ARTICLES

# Detecting and Monitoring Desertification Processes in the Western Tabuk Province, Saudi Arabia Using Remote Sensing and Ancillary Data

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***Abstract:***

**The research discusses desertification processes in the Western Tabuk Province, Saudi Arabia. The main objective was to investigate and analyze desertification processes through using Landsat TM imagery from 1988 and 1999 and ancillary data, in conjunction with fieldwork to detect vegetation sites and human impact. The results showed that spectral reflectance for dry soil and desert vegetation was considered an indication of desertification. Ratio Vegetation Index (RVI) was utilized to produce the image of vegetation change and delineate degraded areas from non-degraded areas. Grazing and woodcutting have been observed and leading to affect the certain vegetation sites in the study area.**

## *INTRODUCTION:*

Heathcote (1983: 296) outlined ‘‘The arid lands constitute one of the worlds major ecosystems, and provide a significant contribution to the global economy.’’ Arid lands are characterized by evapotranspiration that exceeds precipitation (Tueller, 1987), and having ‘‘an important role in the land-atmosphere energy balance and hydrologic’’ (Chen et al, 1998: 255).

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Desertification is one of the main environmental problems in arid environments, which is defined as “Land degradation in arid, semi arid, and dry sub-humid areas resulting from various factors, including climatic variation and human activities” (Williams and Balling, 1996:1-2). Dregne (1983:5) has presented another definition of desertification as: “The process of deterioration ecosystems that can be measured by reduced productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro and macro fauna and flora, accelerated soil deterioration, and increased hazards for human occupancy.”

The Western Tabuk Province has major differences of desertification due to the differences in geologic conditions, rainfall variability, variation of vegetation growth, and differences associated with human activities such as grazing and woodcutting.

There continues to be a lack of desertification studies in the study area and all writings are focused on general information about vegetation and human impact.

In respect to the latter point, Al-Harbi (2001:113) introduced a scientific recommendation as “monitoring becomes a necessity for environmental change by using remote sensing and supported with intensive fieldwork. The focus should be on evaluating the degradation processes, their indicators and consequences in Tabuk Province, and selecting solutions to mitigate the site problem.” Therefore, this recommendation has scientifically been developed to be this research project, focusing on detecting and monitoring the desertification processes in the Western Tabuk Province.

This research is an attempt to discuss desertification processes by using remote sensing technique and ancillary data, in conjunction with intensive fieldwork in the Western Tabuk Province, Saudi Arabia.

## *Study Objectives*

The purpose of this research is to: (1) illustrate the role of remote sensing in detecting desertification; (2) investigate the nature of desertification in the Western Tabuk Province; and (3) discuss the indicators of desertification.

### *Study Hypotheses*

(1) There are no significant differences in Ratio Vegetation Index (RVI) images between 1988 and 1999.

(2) There is no major effect of human impact in the study area.

### *Study Questions*

To examine these hypotheses, three major questions were addressed:

* Can spectral reflectance for dry soil and desert vegetation be used as indicator of desertification?
* Is Merged Ratio Vegetation Index (RVI) image used effectively to detect and monitor desertification?
* Can human impact be a contributing factor for severe desertification in the study area?

### *Previous Studies*

Many studies have been undertaken in the field of desertification. Khalaf (1989) discussed indicators of desertification and applied them in Kuwait desert. He classified the causes of desertification into extensive deterioration of the natural vegetation cover, increase in sand movement, overgrazing, and irrigation application to control sand movement. Sharma (1998) explained how lack of water or mismanagement could be one of the major indicators of desertification. The researcher emphasized that the relationships between water, land, and human activities caused desertification in many areas. Khreast et al. (1998) studied the major causes of land degradation in the area located northwest of Jordan. They classified improper farming practices, overgrazing, displacement of rangelands to croplands, and expansion of urban and rural settlements as the main indicators of degradation.

Remote sensing is *"considered to be a timely tool that allow inventory, monitoring, and management information for arid lands"* (Tueller, 1987:144). It is successfully accepted as a data source of repeated monitoring of land degradation dynamics and a facilitator of implementing development plans and policy for investment of land resources (Hill et al, 1995).

