WADI AR RUMAH THE EARTH LONGEST DRY WATERSHED ANALYSIS SYSTEM USING REMOTE SENSING THERMAL DATA

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Abstract

Wadi Ar Rumah watershed system analysis combining both the information in the Advanced Very High Resolution Radiometer (AVHRR) visible/near-infrared bands in terms of Normalized Difference Vegetation Index (NDVI) and in the thermal-infrared bands in terms of Land Surface Temperature (LST) is presented. The analysis is based in the LST-NDVI feature space. This permits characterizing the distribution and evolution of the different regions according to their vegetation and watershed systems. The Pathfinder AVHRR Land (PAL) data analysis has been carried out to investigate the changes in the biophysical characteristics of land cover and the water system pattern. The PAL data corresponds to the month of February for the years of 1997, 1998 and 1999. The Arabian Peninsula in general was selected as the area of study due to its high environmental diversity. Wadi Ar Rumah was especially selected because it was flooded by heavy precipitation during end of 1997 to beginning of 1998. Precipitation saturated the ground surface soil and kept the wet condition for a time. This work proved the wadi AR RUMAH as the earth longest watershed drainage system in our plant.

Keywords: Watershed system, desert vegetation, AVHRR, NDVI, LST.

1. Introduction

water, Solar radiation, and vegetation govern natural environment in the Arabian Peninsula. This research examines whether space observations are useful on the site to study the phenomena of the region.

They have been numerous investigations in the field of cartography and analysis on land-cover changes considering only the temporal analysis of Normalized Difference Vegetation Index (NDVI) [1][2][3][4]. However, few papers introduced the Land Surface Temperature (LST) parameter obtained from satellite data to study the land cover changes [5][6][7]. One of the motives is the difficulty of obtaining this parameter. Nevertheless, at present it is possible to determine LST within a precision of 1 K. Land cover classification and change detection using temporal series of LST and NDVI requires a good knowledge of the relationships between these biophysical parameters in different ecological conditions [8][9][10][11]. In this paper we present an analysis of the Wadi Ar Rumah watershed system based in the LST-NDVI feature space.

Studying the watershed of the Wadi Ar Rumah is important for several reasons, first to understand the real condition of the land surface temperature and desert vegetation, second the importance of observing the unknown watershed connected system which is passing through an active agriculture and populated area for the benefit of the desert agriculture and settlement landscape. Finally, the historical figure of the region as a trade and pilgrimage route in the Arabian Peninsula.

2. Algorithms

Land Surface Temperature (LST) retrieval from satellite data is mainly influenced by the atmosphere and surface emissivity. If both effects are not corrected for the error in LST may be very large (up to 12 K). In order to obtain accurate estimations of LST, we have applied the following split-window algorithm [7][14] with an error of estimation of 1.3 K.

$$LST = T_4 + 1.4\,(T_4 - T_5) + 0.32\,(T_4 - T_5)^2 + 0.83 + (57 - 5W)\,(1 - e) - (161 - 30W)\,De \quad (1)$$

where T_4 and T_5 are the brightness temperatures measured in Advanced Very High Resolution Radiometer (AVHRR) Channels 4 and 5 respectively, e is the average effective emissivity in both channels, De is the spectral variation of emissivity and W is the total amount of atmospheric water vapor (g cm^{-2}) obtained applying the Split-Window Covariance-Variance Ratio (SWCVR) method [12][14]

$$W = 0.26 - 14.253\,(\cos q\ \ln R_{54}) - 11.649\,(\cos q\ \ln R_{54})^2 \quad (2)$$

where q is the satellite observation angle and R_{54} is the ratio of the spatial covariance and the variance of image brightness temperatures in the split-window Channels 4 and 5. The estimated error is 0.5 g cm^{-2}. To obtain e we have applied the NDVI Threshold Method ($NDVI^{THM}$) [7][14]. This method integrates a wide spectral data set of bare soil reflectivity measurements in the band of 0.4-14 mm and uses different approaches in function of NDVI.

3. Study Area

The study area is the Arabian Peninsula, located between 12º N and 32º N latitude and between 20º E and 35º E longitude (see Fig. 1). This particular geographical position gives the area a great bioclimatic diversity. The desert of Arabian Peninsula is located as a part of the hot desert which extends from the Sahara in Africa in the west to the Thar desert in Indo-Pakistan sub-continent in the east. The overall climate falls within desert and arid climates, except the Asir province where the temperature is lower and the rainfall is greater than that of the remaining part of the peninsula. The area is also subjected to a significant problem with regard to desertification.

The focus will be on the Wadi Ar Rumah watershed region, the main dry river in the peninsula. The midstream part of the wadi comes through Al Qassim oasis located at the center of the peninsula desert.

Figure 1. The Arabian Peninsula study area (Atlas of Saudi Arabia and World, 1996)

3.1. Physical geography

Five geographic regions can be divided. They are: (i) the Western Highlands, (ii) the Central Plateau, (iii) the Northern Deserts, (vi) the Rub al Khali desert, and (v) the Eastern Lowlands. The Central Plateau Geographic region, the mountains of Hejaz and Asir slope eastward toward the Central Plateau, also called Najd. Little vegetation can be found in most of this region (see Fig. 2). In parts of the rocky plateau, fertile oases support large farm communities; Al Qassim is one of these Oasis. Season in the peninsula based on rain, so nomadic herders bring their animals to feed on patches of grass that grow in the region for a short time after occasional rainfall. The peninsula terrain is varied but on the whole fairly barren and harsh, with salt flats, gravel plains, and sand dunes but few lakes or permanent streams. In the south is the Rub Al-Khali (Empty Quarter), the largest sand desert in the world. In the southwest, the mountain ranges of Asir Province rise to over 9,000 feet.

