Geospatial based Land degradation mapping and monitoring in North Eastern India: A case study in Manipur

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ABSTRACT

Land degradation is defined as the decreased in the quality of soil or land physically and chemically due to certain factors and phenomena. Manipur, one of the state of North east India, comes under the Purvachal ranges of Himalaya. The topography of the state is rugged and more than 90% of the total geographic area is hilly terrain. Land degradation assessments becomes a trending way to responds to the environmental concerns in the developing region as it effects significantly on their agriculture and food security. Degradation of the land resources in this part of North Eastern India is quite rapid and prevalent due to various anthropogenic, natural and climatic factors. According to the NRSC report on desertification and land degradation atlas, 2011, 25.74% of the total geographical area of the state comes under the category of vegetation degradation. This paper explore the applicability of the methodology which is based on Land Degradation Assessment in drylands (LADA) to delineate different type of degraded land in the region using remote sensing based derived indices and controlling factors that directly/indirectly triggers the degradation of land resources of the region. In this study, Normalized difference vegetation index (NDVI), Enhanced Vegetation index (EVI) and Drought index (DI) are considered as the controlling variables for mapping the region susceptible to land degradation. The satellite data product (having high spatial and temporal scale) employed in this study was generated or synthesize using Spatio-temporal image fusion model (STI-FM) of the Landsat-8 and Moderate Resolution Imaging Spectroradiometer (MODIS) reflectance. It is expected that this model will provide a mechanism to identify various hot spots degraded region and will help the policy makers to take an effective decision making for conservation of the land resources of the region.

KEY WORDS: NDVI, EVI, VHI, STI-FM.

INTRODUCTION

Land resource is the most abundantly available resource and it produces various products which are essentials for the human to flourish its civilization. However due to the uncheck and relentlessly exploitation of the resource, a serious threat of decrease in the productivity and quality of the land resource product has been faced (Tagore, et al. 2012). Land degradation is defined as the gradual decrease in the quality of soil and land, physically and chemically due to effect of certain factors causing particular phenomenon. Land degradation can be defined as the persistent reduction in the biological and economic productivity of terrestrial ecosystems, including soils, vegetation, other biota, and the ecological, biogeochemical and hydrological processes that operate therein (Reynolds, 2001).

The ecosystem and landscapes of an environment changes in continuous states due to various drivers which are natural as well as anthropogenic. Degradation of the land or soil resource can occur at various spatial and temporal scale. The complexity of the spatial and temporal scale quantifies the degree or severity of the degradation (Waswa, 2012). Aridity, extreme climatic events over a long stress of duration and drought may be consider as the natural cause of land degradation while unchecked or unsustainable land use by the human such as deforestation, shifting cultivation, over-cultivation, overgrazing as well as the socio economic drivers (Eckert, et al. 2015).

On the global scale, land degradation or soil degradation are monitor and assessment are done by LADA (Land Degradation Assessment In Dryland) (Biancalani, et al. 2011) project of FAO (Food And Agriculture Organisation of the United Nation); UNCCD (United Nations Convention To Combat Desertification), GLASOD (Global Assessment of Human-induced Soil Degradation). On the national level or country level, for India, the land degradation mapping monitoring and assessment of soil/ land degradation are done mainly by National Remotes Sensing Centre (NRSC), National Bureau Of Soil Survey And Land Use Planning (NBSSLUP); All India Soil and Land Use Survey (Ais&Lus), Central Arid Zone Research Institute (Cazri).

