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Investigation of Relationship Between Rainfall and Vegetation Index by Using NOAA/AVHRR Satellite Images

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Abstract: Use of satellite images is known as a new technique to study changes in vegetation cover. On the other hand, rainfall plays a key role on the condition of vegetation cover. This article investigates the changes in vegetation and its relation to rainfall days and monthly time intervals over the (2000-2003) period. The region of study is part of Azerbaijan province located in an area surrounded. Using geo-statistical methods, rainfall maps were generated based on the rain gauges in the data collected by area. Maps of daily Normalized Difference Vegetation index (NDVI) were transformed days images using into day composite technique. By maximum preparing a layer representing terrain-mapping units (TMU), the correlation between vegetation cover and rainfall was investigated in different land units. The results demonstrate varying degree of correlation. Specifically, the correlation in alluvial and flood plains was strongest. Meanwhile, the correlation in monthly time days interval was better compares to interval. The multi-variable regression was also determined as the most suited correlation relationship.

Key words: NOAA/AVHRR · NDVI · Rainfall · Azerbaijan province · Remote sensing

INTRODUCTION

Nowadays, study on temporal and special changes of vegetation cover by using remote sensing is a popular method to study land resources. Intense studies performed by using satellites and numeral data to study vegetation cover in land surface have confirmed capabilities of this modern tool. So that it is considered as one of important tools to study vegetation in scientific societies [1,2]. Techniques known as vegetation index are used to define vegetation of land surface [1,3]. These indexes resulting from combination of different proportions of visible and infrared bands of numeral data of a region are applied for representation and segregation of surface land's various phenomena such as water, exposed soil, vegetation etc.

It has advantages like easy calculation, high degree of correlation with changes in vegetative parameters and high frequency of data in this satellite.

Special distribution of vegetation in land surface has a direct relationship with climatic conditions [5]. Among different climatic factors, rainfall is considered as an important and effective factor in rate and distribution of vegetation in arid and semi-arid regions[4]. It affects directly on vegetation rate in these regions. In recent years, many efforts have been taken to study relationship between changes in vegetation and rainfall by using numeral data. Recent studies indicate that NDVI index follows rainfall rate with on time delay [6]. Study on relationship between NDVI vegetation index and rainfall in 1990 in semi-arid regions of Malay and Nigeria indicated that monthly rate of NDVI has best linear correlation with monthly rainfall so that best relation between NDVI and rainfall rate is observed two months ago [7]. In another study performed in same place between NDVI ten days average and estimated rainfall rate, Correlation was observed in a time interval of 10 to 20 days between NDVI and rainfall [8]. Additionally, studies performed in Eastern Africa indicated that relationship between NDVI and rainfall in this region in linear logarithm [9]. In present study, NDVI vegetation index has been used to study relationship between rainfall and changes in studied region's vegetation.

This index is among most common vegetation indexes used in vegetation studies and it permits indirectly to measure growth of plants in a region during growing period. It is necessary to perform field operations to define precisely the amounts of vegetation in a region. And it is essential to take action to calibrate NDVI index with vegetation rate through field operations. Mentioned vegetation index was calculated from band and band 2 of NOAA/AVHRR.

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MATERIAL AND METHODS

Study Area: In present study, Azerbaijan province in northern of the country has been studied in respect of relationship between vegetation and rainfall. Studied area is about 205000 km^2. It is placed in 45°-48° E longitude and 36° 39 ´-39° 49´ N altitudes. Minimum and maximum of altitude sea level in 650 and 3845 m respectively. Average rainfall of this area is 604 mm and minimum and maximum annual rainfall is 239 and 1024mm.

In addition average temperature has been estimated to 24.4 °C and average annual evaporation was 3682 mm.

Method: To perform this study, after providing land units maps, maps of rainfall special distribution and NDVI typical layers of studied region were processed in ten days time scale in 2000-2003 period of time. Then Crossing operation on rainfall and NDVI maps with land unit maps was performed by using ILWIS software. And average ten days NDVI and rainfall were determined for each land units of the region.

Then, this data was analyzed by using SPSS software.

To study relationship between rainfall and NDVI in monthly time scale, 10 days rainfall and NDVI data for each land units were transformed to average monthly NDVI and total monthly rainfall. Then correlation rate between rainfall and NDVI was studied by using various techniques.

NDVI Vegetation Index: Numeral data of NOAA satellite AVHRR evaluator of 2000-2003 was collected. Characteristics such as daily image taking, cheapness of these images compared to other satellites, its wide spread land coverage and sufficient number of satellite bands (5 bands) have provided the ground to increasingly usage of numeral data of this satellite in various land resources studies. Primary numeral data for this study was including two series of satellite images provided and collected through Internet web.