Several remotely sensed studies have been done in the field of desertification. Sujatha et al. (2000) investigated degraded lands of Jaunpur district, India throughout using remote sensing and geographic information systems (GIS) supported with ancillary data and fieldwork. The study mainly focused on evaluating the changes of salt-effected soils, waterlogged areas, and eroded lands. Amissah-Arthur et al. (2000) assessed farmland dynamics and land degradation on Sahelian Landscape using remotely sensed and socioeconomic data. The study utilized geographic information systems (GIS) to map major changes of land-use in the study area. The authors noted that the integration of remote sensing, biophysical, and socioeconomic data contributed to exploring the relationship between carrying capacities and the magnitude of land degradation with emphasis on the comparison between the early and late periods of land change. Mulders and Girard (1993) explained the important role of remote sensing in evaluating desertification. The condition of vegetation cover can be detected using Landsat data together with ground observation. Bush fires can also be monitored using satellite images. In addition to those, overgrazing, water erosion, and sand movement can also be detected through using remote sensing technique. Roozekrans (1994) assessed desertification indicators using remote sensing data. The author utilized NOAA-AVHRR, METEOSAT, and LANDSAT for monitoring vegetation cover, land surface temperature, albedo, and water balance. Warren and Hutchinson, (1984) used remotely sensed data to monitor vegetation deterioration as indicator of land degradation in a significant site located south of central New Mexico. The study is certainly focused on identifying vegetation cover and measuring the ratio of shrubs and grasses integrated with remotely sensed data.

## *The Study Area*

The study area chosen for investigation is located in the Western Tabuk Province, Saudi Arabia, approximately (1800) square km. The area has experienced environmental deterioration, caused by geologic condition, deficiency of rainfall and human impact. The area of study roughly lies within 28°, 00 - 28°, 15 N and 35°, 10 - 35°, 30 E (Fig.1). According to the geologic map of the Tabuk Province published by US Geologic Survey-1963, the geology of the study area contains the oldest geologic structure in Saudi Arabia, which belongs to Precambrian era that consists of granite and granodiorite rocks. On the other hand, the study area has a geologic formation of the Tertiary era that occupied a large area of basalt and the Quaternary period that contains silt and gravel deposits, which occupies the valleys in the area caused by runoff processes. Al-Bad Meteorological Station, which located north of the study area, shows the climate is characterized with aridity. The average temperature is 40°C the highest value for summer and 7.6°C the lowest value for winter. The months of December, January and February represent the more reliable winter rainfall season as a result of the movement of Mediterranean Sea cyclones with the highest value of (50) mm. No or little rainfall is expected throughout the study area in summer. The study area has variations of deposits, which can be classified into three main types gravel, silt and sand (Saudi Soil Map, 1986). The study area has annual vegetation cover caused by seasonal rainfall. However, the spatial extent of perennials does not change from one season to another, but the photosynthetic activity always changes due to rainfall availability for adaptation to prevailing desert condition in the study area.

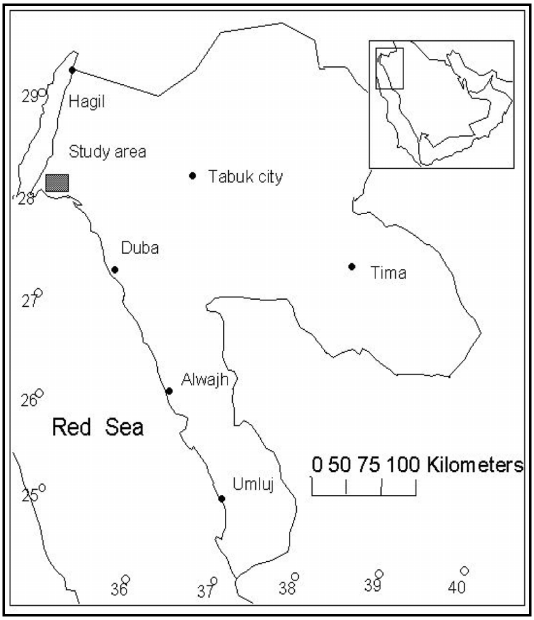


**Figure 1 Location map of the study area**

**Source:** Saudi Ministry of Petroleum and Minerals Resources, Geographic Map of Tabuk Province, (2002)

## *Data and Methodology*

### *Data Sources*

#### *Tabuk Agriculture and Water Department Reports*

General reports that cover field surveys for vegetation types and human impact were reviewed, and used in the study.

#### *Landsat-5 TM data*

The available digital Landsat TM data for April 1988 and April 1999 were acquired from King AbdulAziz City for Science and Technology, Saudi Space Research Institute of the study area (Figs. 2 and 3).

