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ORIGINAL RESEARCH PAPER

Modeling of vegetation index and land surface temperature to identify and compare the changing trends, using generalized estimating equations

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ABSTRACT

Normalized difference vegetation index and land surface temperature data, in a sample plot each from east, center and west of Nepal, from 2000 to 2015, were analyzed to identify and compare the trends of vegetation and temperature changes during the period. The data were obtained from moderate resolutions imaging spectro-radiometer. Normalized difference vegetation index charactiszes a resolution of 250×250 m^2 and a 16-day composite period while land surface temperature has 8 days frequency with resolution of 1×1 km^2. The analysis was separate for normalized difference vegetation index and land surface temperature. The data were seasonally adjusted and then divided into three groups of five year period each, separate for every region. The generalized estimating equations were fitted to each period data. For all three regions, the results showed, there was a trend of significantly rising vegetation in eastern and western sub urban parts while the central urban city had a significant decline in trend. Whereas the temperature showed statistically significant and uniform fluctuating pattern of change in all three regions. The rate of temperature rise is fastest in central region where the vegetation is continuously declining. However, the results revealed no relationship of trend of changing temperature with that of vegetation.

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INTRODUCTION

Vegetation is the plant life of a region that indicates to the ground cover and is the most abundent biotic element growing on the earth. It is essential for sustaining ecological structures and functions at all possible spatial scales. Therefore, quantifying the characteristics of vegetation by time is utmost important for resource management, addressing the climatic issues and hence its values can be fully retained on earth's natural system. The temperature is another equally important ecological factor to determine the future of earth. Moreover the factors that cause climate change issues are mostly correlated with vegetation and temperature (Julien and Sobrino, 2009; Karnieli *et al*., 2009). The worldwide studies of vegetation (Eckert *et al.,* 2014; Liu *et al.,* 2015) and temperature (Kaufmann *et al.*, 2003; Chooprateep and McNeil, 2015) shows it has been variously changing in many of the places. However, the study of the time series events in any climate component is mostly difficult due to lack of reliable data in many parts of the world. To get rid of

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this problem, the satellite based remote sensing data are being poular in many subject areas throughout the world. Every remote sensing data has spatio-temporal characteristics which are considered to be the primary advantage in environmental studies. MODIS is a sensor, fitted aboard the Terra and Aqua satellites by the National Aeronautics and Space Administration (NASA) and monitors environmental changes due to fire, vegetation, temperature, earthquakes, droughts and flood on earth (NASA, 2015). The Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) are the data products from Moderate Resolutions Imaging Spectro-radiometer(MODIS). LST is the day time surface air temperature of earth while NDVI is a type of vegetation index which is dependent on its photo reflectance behavior that characteristically absorbs in the red and blue wavelengths, reflects in the green wavelength, strongly reflects in the near infrared (NIR) wavelength. Based on this principle, the data is calculated by the given Eq. 1:

$$NDVI = (NIR - RED) / (NIR + RED) \quad (1)$$

This relationship is often described as vegetation index. The linear regression model was common in various previous studies, showing positive and negative trends of vegetation (Kaufmann *et al.*, 2003; Karnieli, 2010; Zhang *et al*., 2013) and the LST change (Bounoua *et al*., 1999; Chooprateep and McNeil, 2013). Moreover, a lot of variations did exist among their works regarding the methods, data types and management (Piao *et al.*, 2003; Chandola *et al*., 2010; Eckert *et al.*, 2014; Mishra and Chaudhuri, 2015). The knowledge of annual trend of vegetation and temperature in Nepal is still rare. Therefore, the aim of this study is to assess the trend of vegetation and temperature for a comparative study in three different sites from east, central and west region, in the same ecological zone of Nepal, using appropriate statistical methods.

MATERIALS AND METHODS

This study was carried out in Nepal (Fig. 1) where three districts, Dhankuta, Kathmandu and Surkhet (Fig. 2), located from east to west, were randomly selected.

