

Effects of polluted rainfall related to burning Kuwaiti oil wells on vegetation in south of Iran

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Abstract

The products of NOAA-AVHRR are an appropriate data to detect any changes in vegetation cover and to determine its distribution pattern. The most valuable effect of the use of NOAA-AVHRR is that this satellite source is the only instrument that is capable of demonstrating a change of vegetation cover over a large area. AVHRR data are useful for large scale land cover because of their multi-temporal nature; daily AVHRR data are formed into normalized difference vegetation index (NDVI) composites. NOAA-AVHRR were used to monitor the vegetation cover change due to pollution resulted from the Kuwaiti oil well fires. NOAA-AVHRR data sets, maximum 10-days NDVI images (GAC) time series for 1989-1993 were used. They have shown that NDVI is an excellent indicator to study green vegetation cover globally or locally. The NDVI profiles which were produced for many points for 1989 to 1993 shows high reduction in NDVI values in most parts in 1991. Not only the peak of NDVI values in the growing season decreased, but also the area under the NDVI curve decreased in 1991.

1 Introduction

The NOAA-AVHRR (Advanced Very High Resolution Radiometer) is a part of a system which has been operational for over 15 years and which looks like being operational beyond the end of the present century. AVHRR was designed as an instrument of polar-orbiting satellite for meteorological purposes. The data collected by the AVHRR have come to be used for a whole range of purposes, not just in meteorology and oceanography for which it was planned but in a whole range of applications that were never envisaged when the system was originally specified and designed (Cracknell, P., 1996). The data from NOAA-AVHRR have been an appropriate tool to detect any changes in vegetation cover and to determine its distribution pattern. Using interpretation of time series, the main locations that changed are identified. The most valuable effect of the use of NOAA-AVHRR is that this satellite source is the only instrument that is capable of demonstrating a change of vegetation cover over a large area. In this study the NOAA-AVHRR were used to monitor the vegetation cover change due to pollution resulting from the Kuwaiti oil well fires since 1991.

2 Objectives

The main objective of this study is to demonstrate the changes in NDVI values, i.e. the index for detecting of changes of vegetation cover in the growing season (January to June) in south and southwest of Iran in 1991 using the NOAA-AVHRR data.

3 Methods and approach

NOAA-AVHRR 8km resolution (GAC) time series data for five years (1989-1993) were used to study vegetation cover, 10-days maximum NDVI values produced by NASA and re-scaled from 0 to 255. In order to distinguish variations in NDVI values in different years, the vegetation map was superimposed on the NDVI images. Sample points were selected in each vegetation cover type. The sample points were stratified and randomly distributed in different vegetation units. The vegetation types that cover the south and south-west of Iran are important for animal husbandry. Therefore, the investigation of vegetation change is focused on this region. For each sample point a NDVI profile was drawn for the whole year in the period of 1989-1993. These points were randomly selected and the NDVI profiles of these points during the five years (1989-1993) were plotted. In order to follow the variations of NDVI values in the five years, the 10 days maximum NDVI value for some were plotted points versus decades (from 1 January). To visually interpret the changes in NDVI values in different years, the values were calculated and the NDVI profiles were plotted for the sample points in the same scale for different vegetation cover types. In order to find the variation of NDVI values in relation to the distance from the source of the pollution, several samples

were taken in different (or the same) land covers with different distances from the source of the pollution. Based on the NDVI profiles of many points, the growing season was distinguished, then the average NDVI of this period (February to June) were calculated and new NDVI image were generated. These NDVI images were used to calculate changes of vegetation greenness in the study area, figure 1 shows the study area.

