STUDYING VEGETATION RENSPONSES AND RAINFALL RELATIONSHIP BASED-ON NOAA/AVHRR IMAGES

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ABSTRACT

Use of sattlite images has been growing as an effective technique to study changes in vegtation cover. On the other hand, rainfall exerts strong influence on the condition of vegetation cover. This article investigates the changes in vegetation and its relation to rainfall in 10-days and monthly time intervals over the (1995-1997) period. The region of study, 15000 km^2 in area, is part of Kol river basin located in southwestern part of Iran with a semi-arid climate. The annual average rainfall and tempreture have been reported as 204 mm and 24.4 ^{o}C, respectively. Using geo-statistical methods, 126 daily rainfall maps were generated based on the data collected by 22 raingauges in the region. Furthermore, cloud-free NOAA images for the period of study were obtained and geo-referenced for further analysis. Maps of daily Normalized Difference Vegetation Index (NDVI) were transformed into 10-days images using maximum 10 day composite technique. By preparing a layer representing terrain mapping units (TMU), the correlation between vegetation cover and rainfall was investigated in different land units. The results demonstrated varying degree of correlation. Specificially, the correlation in alluvial and flood plain mapping units was strongest. Meanwhile, the correlation in monthly time interval was better compared to 10-days interval. The multi-variable regression was also determined as the most suited correlation relationship, such that the NDVI generally showed hightest dependence on the rainfall in the previous month.

INTRODUCTION

The monitoring of vegetation by remote sensing is an accepted technique of resources assessment. Remote sensing can provide an indirect measurement of vegetation growth through the calculation of vegetation indices (Hess et al. 1996). One of the most widely used indices for vegetation monitoring is the Normalized Difference Vegetation Index (NDVI). This index is calculated as the normalized ratio between channel 1 (red) and channel 2 (near infrared) data sensed by NOAA-AVHRR. Comparing to other satellite data, the main advantage in using NOAA/AVHRR data is high temporal frequency. The spatial distribution of the vegetation cover is strongly related to mean climatic conditions. On the other hand, the vegetation has a feed back effect on climate through roughness, evaporation, and albedo.

Recent works show that NDVI follows rainfall with varying time lags dependent on environmental factors such as soil type (Richard and Poccard, 1998). Malo and Nicholson (1990) studied the relationship between NDVI and rainfall in the semi-arid Sahal of Mali and Niger. They concluded that the monthly NDVI was correlated with monthly rainfall. The best correlation was achieved when the rainfall of the two preceding months was also included. Justice et al. (1991) studied a similar region of Mali and Niger and compared mean decadal NDVI with rainfall estimates from cold cloud duration. They observed a lag between rainfall and NDVI between 10 to 20 days. Similar observations were made in East Africa (Davenport and Nicholson, 1989) although in that case the NDVI response to rainfall was 1og-linear.

In this paper, we assess the correlation between rainfall and NDVI in 1995-1997 period in two time scales, namely decadal and monthly. The study area, Kol river basin, is located south of Iran with an area of 15000Km^2 The approximate geographic coordinates of the study area is 55,00 – 57,00 E longitude and 27,49 – 28,49 N latitude. The rainfall, chiefly falling in December-May period, is characterized by high spatial and temporal variation.

DATA AVAILABLE

Rainfall Data

Daily rainfall data was obtained over the period 1995-1997 for twenty-two stations within the study area and its close neighborhood. The daily data was grouped into decadal (10-day) data and a total of 126 decadal rainfall maps were generated by interpolation techniques. Figure 1 shows a typical rainfall map corresponding to the third dacade in Febreuary 1996.

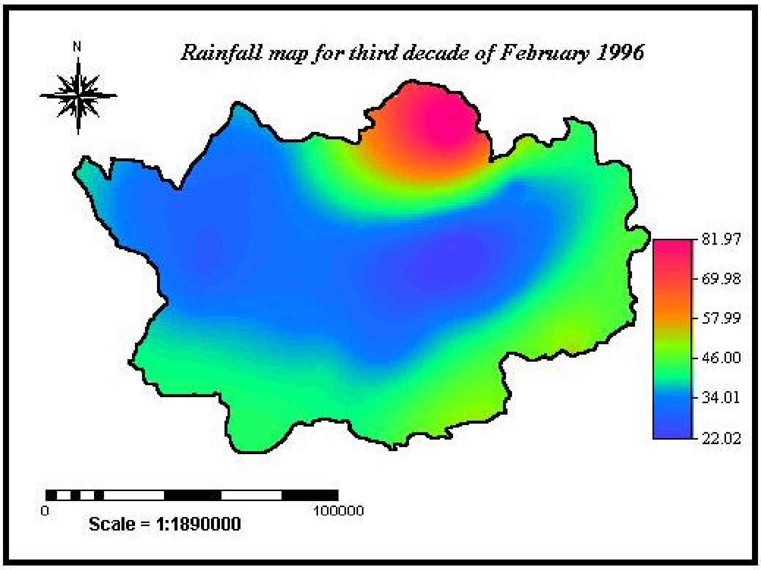

Fig. 1 Rainfall (in mm) map for the third decade of February 1996

Terrain Mapping Units (TMU)

