in below table which pattern for increasing and decreasing in forest cover is exactly matching the same in our result also. But due to the acquired data from different sensors having different spatial as well as different spectral resolution there is no exact matching in area values. According to the GOI report the forest has increased rapidly from 2015 to 2017 and again it started decreasing slowly from 2017 to 2019. The same showing in our result also. For year 2020 it's showing again decreasing as the pattern of year 2015 which has to be clarified in the further study.

Year	NDVI Range	Area (km^2) [present study]	Area in Area (km^2) [GOI]	Difference Area (km^2)
2015	MDF (Moderate forest)	852.30	1353	500.7
2017	MDF (Moderate forest)	2123.85	1575	548.85
2019	MDF (Moderate forest	1792.39	1552.31	240.08

The result of this work is also the same as shown in the report by the government of Sikkim for the year of 2015, 2017 and 2019 as carried out by GOI. This report also states that the forest cover over the Sikkim is higher in 2015 than its decrease in 2017 and again it's almost the same in 2019. Result of this work also showing the same pattern vegetation cover variation over the Sikkim region.

CONCLUSIONS

Motivation of this work is to estimate spatio-temporal variation of vegetation cover over the state of Sikkim which is a better guidance for the ecosystem and biodiversity study over the region in NE India using the state of art GEE and the updated Landsat 8 remote sensing data at high resolution. The NDVI analysis for the period 2015 to 2020 are being analysed in the GEE platform and the high resolution maps are generated. The spatio-temporal assessment of the NDVI distribution is presented. The validation of the present methodology also carried out against the GOI analysis and it is observed that the method complements for the vegetation analysis using the remote sensing data in GEE in very user friendly manner, which can be used by any researchers with minimal trainings. Limitation of this work is less time span due to unavailability of Landsat 8 images before 2015 for Sikkim region. The available data i.e. Landsat 5 and Landsat 7 can be integrated further for robust trend analysis. Improvement in the GEE available resources and algorithms like segmentation etc. will further open new ways for the high resolution vegetation mapping and studying the associated dynamics to address the issues like regional climate change and its impact on the sectors like forest, agriculture, biodiversity etc. in future.

REFERENCES

[1] Chen, X., & Pan, W. (2002). Relationships among phenological growing season, time-integrated normalized difference vegetation index and climate forcing in the temperature region of Eastern China. International Journal of Climatology, 22(14), 1781–1792. https://doi.org/10.1002/joc.823

[2] Goetz, S. J., & Prince, S. D. (1999). Modelling Terrestrial Carbon Exchange and Storage: Evidence and Implications of Functional Convergence in Light-use Efficiency. Advances in Ecological Research, 28(C), 57–92. https://doi.org/10.1016/S0065-2504(08)60029-X

[3] Hou, G., Zhang, H., & Wang, Y. (2011). Vegetation dynamics and its relationship with climatic factors in the Changbai Mountain Natural Reserve. Journal of Mountain Science, 8(6), 865–875. https://doi.org/10.1007/s11629-011-2206-4

[4] http://sikenvis.nic.in/WriteReadData/UserFiles/file/2019%20FSI%20SIKKIM.pdf.

[5] https://developers.google.com/earthengine/datasets/catalog/LANDSAT_LC08_C01_T1_TOA

[6] https://www.usgs.gov/ (accessed on 1 June 2021).

[7] Irons, J.R.; Dwyer, J.L.; Barsi, J.A. The next Landsat satellite: The Landsat Data Continuity Mission. Remote Sens. Environ. 2012, 122, 11–21.

[8] Javadinejad, S., Eslamian, S., & Ostad-Ali-Askari, K. (2019). Investigation of monthly and seasonal changes of methane gas with respect to climate change using satellite data. Applied Water Science, 9(8), 1–8. https://doi.org/10.1007/s13201-019-1067-9

[9] Mutanga, O., & Kumar, L. (2019). Google earth engine applications. Remote Sensing, 11(5), 11–14. https://doi.org/10.3390/rs11050591

[10] Piao, S., Fang, J., Zhou, L., Guo, Q., Henderson, M., Ji, W., et al. (2003). Interannual variations of monthly and seasonal normalized difference vegetation index (NDVI) in China from 1982 to 1999. Journal of Geophysical Research: Atmospheres, 108(14), 1–13. https://doi.org/10.1029/2002jd002848

[11] Qin, Y., Xiao, X., Dong, J., Zhang, G., Shimada, M., Liu, J., et al. (2015). Forest cover maps of China in 2010 from multiple approaches and data sources: PALSAR, Landsat, MODIS, FRA, and NFI. ISPRS Journal of Photogrammetry and Remote Sensing, 109, 1–16. https://doi.org/10.1016/j.isprsjprs.2015.08.010

[12] Scherler, D., Bookhagen, B., & Strecker, M. R. (2011). Spatially variable response of Himalayan glaciers to climate change affected by debris cover. Nature Geoscience, 4(3), 156–159. https://doi.org/10.1038/ngeo1068

[13] Schmid, J. N. (2017). Using Google Earth Engine for Landsat NDVI time series analysis to indicate the present status of forest stands. Institute of Geography, Bachelor(October 2017), 38. https://doi.org/10.13140/RG.2.2.34134.14402/6

[14] Schwartz, M. D., & Reed, B. C. (2010). Surface phenology and satellite sensor-derived onset of greenness: An initial comparison. International Journal of Remote Sensing, 20(17), 3451–3457.

[15] Tucker, C. J., Townshend, J. R. G., & Goff, T. E. (1985). African Land-Cover Classification Using Satellite Data. Science (New York, N.Y.), 227(4685), 369–375.

[16] Wang, Y., Wang, L., Li, H., Yang, Y., & Yang, T. (2015). Assessment of snow status changes using L-HH Temporal-coherence components at Mt. Dagu, China. Remote Sensing, 7(9), 11602–11620. https://doi.org/10.3390/rs70911602