Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.6, No.6, 2016
www.iiste.org

Studies on Temporal Relationship between Normalized Difference Vegetation Index and Rainfall in the Southern Part of Ethiopia

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Abstract

Nowadays remote sensing has become a powerful tool for many aspects of global monitoring for its convenience and high efficiency. This study analyzed temporal distribution of normalized differences vegetation index (NDVI) on the southern Ethiopia and their correlation with rainfall factors from 1995 to 2004. Monthly and annual data of NDVI and rainfall are examined to determine the consequence of rainfall variability on the NDVI of vegetation cover. Normalized Difference Vegetation Index (NDVI) data from the National Oceanic and Atmospheric Administration (NOAA) satellites and rainfall data from National Meteorology Agency (NMA) were used to investigate the temporal pattern of rainfall and the response of vegetation to rainfall in Southern part of Ethiopia. Thus, NDVI is an important variable for climate applications and agricultural productions. It is also important to study the NDVI for different seasons and at different agro-ecological areas to investigate its effects. The temporal pattern of NDVI and rainfall revealed that vegetation responded directly to rainfall. The temporal patterns showed that there was between 0 to 1 months lag between rainfall and vegetation. However it was not possible to draw conclusion regarding the annual and monthly relationship between rainfall and NDVI because, it is not solely explained by rainfall parameter. Determining time series relationship between rainfall and vegetation (NDVI) will improve the prediction of local level rainfall distribution. Effective dissemination of this information to stakeholders will enhance the suffering of communities from vulnerability to climate related risk by improving their management.

Keywords: NDVI, Rainfall, Correlation, Variability, Southern Ethiopia

1. Introduction

Vegetation change plays a crucial role in the environmental process. Vegetation indices can serve as a sensitive indicator of climate and anthropogenic influences by altering energy balance, climate, hydrologic and biological cycles (Rousvel.et al. 2013). The Normalized Difference Vegetation Index (NDVI) is one of the most important and commonly used satellite-based vegetation indexes for monitoring vegetation changes and its interaction with various climatic variables to interpret its impact on biosphere (Lei and Bian, 2010). The fundamental knowledge of the vegetation response to the climatic factors serves as the potential for discrimination of threatened areas, for effective forecasting and assessment of risk events.

The vegetation data sets of National Oceanic and Atmospheric Administration (NOAA) AVHRR, popularly known as Normalized Difference Vegetation Index (NDVI) are of useful in studying the ground vegetal cover. It is reported that NDVI is commonly used to monitor the seasonal and annual vegetation (Jackson et al., 1983; Tucker et al., 1991). Several studies have conducted over the world on different applications of NDVI in studying the climate feedback mechanism (Lu et al., 2001; Mabuchi and Sato, 2005), crop growing pe riods (Sarma and Kumar, 2006) and drought assessment (Savin and Flueraru, 2006; Sarma and Kumar, 2007). The strong relationship between natural vegetation and climatic elements has been described in wide range of research (Anyamba and Tucker, 2005; Fabricante et al., 2009; Lei and Peters 2004; Yang et al., 1998). Remote sensing plays important role in and provides an effective tool for monitoring different parameters of complex ecosystem (Zhong et al.,2010) in big countries like Ethiopia. Using remote sensing technology, different indices have been developed to study the properties of vegetation and vegetation dynamics. Moreover, the availability of high spatial and temporal resolution precipitation data increases interest in hydrology, meteorology and ecology research (Shaofeng, 2011). Rainfall plays a crucial role in the vegetation growing cycle and is a determining factor for agriculture and food security. Therefore, it is very important to study the relationship between rainfall and their impact on the general ecosystem and particularly on the vegetation.