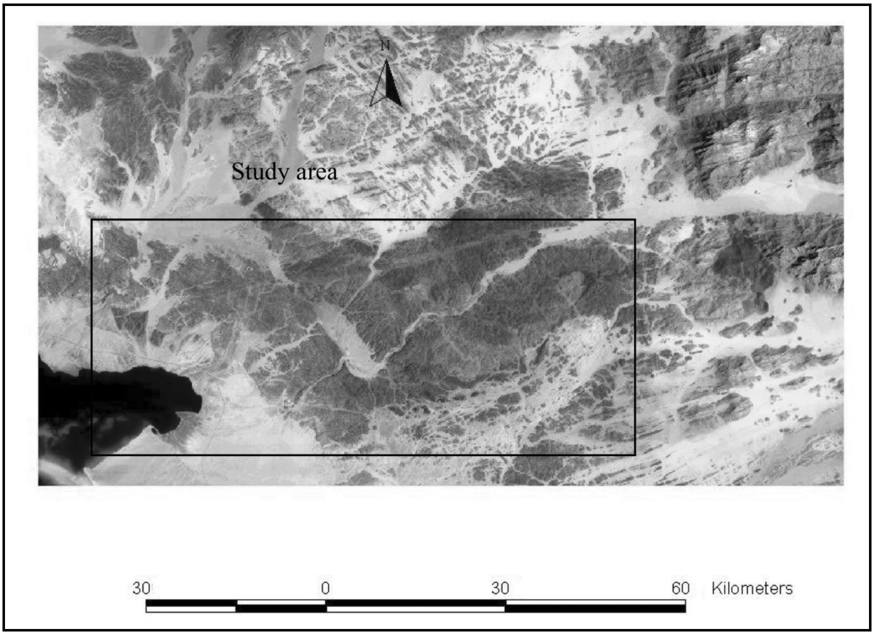


**Figure 2 1988 TM image for the study area**

**Source:** King AbdulAziz City for Science and Technology, Saudi Space Research Institute, TM data, bands 2,3, and 4 (2000).

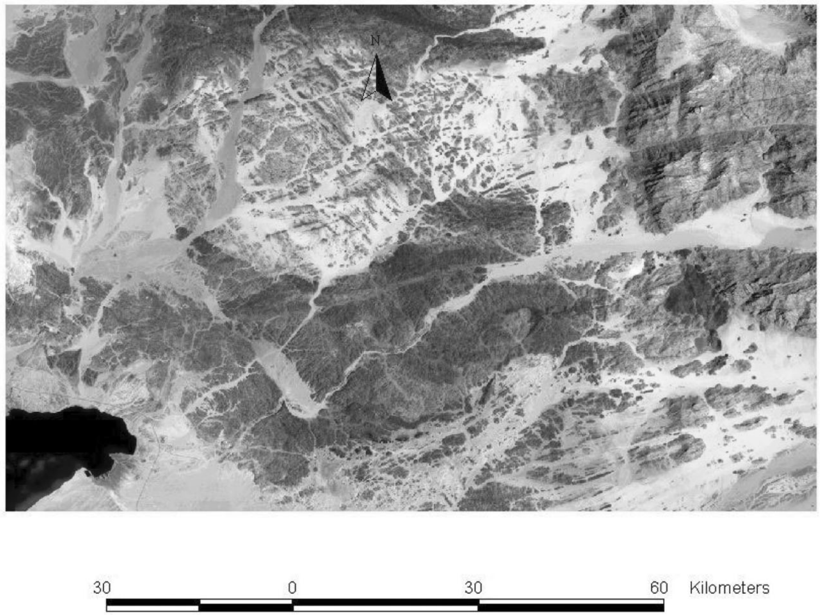


**Figure 3 1999 TM image for the study area**

**Source:** King AbdulAziz City for Science and Technology, Saudi Space Research Institute, TM data, bands 2,3, and 4 (2000).

### *Field data collection*

The main objective for the fieldwork is to collect qualitative data about the presence or absence of vegetation and human impact. A total of twenty-five vegetated field sites were established and taken from the 1999-image for the study area (Fig.4). These sites were visited in April 2002. Each site was about 90*90m quadrate. Within each site, the researcher observed the current vegetation and human impact and assigned 1 for existence of vegetation, 0 value for none, and ‘‘—‘‘for no human impact as shown in Table 1.

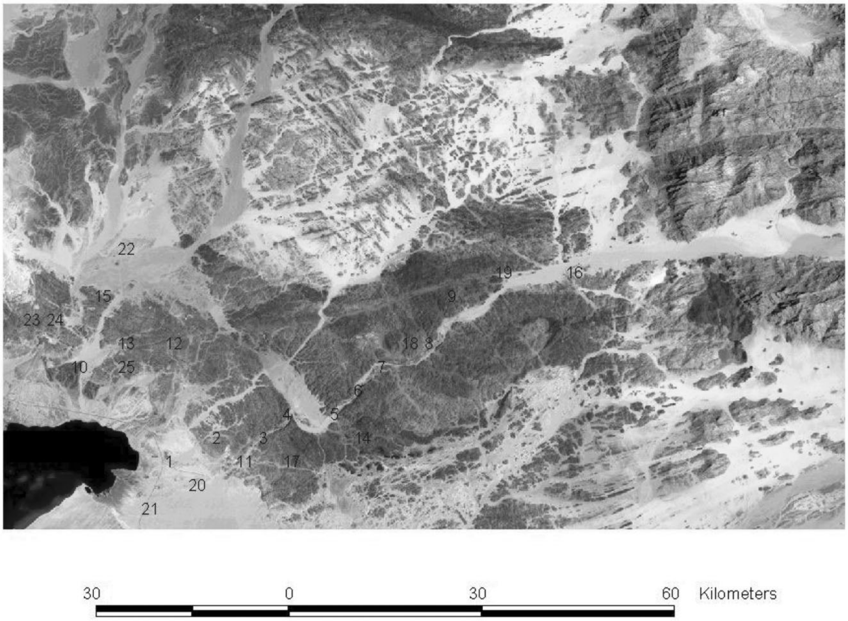


**Figure 4 Location map of the twenty-five vegetative sites**

**Source:** King AbdulAziz City for Science and Technology, Saudi Space Research Institute, TM data, bands 2,3, and 4 (2000).