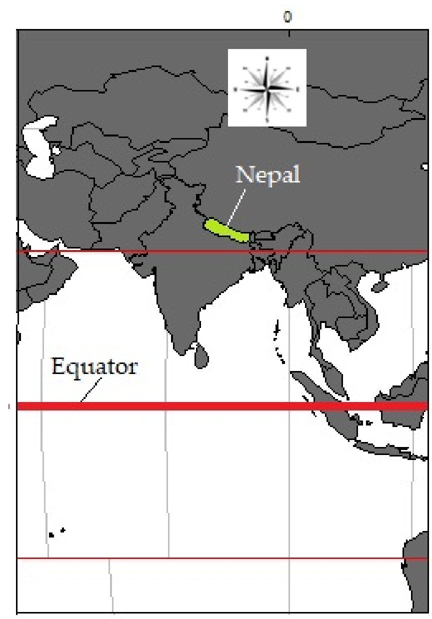

Fig. 1. Geographic location of Nepal in Asia

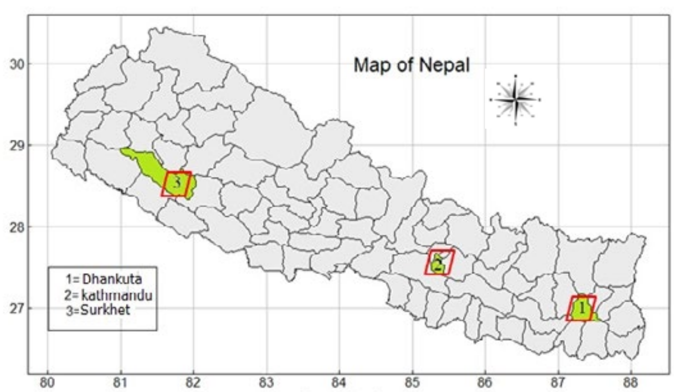

Fig. 2. The study area within Nepal country (b)

They were from hilly, sub tropical ecological zone of Nepal. Department of Forest resource and Suvey (DFRS) and Department of Hydrology and Meteorology (DHM) of government of Nepal report (Table 1) that, Dhankuta is a suburban area located in eastern region, having 679 km^2 area with population density 170/km^2 , annual temperature ranging from 3 °C - 25 °C, rainfall from 24 mm - 1260 mm and have average altitude of 1530 m. Kathmandu is an urban area located in central region, having 899 km^2 area with population density 20289/km^2 , annual temperature ranging from 2.4 °C –29 °C, rainfall from 13 mm - 360 mm and have average altitude of 1400 m. Surkhet is a suburban area located in western region, having 2451 km^2 area with population density 140/km^2, annual temperature ranging from 6 °C – 37 °C, rainfall from 0.02 mm - 519 mm and have average altitude of 875 m (DFRS, 2015; DHM, 2015).

The NDVI and LST data were downloaded from MODIS's website (ORNL DAAC, 2015). While ordering the data, the area of the central point coordinates (eg., Dhankuta: 27.15 N, 87.35 E; Kathmandu: 27.59 N, 85.39 E and Surkhet: 28.62 N, 81.88 E) was 250×250 m^2 in NDVI and 1×1 km^2 in case of LST data. This central area was then extended 10 km each to the north and the south, and 10 km each to the east and the west. As a result, the area of 410.06 km^2 (20.25×20.25 km^2) with 6561 grids for NDVI and 441.00 km^2 (21×21 km^2) with 441 grids for LST were created by MODIS's website (Fig. 3). Both the data were specified for a period from 2000 to 2015. The NDVI data were observed in every 16 day interval period, had around 23 observations every year and hence a total of 345 observations for a period of 15 years. For LST the data recorded were of 8 days interval period making 46 observations a year and 690 observations during 15 years period. The data for east and west regions were also retrived by the same process.