In this paper, the primary objective is to analysis temporal relationship between NDVI and Rainfall in the Southern Part of Ethiopia

2. Materials and Methods

2.1 Description of the Study area

The study area comprises of three zones and one Special Woreda which are situated in the southern part of Ethiopia. The zones are Gamo Goffa (5.5 N to 6.75 N; 36.50 E to 37.80 E), Welayta (6.5 N to 7.15 N; 37.50 E to 38.25 E), Guraghe (7.75 N to 8.5 N; 37.50 E to 38.75 E) and Konso (5.1 N to 5.5 N; 37.0 E to 37.50 E). The area is characterized by sparsely vegetated as a result of excessive deforestation mainly for agricultural land. The sparse vegetation cover results in excessive soil erosion and the soils have been deeply leached. Based on the rainfall distribution, the area have three main seasons, namely; *Bega*, *Belg* and *Kiremt*. The mean annual temperature of the zone ranges between 13.10-24.20c and the annual mean rainfall ranges between 850-1500 mm.

2.2. Data and Analysis Methods

Normalized Difference Vegetation Index (NDVI) data is downloaded for the whole East Africa region from the website http://www.jisao.washington.edu on global scale and are retrieved for the period 1995–2004 with the grid resolution of 1°x1 °. Monthly rainfall data obtained from The National Meteorological Agency, Ethiopia, which covers the time period of 1995 to 2004, was used for analysis in this research. The NDVI value of gridded data sets varies from –1 to +1. if NDVI varies from 0 to 0.2, it is considered as low vegetation. if the value lies in between 0.2 to 0.4, then the vegetation status is taken as medium and if NDVI is more then 0.4, it can be treated that the vegetation reached to matured status (high vegetation). Negative values of NDVI impart the non-vegetated areas like snow, ice, water, rock (http://metart.fao.org). The methodology involves the use of temporal approach, to analyze temporal relationships between rainfall and vegetation (NDVI). The Normalized difference Vegetation Index (NDVI) is calculated as the difference between near infrared (NIR) and visible reflectance value normalized over the sum of both (Eidenshink, 1990). NDVI is therefore estimated as:

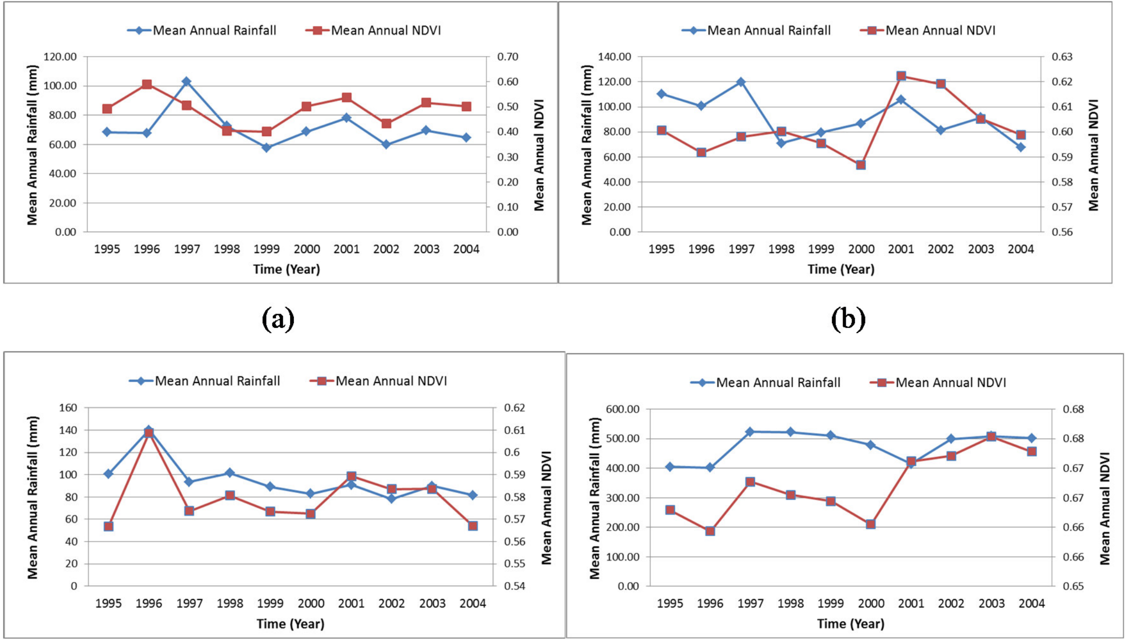
$$NDVI = \left(\frac{NIR-RED}{NIR+RED}\right) \qquad 1$$

Where, NDVI = Normalized Difference Vegetation Index, NIR = Reflection from Near Infrared wavelength region, RED = Reflection from Red wavelength region

The data were averaged for every month from January to December for ten year's period and yearly averages were also calculated for the same period. The NDVI and rainfall datasets had been processed in Microsoft Excel. Correlation statistic has been applied to understand the relation between NDVI and rainfall of southern Ethiopia. With the help of student t-test, the significances of these correlations are verified and the linear fit approximations are suggested for further use.