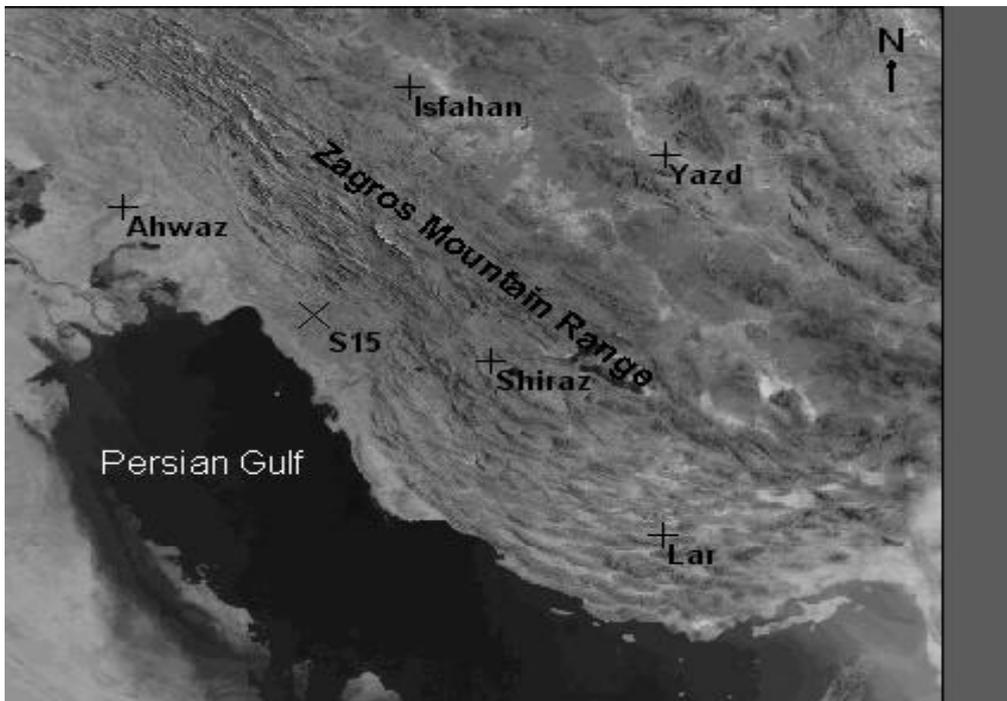


Figure 1: the study area. NOAA False Color composite. The Kuwaiti oil wells located in west of the Persian Gulf.

4 NOAA-AVHRR (GAC) NDVI profiles

The growing season starts from decade 1 and ends approximately in decade 13. In this period the rainfall and temperature did not change significantly in 1990,1991 and 1992, therefore year 1990 selected as reference year

are much less than in 1990,1992 or 1993. Therefore this reduction of NDVI in 1991 and also 1992 was not because of rainfall and temperature, but it was due to the effects of the polluted rain. Figure 2 show NDVI profile of point S15 (for example) in different years (1989-1993).

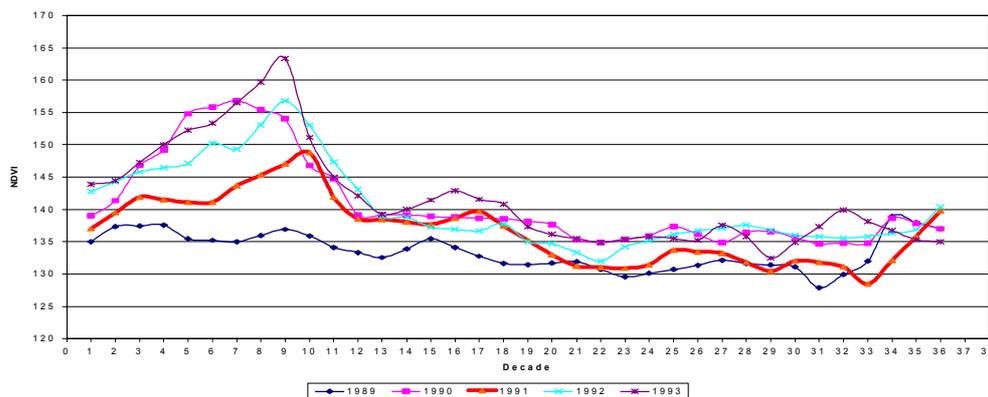


Figure 2: Comparison of NDVI profiles of points S15 (see figure 1) in five years (1989-1993). The elevation of this point is 530 metre above sea level. The vegetation type is mixed forbs and bushes. The NDVI values are low in 1989 because of less rainfall (Jalali et al 1999). The NDVI values in 1991 are lower than 1990 and 1993, while the rainfall in 1991 was higher than in 1990. Also the rainfall was higher in 1992 than in 1990 in this area, therefore the reduction of NDVI values in 1991 is due to pollution and in 1992 due to very little recovery.

5 Statistical analysis

An attempt was made to show whether any differences in NDVI values will come up when using methods like Box Plot or an other statistical analysis. Figure 3 is an exploratory diagram of the NDVI values from 1989 to 1993 in the study area. As figure 3 shows the NDVI values in 1989 generally lower than in the other years. The result of meteorological study show that there was very little rainfall in 1989 (Jalali et al 1999). The NDVI values of 1989 are very low as compared with the other years, therefore the NDVI values of 1991 are compared with other years except on 1989.