First series were including images of 2000. These images processed according to Eidenshink and Faundeen [10] and transformed to ten days images are saved and kept on http://edcwww.cr.usgs.gov.landdaac/1km.

Second data series including 2000 and 2003 pictures were daily and are saved under level 1 B format in Internet on the http://www.saa.noaa.gov.

These pictures have been processed by using NPR1a software designed by Gieske in ITC institute of Netherland and then were transformed to 10 days images.

In present study, NDVI vegetation index was used to study vegetation changes. This index is provided from visible and infrared bands ratios. And it is calculated through following method for NOAA/AVHRR images:

$$NDVI = (Band\ 2 - Band\ 1) / (Band\ 2 + Band\ 1).$$

Band 1 represents visible band, has a wave length in 68.0-0.58 micro meter range and Band 2 represents near infrared band of NOAA satellite and has a wave length in 0.725-1.1 micro meter. present study has been performed in two time scales of 10 days and monthly time scales. Thus, daily NDVI maps were transformed to ten days NDVI maps by using maximum combination method. In this method, images were under radiometric correction followed by geometric correction by using a reference image including 59 geometric control points (GCP). Then by using software of ILWIS geographic information system among daily images of each 10 days period, pixels with highest NDVI figure were defined and finally NDVI ten days images of each period were provided.

Using ten days maximum combination significantly removes errors relating to atmosphere cloudiness in addition to decrease of errors resulting from sun location. Also average 10 days NDVI images for each month was determine and studied.

Rainfall Data: One another required information for performing present study is statistics of rainfall in studied region. Firstly, daily rainfall statistics of 44 rain gauging and evaporation gauging stations of power were collected and transformed to 10 statistics. Then they were transformed to 10 days rainfall maps by using interpolation method. So that by using statistical land analysis, 10 days statistics of region stations were analyzed. Finally by using Simple Kriging method, 86 ten days rainfall map were obtained for second 6 months period of 2000 to end of 2003.

Land Units Map: Relationship between rainfall and NDVI in various units of the region was studied according to Terrain Mapping units For this reason, Potential of region's land and geology was studied by using available and also numeral data of LANDSAT satellite for May 2003 for terrain mapping units were provided. Due to low capability of NOAA satellite for ground resolution equal to 1.1 km, only main units of the region were separated to study correlation of rainfall and NDVI index and smaller unit's determination was avoided.

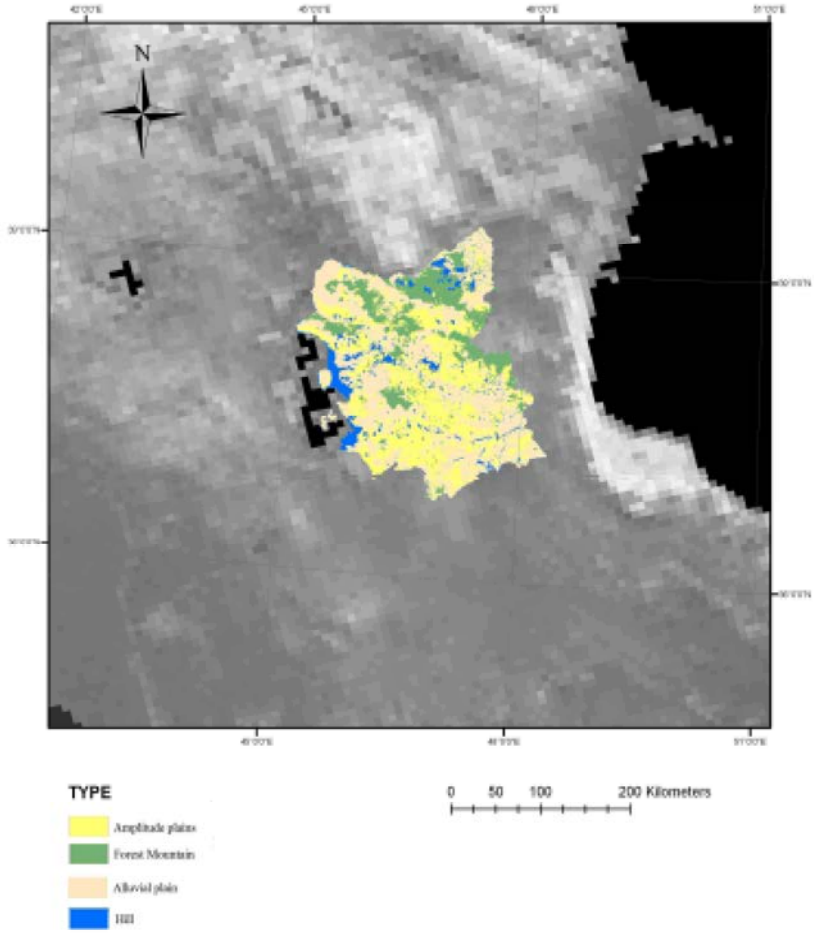

Fig. 1: Terrein map units of Azerbaijan province in north of Iran

Totally four alluvial plain units (AP), amplitude plains (A), hill (H) and forest mountain (FM) were determined as main units of regional lands (Figure 1).