3. Results and Discussion

The mean annual rainfall and NDVI data used for the following presentation was the short term means that were calculated using the time period (1995 to 2004). Figures 1 (a-d) Shows the effect of annual rainfall variability on NDVI in selected stations of southern Ethiopia. These results show that annual vegetation is well defined which in turn has a direct relationship to the annual of rainfall. The temporal distribution of mean annual NDVI and rainfall reveals strong relations in the southern part of Ethiopia. The results reveal the distribution of rainfall in turn determines the distribution of vegetation in the study area. The results reveal that the driest years had the lowest NDVI values while the wettest years had maximum NDVI values. For instance, during year 1999 and 2002 recorded the lowest amounts of rainfall and consequently the NDVI values are low during this year.



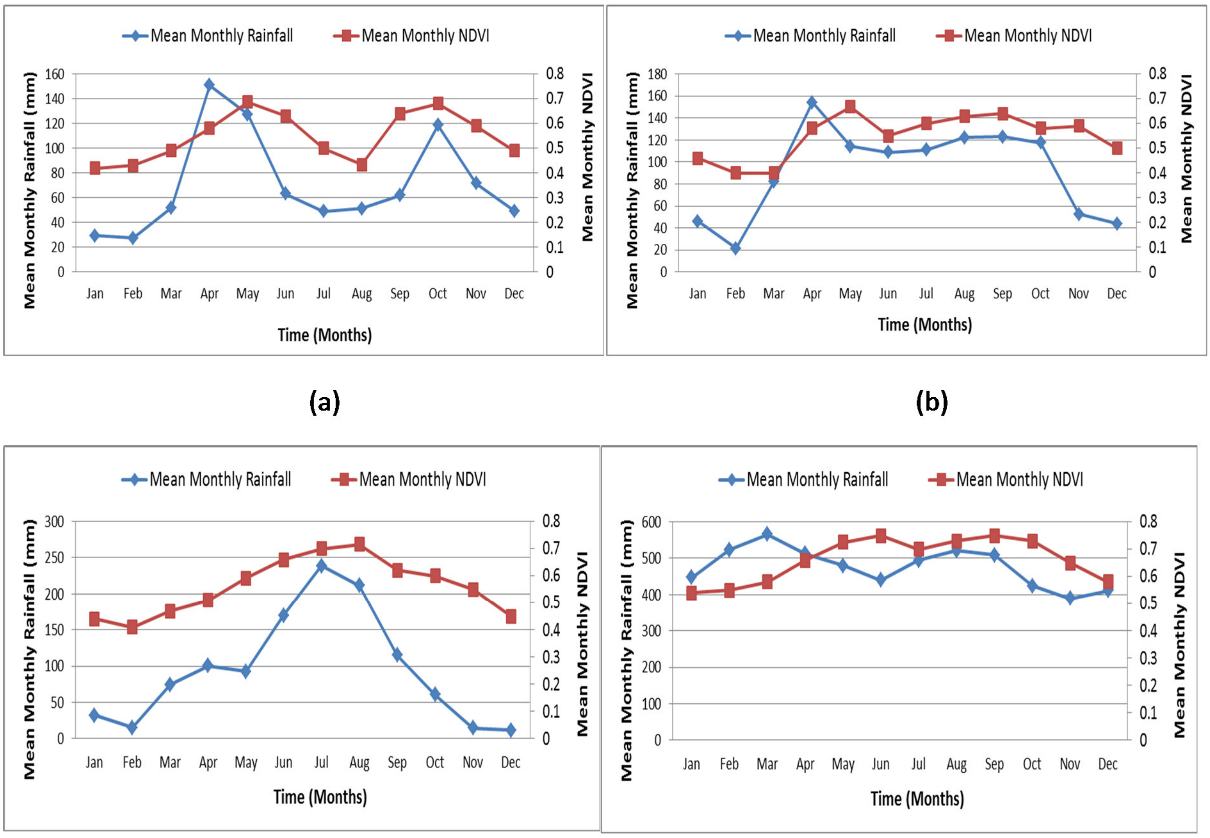
(a) (b)