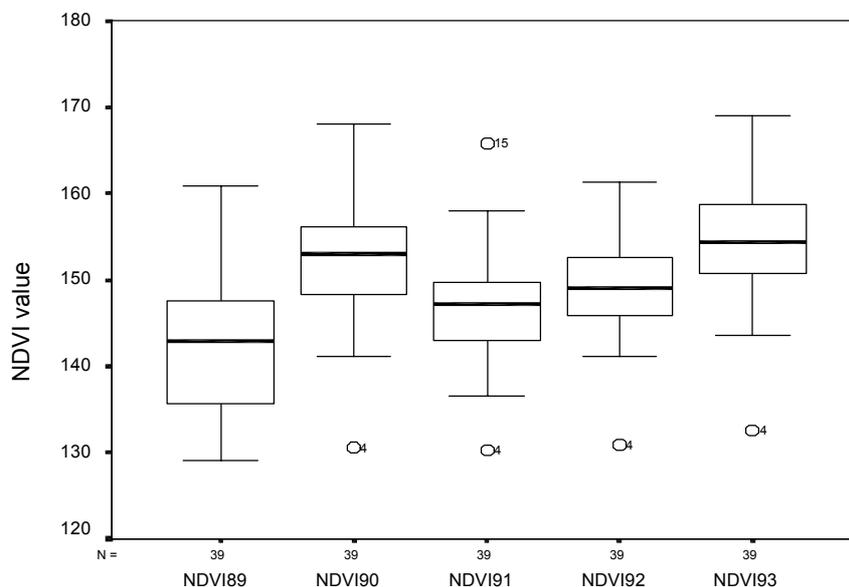


Figure3: Box plots of average NDVI values of growing season in period 1989-1993. N is size of data, x-axis is year and Y-axis is NDVI values. This figure shows that the maximum and also minimum NDVI value of 1991 is lower than 1990, 1992, and 1993. The median of NDVI values in 1991 is also lower than in 1990, 1992 and 1993, therefore greenness highly decreased in 1991. Moreover, to see weather there were any significant changes between NDVI values of different years the t-test was applied on the NDVI value of 1990,1991,1992 and 1993. The results are shown in table 1. The number of sample, mean, standard deviation, standard error, degree of freedom and t values are shown in table 1. Result that is shown in this tables indicated decreasing of NDVI values in 1991 as compare with 1990, 1992, and 1993 are significant with 95% confidence interval as shown in the last column of table 1.

Table 1: Result of t-test on the NDVI

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	NDVI90 - NDVI91	5.4149	3.2815	.5255	4.3511	6.4786	10.305	38	.000
Pair 2	NDVI91 - NDVI92	-2.5800	4.0753	.6526	-3.9011	-1.2589	-3.954	38	.000
Pair 3	NDVI91 - NDVI93	-7.8010	2.9613	.4742	-8.7610	-6.8411	-16.451	38	.000

df = degree of freedom, sig. = related significant level to the t number. This table shows sig. Is less than 0.05 (considering 95 % confidence) therefore differences of NDVI values between 1991 and 1990, 1991 and 1992, and 1991 and 1993 are significant. This difference of NDVI values in 1991 is reduction in vegetation cover caused by the pollution in 1991

6 Relationship between AVHRR (GAC) NDVI values and distance from the source of the pollution

Rainfall was similar in 1990 and 1991 and there was no significant change between these two years in temperature therefore, 1990 was selected as reference year to do comparison on change of vegetation greenness (NDVI).

Therefore, the image of 1990 (non-polluted year) with the 1991 image (polluted year) were used to investigate the relation between NDVI and distance. Two pathways were selected. The first one was along the gradient of height and distance from the source of the pollution, the second one was along the coast. Figure 4 shows the relation between NDVI values and distance (first one), from near the source of the pollution to the mountains.