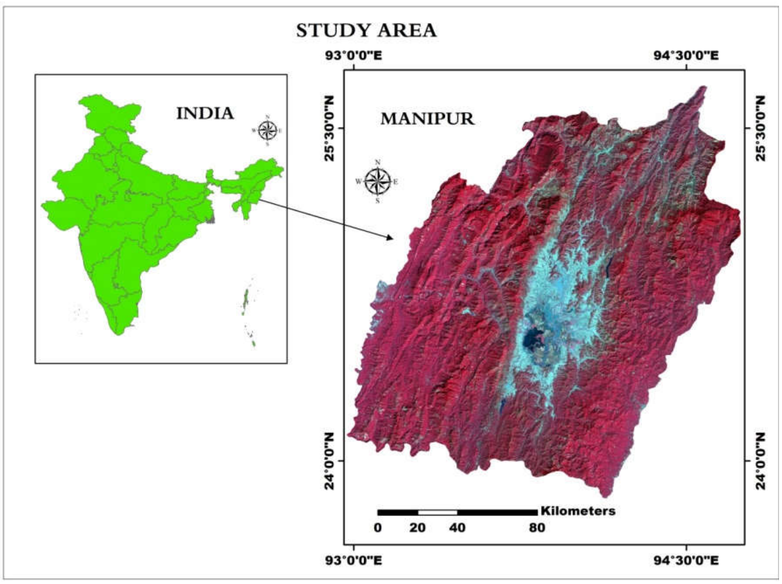
Space Application Centre (SAC), Indian Space Research Organisation (ISRO), Ahmadabad, India published, 'Desertification and land degradation atlas of India' in 2016. According to the analysis, 96.40 mha area of the country is undergoing process of land degradation i.e., 29.32% of the Total Geographic Area (TGA) of the country during 2011-13, while during 2003-05 the area under land degradation is 94.53 mha (28.76% of the TGA). Rajasthan, Maharashtra, Gujarat, Jammu & Kashmir, Karnataka, Jharkhand, Odisha, Madhya Pradesh and Telangana contributes around 23.95% (2011-13) and 23.64% (2003-05) of desertification/land degradation with respect to total TGA is contributed by in descending order. All other remaining states are contributing less than 1% (individually) of desertification/land degradation (ISRO, 2016).

As for the state of Manipur, the total percentage of area under desertification/ land degradation for the period of 2011-13 is observed to be 26.96% of the total geographical area. The desertification/ land degradation area in Manipur has increased about 0.40% since 2003-05. Vegetation Degradation is observed to be the most significant process of desertification/ land degradation in the state which accounts about 25.78% in 2011-13 and 25.74% in 2003- 05 (ISRO, 2016). For mapping and monitoring the changes, SAC adopted the remote sensing and GIS techniques. Satellite imageries of Indian Remote Sensing Satellite (IRS) AWiFS (Advanced Wide Field Sensor) (2003- 2005, 2011) has been used.

In this study, the concept of land degradation mapping on sub national level using the vegetation index, NDVI as proposed by LADA (Biancalani, et al. 2011) has been adopted. Moreover, the Vegetation health index is also integrated with the NDVI to map and monitor the trend and rate of land degradation in the state of Manipur (Amalo, et al. 2017).

STUDY AREA

Figure 1: Study Area (Manipur)



In this study, the land degradation is mapped and monitored for the state of Manipur, north- eastern India. The study is part of the eastern extended range of Himalaya namely Purvachal and share the international boundary with Myanmar in the eastern front. The state constitute of valley region in the centre which surrounded by the hill ranges in all direction and has the total geographic area (TGA) of 22,327km^2. The states extends from 92.6019450 deg E to 95.1753321 deg E longitude and 23.4759838 deg N to 25.5746684 deg N latitude. The valley region comprises of almost 10% of the TGA of the state and the remaining area is cover with hill ranges. The average elevation of the valley is about 790 m above the sea level and that of the hills is ranges between 1500 m and 1800m above mean sea level. Barak river basin, Manipur river basin, Yu and Lanye river basin the main river basin of the state. The southwest monsoon climate is prevailed in the region and receives the average rainfall of 1500mm per year and temperature ranges from sub zero to 36° C (ISRO, 2016).

DATA SET

In this study, remote sensing based data is adopted to map and monitor the trend in land degradation. The time period considered in the study are 2006; 2009; 2011 and 2017. Periods between end of the winter season and the starting of pre-monsoon for each selected year before the onset of southwest monsoon is used, so as to avoid the problem of cloud contamination in the satellite imagery data used.

