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Application of NDVI in Vegetation Monitoring Using GIS and Remote Sensing in Northern Ethiopian Highlands

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ABSTRACT

Vegetation plays an important role in stabilizing global environment. Reliable information on the status of vegetation using different techniques is necessary in solving environmental problems. Normalized Indifference Vegetation Index (NDVI) is a new technique that helps in quantifying vegetation cover change. Hence the major objective of this paper is to apply NDVI in the assessment of vegetation monitoring using Geographic Information System (GIS) and Remote Sensing (RS) in Bahir Dar Zuria District. In this case the NDVI analysis for vegetation cover change using 1986 and 2003 satellite images was analyzed. NDVI indicators like (NDVI minimum, maximum, mean, and standard deviation) are computed for the year 1986 and 2003. The result of the present study showed that the maximum NDVI values are decreased from 0.9 in 1986 to 0.16 in 2003. The minimum value of the NDVI increased from -0.8 in 1986 to -0.2 in 2003. In addition, the mean and standard deviation values decreased from 0.04 in 1986 to 0.03 in 2003 and from 0.06 in 1986 to 0.05 in 2003 respectively. The result showed that the average vegetation cover was decreased in 2003 when compared to that of 1986. This is due to an increased rate of deforestation which in turn caused by increasing population pressure. As a result, there should be a change in policy to prevent the negative impact of land use and cover change and increase the agricultural productivity per unit area and the vegetation cover through different forest rehabilitation mechanisms (afforestation and reforestation).

Keywords: Geographic Information System, Normalized Difference Vegetation Index, Remote Sensing, Vegetation.

INTRODUCTION

Vegetation plays an important role in providing different ecosystem services and goods so as to adapt and mitigate the global climate change. Spectral vegetation index data have been used to investigate the interactions between climate and vegetation at the landscapes level, to assist land management and sustainable utilization of forest and other vegetation resources and also to investigate climate change impacts and carbon sequestration by different vegetation types. However, global vegetation cover is decreased due to anthropogenic interference mainly through deforestation by human beings which need the land for different uses.

Ethiopia is one of the most well endowed countries in Sub-Saharan Africa in terms of natural resources (Zeleke & Hurni 2001). The country's forest coverage is estimated to be 40% over a century ago and to less than 3% today (Gashaw et al., 2014). Natural resource degradation in Ethiopia has been going on for centuries (Zeleke & Hurni 2001). Food and Agricultural Organization of the United Nations (2010) estimates that 141,000 ha of forest have been lost annually between 1990 and 2010 and the average annual deforestation rate, based on forest cover change from 2005-2010, amounts to 1.11% of total forest cover. This significant decrease of vegetation cover is due to the expansion of cultivated land (Zeleke & Hurni 2001).

Environmental Protection Authority (1997) estimates that the annual deforestation in Ethiopia mainly for expansion of rain fed agriculture varies from 80,000 to 200,000 hector per annum. There are also different quantifications presented on deforestation and level of vegetation in Ethiopia. This is due to the fact that the use of new technologies for natural resource assessment is very limited.

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Timely and reliable information on global trends in forest and vegetation areas have great importance for researchers, research organizations, educational organization, governments, nongovernmental organizations and commercial sectors in further studying and using the data for the organization purpose. Vegetation indices have long been used in remote sensing for monitoring temporal changes associated with vegetation (Tarpley et al., 1984). In recent years, many different vegetation indices have been proposed for different purposes. Cunyong et al. (2011) employed NDVI, as an indicator to estimate percent vegetation cover in heterogeneous topographical features and vegetation cover at Muus sandy land, mid west china.

Vegetation indices among other methods have been reliable in monitoring vegetation change. The use of vegetation index can normalize the effects of differential illumination of features in an area and can also help in extracting specific vegetation classes in an area (Reddy & Reddy, 2013). One of the most widely used indices for vegetation monitoring is NDVI. Data on vegetation bio-physical characteristics can be derived from Visible, Near Infrared Red and Mid-Infra Red portions of the electromagnetic spectrum (Campbell, 1987).

NDVI, an indicator of vegetation growth and coverage, has been widely employed to describe the spatio-temporal characteristics of land use and land cover, including percent vegetation coverage (Kaufmann et al., 2003). The generation of vegetation indexes calculated from the combination of spectral bands stands out (Turner et al., 2003). NDVI relates spectral information of the red and near infrared generating a variable able to estimate quantity, quality and development of vegetation (Pettorelli et al., 2005). The visible and near infrared bands on the satellite multi spectral sensors allow monitoring of the greenness or vigor of vegetation (Burrough, 1986). Cunyong et al. (2011) employed NDVI, an indicator to estimate percent vegetation cover in heterogeneous topographical features and vegetation cover at Muus sandy land, mid west china. Studies of vegetation are often carried out using the so-called vegetation index.