The NDVI values ranged from -1 to 1. The negative

Table 1. Detail about the three study sites

Details	Dhankuta	Kathmandu	Surkhet
Location in Nepal	East	Center	West
Urban/ Sub urban	Sub urban	Urban	Sub urban
Latitude/ Longitude of the data center	27.15° N, 87.35° E	27.59° N, 85.39° E	28.62° N, 81.88° E
Area (km^2)	892	899	2451
Population density (/km^2)	183	20289	140
Annual temperature (°C)	14.6-24.9	2.4-29	6-37
Annual rainfall (mm)	1120.8	13-360	0.02-519
Average altitude (m)	1192	1400	875

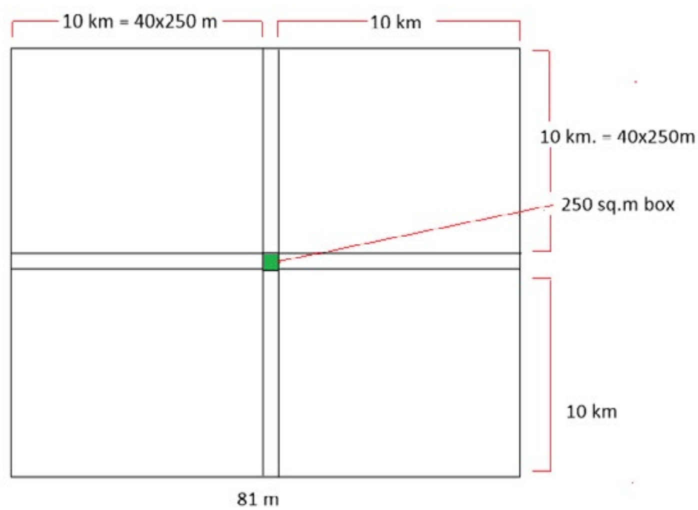

Fig. 3. The study area showing central grid and the four way extention in NDVI data

values upto 0 corresponded to water. The values from 0 to 0.1 meant soil, rocks or concrete, snow land and barren land. Low positive values (0.2 to 0.4) represented shrubs and grass land. The value close to 1 (0.6 and above) meant the forest (Weier and Herring, 2000). Therefore, greater the NDVI value was, denser was the vegetation in the area. Similarly, the temperature given in kelvin were substracted by 273.5 to convert into degree Celcius. All the grids are not taken for analysis to avoid the special correlation of the data and hence, 49 grids for LST and 196 (4x49) grids for NDVI were systematically selected to represent the whole study site. Finally generalized estimation equations (GEE) was used, that can adjust for the autocorrlation of the data. GEE are the extensions of linear model, specially designed for correlated data (Liang and Zeger 1986). The process was repeated for all three sites one by one. At the end, the confidence interval (CI) plots were drawn from GEE coefficients of NDVI and LST, which were compared to interprete the trends in the study area.

The statistical methods

The time series data were checked for seasonality and the trend by time series plots (Fig. 4). First, the data were seasonally adjusted to stabilize the mean.

The trends of 196 NDVI grids (n=6561) and 49 LST grids (n=441) were chosen to represent the whole study area. However, if the trends were observed for each individual grid, it would be difficult to conclude for an overall change of trend in the whole area, since the trend can vary even among the grids. Therefore, as a next step, the data for all sampled grids were divided into 3 groups of 5 years each (2000-2004, 2005-2009, 2010-2015) for analyzing and comparing the NDVI and LST change in smaller time frames by applying Generalized Estimation Equations (GEE) (Eq. 2) (Dormann, *et al.,* 2007).

