LAND COVER CHANGE ANALYSIS AND TREND IDENTIFICATION IN TIME SERIES MODIS EVI USING WAVELET TRANSFORM

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ABSTRACT

Spatio-temporal analysis of land cover changes and vegetation condition assessment are important to understand the tropical vegetation response under different natural and anthropogenic factors. Moderate Resolution Imaging Spectroradiometer (MODIS) Enhance Vegetation Index (EVI) data is widely used for monitoring long term vegetation changes. MODIS EVI time series data with systematic and uniform temporal profile pattern represents the existing vegetation conditions on the land surface. Inherent properties of time series MODIS EVI such asseasonal variations, long and short term fluctuations etc., affect its overall variance structure. Inter-annual variation of long term time series MODIS EVI data provides important information such as drought, land/vegetation degradation etc. Any change in the temporal profile and its pattern can be easily identified through the wavelet transform. Further, time series MODIS EVI data has inherent noise introduced by clouds and poor atmospheric conditions and are not in relation with vegetation changes.

The present study is carried out to assess the spatio-temporal variations (inter-annual variation) and patterns in time series MODIS EVI data using wavelet analysis. Particularly, integration and analysis of remote sensing and spatially explicit data helps in understanding land use/land cover change trends. The Wavelet Transform (WT) is used to analyze signals in time-frequency domain and to detect overall trend in the signal. Wavelets are functions that decompose a complex signal into component sub-signals. It decomposes signal and derives the wavelet coefficients. Further, inverse transform is applied to obtain modified coefficients. In this study, MODIS 16-day MOD13Q1 global products with spatial resolution of 250m from NASA Earth observing system (EOS) for the period 2005-2014 have been used. Time series EVI data is used to identify trends in the land cover and subsequently Mann-Kendall test is conducted to confirm the significance of the identified trends.

1. INTRODUCTION

Time series satellite remote sensing MODIS data is an important source of information to characterize land cover change and its dynamics. In this study, wavelet analysis was used to detect the spatio-temporal variation in land cover using MODIS EVI data. MODIS EVI time series data (MOD13Q1 global products with 250 meter spatial resolution) for the period 2005-2014 was used to identify trend in the land cover changes. Subsequently Mann-Kendall test (Mann 1945; Kendall 1975) was conducted to confirm the significance of the identified trends.

Researchers in the past proposed various change detection algorithms based on different requirements and conditions (Lunetta et al., 2006). Most of these change detection techniques use differences between two or more images collected on different dates and not well-suited for the massive high-dimensional spatio-temporal data sets available for Earth Science (Boeiah et al., 2008). Time series based change detection has advantage to analyze the temporal dynamics of landscape changes. In the past, there has been limited work in time series-based land cover change detection, but this work has had limited success (Boriah et al., 2008).

Various time series parameters derived from NOAA (AVHRR), SPOT (Vegetation) and TERRA/AQUA(MODIS) sensor such as Enhanced Vegetation Index (EVI), Normalized Difference Vegetation Index (NDVI), Leaf Area Index(LAI) etc. have been extensively used for different ecosystem applications (Priyadarshi et al., 2017; Lu et al. 2007). Vegetation Index (VI) is used to measure the presence of green vegetation on the land surface. MODIS EVI data is useful for land cover change detection due to its high revisit capability and wide spectral range especially over tropical region where cloud and atmospheric contamination is very high.

Clouds and poor atmospheric conditions usually induce noise in the VI values, which are not compatible with the gradual process of vegetation change (Priyadarshi et al., 2017; Lu et al., 2007). EVI time series data may have missing information and noise (Priyadarshi et al., 2017; Moody et al., 2005). Such noise degrades the data quality and introduces considerable uncertainty in time series and complicating the temporal pattern analysis (Priyadarshi et al., 2017; Lu et al., 2007). Hence, this data needs to be corrected before deriving any meaningful information on land cover changes and its trend.