RESULTS

Relationship Between Rainfall and NDVI in 10 Days Time Periods: Relationship between 10days rainfall and vegetation was performed firstly based on determination of linear correlation between 10 days NDVI and 10 days rainfall logarithm. Table 1 indicates correlation coefficient between average rainfall and average NDVI in regional land units. In this method, rate of correlation between NDVI and rainfall was studied in various time intervals.

Zero column of this table represents coefficient of correlation between rainfall and NDVI without time interval and other columns represents relationship between NDVI and rainfall for 10 days before it (column 1), 20 days before it (column 2) and etc.

According to table 1, in most units highest correlation rate is observed in fifth time interval (50 days). Following it, fourth and sixth time intervals have highest correlation for other land units. A month various units of this region, unit (A) with 0.46 correlation coefficient indicates highest correlation. Totally, table results represent low correlation and in significance of relationship between 10 days rainfall and NDVI.

Rainfall and NDVI relationship based on monthly time scale.

To Study Rainfall and NDVI Relationship in Monthly Time Scale: Firstly average rate of NDVI for all 3 ten days period were calculated and considered as monthly NDVI and then total rainfall of all three 10 days rainfall was calculated as monthly rainfall amount and analyzed by using three following methods:

Table 1: Coefficients of correlation between NDVI and total ten days rainfalls of previous decades in various land units

Unit area	0	1	2	3	4	5	6	7	8	9	10
AP	0.013	0.10	0.17	0.25	0.26	0.30	0.27	0.14	0.13	0.16	0.11
A	0.13	0.24	0.36	0.38	0.4	0.46	0.38	0.37	0.25	0.22	0.10
H	0.03	0.20	0.24	0.27	0.33	0.42	0.27	0.23	0.20	0.18	0.11
FM	0.06	0.11	0.13	0.20	0.26	0.31	0.24	0.28	0.21	0.19	0.15

Table 2: Coefficients of correlation between NDVI and total monthly rainfall for previous months in various land units

Unit area	0	1	2	3	4
AP	0.05	0.68	0.37	0.15	0.06
A	0.32	0.44	0.33	0.28	0.1
H	0.33	0.50	0.41	0.32	0.13
FM	0.30	0.62	0.50	0.37	0.18

Table 3: Coefficients of correlation between NDVI and logarithm of monthly accumulated rainfall for previous months in various months

Unit area	1+0	2+1	2+1+0	3+2+1	3+2+1+0
AP	0.49	0.71	0.67	0.73	0.72
A	0.01	0.41	0.22	0.53	0.42
H	0.15	0.52	0.34	0.62	0.60
FM	0.06	0.48	0.31	0.59	0.51

Table 4: Correlation coefficient between NDVI and monthly accumulated rainfall logarithm for previous months in different land units by using multivariate regression method

Unit area	Coefficient	Constant	Lag0	Lag1	Lag2	Lag3
DF	0.63	0.045	-0.0005	0.01	0.009	0.007
F	0.77	0.01	0.0057	0.01	0.4	0.02
R	0.64	0.05	-0.005	0.01	0.02	0.01
A	0.86	-0.02	0.02	0.04	0.03	0.02

Common Method of Monthly NDVI and Rainfall: This method is like method of 10 days study of NDVI and rainfall relationship. So those amounts of correlation between monthly NDVI and same month rainfall as well as NDVI and rainfall for previous month were determined by using linear regression. Table 2 indicates correlation coefficient between NDVI and monthly rainfall in different time interval for every units of the region.

According to this table, there is higher correlation between NDVI and rainfall compared to 10 days time scale. Additionally best correlation is observed between NDVI and rainfall of one month before and in some cases two months before it. Mean while alluvial plains indicate highest correlation among all units.