NDVI and EVI and Land Surface Temperature (LST)

16 days composite vegetative indices namely NDVI and EVI of MODIS with spatial resolution of 250 metres is retrieve from the data pool of Land Processes Distributed Active Archive Center (LPDAAC) of United State Geological Survey (USGS). 16 days composite dataset of the month of February and March for the time period mentioned above. (Didan, et al. 2015).

8 days composite land surface temperature data of MODIS with spatial resolution of 1km is retrieved from the same source as that of NDVI and EVI for the similar study time period. These dataset are pre-processed and reproject so that it can be overlay with Landsat image . (Wan 2013).

The NDVI, EVI and LST dataset, which acquisition dates correspond to the date of acquisition of Landsat dataset used, are generated from the daily Surface Reflectance dataset of MODIS with 500 metre spatial resolution and LST dataset with 1km resolution. However the NDVI and EVI dataset are resample to 250 metre so that it can be integrated with the 16 days composite dataset. As in case of LST dataset, the pixel size is similar to that of the 8 days composite (Vermote, Roger and Ray 2015).

Landsat Dataset (5 Thematic Mapper (TM), 7 Enhanced Thematic Mapper and Landsat 8- OLI)

The Landsat dataset is retrieved from the USGS Earth explorer. The Collection -1 Higher level product are order for the single time period for each year within the study time period. Both the dataset has the spatial resolution of 30 metres and temporal resolution of 16 days. NDVI, EVI and LST dataset are generated by using the NIR, RED and TIR bands for each year (Department of the Interior 2016) (Department of the Interior 2017) (Didan, et al. 2015).

NDVI = (NIR- RED)/(NIR+RED)

EVI = 2.5*{(NIR- RED)/(NIR+1+(2.4*RED)}

T = K2 ln(K1 Lλ + 1)
where: T = TOA Brightness Temperature, in Kelvin.
Lλ = Spectral radiance (Watts/(m2 * sr * µm))
K1 = Thermal conversion constant for the band (K1_CONSTANT_BAND_n from the metadata)
K2 = Thermal conversion constant for the band (K2_CONSTANT_BAND_n from the metadata)

Dataset

YEAR	LANDSAT DATASET [Path 135; Row: 42 and 43]
	DATE
2006	6th February
2009	14th February
2011	4th February
2017	4th February

Table 1: LANDSAT Dataset

METHODOLOGY

The approach of integrating MODIS and Landsat dataset is to generate an output with high spatial and temporal resolution. So as to generate such dataset, Spatio-Temporal image fusion model (STI-FM) has been adopted. Regression equation is generated between two MODIS dataset of two time period M1 and M2; and the equation is employed to the Land sat dataset of time period L1 which correspond to the time period of M1 and thus L2 is synthesized which have high spatial resolution of Landsat and high temporal resolution of MODIS (Hasan 2015).

In this study, the MODIS dataset, which acquisition date corresponds to that of Landsat image, is assumed as M1 and the composite datasets as M2(NDVI; EVI and LST) for the study time period. Implying the STI-FM, the datasets (NDVI; EVI and LST) are synthesize for each study time period having high spatial and temporal resolution. The synthesize NDVI dataset for a study time period is composed together to generate a dataset which signifies the average value of that time period for every year. In similar manner, the average composite dataset is generated for EVI and LST for the respective years.

The synthesize composite NDVI is classified into classes according to the density of vegetation covers such that (0 to 0.05) is classified as very poor, (0.05 to 0.25) as poor, (0.25 to 0.75) as average, (0.75 to 0.95) as good, and (0.95 to 1) as very good (Peters, et al. 2002).

EVI and LST dataset are employed to calculate the Vegetation condition index (VCI) and Temperature condition index (TCI) respectively. Integrating these two indices, Vegetation health index is generated which signifies the health of the vegetation.