Time series MODIS EVI data has different frequency components and is non-stationary (Piao et al., 2012; Martinez & Gilabert. 2009). Further, time series data is characterized by patterns like seasonality and trends. Thus, seasonal variation and fluctuations in time series data affects its overall series structure. MODIS time series VI data allow characterization of temporal profile and vegetation dynamics at different temporal scales due to its high temporal resolution.

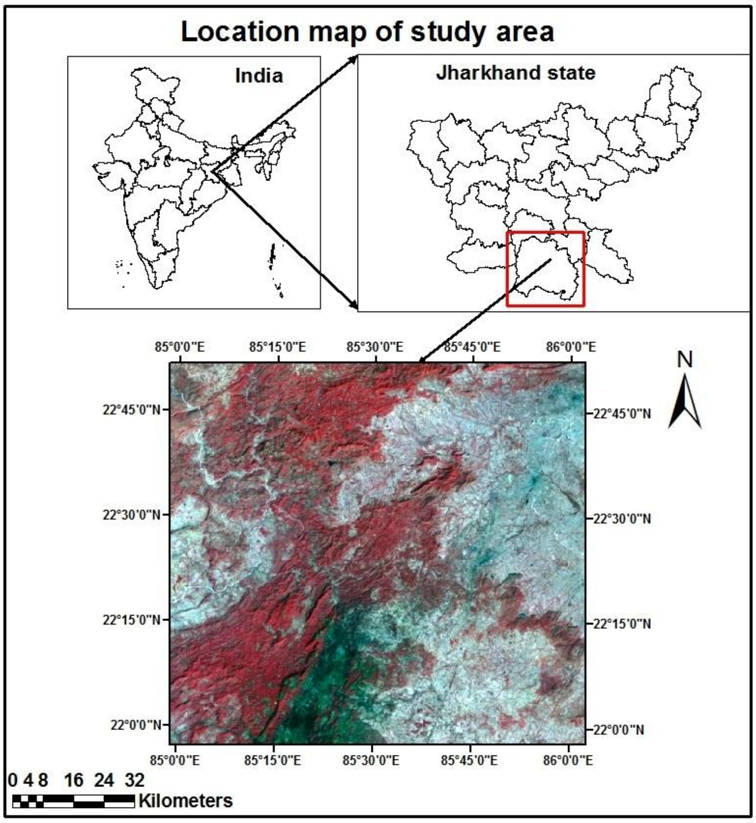

Figure 1. Location map of the study area.

Analysis of MODIS EVI time series data and trend identification is useful for studies on long term vegetation and land cover changes. In this study, WT was used for land cover change analysis as this technique found to be useful for studying multiscale and non-stationary processes for different temporal and spatial scales (Martinez & Gilabert. 2009; Furon et al., 2008). Fundamental principle of WT is to analyze the signal according to different scales and resolutions. Inter-annual variation was used to identify the trend and detect land cover change by estimating magnitude of change. Seasonal changes and fluctuation in the signal act as noise in the time series EVI data, which may introduce the error in the signal trend. Removal of noise in the signal using wavelet analysis helps to detect and quantify the trend in the signal thus increases the significance of the land cover change (Piao et al., 2012; Martinez & Gilabert. 2009). In this study, time series EVI data was used to identify trends and to detect land cover change. The slope of identified trend was also calculated using the Sen's method and subsequently Mann-Kendall test was conducted to confirm the significance of the identified trends.

2. STUDY AREA

This study area is part of West Singhbhum district, Jharakhand State, India and is geographically located between 21.95° - 22.89°N and 84.95° - 86.06°E (Figure 1). The study area occupies ~ 13,000 km^2. Dense forest with best Sal trees and famous Saranda forest is major land cover of the study area. Average annual rainfall of the study area is nearly 1400 mm. Terrain of the study area is highly undulating and average elevation is 244 m above mean sea level (MSL). The study area is considered to be an important ecologically sensitive zone as large deposits of iron ore are being mined for meeting the growing demand for steel production.