Accumulated Rainfall Technique: Another method using for determining rainfall and NDVI relationship is accumulating rainfall technique developed by Richard and Poccard in southern Africa. This method is based on determination of monthly NDVI correlation rate and accumulating rainfall of previous months in different time intervals. Table 3 indicates coefficients of correlation between NDVI and rainfall in different units according to accumulating method. In this table, columns are including from left to right: current month rainfall, (0), total rainfall of current month and previous month (0 + 1), total rainfall of two previous months (2 + 1), total rainfall of current month and two previous months (2 + 1 + 0), rainfall of 3 previous months (3 + 2+ 1) and finally total rainfall of 3 previous months and current month (3 + 2 + 1 + 0).

Additionally in this technique, accumulating rainfall rate logarithm provides better results.

According to table 3, highest correlation is observed in two last columns representing in tense dependence of vegetation to previous months, rainfall. Additionally effect of soil depth (as water reserve place) can be observed by comparing correlation rate in units with flat and deep soil (such as alluvial and flood plains) compared to sloped units and low depth soils (such as mountainous land units) together using this technical indicates considerable increase in correlation rate compared to previous method.

Multivariate Regression Method: Another method used for studying NDVI and rainfall relationship was multivariate regression.

In this method performed by using SPSS software, monthly NDVI rate and rainfall logarithm for four 1 month time interval (current month to three previous months) were considered to determine correlation rate as following equation:

$$\text{NDVI constant} + B_0\,(\text{Lag}_0) + B_1\,(\text{Lag}_1) + B_2\,(\text{Lag}_2) + B_3\,(\text{Lag}_3). \quad (2)$$

Where Lag0-Lag3 are current month rainfall to monthly rainfall of three previous months respectively and constant B0-B3 are constant coefficients of different land units.

According months have different weight and effect on NDVI rate, using this method has better results compared to accumulating rainfall method suggested by Richard and Poccard.

DISCUSSION

In present study different methods were used to study vegetation and rainfall relationship in 10 days and monthly time intervals. Among used methods, multivariate regression method indicated better correlation rate between rainfall and NDVI index in monthly scale. Also, land units of alluvial and flood plains respectively represent most strong correlation.

Various factors make negative effect on correlation rate between rainfall and vegetation in the region. Among these factors are severe changes in rainfall time pattern so that most times large volume of monthly rainfall falls in a short time and resulting floods exit rapidly from the region. This will cause that regional plants can't use these rains completely.

Thus it will be effective in results improvement to provide methods considering negative effects of these factors. Additionally it is recommended to study rainfall and other vegetation indexes relationship being able to decrease soil effect without ground covering.

REFERENCES

1. Camacho-De Coca, F., F.J. Garcia-Haro, M.A. Gilabert and J. Melia, 2004. Vegetation cover seasonal changes assessment from TM imagery in a semi-arid landscape. Intl. J. Remote Sensing, 25(17): 3451-3476.
2. Ferreira, L.G. and A.R. Huete, 2004. Assessing the seasonal dynamics of the Brazilian Cerrado vegetation through the use of spectral vegetation indices. Intl. J. Remote Sensing, 25(10): 1837-1860.
3. Al-Bakri, J.T. and J.C. Taylor, 2003. Application of NOAA AVHRR for monitoring vegetation conditions and biomass in Jordan. J. Arid Environ., 54(3): 579-593.
4. Malo, A.R. and S.E. Nicholson, 1990. A study of rainfall dynamics in the African Sahel using normalized difference vegetation index. J. Arid Environ., 19: 1-24.
5. Marsh, S.E., J.L. Walsh, C.T. Lee, L.R. Beck and C.F. Hutchinson, 1992. Comparison of multi-temporal NOAA-AVHRR and SPOT-XS satellite data for mapping land cover dynamics in the West African Sahel. Intl. J. Remote Sensing, 13: 2997-3016.
6. Richard, A.Y. and I. Poccard, 1998. A statistical study of NDVI sensitivity to seasonal and internnual rainfall variation in southern Africa. Intl. J. Remote Sensing, 19(15): 2907-2720.
7. Malo, A.R. and S.E. Nicholson, 1999. A study of rainfall and vegetation dynamic in the African Sahel using normalized difference vegetation index. J. Arid Environ., 19: 1-24.
8. Justicec, O., G. Digdale, D.Y. Townshen, A.S. Nallacott and M. Kumar, 1991. Synergism between NOAA/AVHRR and Meteosat data for studying vegetation development in semi-arid West Africa. Intl. J. Remote Sensing, 12(13): 1349-1368.
9. Devenport, M.L. and S.E. Nicholson, 1989. On the relation between rainfall and normalized difference vegetation index for diverse vegetation type in the East Africa. Intl. J. Remote Sensing, 12: 2369-2389.
10. Eidenshink, J.C. and J.L. Faundeen, 1998. the 1Km AVHRR global land data set first stage in the implementation. Internet website http://edcwww. cr.usgs.gov.landdaac.