Normalized Vegetation indices are generally calculated by rationing, differencing, summing, and linearly combining data from two or more spectral bands. They are dimensionless and radiometric measures that are intended to minimize the solar irradiance and soil background while enhancing the signal from vegetation (Reddy & Reddy, 2013). GIS is a computer based that deals with spatial collection, storage management, retrieval, conversion/changing, analysis, modeling and display information about the features that make up the earth's surface (Abbas et al., 2010). It also provided the potential for mapping and monitoring the spatial extent of the built environment and associated land/land cover changes. It is also important for land degradation assessment, soil erosion modeling, and vegetation change detection to mention few of them. However, the use of this powerful tool for natural resource management is very much limited until recent years. Hence the major objective of this paper is to apply the NDVI in the assessment of vegetation monitoring by comparative study of 1986 and 2003 satellite images using GIS and Remote Sensing in Bahir Dar Zuria District. In the study area, there is no previous studies done in similar issues; hence this paper will help researchers, local government, Nongovernmental organizations that are working in similar issues and the society at large. The paper can give an alarm for every that direct or indirect contact with vegetation so as to use vegetations wisely without compromising the need of the feature generation.

MATERIALS AND METHODS

Study area:

This study was conducted in Bahir Dar Zuria District, Amhara Regional State, Ethiopia (Fig. 1). Bahir Dar Zuria District is located within 29^0 27' 34", 35^0 58' 40" East of longitude and 13^0 38' 19'', 12^0 1' 37" North of latitude. It is about 578 km North West of Addis Ababa. The District has 32

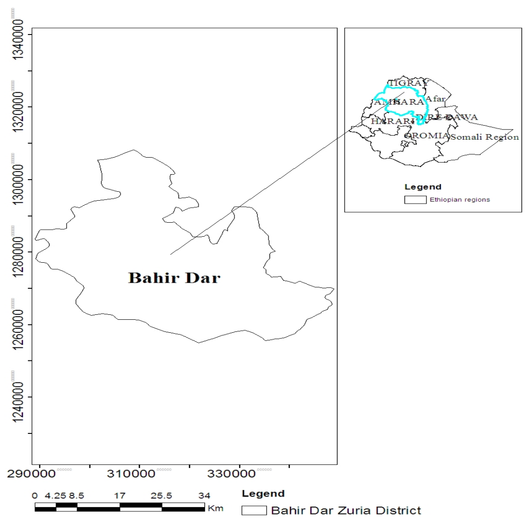

Fig. 1: Map of Bahir Dar Zuria District, Amhara, Ethiopia

Kebelles and covers a total area of 128,360.48 ha. It is also located in West Gojjam zone, Amhara National State, Ethiopia. It is bounded by Lake Tana and North Gonder in North, Yilma and Dense District in South, Metcha and Achefer District in West and river Abay in East.

The area lies within the central highland geographic region of Ethiopia at elevations ranging between 1879 m and 2070 m. In addition to this, 10, 2242 ha (79%) of the area is found in the slope <5% and 12,544.5ha (9.8%) is found in the slope between 5-10% and the rest share of the area is found in the slope >10%. In relation to the climatic data, the long term climatic data of the area shows that, the area receives a mean annual rainfall of 1447 mm ranging from a maximum of 2036 mm to a minimum of 895mm. The area also experiences a warm temperature climate, with average temperature of 21.3°C

Materials:

For the analysis of quantifying vegetation cover change using NDVI, GIS and remote sensing techniques Land sat TM of 1986 (specific location of the area: path and row: 170p52r and 169p52r, with date of acquisition: 01-03-1986, and seven bands) and Land Sat TM of 2003 (specific location of the area: path and row 170p52r and 169p52r, with date of acquisition: 26-01-2003, and seven bands) was used. After the data was collected, GIS and remote sensing software's was used for the process of the data like radiometric correction to correct atmospheric noises, image enhancement for better visualization, image layer stacking to analyze all bands as one coordinated band, and sub setting to clip only parts of the image in that specific area. After the data was processed, analysis of the data using the techniques of NDVI, GIS and remote sensing was made.