3. DATA

MODIS 16-day vegetation index (EVI) MOD13Q1 global products with Quality Assurance (QA) flags were obtained from NASA Earth observing system (EOS) for the period 2005 to 2014 (10 years) (http://e4ftl01.cr.usgs.gov/MOLT/MOD13Q1.005/). The MOD13Q1 product include vegetation indices NDVI and EVI, is one of the most widely used MODIS product for land applications such as land cover/use change analysis, crop monitoring and ecosystem monitoring (Lunetta et al., 2006). MODIS 16-day EVI MOD13Q1 global products are having a spatial resolution of 250 m in sinusoidal projection and were re-projected to geographic lat/long using MODIS Re-projection Tool. Further, noise in the time series data was removed using Wavelet analysis (Priyadarshi et al., 2017)

4. METHODOLOGY

Wavelet analysis is a widely used approach to analyze the land use/land cover trends at different time scales ranging from months to years. Particularly, integration and analysis of remote sensing data and spatially explicit data helps in understanding land use/land cover change trends (Fung, 1990). The WT was used to analyze signals in time-frequency domain and to detect overall trend in the signal (Sifuzzaman et al., 2009). Wavelets are functions that decompose a complex signal into component sub-signals (Martinez & Gilabert. 2009; Galford et al., 2008). The WT was applied to analyse stationary and non-stationary levels of variation in time series EVI data. The stationary level excludes the noise and anomalous variations, and provides the stable pattern like the seasonal mean, monthly mean and annual mean. These are also known as approximation coefficients or stable mode that represents high-scale and low frequency signal components. Detailed coefficients, which are also known as non-stationary or abnormal level or detail level shows the high frequency, localized, abrupt changes or discontinuities in the time series data.

The Mann-Kendall (MK) test (Mann 1945; Kendall 1975) used to detect monotonic trends in the EVI time series whereas Sen's method (Sen, 1968) used to estimate the magnitude of the trend. MK test works for all distributions due to its non-parametric nature. MK test is widely used because it is robust, easy to calculate and handle missing value against anomalous condition. The magnitude of trend is calculated using Sen's slope in time series data and MK test is conducted to confirm the significance of the identified trends.

5. RESULTS & DISCUSSION

5.1 Wavelet Analysis

Forest cover change trends identified through wavelet decomposition located in west Singhbhum district of Jharkhand, India are shown (Figures 2&3). Overall trend of time series EVI data identified using (negative change and positive change locations) wavelet analysis is shown in Figure 2&3. In this study, discrete wavelet transforms (DWT) with Daubechies wavelet (db5) as mother wavelet with level 6^{th}decomposition was applied to the time series EVI data for identification of change location for the period 2005-2014. It can be clearly seen in Figures 2&3 that the trend becomes more and more clearer with each approximation from 1st level decomposition (A1) to 6^{th} level decomposition (A6) in wavelet analysis. Decreased trend for the change location (Fig. 2) and increased trend for positive change location (Fig. 3) for the time period 2005-2014.

Figures 2&3 clearly shows how the wavelet analysis (DWT) decomposes the original signal into its fine scale or detailed modes (D_j) and large scale information or approximation mode (A_j). The large scale coefficients or approximation mode present the global view of the signal while the high frequency coefficients provide the detailed signal information. The approximation modes are denoted by A1, A2, A3, A4, A5 and A6 and the detailed modes are denoted by D1, D2, D3, D4, D5 and D6 as shown in Figures 1&2.