$$E(Y) = \mu = g/(T\gamma) \quad (2)$$

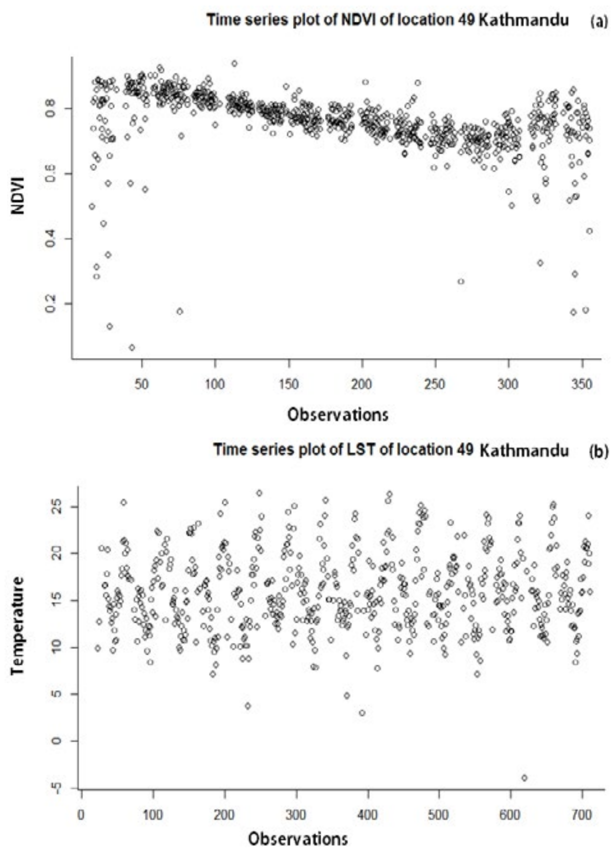

Fig. 4. Time series plot of NDVI (a) and LST (b)

Where, T is a vector of seasonally adjusted NDVI, E(Y) or μ is an expected value of Y, g/(Yγ) is an inverse link function, $T$is a matrix of observation days and γ is a vector of regression coefficients. A 95% CI plots were drawn using the predicted values, derived from the coefficients of the model, to show vegetation and temperature trends in three time sections. The NDVI changes at different time frames were compared among the groups and the overall temporal change was compared among the study sites. Finally, the changing trends of NDVI were compared with the trends of LST, during the study period. All data analysis and graphical displays were carried out using R Statistical Programming version 3.2.1 (R Core Team, 2015).

RESULTS AND DISCUSSION

The CI plots were produced to show 5 yearly changes of NDVI and LST in three different districts of Nepal. The red horizontal line is the level of no change and the vertical black lines are the CI plots of decadal coefficients from GEE model. The results reveal that the NDVI in Dhankuta showed significant increasing trends of vegetation with highest rate in first period from 2000-2004 and lowest rate in latest phase, 2010-2015 (Fig. 5). Hence eastern area has an overall increasing trend but the trend is in deccelerating phase. The recent trend showed that the mean increase of NDVI is 0.019 per decade. In the central Kathmandu region the negative values of NDVI showed that vegetation is declining with faster rate in the latest period. The recent mean decline was calculated to be NDVI -0.006 per decade. In the western region, the vegetation is significantly increasing in overall study period same as in eastern area. However this area showed accelerating phase of increament in the overall period. The recent five year showed that mean increase rate is NDVI 0.014 per decade. Similarly, the changing trend of LST showed almost same pattern in all three regions, that is, increasing during 2000-2004, decreasing 2005-2009 and increasing in the latest 2010-2015 period (Fig. 6). The rate of temperature rise is fastest in central region where the vegetation is continuously declining. Similarly, the rate of vegetation rise is highest in eastern region where the rate of temperature rise is lowest of all three regions. Hence, the study identified that the annual vegetation trend is considerably rising in east and west region of Nepal while the central Kathmandu showed declining trend. In addition, the Kathmandu being the fastest growing city in Nepal, has shown the highest rate of temperature increament in the recent years. The previous study had shown that faster the urbanization process is, faster is the rate of temperature rise and vegetation decline (Bobrinskaya, 2008). The Global