### *Rainfall data*

Rainfall records have been collected from Al-Bad meteorological station for the period from 1978 to 1992. Unfortunately, there is no data available on rainfall for the following years.

### *Geologic formation and deposits data*

From Saudi Soil map, the researcher digitized a new map for the study area using ArcView 3.2 a. The new map is showing mountains distribution and types of deposits in the study area.

## *Data Analysis*

#### *Image preprocessing*

The TM data were digitally registered image to image using topographical map of the study area sheet NH 36-16 at scale 1:

250,000. Several ground control points were identified for geometrical correction and obtaining accurate images for both dates.

### *False color composite*

Lillesand and Kiefer, (2000:389) explained *"color composite can be generated for any remotely sensed images by printing three bands in registration onto color film or by displaying three bands data digitally."*

In this research, false color composite was generated for the two images of the study area by using three bands green, red (R), and near infrared (NIR). This technique helped to recognize major differences of land cover.

### *Spectral reflectance*

Spectral reflectance of objects has been considered the main part of remote sensing to recognize major differences between vegetated and nonvegetated areas (Campbell, 1996), and to be used for measuring the type and condition of various features (Lillesand and Kiefer, 2000).

In this research, the spectral reflectance for dry soil and desert vegetation sites was tested for 1988 and 1999.

### *Ratio Vegetation Index (RVI)*

Ratio Vegetation Index (RVI) was utilized in this research. The equation of RVI involved red and near infrared wave bands and expressed as follows: band 4 / band 3 (Campbell, 1996). The calculation for the two images was done by using ERDAS imagine 8.4 software.

## *Results and Discussion*

### *Visual image interpretation of FCC*

The visual interpretation of false color composite images presented temporal and spatial variations in vegetation cover (Fig.5) and showed very minor changes of vegetation that may be due to negative impact on the remaining vegetation cover.

Spectral reflectance for any arid site is always affected by total vegetation cover, vegetation structure, bare ground percentage, amount of shadow, grave, and topography (Tueller, 1987).

The average spectral reflectance values for multiple dry soil and desert vegetation sites were identified. Figure 6 shows that the spectral reflectance curve of dry soil-1988 has a low value in band 2 and increased to a high value for band 3 (red), with depth at band 4 (near infrared). The differences in spectral reflectance curve due to soil color, texture, presence gravel and rock, surface roughness, and possibly other factors (Tueller, 1987). On the other hand, desert vegetation curve-1988 represents a low value of spectral reflectance for band 3 as result of pigment absorption, and jumped to a high value in band 4 as a result of leaf scattering. Therefore, the area shows dryness in soil with a high value of vegetation.

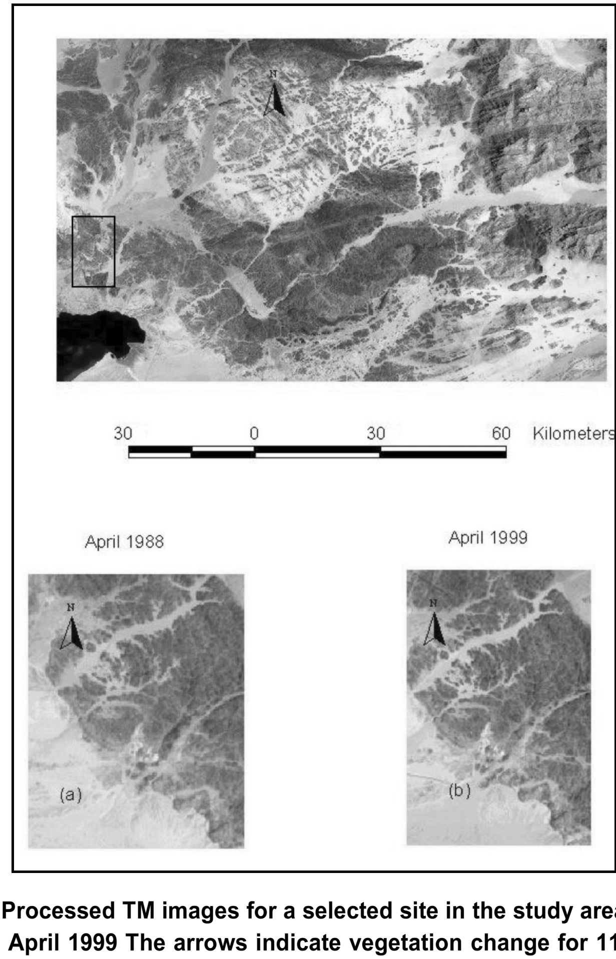


**Figure 5 Processed TM images for a selected site in the study area (a) April 1988 and (b) April 1999 The arrows indicate vegetation change for 11-year period.**

**Source:** King AbdulAziz City for Science and Technology, Saudi Space Research Institute, TM data, bands 2,3 and 4 (2000).