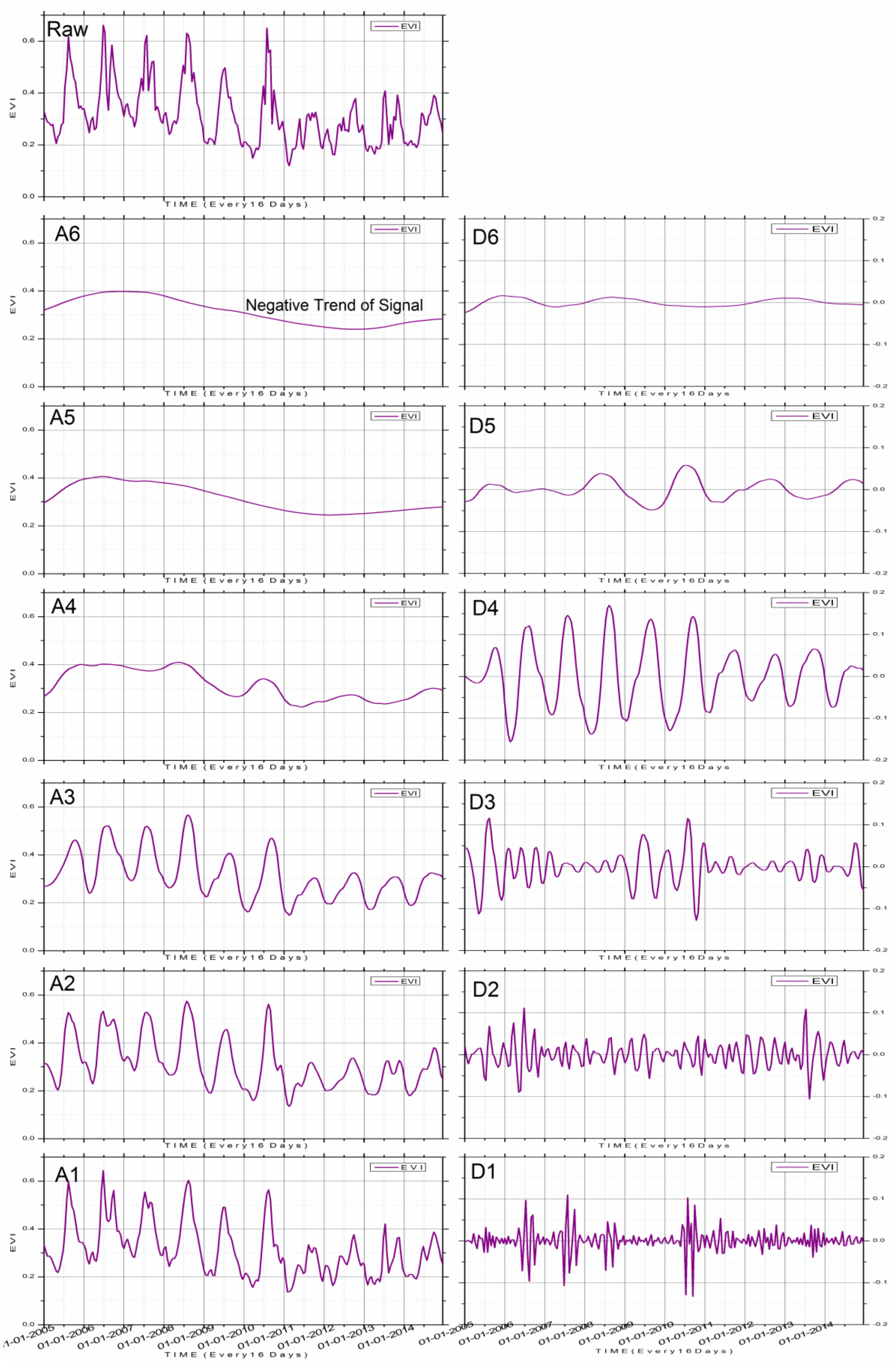

Figure 2. Wavelet decomposition of time series EVI data during the period 2005-2014 for forest cover (Representation of negative trend).