VCI = (EVIi- EVImin)/(EVImax- EVImin) × 100

Where EVIi is the the EVI value of the pixel; EVImin is the minimum value and EVImax is the maximum value respectively.

TCIi= LSTmax- LSTiLSTmax- LSTmin × 100

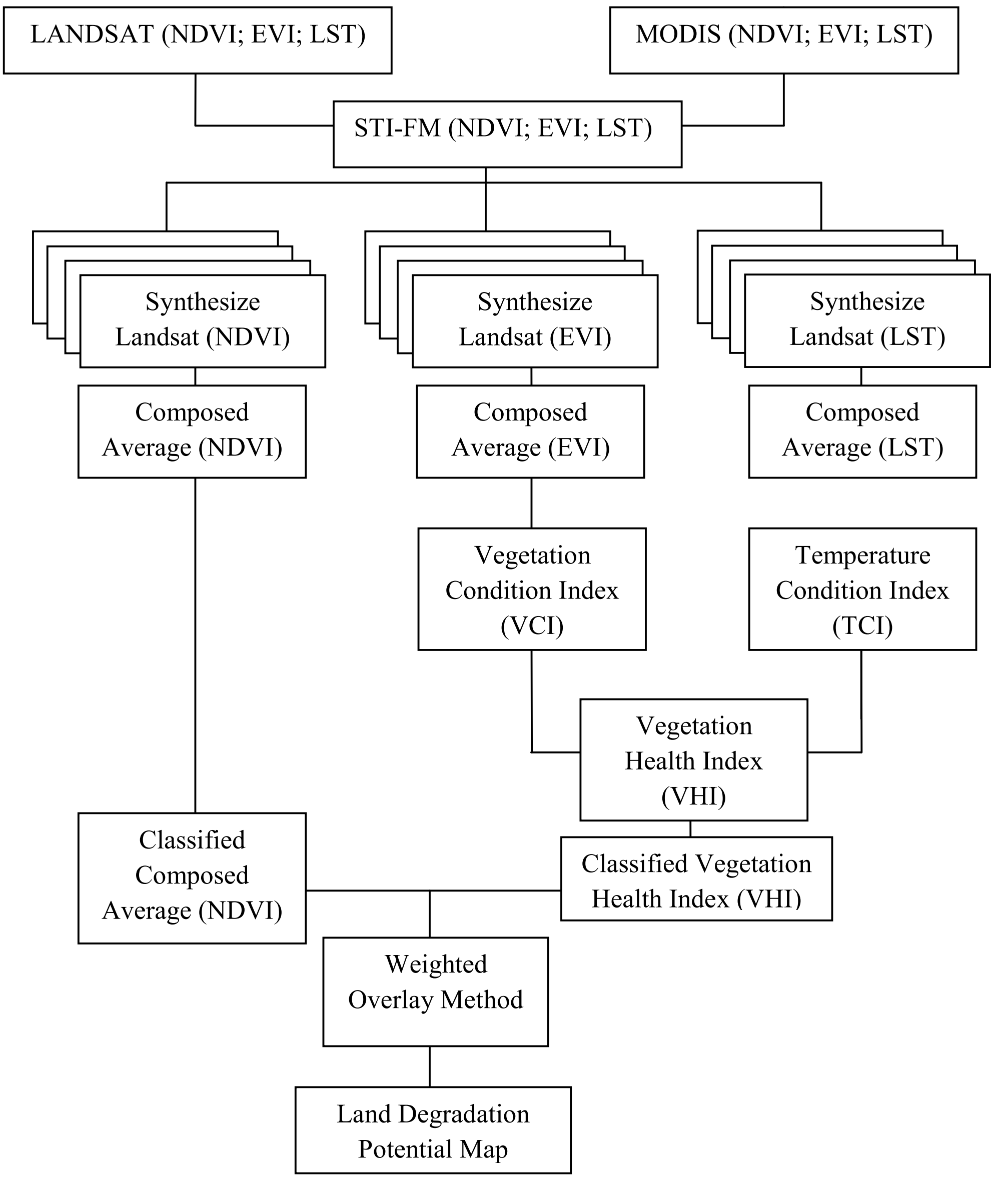
Where TCIi is the the TCI value of the pixel; TCImin is the minimum value and TCImax is the maximum value respectively.