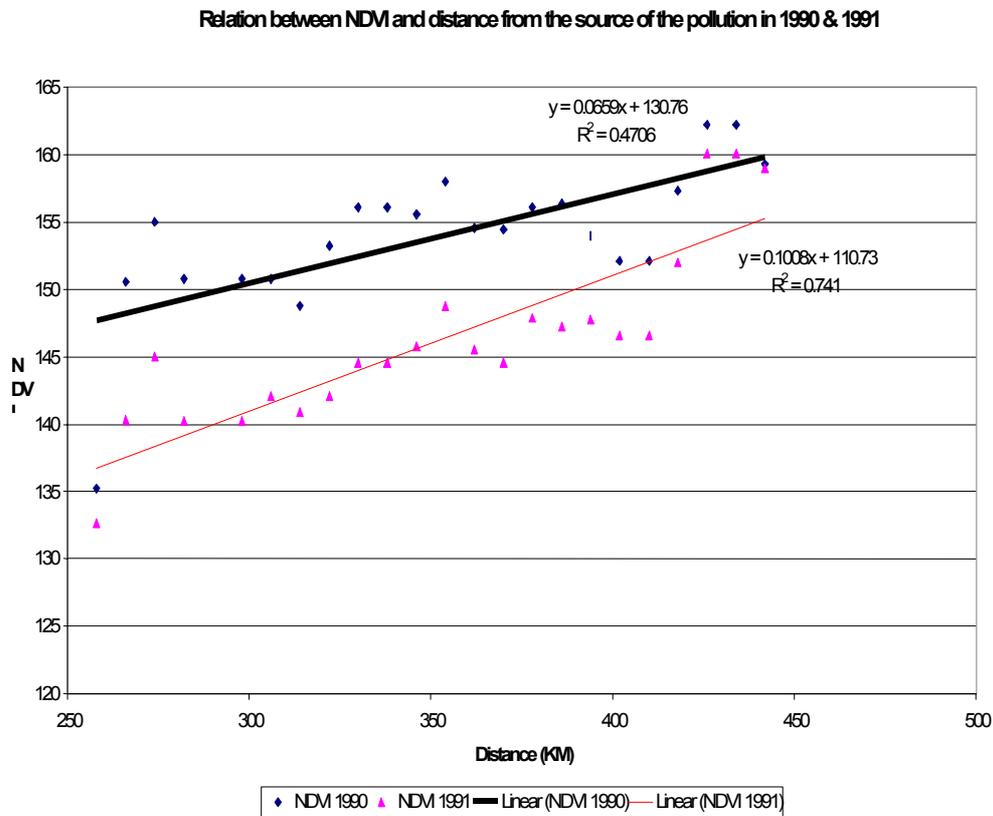


Figure 4: Relationship between NDVI values and distance to the source of the pollution in 1990 and 1991. Direction of the sampling path is eastward starting from the coast of the Persian Gulf and ending in the Zagros Mountains range. As the graph shows the gradient of the best fit line is steeper in 1991 because the NDVI values near the source of the pollution decreased very much while far from the Persian Gulf in the mountain area these differences are reduced.

7 Image differencing for investigation of AVHRR (GAC) NDVI changes

Changes in NDVI between 1990 and 1991 were studied. For this purpose the average NDVI images of the growing seasons of these years were produced, then the difference of those average NDVI images was calculated. The NDVI Difference map (NDVI191-NDVI190) shows a maximum change of NDVI values close to the Persian Gulf north of Busheher, Ahwaz, Dezfool and Ilam. Figure 5 show sliced map that produced from NDVI1991-NDVI1990,