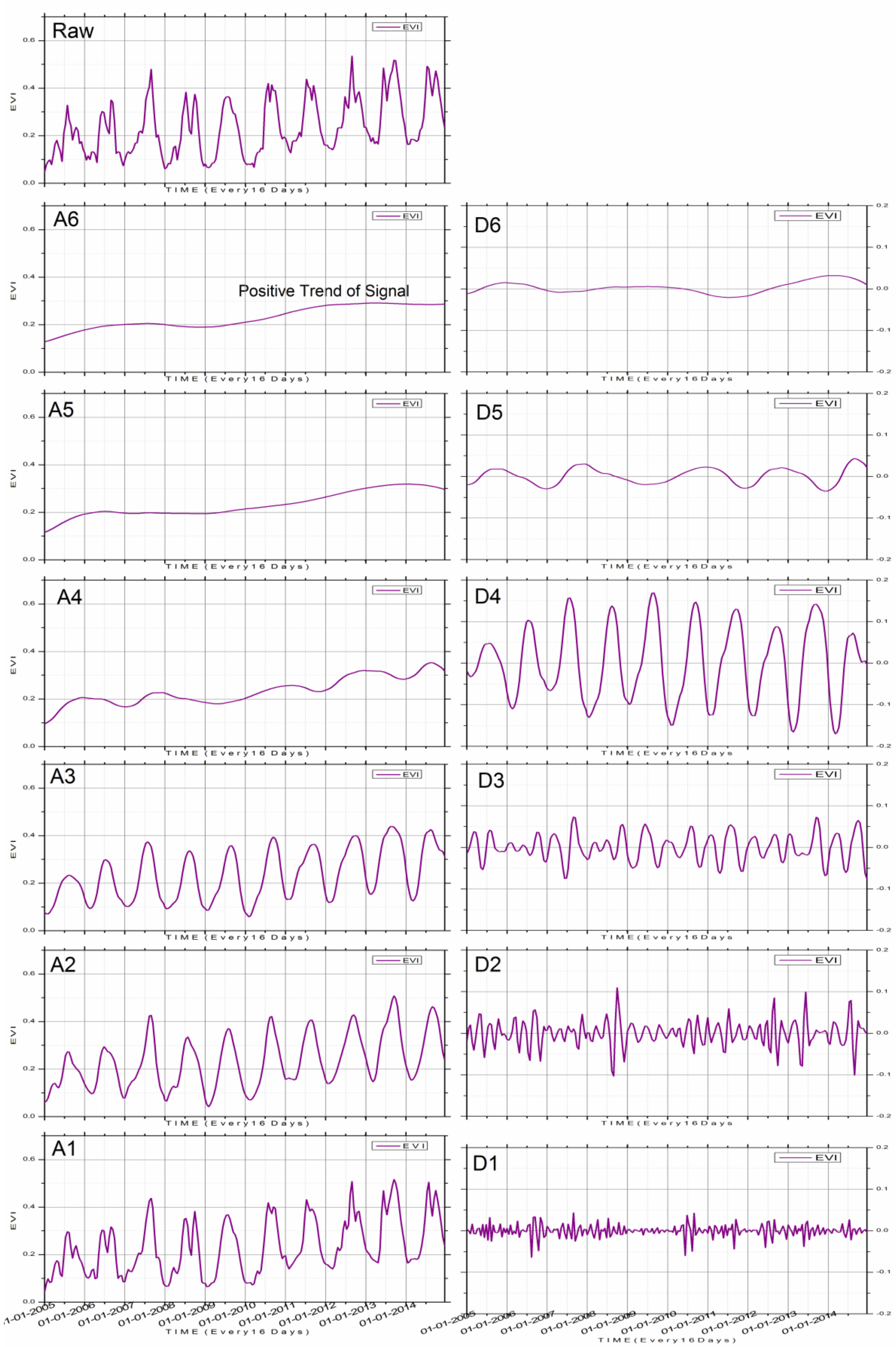

Figure 3. Wavelet decomposition of the time series EVI data during the period 2005-2014 for forest cover (Representation of positive trend).