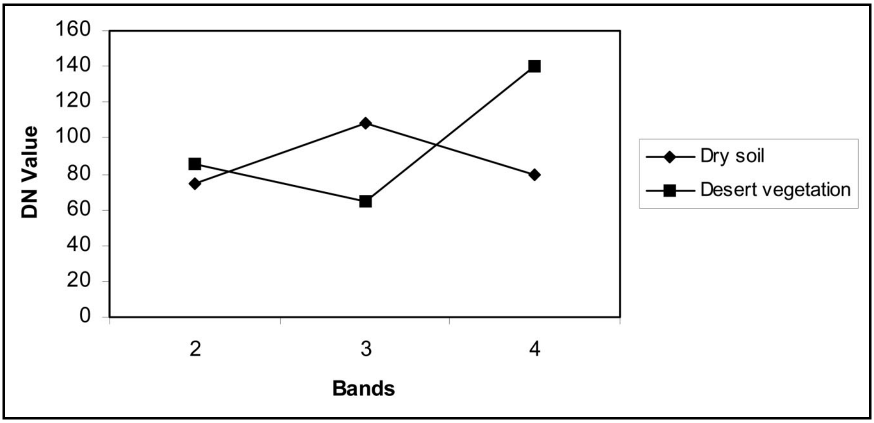


**Figure 6 The average spectral reflectance curves for dry soil and desert Vegetation-1988**

**Source:** Using ERDAS Imagine software

Figure 7 shows the curve of dry soil-1999 and the area has a dry season in which the curve indicates a high value for band 3 and a low value for band 4. Biologically, the desert vegetation curve-1999 represents a little increase from band 3 to band 4, which means the area had an indication of low value of greenness.

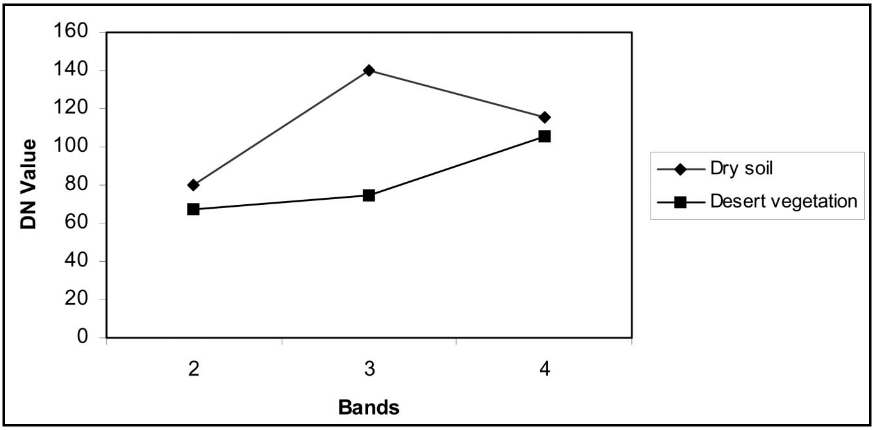


**Figure 7 The average spectral reflectance curves for dry soil and desert vegetation-1999**

**Source:** Using ERDAS Imagine software

## *The use of RVI technique in detecting desertification*

Ratio vegetation Index can be a useful technique for monitoring and mapping arid lands. It helped to distinguish between natural vegetation and cultivated fields by merging three layers of images into one scene coverage (Alwashe and Bokhari, 1993). Figure 8 presents the data obtained from the RVI images for the twenty-five vegetated sites. All sites have higher values of RVI for 1988 than those of 1999, as a result of high reflectance of near-infrared (band 4) and indication of a high greenness. These differences in values of RVI indicate that the area has much greenness for 1988 than 1999. Moreover, the 1999 period has lower values of RVI, which indicates that a deterioration process has occurred in the study area.