Measurement of vegetation index:

Vegetation Index using NDVI is widely used, and has been found to produce satisfactory results with respect to describing vegetation density and condition (Baldi et al., 2008). An image differencing technique was used whereby NDVI values from two images were subtracted from each other to obtain changes in NDVI. This was subsequently converted to a NDVI (representing vegetation density) change map.

Thus, by using the NDVI result of two different years's image (1986 and 2003) vegetation changes were calculated with NDVI= (NIR-RED) / (NIR+RED) (Gashaw et al., 2014). Where NIR is the near infrared band response for a given pixel and RED is the red response. Green and healthy vegetation reflects much less solar radiation in the visible (channel 1) compared to those in the near-infrared (channel 2). More importantly when vegetation is under stress, the channel 1 value may increase and the channel 2 values may decrease. The NDVI were generated using the radiation measured in red and near infrared spectral channels. Because of close relationship between vegetation and available soil moisture, NDVI was widely used to evaluate drought condition by directly comparing it to precipitation or drought indices. It is indicated that NDVI not only assessment the behavior of vegetation over time, it can monitor the rainfall and drought situation. The data used in compiling the NDVIs are closely related to the radiation absorbed and reflected by vegetation in the photosynthetic processes.

To calculate this index, it is possible to count on lifting decades of satellite sensor information, which highlights the potential of the Land Sat time series (Devries et al., 2015; Ding et al., 2014; Du et al., 2010; Maxwell & Sylvester, 2012; Zheng et al., 2015). Index values can range from -1.0 to 1.0, but vegetation values typically range between 0.1 and 0.7. NDVI values little higher than zero, which indicates the presence of vegetation classes, moderate and high values indicate stressed vegetation and healthy vegetation respectively; whereas near zero and negative values indicate non-vegetation class such as water, snow, built- up areas and barren land. Only active vegetation has a positive NDVI being typically between about 0.1 and 0.6 values at the higher end of the range indicating increased photosynthetic activity and a greater density of the canopy (Tarpley et al., 1984). In this case the NDVI analysis of 1986 and 2003 images for Bahir Dar Zuria District was analyzed. NDVI indicators (NDVI minimum, maximum, mean, and standard deviation) are computed for the year 1986 and 2003. Hence the changes in the vegetation of the two periods shows that the quantification of vegetation change in the two periods. The NDVI map of the 1986 and 2003 was designed in addition to their statistics using the Erdas Imagine 10 software. The map of the two images shows that the distribution of vegetation changes in the study area.

RESULTS AND DISCUSSION

Comparison of NDVI results of 1986 and 2003:

The maximum values of the vegetation index were reduced from 0.9 in 1986 to 0.16 in 2003 (Table 1). This shows that the vegetation cover was by far reduced in some parts of the area from 1986 to 2003. You can observe the result as well in the map

(Fig. 2) as dark green color in both images. The darker the green color in the image the highest NDVI values were recorded and highest vegetation cover and vice versa. In the same way the minimum values are increased from -0.8 in 1986 to -0.2 in 2003. This means that status of vegetation in 2003 is better than the vegetation in 1986. We can observe the result as well in the map (Fig. 2) as dark red Color. The darker the red color the lower the NDVI map and the less the vegetation and vice versa. This comparison result shows that highest vegetation cover was observed in 1986 where as average vegetation cover was observed in 2003.

Table 1: NDVI statistics of 1986 and 2003

NDVI	Year	
	1986	**2003**
Minimum	-0.8	-0.2
Maximum	0.9	0.16
Mean	0.04	0.03
Standard deviation	0.06	0.05

This comparison can be better explained by its mean and standard deviation of the two period images. The mean values are decreased from 0.04 in 1986 to 0.03 in 2003(Table 1). This means that the highest mean value of NDVI in the 1986 image shows that highest level of vegetation and the lowest value of NDVI in 2003 satellite image show the lowest vegetation coverage. Hence the status of vegetation cover was better in 1986 than 2003 satellite images in the study area. However, the standard deviation of the NDVI value shows that there is a decrease from 0.06 in 1986 to 0.05 in 2003. This means that the status of vegetation change from its mean value of NDVI is varies more in the 1986 image when it is compared with 2003 satellite image. Hence the change of vegetation is average in 2003 satellite image than the change of vegetation in 1986. Generally, the result of the NDVI values shows that the vegetation cover in general was reduced and the forests in particular ware depleted from time to time even though the change was very insignificant the trend shows there was depletion of natural vegetations.