Detail component of the signal is present due to intra-annual variation or noise and its significance increases with the increase of scale (right panel of Fig. 2&3) and smoother signal are present in the approximation series associated with low-frequency component (left panel of Fig. 2&3). The detail component of the signal offers to analyze the influence of the inter-annual variations. The first decomposition level of detail component has high frequency in the signal and enables us to identity local features of short duration or abnormal fluctuation as well as noise in the signal. The approximation component A6 series linked with inter-annual variation & land cover change and identified the trend in the signal.

5.2 Identification of land cover change trend and its magnitude

In this study, the non-parametric Mann-Kendall (MK) test was used to calculate significance and the p-value using MATLAB. MK test provide strength and direction of the trend but it can't estimate the magnitude of the trend. Hence, the non-parametric Sen's method has been used to calculate the slope Q of the trend.

The inter-annual series A6 represents signal trend after smoothening the original time series EVI data. The MK tests have been applied to the inter-annual A6 series. The non-parametric MK tests were used to identify trends in the time series EVI data. The significance of these tests is tested at 95% confidence level by considering the hypothesis H coefficient (H=1: significant; H=0: non-significant) and two-sided p-value ($p<0.05$). The p-value is the probability of the data that is randomly distributed and p-value <0.05 indicates a significant trend. The magnitude of the land cover change trend for the study area is computed by Sen's slope method (Figure 4) for the period 2005-2014.

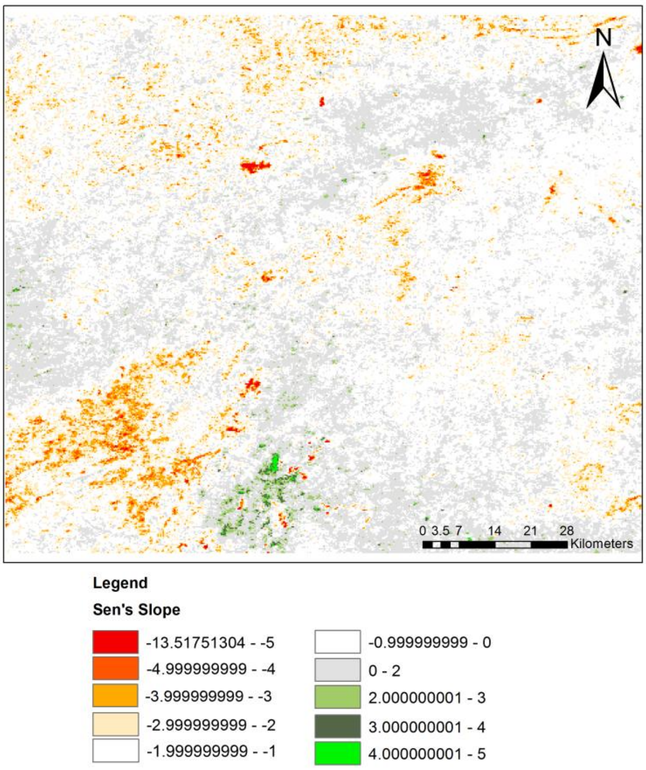

Figure 4. The map shows the magnitude of the land cover change.

An analysis was carried out to find out the optimum threshold for land cover change analysis using different slope thresholds like -2, -3, -4, -5 and -6. From this analysis, it is found that the magnitude Q crossing the threshold value of -5 (negative) signifies change. Figure 5 shows the identified land cover changes locations in map associated with negative trends in vegetation cover (Red colour depicts land cover change). Figure 5 focuses on the identification of the land cover change locations with $H = 1$, p-value < 0.05 and $Q \leq -5$. Figure 5A&B shows change location corresponding to villages Banskata and Nuia respectively with Landsat image of January 2011 as background. Proposed approach had identified nearly 358 locations as change locations in the study area. It provides information about the region of land cover change from long term time series EVI data of study area during the period 2005-2014.