(c) (d)

Figure 1: Time series annual rainfall and NDVI variability over selected stations of southern Ethiopia. (a) Gamo Gofa, (b) Welayta, (c) Guraghe and (d) Konso respectively

Figures 2 (a-d) Shows monthly rainfall effects on NDVI in selected stations of southern part of Ethiopia. (Figures 2 (ab) shows that the April and October months are the peak rainfall and May and October are the peak NDVI months in the Gamo Gofa and Welayta station. Thus, after rainfall onset, there is a one month lag period for NDVI to reach its peak. A lagged effect of NDVI was also observed when February and November low rainfall showed high correlation with March and December low NDVI respectively. Funk and Brown, (2006) have used the lagged relationship between rainfall and NDVI to estimate vegetation response to current climatic conditions, helping to make early warning systems earlier. In other studies,

Anyamba et al., 2001 reported a lagged response of rain-fall and NDVI in Eastern Africa and Wang and You, 2004 found that vegetation response to North Atlantic Oscillation delayed by 1.5 years. Following the low rainfall distribution (January, February, July and December) when total monthly rainfall was below 50mm, NDVI displayed its lowest value which was below 0.50 (Figure 2(ab). The maximum NDVI is found in the month of May and October, when the mean annual rainfall reach its maximum. This reveals good periodic variation in relation to rainfall.