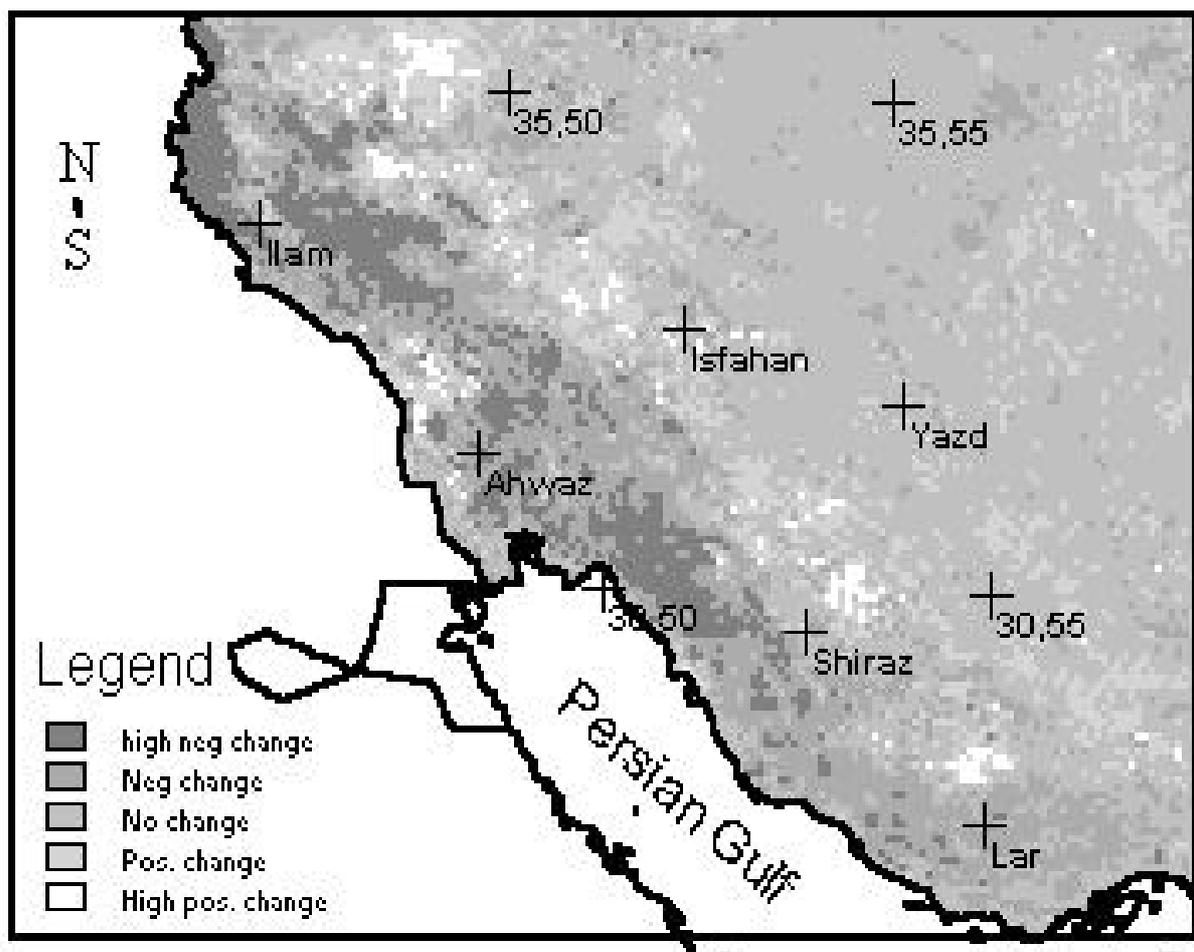


Figure 5: Sliced map of difference of NDVI values in 1991 and 1990 (NDVI1991-NDVI1990) Red=highly decreased NDVI values in 1991, yellow=decreased NDVI values in 1991, white=no change NDVI values in 1991, blue=increased NDVI value in 1991.

8 Results

Normalised Difference Vegetation Index (NDVI) data obtained from the Advanced Very High Resolution Radiometer (AVHRR) on board NOAA-11 were analysed to assess the changes of vegetation cover in south and southwest Iran.

As the results of the analysis of the meteorological data show (Jalali et al 1999), there was no significant change on rainfall and temperature in 1990 and 1991. The NDVI profiles which, produced for many points in 1989 to 1993 shows a high reduction in NDVI values in some parts in 1991.

The exploratory Box plot (figure 3) of the NDVI values for the sample points shows the NDVI values in different years (1989 to 1993). It is clear that NDVI values of 1991 were lower than in the others years, especially when compared with 1990. The statistical analysis and t-test carried out on the NDVI values in different years show that the reduction of NDVI values in 1991 was significant. This reduction of NDVI values in 1991 take place stretching from the top of the Zagros mountain ridge towards the area near the source of the pollution.

A relation between NDVI values and distance from the source of the pollution was established. The scatter plot of these values shows some differences between the two graphs drawn for the two years 1990 and 1991 (figure 4). The gradient of best fit line is steeper in 1991 (from source of the pollution towards the mountain) because the NDVI values near the source of the pollution decreased much while far from the Persian Gulf towards the mountain area, these differences are low. The relation between NDVI and distance from the source of the pollution in the same vegetation cover type explains the decrease in NDVI values near the source of pollution in 1991 as compared with 1990 (figure 4). To determine whether there are significant changes between the two sets of values the t-test was applied on the NDVI values. The result of this test shows a significant decrease of

NDVI in 1991 as compared to 1990. The maximum reduction of NDVI values in 1991 as compared with 1990 have occurred from the top of the Zagros mountain ridge to the Persian Gulf causes of which can be:

- (1) The mountain range acts as a barrier and causes the smoke to accumulate to the west of it.
- (2) The vegetation cover type in flat and hilly area more sensitive to pollution.
- (3) Both could be correct, therefore reduction of vegetation cover in 1991 is due to the pollution which produced from Kuwaiti oil wells in this area in 1991.

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