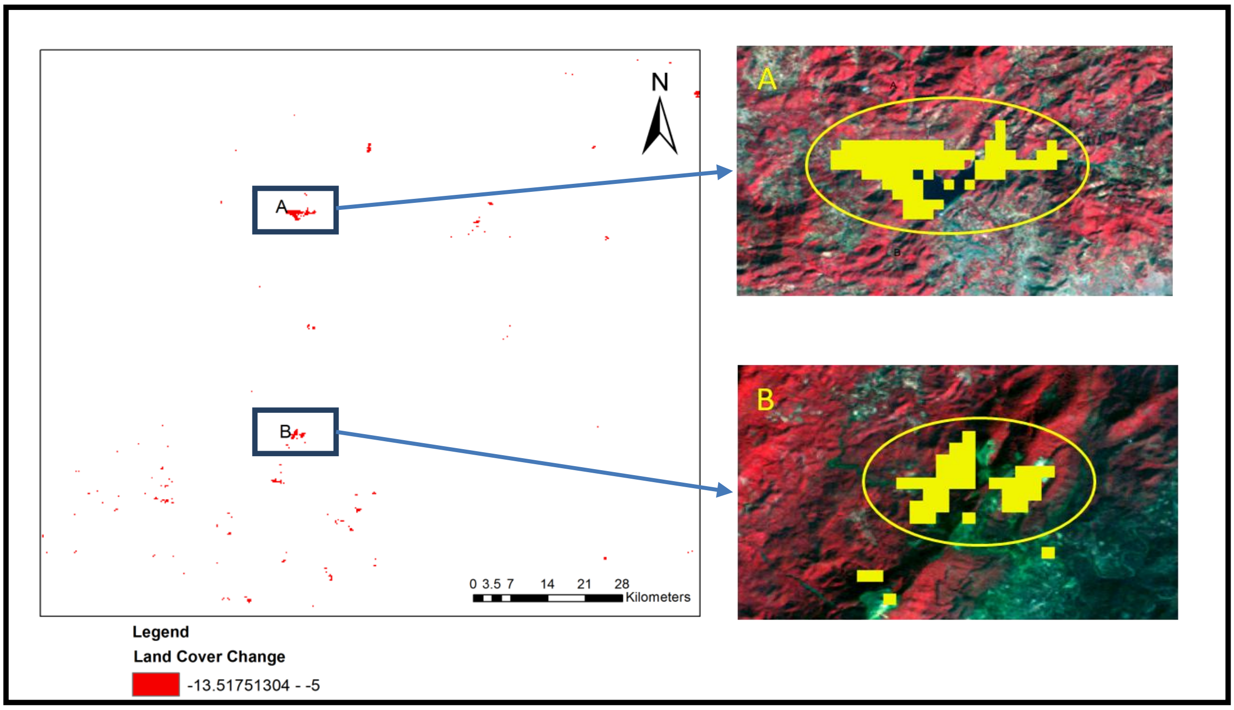

Figure 5. Identification of land cover changes associated with negative trends in vegetation cover. In particular, red colour represents land cover change.

6. CONCLUSION

Wavelet based proposed methodology for analysis of time series EVI data is quite useful for identification of land cover changes and also to quantify its magnitude. The inter-annual series A6 was used to detect trends in the time series EVI data, while it's magnitude of the trend was calculated using non-parametric Sen's slope Q method. The magnitude of the trends was used to quantify the positive or negative changes using the slope Q. Wavelet trend analysis was performed on inter-annual series A6 as it is not influenced by noise, seasonal variability or abnormal fluctuation in the signal. This methodology allows us to identify gradual and abrupt land cover changes such as land degradation and land cover change due to forest fires. This methodology is very useful for monitoring & management of land resources.

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