$$VHI=0.5VCI+0.5TCI$$

VHI value is generated by using the above equation. The values of VHI is classified into five classes namely Extreme Drought (VHI < 10), Severe Drought (VHI <20), Moderate drought (VHI<30), Mild drought (VHI<40) and No drought (VHI>40) (Amalo, Hidayat and Haris, Comparison between remote-sensing based drought indeces in East Java 2017).

In this study, hypothetically, assumption is being made that the NDVI and VHI influences equally in the detection of land degradation. Thus the two variables are integrated using weighted overlay technique both having equal weightage. Hence, the land degradation image is generated for the study area.

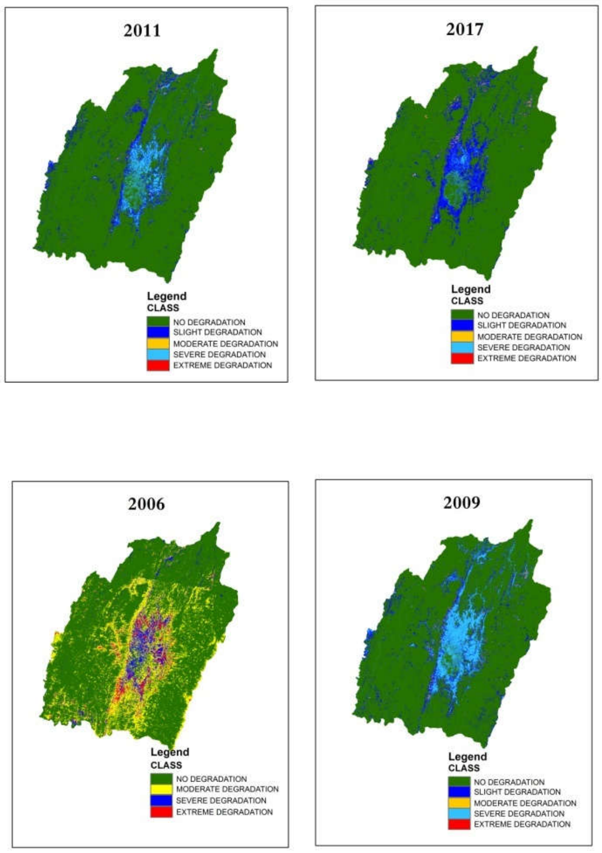
Figure 2:Methodology Flow Chart



RESULTS AND DISCUSSION

The land degradation data of the study area for different time period are generated in this study. The generated data are classified into five class such as No degradation, Slight degradation, Moderate degradation, Severe degradation and Extreme degradation. Since, in this study, vegetation indices and land surface temperature are the main factor, the result thus observed infer mainly the vegetation degradation. Water bodies is restricted from degradation in this study.

The overall degradation is highest in the year 2006 with 28% of the TGA under various rate of degradation and least rate of degradation is observed in the year 2017, with 12.59%. The rate of overall degradation is trending in descending trend from the year 2006 to 2017.



Conclusion

The study depicts the changing trend of land degradation in the state of Manipur, India within a time period (2006, 2009, 2011 and 2017). For each year, the dataset procured in the month of February and March is adopted in the study, so as to avoid the cloud contamination problem. The cloud contamination affect in the satellite imageries data in most part of the year. Moreover, the variables employed in the study is limited to vegetation indices and land surface temperature, it is restricted mostly to the vegetation degradation. Thus the model has limitation in depicting the land degradation caused by other factors such as soil erosion and water logging and degradation due to access salt effects. The prevailing limitations in the current study will be looking forward to overcome in the future works and to generate more prominent results depicting the land degradation in the state of Manipur, India.