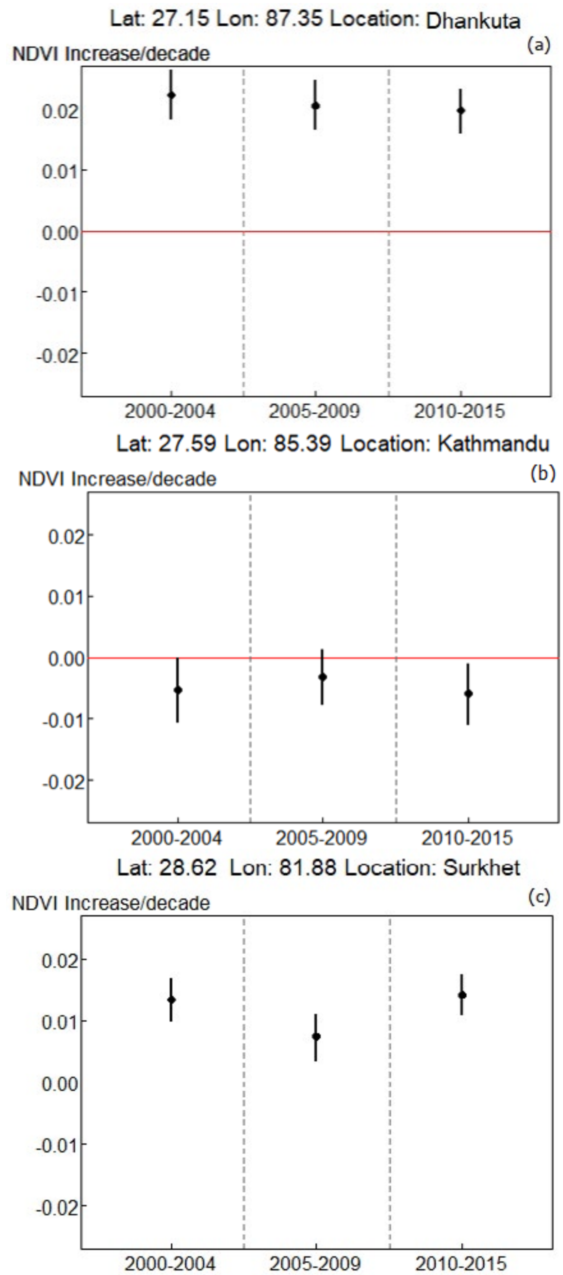

Fig. 5. A 95% CI plot of NDVI temporal change in Dhankuta (a), Kathmandu (b) and Surkhet (c)

NDVI trend studied during 1982-2012 showed an increasing trend in many parts of the world including India and southeast China (Liu et al., 2015). Nepal lies in between these blocks and possibly have similar rising trend overall. But Kathmandu being a growing urban area and densely populated city, might have been affected by several local environment factors to show a decline of vegetation. Hence, detecting local variation of vegetation change within a country is unique in this study. Regarding LST, the pattern is uniform in all three regions, that is, increasing, decreasing and increasing in 3 above mentioned time periods. The recent increasi ng trend in whole county is alarming one and might be due to the global warming effect. the recent rise of the temperature is consistent with the studies in Nepal(Joshi *et al*, 2011) and South East Asia (Chooptrateep and McNeil, 2015) The result When we compare the changing patterns of NDVI and LST, the changes of NDVI seems to be independent of changes of LST as the patterns of those two factors are indifferent of eachother. The limitation of this study was that, it was done in Nepal and can efficiently be extended to a bigger region in future. Further investigation is required to understand the potential reason behind this seasonal pattern and trend phenomenon.