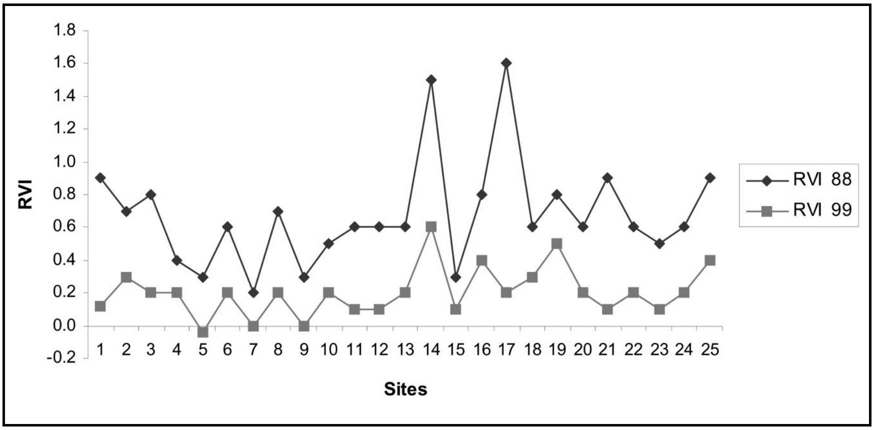


**Figure 8 RVI values for twenty-five vegetated sites in the study area**

**Source:** Using ERDAS Imagine software

On the other hand, Figure 9 is considered the main contribution of this research, showing the differences of land surfaces. The new image shows the three main categories of vegetation change, which are assigned red for vegetation decrease, cyan for vegetation increase and white for no change. In addition, the image has two main sub-areas of vegetation due to the variability of geological structure and soil moisture in the area. Also, large degraded areas of mountains broadly occupied the area.

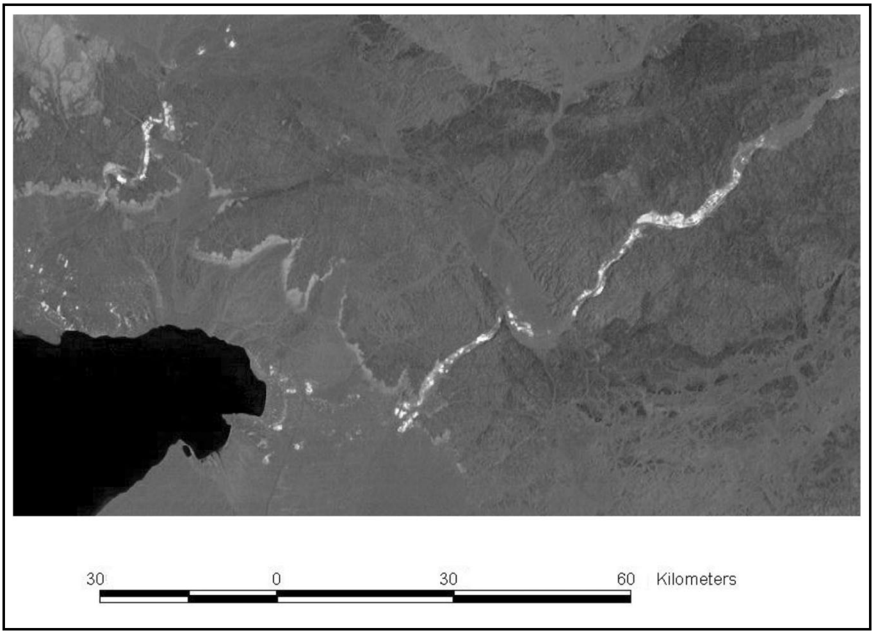


**Figure 9 Merged RVI images for the study area**

**Source:** Using ERDAS Imagine software

## *The Impact of geologic on desertification*

The variation of geologic formation that contains the oldest granite, the largest area of basalt, and the silt and gravel deposits was led to be considered as a responsible factor for existing desertification processes. Silt and gravel deposits occupied valleys as a result of runoff, with a chance of growing some dense vegetation, especially after rainfall a season. The deposits of the study area (Fig.10) were formed over long periods of time. Mountains and outcrops, two main landforms in that area, occupied the majority of land with highly sloped areas. Concerning the aridity condition of the study area, there are many geomorphologic processes that occur periodically such as sliding, soil creep, and runoff processes that contributed to increasing the forms and magnitude of desertification processes.