For assessment of vegetation spatial variation in different units, a Terrain Mapping Unit (TMU) map was generated. A TMU describes natural variation of terrain that can be distinguished on aerial photo or satellite images and can be verified on the ground. Due to the low NOAA/AVHRR image resolution, only a classification in main land units was made. For this reason, five land units were selected as follows: alluvial plains (AP), alluvial/colluvial fan (A), flood plain (F), mountain (M) and hills (H). For each of these units, four representative samples were selected in different parts of the study area.

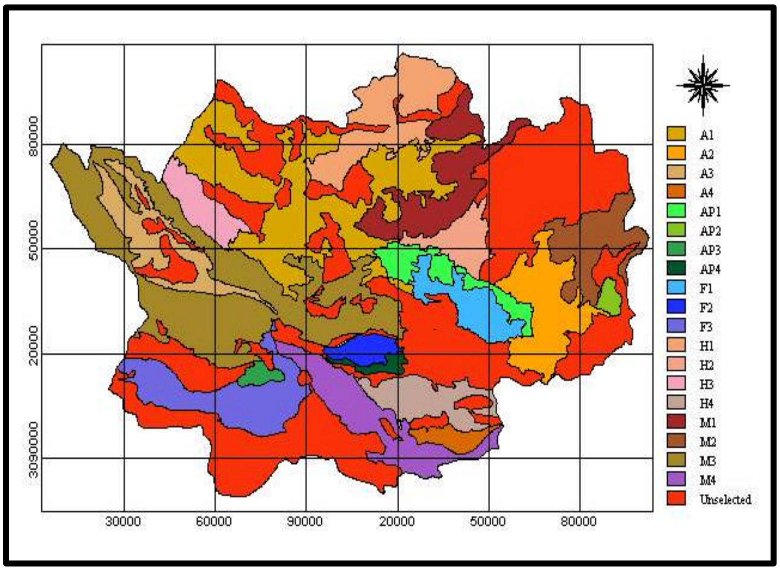

Fig. 2 Terrain Mapping Units map showing location of representative units in the study area

Vegetation Index

Vegetation absorbs a great part of the incoming radiation in the visible portion of the spectrum (VIS=0.22-0.68 µm) and reaches maximum reflectance in the near infrared channel (NIR= 0.73- l.1 µm)(Tucker and Sellers 1986). The NDVI is defined as NDVI= $(Ch_2 - Ch_1) / (Ch_2+Ch_1)$, where Ch_1 and Ch_2 refer to the channels 1 and 2 of the NOAA/AVHRR.

Ten-day composite images for the period of 1995 was downloaded from the internet as processed by Eidenshink and Faundeen (1998) method. Further, ordinary level 1B Local Area Coverage (LAC) images was downloaded from Satellite Active Archive (SAA) for the period 1996-1997. The latter data was transformed into daily NDVI and later maximum cloud-free 10-day values were extracted. Thus a total of 106 10-day composites were generated for the study. The use of maximum 10-day values is believed to reduce some of the variability inherent in the NDVI caused by differences in atmospheric conditions, position of the sun, or scan angle of the satellite.(Holben 1986)

NDVI-RAINFALL RELATIONSHIP ON 10-DAY TIME SCALE

For each of the TMU map units, the linear correlation between decadal NDVI and bgarithm of rainfall was calculated. The correlation was assessed for concurrent decadal values of rainfall and NDVI as well as for up to 10 lag time intervals of rainfall occuring prior to the time of NDVI. Table 1 shows the correlation coefficient for each unit of the TMU and 10 different lag time intervals, where 0 corresponds to concurrent or (0-10) day period, 1 to (10-20) days before, 2 to (20-30) days before, etc. The highest correlation coefficients are indicated in Table 1 in boldface. Based on this table, the highest correlation between NDVI and rainfall for most of the units occurs for a lag of 5 decades and, in the some cases, for a lag of 6 decades. Overall the correlation on a 10-day basis is not strong.