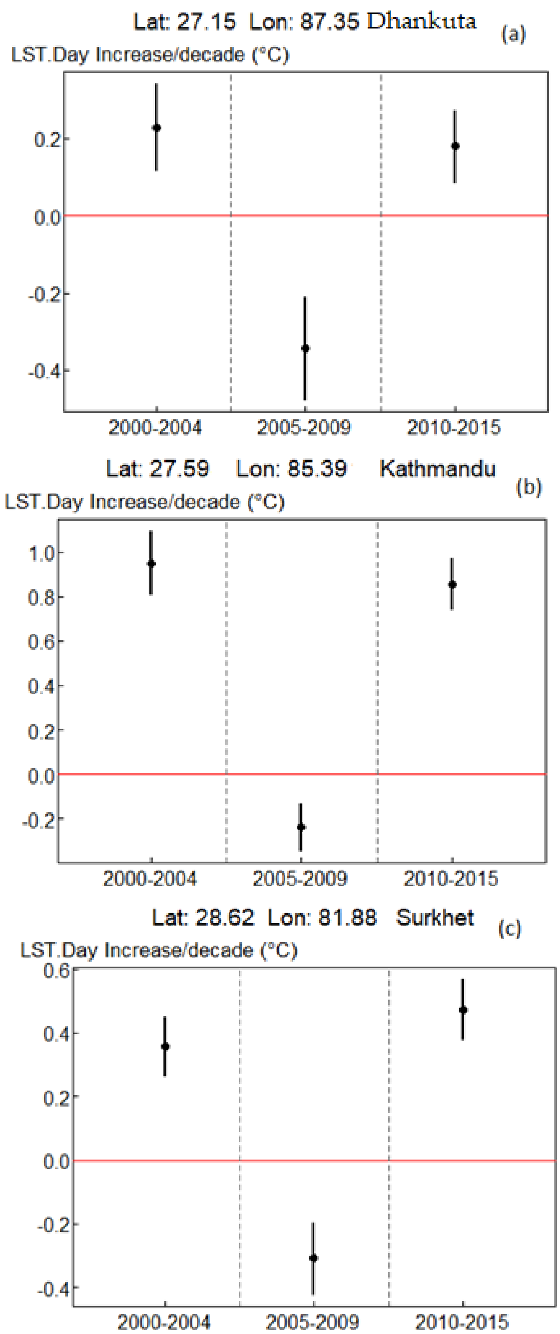

Fig. 6. A 95%CI plot of LST temporal change in Dhankuta (a), Kathmandu (b) and Surkhet (c)

CONCLUSION

This study showed the changing pattern of NDVI and LST, adjusting the seasonal factor and considering the spatial correlation as well as autocorrelation of the time series data. In addition, a comparison of rates of changes within specified time segments can be made clear by CI plots after GEE model. It can be concluded that vegetation in Nepal was increasing during 2000 to 2015 except in urban Kathmandu and the rate is fastest in eastern region. The recent trend of temperature is constantly rising in all over the country. The study shows an easy method of finding the changing pattern in any climate variable using the satellite data. Therefore it has academic values for researchers and managerial implication for local stakeholders.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

°C	Degree Celsius
CI	Confidence interval
DFRS	Department of Forest Resource and Survey
DHM	Department of Hydrology and Meteorology
E	Symbol (in equation)
Eq.	Equation
Fig.	Figure
g	Inverse link function
GEE	Generalized estimating equations
km	Kilometer
LST	Land surface temperature
m	Meter
mm	Milimeter
MODIS	Moderate resolutions imaging spectro-radiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized difference vegetation index
NIR	Near infrared
R	Symbol (A statistical programming language)
T	Matrix of observation days
Y	Vector of seasonally
γ	Vector of regression coefficient
μ	Expected value of *Y*
°C	Degree Celsius

REFERENCES

Bounoua, L.; Collatz, G.J.; Los, S.O.P.; Sellers, J.; Dazlich, D.A., Tucker, C.J.; Randall, D.A., (2000). Sensitivity of Climate to Changes in NDVI. J. Clim.13: 2277-2292 **(15 pages**).

Chandola, V.; Hui, D.; Gu, L.; Bhaduri, B.; Vatsavai, R.R., (2010). Using time series segmentation for deriving vegetation phenology indices from MODIS NDVI data. IEEE International Conference on Data Mining Workshops. 202-208 **(6 pages)**.

Chooprateep, S.; McNeil, N., (2015). Surface air temperature changes from 1909 to 2008 in Southeast Asia assessed by factor analysis. Theor. Appl. Climatol., 123(1-2): 361–368 **(8 pages).**

DFRS, (2015). State of Nepal's Forest. Department of Forest Research and Survey, MFSC, Government of Nepal. Kathmandu. Nepal.