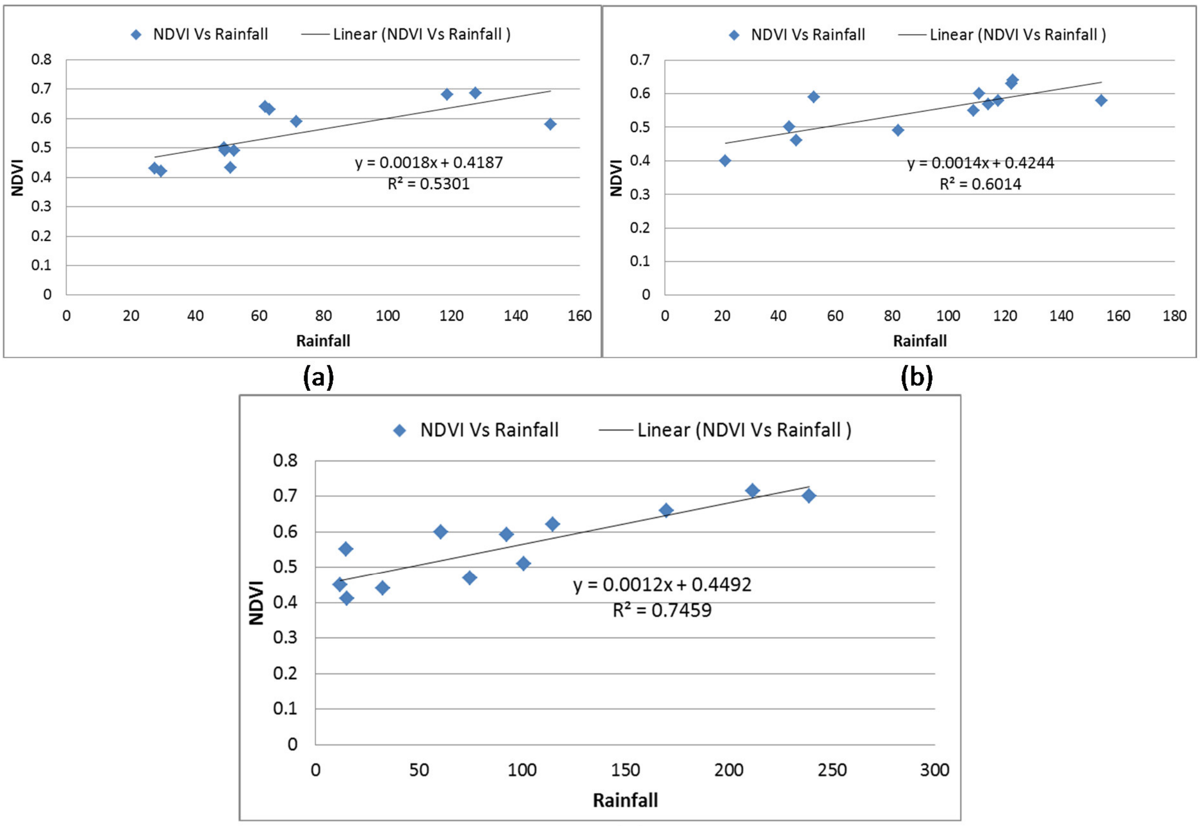


(a) (b)

(c) (d)

Figure 2: Monthly rainfall effects on NDVI over selected stations of southern Ethiopia. (a) Gamo Gofa, (b) Welayta, (c) Guraghe and (d) Konso respectively

As shown in Figure 1(c) in the month July the peak rainfall is observed and consequently the NDVI peak observed in the month of August for Guraghe station. Thus, after rainfall onset, there is a one month lag period for NDVI to reach its peak. Resulting from low rainfall (February, November and December), NDVI displayed its lowest value (Figure 2c). Generally, the vegetation cover is high during the rainy season than dry season. It reveals that the increased status of NDVI over rainy seasons is due to the increased in vegetation coverage.



(a) (b)

(c)

Figure 3: Monthly correlation between rainfall and NDVI over selected stations of southern Ethiopia. (a) Gamo Gofa, (b) Welayta and (c) Guraghe respectively

Figures 3 (a-c) Show monthly correlations between rainfall and NDVI in selected stations of southern Ethiopia. There are many studies presented to establish relation between rainfall and NDVI. This section deals with the relationship of rainfall with NDVI over southern part of Ethiopia through the use of temporal correlation and scatter plot for the period 1995 to 2004 for the selected stations. The correlations were calculated, for the driest and the wettest year of the whole time series for each station. The correlation coefficients (R^2) of NDVI with rainfall are about 0.50, 0.60 and 0.75 in the selected stations Gamo Gofa, Welayta and Guraghe respectively. Most stations presented a significant positive correlation between NDVI and rainfall.

Generally, rainfall and NDVI shows a high positive correlation for the selected stations of southern Ethiopia.

Conclusion

This study reveals that, the ability of remotely sensed satellite derived NDVI in the monitoring of vegetation greenness in southern part of Ethiopia. Annual and monthly pattern of NDVI is dependent on the rainfall condition of study area

The annual and monthly variability of NDVI is depending on the vegetation status and crop performance; thus it can be used to monitor the vegetal cover over the southern part of Ethiopia. The vegetation cover is high during the rainy season than dry season. It is believed that the increased status of NDVI over rainy seasons is due to the increased in vegetation coverage and cropping season. On monthly basis, the relation between rainfall and NDVI is strong but. The correlation is not such strong, when the cumulative annual amounts of rainfall are involved.

Determining time series relationship between rainfall and vegetation (NDVI) will improve the prediction of local level rainfall distribution. Effective dissemination of this information to stakeholders will enhance the suffering of communities from vulnerability to climate related risk by improving their management. However it was not possible to draw conclusion regarding the annual and monthly relationship between rainfall and NDVI because, it is not solely explained by rainfall parameter. Therefore, it required to develop a methodology to determine the relationship between climate induced and human-induced factors.

Acknowledgements

I would like to thank the National Meteorology Agency (NMA) for providing me with rainfall data and National Oceanic and Atmospheric Administration (NOAA) for providing the satellite data.

References

Anyamba, A and Tucker C.J (2005). Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981–2003. Journal of Arid Environments, 63: 596–614.