Table 1: Correlation coefficients for different units at different time intervals

Unit	0	1	2	3	4	5	6	7	8	9	10
A1	-0.013	0.090	0.166	0.172	0.248	**0.287**	0.259	0.224	0.130	0.180	0.114
A2	0.117	0.188	0.279	0.286	0.258	**0.325**	0.235	0.223	0.164	0.125	-0.002
A3	0.075	0.179	0.197	0.231	0.280	**0.304**	0.300	0.200	0.125	0.155	0.065
A4	-0.023	0.197	0.247	0.288	0.267	**0.337**	0.328	0.326	0.202	0.150	0.045
AP1	0.247	0.390	0.444	0.469	0.457	**0.473**	0.390	0.324	0.176	0.154	0.035
AP2	0.130	0.246	0.367	0.382	0.393	**0.404**	0.356	0.277	0.180	0.108	0.013
AP3	0.183	0.370	0.348	0.369	0.398	**0.461**	0.380	0.338	0.228	0.250	0.109
AP4	0.260	**0.428**	0.405	0.428	0.424	0.419	0.373	0.286	0.175	0.222	0.116
F1	0.190	0.327	0.391	0.427	0.467	**0.514**	0.412	0.383	0.256	0.226	0.107
F2	0.091	0.192	0.253	0.322	**0.382**	0.354	0.260	0.229	0.133	0.206	0.171
F3	0.155	0.307	0.270	0.298	0.376	**0.398**	0.308	0.243	0.165	0.219	0.089
H1	-0.020	0.023	0.153	0.161	0.220	0.223	**0.265**	0.221	0.148	0.177	0.135
H2	0.176	0.236	**0.316**	0.310	0.315	0.313	0.226	0.191	0.083	0.113	0.059
H3	-0.109	-0.008	0.018	0.109	0.224	**0.296**	0.253	0.246	0.154	0.257	0.161
H4	0.031	0.201	0.245	0.272	0.326	**0.381**	0.302	0.283	0.188	0.181	0.114
M1	-0.090	-0.063	0.084	0.050	0.107	0.163	**0.226**	0.188	0.117	0.166	0.177
M2	-0.163	-0.131	0.040	0.050	-0.008	0.077	**0.157**	0.146	0.115	0.141	0.061
M3	-0.062	0.101	0.130	0.200	0.268	**0.318**	0.247	0.240	0.129	0.221	0.104
M4	-0.165	0.056	0.102	0.187	0.196	**0.286**	0.258	0.262	0.183	0.206	0.114

NDVI-RAINFALL RELATIONSHIP ON MONTHLY TIME SCALE

The monthly NDVI was calculated as the average of consecutive three decades in each month, while the sum of the rainfall in the same three decades was assigned as the monthly rainfall. In this stage, the correlation between NDVI and rainfall was computed for all units similar to how it was done in the 10-day analysis. Lag intervals of up to 5 was examined. Table 2 shows the correlation coefficients for all TMU units and five different time intervals.
As this table shows, the correlation coefficients for the units are higher than those in the ten-day time scale. Yet, no strong correlation between NDVI and monthly rainfall is observed in most units. On average, the highest correlations occur at lag 1 and lag 2. Thus the vegetation cover in each month is mostly affected by the rainfall occuring in the two previous months. The alluvial plain units have the highest correlation between NDVI and rainfall. The maximum coefficient is 0.635 for AP2 unit. The lowest correlation in the study area is seen in the mountainous units. In this case the M2 unit has a correlation coefficient of only 0.167.

Table 2 Correlation coefficients between monthly NDVI and rainfall at 5 different lag intervals

TMU	**0**	**1**	**2**	**3**	**4**
A1	0.051	0.282	**0.384**	0.261	0.037
A2	0.32	**0.457**	0.358	0.27	-0.144
A3	0.134	**0.426**	0.376	0.236	-0.035
A4	0.172	**0.492**	0.482	0.24	-0.03
AP1	0.351	**0.621**	0.53	0.342	-0.102
AP2	0.285	**0.635**	0.469	0.179	-0.145
AP3	0.387	**0.620**	0.561	0.404	-0.055
AP4	0.335	**0.542**	0.403	0.38	-0.03
F1	0.332	0.581	**0.604**	0.419	0.035
F2	0.174	**0.486**	0.344	0.318	-0.023
F3	0.412	**0.57**	0.477	0.315	-0.104
H1	-0.058	0.25	**0.411**	0.25	0.077
H2	0.368	**0.51**	0.377	0.223	-0.118
H3	-0.072	0.18	**0.404**	0.275	0.136
H4	0.23	**0.497**	0.439	0.282	-0.011
M1	-0.142	0.138	**0.347**	0.201	0.09
M2	-0.086	0.058	**0.167**	0.09	-0.057
M3	-0.008	0.329	**0.381**	0.287	0.083
M4	-0.058	**0.352**	0.352	0.265	0.056