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Bibliography

Amalo, Luisa Febrina, Rahmat Hidayat, and Haris. “Comparison between remote-sensing based drought indeces in East Java.” *IOP conference Series: Earth and Environmental Science.* 2017. 54 012009.

—. “Comparison between remote-sensing based drought indeces in East Java.” *IOP conference Series: Earth and Environmental Science.* 2017. 54 012009.

Biancalani, R, F Nachtergaele, M Petri, and S Bunning. “Land degradation assessment in drylands: methodology and results.” LADA project report, FAO, ROME, 2011.

Department of the Interior, USGS. July 2017. https://landsat.usgs.gov/sites/default/files/documents/ledaps_product_guide.pdf (accessed August 5, 2017).

—. 29 March 2016. https://landsat.usgs.gov/sites/default/files/documents/Landsat8DataUsersHandbook.pdf (accessed August 5, 2017).

Desertification and Land Degradation Atlas of India (Based on IRS AWiFS data of 2011-13 and 2003-05). Ahmedabad: Space Applications Centre, ISRO, Ahmedabad, India, 2016.

Didan, Kamel, Armando Barreto Munoz, Ramon Solano, and Alfredo Huete. June 2015. https://vip.arizona.edu/documents/MODIS/MODIS_VI_UsersGuide_June_2015_C6.pdf (accessed September 14, 2017).

Eckert, Sandra, Fabia Hüsler, Hanspeter Liniger, and Elias Hodel. “Trend analysis of MODIS NDVI time series for detecting land degradation and regeneration in Mongolia.” *Journal of Arid Environment*, 2015: 16-28.

Hasan, Khaled Hazaymed and Quazi K. “Spatiotemporal image-fusion model for enhancing the temporal resolution of Landsat-8 surface reflectance image using MODIS image.” *Journal of Applied Remote Sensing*, 2015: Vol. 9.

Joshi, P.S. Roy and P.K. “Forest cover assessment in the north-east India-- the potential of temporal wide swath satellite sensor data (IRC-1C WiFS).” *International Journal of Remote Sensing*, 2002: 23:22, 4881-4896.

Peters, Albert J., Elizabeth A. WalterShea, Lel JI, Andres Vliia, Mlchael Hayes, and Mark D. Svoboda. "Drought Monitoring with NDVI based standardized vegetation index." *Photogrammetric Engineering & Remote Sensing.* American Society for Photogrammetry, 2002. Vol. 68, No. 1, 71-75.

Reynolds, J.F. "New initiative on desertification and land degradation." *LUCC Newsletters*, 2001: Vol No. 7.

Tagore, G.S., G.D. Bairagi, N.K. Sharma, R. Sharma, and S. Bhelawe and P.K. Verma. "Mapping of degraded lands using the remote sensing and GIS techniques." *Journal of Agricultural Physics*, 2012; : Vol.12, No. 1; 29-36.

Tran, Hao Thi, James B. Campbell, Tri Dinh Tran, and and Ha Thanh Tran. "Monitoring drought vulnerability using multispectral indices observed form sequential remote sensing (Case Study: Tuy Phong, Binh Thuan, Vietnam)." *GIScience and Remote Sensing*, 2017.

Vermote, E. F., J. C. Roger, and J. P. Ray. May 2015. https://lpdaac.usgs.gov/sites/default/files/public/product_documentation/mod09_user_guide_v1.4.pdf (accessed August 5, 2017).

Wan, Zhengming. December 2013. https://lpdaac.usgs.gov/sites/default/files/public/product_documentation/mod11_user_guide.pdf (accessed September 14, 2017).

Waswa, Boaz S., P. L. G. Plek, T. Lulseged, P. Okoth, and D. Mbakaya. "From space to plot: Assessment of land degradation patterns in kenya and its implication for sustainable land management." *Agro Environ*, 2012.