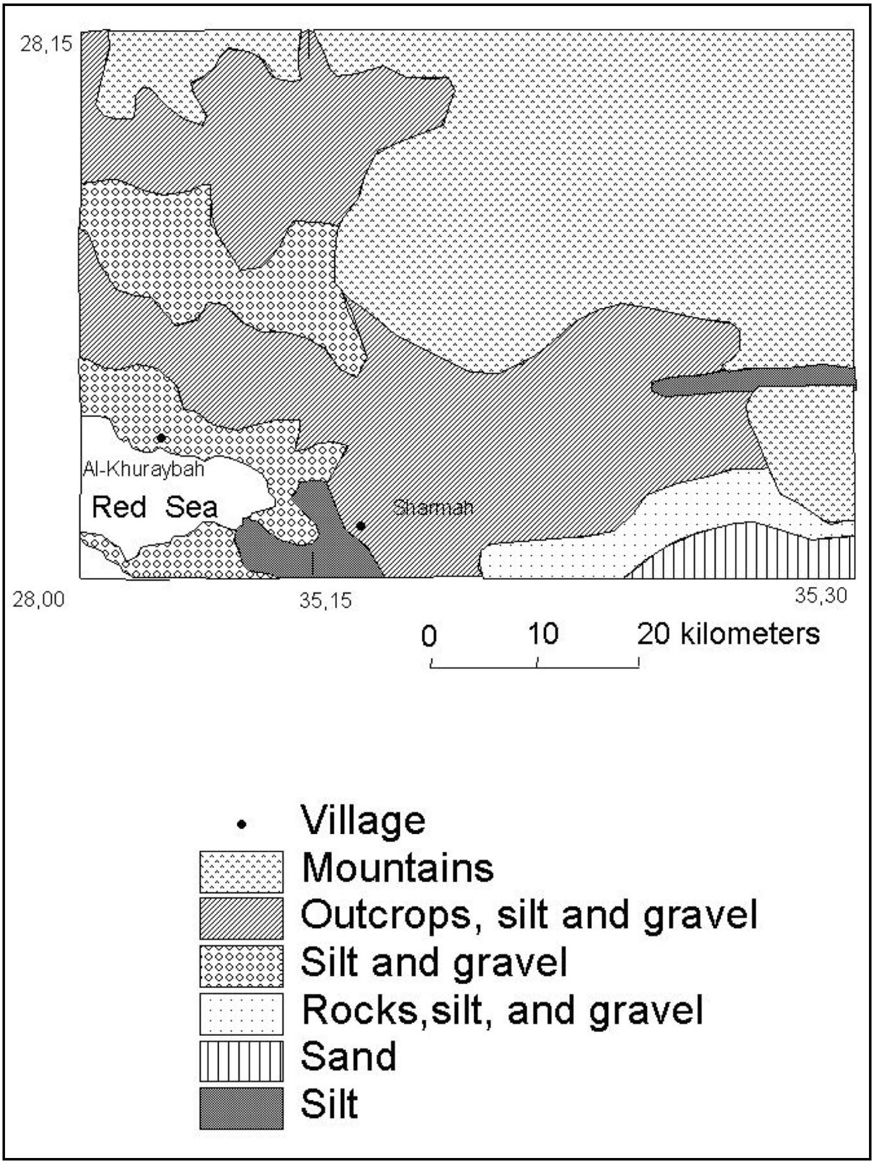


**Figure 10 Deposits in the study area**

**Source:** Saudi Ministry of Agriculture and Water, Saudi Soil Map, 1986

### *Rainfall variability*

The available data of rainfall for the study area shows a wide variation of the annual rainfall. Figure 11 presents annual rainfall values over 15-year time period with relatively high values in 1980, 1984, and 1985, low values in 1987, and 1990 and no rainfall for 1981. The rain record of the study area presents a great fluctuation in the values of rainfall. This finding indicates the area has been experiencing deficiency of rainfall. This deficiency is considered to be one of the main environmental factors, caused decrease in the local grasses, which can be used for temporary grazing activity.


**Figure 11. Annual precipitation in the study area**

**Source:** Al- Bad Meteorological Station, 1977 to (1992)

### *Vegetation sites and human impact*

Vegetation is one of the most important ecosystem components that must be investigated and understood for managing arid landscape (Tueller, 1987). Kassas and Girgis (1970:338) explained *"Plant growth presents local differences, due to the variation of soil moisture, and is mostly confined to drainage systems, which collect and contain runoff water in the arid environments."* The outstanding feature of the vegetation through the study area are Acacia trees (Plate 1) associated with different shrubs that have adopted aridity condition, and grasses as the second type of vegetation.

**Plate 1 Acacia trees in the study area**

As previously explained, fieldwork for the study area was undertaken by the researcher in April 2002 to investigate the presence or absence of vegetation and human impact. Table 1 shows that sixteen sites have presented vegetation and nine sites have no vegetation. Grazing has been considered an important variable, contributing to change vegetation cover completely. It was observed in two Acacia trees sites and the third site was covered by grasses. The fieldwork also shows that seven Acacia trees sites have deteriorated by woodcutting and are classified as harmful plots experiencing soil erosion, leading to severe surface runoff.

The fieldwork shows that the main problem of grazing activity is using goats that completely remove roots of trees during their browsing. On the other hand, the movement of nomads to dense vegetation places can disturb the local ecosystem and increase the rate of soil erosion. They can bring severe desertification to the whole area by misuse of the natural components.