Cumulative Rainfall Method

For assessment of NDVI and rainfall relationship, various combination of cumulative rainfall in the preceding months was examined as suggested by Richard and Poccard (1998). The logarithm of monthly rainfall was used for the correlation assessment. This was found to produce better results. Table 3 shows the correlation coefficients between monthly NDVI and logarithm of (cumulative) monthly rainfall in various time intervals for all TMU units. The highest correlation of each row is indicated in boldface. The columns, respectively from left to right, show the correlation between NDVI and rainfall recorded in the current plus previous months (1+0), in the two previous months (2+1), in the current plus two previous months (2+1+0), in the three previous months (3+2+1), and in the current month plus three previous months (3+2+1+0).

In most cases, the highest correlation occur in the last two columns of the table, which means that a sequence of about four months of rainfall is a good predictor for the NDVI. The lag appears to imply that vegetation does not respond to the immidiate rainfall, rather it is affected by the history of the soil moisture buildup. Compared to other techniques of NDVI-rainfall correlation evaluation on decadal and monthly basis, the correlation between NDVI and cumulative rainfall amounts has improved considerably.

Table 3: Correlation between NDVI and the logarithm of cumulative monthly rainfall

Unit	1+0	2+1	2+1+0	3+2+1	3+2+1+0
A1	0.164	0.464	0.327	**0.535**	0.427
A2	0.37	0.472	0.487	0.508	**0.547**
A3	0.304	0.569	0.467	**0.627**	0.558
A4	0.276	0.556	0.449	**0.582**	0.51
AP1	0.583	0.746	0.722	0.729	**0.747**
AP2	0.508	0.683	0.662	0.682	**0.704**
AP3	0.529	0.705	0.683	0.754	**0.766**
AP4	0.649	0.741	0.775	0.781	**0.839**
F1	0.494	0.718	0.671	**0.735**	0.728
F2	0.372	0.57	0.495	**0.629**	0.584
F3	0.421	0.553	0.541	0.596	**0.609**
H1	0.112	0.457	0.298	**0.543**	0.413
H2	0.471	0.527	0.534	0.529	**0.558**
H3	0.001	0.416	0.223	**0.537**	0.374
H4	0.304	0.554	0.485	**0.62**	0.527
M1	-0.019	0.311	0.14	**0.404**	0.258
M2	-0.076	0.205	0.071	**0.297**	0.18
M3	0.153	0.522	0.343	**0.618**	0.475
M4	0.06	0.484	0.27	**0.589**	0.411

Multiple Regression Method

Multiple regression method was applied as a more general method to examine the correlation between monthly NDVI and logarithm of monthly rainfall. The analysis was performed for NDVI as dependent variable and logarithm of monthly rainfall values corresponding to four lag intervals (lag 0, lag 1, lag 2, and lag 3) as independent variables. The results of the multiple regression analysis for each unit demonstrated slight improvement in the correlation coefficient, while the dependency on lag 1 rainfall was strongest. Therefore, this type of regression analysis gave better results in the study area than the results obtained by the application of the method proposed by Richard and Poccard (1998).

Table 4: Result of the multiple regression analysis

TMU	A1	A2	A3	A4	AP1	AP2	AP3	AP4	F1	F2	F3	H1	H2	H3	H4	M1	M2	M3	M4
R	0.55	0.55	0.63	0.6	0.79	0.74	0.79	0.86	0.77	0.64	0.63	0.58	0.58	0.6	0.63	0.49	0.37	0.64	0.62

CONCLUSIONS

In this study several methods were used for monitoring of vegetation and its relationship to variation of rainfall on the time. The result show that time series of 10-day and monthly AVHRR NDVI are related to lagged rainfall in the study area. The weakest relation between NDVI and rainfall occur at 10-day time interval. But the relation improve when NDVI is aggregated into monthly composites. Monthly NDVI data fllow monthly rainfall data with a lag of one to two months and are best correlated with the bimonthly antecedent rainfall. The multiple regerassion method shows the better result comparing the others methods.

There are unaccounted differences in rainfall intensity and duration, which may have had a negative effect on the relations. High intensity rains manifested more as an increase runoff, particularly if the soil is already moist. Thus the increased rainfall is relatively ineffective for vegetation growth.

Soil moisture availability also is one of the most factors for growing of vegetation. Depend on capability of soil for storage moisture the vegetation variation can be changes. It is likely that the lack of strength of the relations could be partly explained with detail ground information such as soil type, vegetation type, soil moisture capability and so on. More detail field information and the inclusion of data from high-resolution sensors might provide additional explanation of low correlation in the units of the study area.

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