DHM, (2015). Study of climate and climatic variables in Nepal. Ministry of Science, Technology and Environment. Government of Nepal.

Dormann, C.F.; McPherson, J.M.; Arau´jo, M.B.; Bivand, R.; Bolliger, J.; Carl, G.; Davies; R.G.; Hirzel; A.; Jetz; W., Kissling, W.D.; Ku¨hn,I.; Ohlemu¨ller, R.; Peres-Neto, P.R.; Reineking, B.; Schro¨der, B.; Schurr, F.; Wilson, R., (2007). Methods to account for spatial autocorrelation in the analysis of species distributional data: a review. Ecography. 30: 609–628 **(20 pages).**

Eckert, S.; Husler, F.; Liniger, H.; Hodel, E., (2014). Trend analysis of MODIS NDVI time series for detecting land degradation and regeneration in Mongolia. J. Arid. Environ., 113: 16-28 **(13 pages)**.

Joshi, N.P.; Maharjan, K.L.; Piya, L., (2011). Effct of climate variables on yield of major food-crops in Nepal -A time-series analysis. Journal of Contemporary India Studies: Space and Society. 1 (2011): 19-26 **(8 pages).**

Julien, Y.; Sobrino, J.A., (2009). The Yearly Land Cover Dynamics (YLCD) method: An analysis of global vegetation from NDVI and LST parameters. Remote Sens. Environ., 113: 329–334 **(6 pages).**

Karnieli, A.; Agam, N.; Pinker, R.T.; Anderson, M.; Imhoff, M.L.; Gutman, G.G.; Panov, N., (2010). Use of NDVI and Land Surface Temperature for Drought Assessment: Merits and Limitations. J Climate, 23: 618-633 **(16 pages).**

Kaufmann, R.K.; Zhou L.; Myneni, R.B.; Tucker, C.J.; Slayback, D.; Shabanov, N.V., (2003). The effect of Vegetation on surface Temperature: A Statistical Analysis of NDVI and Climate Data. Geophys Res Lett., 30 (22): (3)1-(3)4 **(4 pages).**

Liu, Ya.; Li, Y.; Li, S.; Motesharrei, S., (2015). Spatial and temporal patterns of global ndvi trends: Correlations with climate and human factors. Remote Sens., 7(10): 13233-13250 **(18 pages).**

Liang, K.; Zeger, S.L., (1986). Longitudinal data analysis using generalized linear models. Biometrika, 73: 13–22 (**10 pages**).

Bobrinskaya, M., (2012). Remote Sensing for Analysis of Relationships between Land Cover and Land Surface Temperature in Ten Megacities. School of Architecture and the Built Environment Royal Institute of Technology (KTH), Stockholm, Sweden.

Mishra, N.B.; Chaudhuri, G., (2015). Spatio-temporal analysis of trends in seasonal vegetation productivity across Uttarakhand, Indian Himalayas, 2000-2014. Appl Geogr, 56: 29-41 **(13 pages).**

NASA., (2015). Global climate change: Vital Signs of the Planet.

ORNL DAAC., (2015). MODIS subset of NASA Earth Data.

Piao, S.; Fang, J.; Zhou, L.; Guo, Q.; Henderson, M.; Ji, W. ,(2003). Interannual variations of monthly and seasonal normalized difference vegetation index (NDVI) in China from 1982 to 1999. J. Geogr. Res., 108 (D14): ACL 1-13 **(13 pages).**

R Core Team, (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Weier, J.; Herring, D., (2000). Measuring Vegetation (NDVI and EVI). NASA Earth Observatory.

Zhang, Y.; Gao, J.; Liu, L.; Wang, Z.; Ding, M.; Yang, X., (2013). NDVI-based vegetation changes and their responses to climate change from 1982 to 2011: A case study in the Koshi River Basin in the Middle Himalayas. Global Planetary Change, 108: 139-148 **(10 pages).**

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