***Table1 Properties of the twenty-five field sites***

| Site | Vegetation | Human impact |
|---|---|---|
| 1 | 1 | - |
| 2 | 0 | - |
| 3 | 1 | grazing |
| 4 | 0 | - |
| 5 | 1 | woodcutting |
| 6 | 1 | - |
| 7 | 1 | woodcutting |
| 8 | 0 | - |
| 9 | 1 | - |
| 10 | 0 | - |
| 11 | 1 | grazing |
| 12 | 1 | woodcutting |
| 13 | 0 | - |
| 14 | 0 | - |
| 15 | 1 | - |
| 16 | 1 | woodcutting |
| 17 | 1 | - |
| 18 | 1 | grazing |
| 19 | 0 | - |
| 20 | 1 | - |
| 21 | 0 | - |
| 22 | 1 | woodcutting |
| 23 | 1 | woodcutting |
| 24 | 0 | - |
| 25 | 1 | woodcutting |

In respect to woodcutting activity, much of the desert shrubs are used for woodcutting, which is impacting the remaining vegetation cover, leading to the desertification of certain vegetation sites (A Comprehensive Report of Vegetation and Human impact in Tabuk area, 2002). Traditionally, it can be considered one of the main environmental problems and the common Bedouin occupation (Plate 2). The researcher noticed people used power saws to cut trees (Plate 3), and pickup trucks were carrying woods that Bedouins collected to sell in Tabuk city, especially during the winter season.

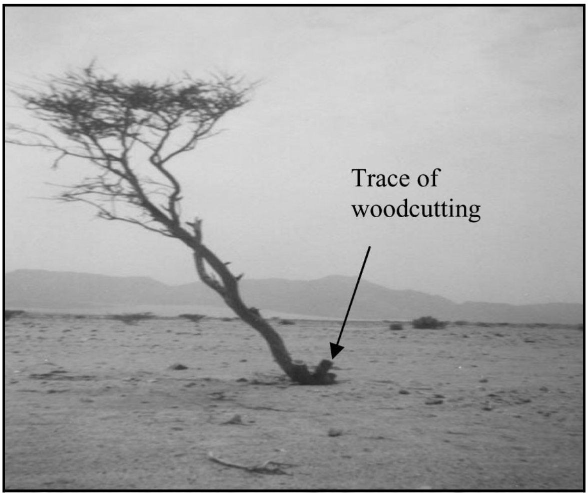


**Plate 2 General view of woodcutting in the study area**

Finally, Tabuk Agriculture and Water department has long recognized the deterioration of vegetation, so several works have been made in this field. These are: (1) plant grass in some deteriorated vegetative sites; and (2) construct dikes for redistributing rainfall.

**Plate 3 Selling firewood in the study area**

## *Conclusions*

Desertification processes were investigated using original information and supported with fieldwork in the Western Tabuk Province, Saudi Arabia.

Remote sensing data were utilized in this research and played a major role in detecting and monitoring desertification processes. Ratio Vegetation Index (RVI) was used to investigate desertification and their indicators and helped to distinguish vegetated areas from non-vegetated areas in the study area.

Geologic information assisted in understanding the major differences in desertification processes. The study of geologic structure and deposits showed the area has been affected by many geomorphologic processes that occur periodically such as sliding, soil creep and runoff, leading to increase the magnitude and forms of desertification processes

Rainfall variability was considered one of the main environmental factors, caused major differences in soil moisture availability and vegetation cover.

Vegetation cover presented local differences, confined to drainage systems and affected by human impact (grazing and woodcutting).

This research has discussed desertification processes in the Western Tabuk Province, Saudi Arabia and came to the following results:

a - False color composite was widely utilized to recognize the main differences in land cover components. Spectral reflectance for dry soil and desert vegetation can be used as indicator of desertification. RVI, the equation of measuring vegetation variation, significantly showed differences between 1988 and 1999 by leading to a classification of three major categories of vegetation change.

b - Geologic differences helped to understand the variation of desertification processes and showing multiple types of deposits.

c - Rainfall has varied from one year to another. This was considered a responsible factor for differences in grass growth, controlling the distribution of vegetation.

d - Human impacts (grazing and woodcutting) have affected the study area by two factors. Grazing activity, which is observed in three sites, caused decreasing of vegetation cover. Woodcutting, a common occupation, has had two effects: decreasing Acacia trees and increasing soil erosion.

e - Many areas in the study province are characterized by no vegetation, and might be expanded in the next few years due to the continuing rainfall deficiency and misuse of vegetation cover. Therefore, the area needs a well-managed and a practical approach that will successfully protect the environment from desertification.

***Recommendations***

Some recommendations should be adopted theoretically and applied empirically. They are:

a - Establish multiple meteorological stations over the entire study area to provide more detailed climatic data.

b - Monitor environmental change monthly using remote sensing techniques and supported with intensive fieldwork.

c - Establish a governmental environmental center, which can be coordinated with multiple governmental sectors to conduct serious research in the Tabuk Province (Al-Harbi, 2001).

d - Prohibit woodcutting, the major human impact, which deteriorates woody plant cover and accelerates desertification indicators such as water erosion.

e - Create a geographic database using remote sensing and geographic information systems (GIS). The database should consider all environmental processes, which affect the biosystem of the entire Tabuk Porvince. This database would be the main source of information to analyze several problems relating to the variations of vegetation, soil, and climate there.

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