The major reason for depletion of the vegetation in general and natural forests in particular is due to high deforestation rate, and high population pressure. Similar results were observed in study of Zeleke & Hurni (2001) and report of Environmental Protection Authority (1997). The study and the report showed that the major factor for the depletion of vegetation in Ethiopia is due to high deforestation rate which is greater than the rate of afforestation and reforestation. It is clear that as the population increases in a particular area their need to have additional land for agricultural and settlement purposes also increases. This can only possible to meet by cutting vegetations in

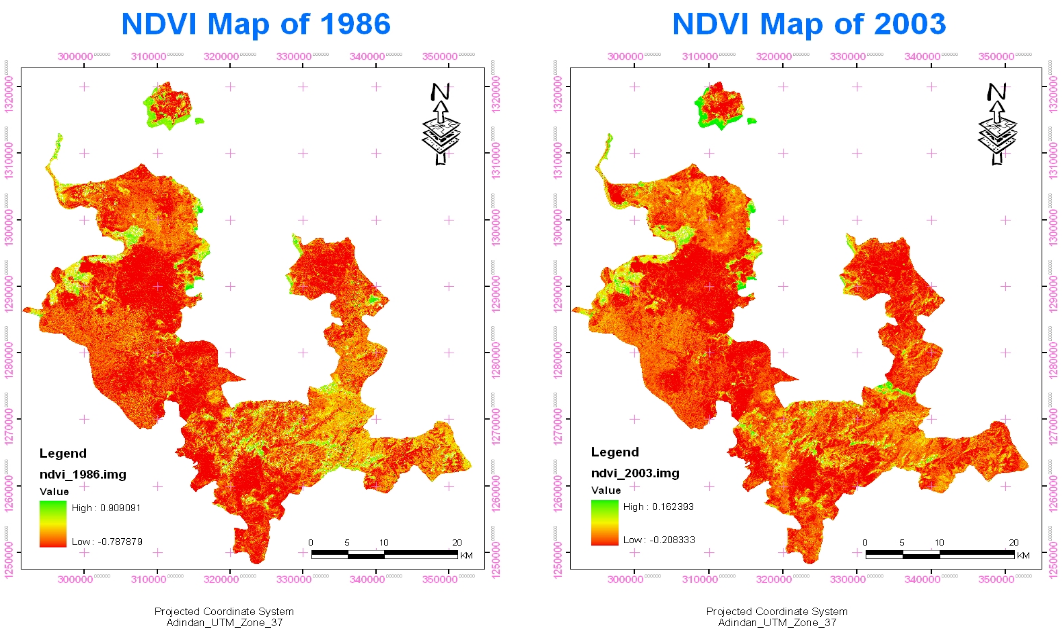

Fig. 2: NDVI Map of vegetation cover

general and natural forests in particular.

Similar results were found in the studies of Gashaw et al. (2014) in the studies of detection of vegetation change using GIS techniques in Hulet Wegedamea area, Northern Ethiopia (nearer to my study area) from 1985 to 2011. According to his research there is a demolishment of vegetation change between the two periods. In addition to this Zeleke & Hurni (2001) indicated that there is a decrese in natural vegetation due to expansion of cultivated land.

The research of Gashaw et al., (2014) is based on the use of GIS techniques of NDVI values to compare the quantification of vegetation change in different periods. However, their focus is only to give the mean NDVI value in relation to the quantification of vegetation change. In addition to this the research of Zeleke & Hurni (2001) in their study on implication of land use /land covers change for mountain resource degradation shows that there is a reasonable change of vegetation due to expansion of agricultural land. Thus full information in relation to the quantification of vegetation change in addition to the possible reasons for the problem should be addressed. Hence this research tried to combine the NDVI values with possible causes in the study area. For this purpose, the report of Environmental Protection Authority (1997) and Zeleke & Hurni (2001) ware identified for the support of the possible reasons for the problem.

In quantifying all biophysical changes, the time series land sat images using remote Sensing and Geographic Information System in conjunction with field observation can provide the degree, extent, and direction of vegetation index. The NDVI analysis of the study area showed that the vegetation cover is decreasing from time to time. Different rehabilitation mechanisms for degraded lands should be motivated so as to reduce the problem. Afforestation and reforestation of different species should be motivated by different governmental and non-governmental organizations. Sound and practical policy with the participation of the society from its beginning to end is necessary to increase the vegetation cover. In addition to this emphasis should be given for areas that are recorded as low NDVI values. The governmental organizations, the nongovernmental organizations and other researchers should provide other complementary products that can substitute the need of vegetations.

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