Anyamba A., Tucker C. J and Eastman J. R., (2001). "NDVI Anomaly Pattern over Africa during the 1997/98 ENSO Warm Event," International. Journal of Remote Sensing, Vol. 24, No. 10, 2001, pp. 2055-2067.

Eidenshink J. C., (1990). "The Conterminous US AVHRR Data Set," Photogrammetric Engineering and Remote Sensing, Vol. 58, No. 6, 1992, pp. 809-813.

Fabricante, I., M. Oesterheld, J.M. Paruelo (2009). Annual and seasonal variation of NDVI explained by current and previous precipitation across Northern Patagonia. Journal of Arid Environments, 73: 745–753.

Funk C. C. and Brown M. E., (2006). "Intra-Seasonal NDVI Change Projection in Semi-Arid Africa,"Remote Sensing of Environment, Vol. 101, pp. 249-256. doi:10.1016/j.rse.2005.12.014.

Jackson, R. D., Slater, P. N. and Pinter, P. J. (1983): Discrimination of growth and water stress in wheat by Various vegetation indices through clear and turbid atmosphere, Remote Sens. Environ., 13, 187– 208.

Lei J. and Peters A. J. (2004): A spatial regression procedure for evaluating the relationship between AVHRR-NDVI and climate in the northern Great Plains , International Journal of Remote Sensing, 25:2, 297-311.

Lei S. and Bian Z.,(2010). "Analysis of spatiotemporal difference of NDVI in an arid coal mining region using remote sensing," In: Wagner W., Székely, B. (eds.): ISPRS TC VII Symposium – 100 Years ISPRS, Vienna, Austria, IAPRS, Vol. XXXVIII, Part 7A.

Lu, L., Pielke Sr, R. A., Liston, g. E., Parton, W. J., Ojima, D. and Hartmann, M. (2001). Implementation of a two way interactive atmospheric and ecological model and its application to the Central United States, J. Climate , 14, 900–919.

Mabuchi, K., Sato, Y. and Kida, H. (2005). Climatic impact of vegetation change in the Asian tropical region. Part I: Case of the Northern hemisphere summer, J. Climate. , 18, 410–428.

Rousvel S., Armand K., Andre L., Tengeleng S., Alain T. S. and Armel K.,. "Comparison between Vegetation and Rainfall of Bioclimatic Ecoregions in Central Africa," Atmosphere, vol. 4, pp. 411-427, doi: 10.3390/atmos4040411, 2013.

Sarma, A. A. L. N. and Kumar, T. V. L. (2006). Studies on crop growing period and NDVI in relation to water balance components, Indian J. Radio Space, 35, 424–434.

Sarma, A. A. L. N. and Kumar, T. V. L. (2007). An approach in understanding drought condition using NDVI, Proc. AP Acad. Sci. , 11, 74–80.

Savin, E. and Flueraru, C. (2006). Use of vegetation NDVI time series for drought monitoring in Romania, Geophys. Res. Abstr., 8, 07345.

Shaofeng Jia, Wenbin Zhu, Aifeng Lű, Tingting Yan (2011). A statistical spatial downscaling algorithm of TRMM precipitation based on NDVI and DEM in the Qaidam Basin of China. Remote Sensing of Environment, 115: 3069–3079.

Tucker, C. J., Dregne, H. E. and Newcomb, W. W. (1991). Expansion and contraction of Sahara Desert from 1980 to 1990, Science, 253, 299–301.

Wang G. and You L., 2004. "Delayed Impact of the North Atlantic Oscillation on Biosphere Productivity in Asia," Geophysical Research Letters, Vol. 31, No. 1-4.

Yang, L., Bruce K. Wylie, Larry L. Tieszen, and Bradley C. Reed (1998). An Analysis of Relationships among Climate Forcing and Time-Integrated NDVI of Grasslands over the U.S. Northern and Central Great Plains. REMOTE SENS. ENVIRON. 65:25–37.

Zhong L., Yaoming Ma, Mhd. Suhyb Salama and Zhongbo Su (2010). Assessment of vegetation dynamics and their response to variations in precipitation and temperature in the Tibetan Plateau. Climatic Change, 103:519–535.

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