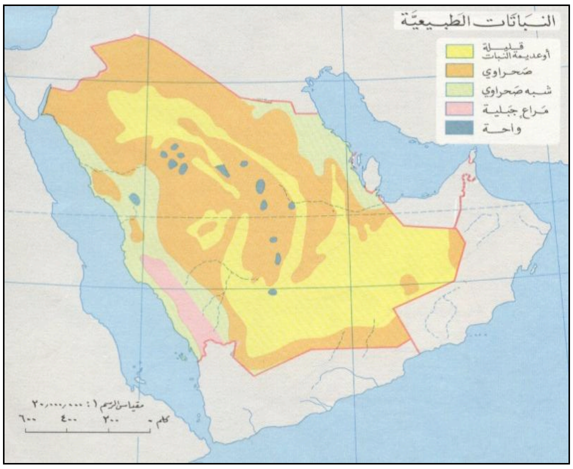


Figure 2. The Arabian Peninsula natural vegetation (Atlas of Saudi Arabia and World, 1996)

3.2. Wadi Ar Rumah

Wadi Ar Rumah is the biggest and longest dry river in the Arabian Peninsula about 2000 km long. The main part of the wadi come through Al Qassim oasis which is one of the main agricultural region, Sultan (1997). According to the physical geography and watershed system, the wadi can be divided into four integrated areas: (A) Upstream (Arabian shield), (B) Midstream (Al Qassim), (C) Anafud desert, and (D) Downstream (Al Batin and the delta in Shut Al Arab) (see Fig. 3).

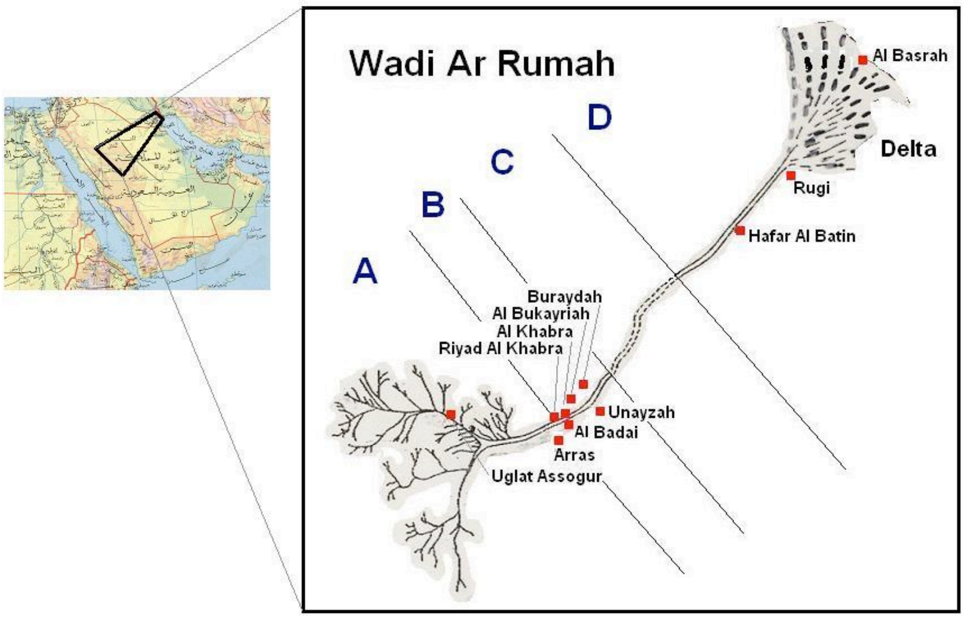


Figure 3. Wadi Ar Rumah watershed areas (A,B,C,D)

3.4. Precipitation

There is no precipitation during the months from June to September. The months from January to March are of highest precipitation (see Fig. 4). The mean annual precipitation of the past ten years is 110 mm. which is very low and it is characterized by an irregular distribution both in quantity and frequency.

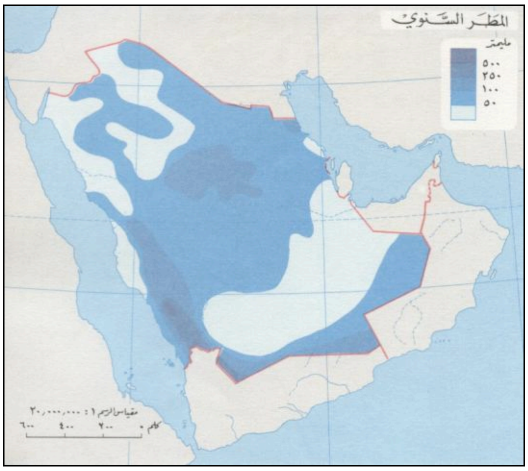


Figure 4. The Arabian Peninsula annual precipitation (Atlas of Saudi Arabia and World, 1996)

4. Analysis and Results

The Pathfinder AVHRR Land (PAL) has been used for the study of the Arabian Peninsula. NOAA and NASA are the sponsors of the PAL project responsible of producing a set of global data calibrated and processed regularly for the investigation on climatic change. The AVHRR data used are the Global Area Coverage GAC [13] with a resolution at nadir view of 4 Km. In this paper we have used the images corresponding to the composite period from 21 to 30 of February 1997, 1998 and 1999.

Figure 5 shows the NDVI corresponding to the month of February for the years of 1997, 1998 and 1999. A clear increasing in the NDVI is observed for the wet year of 1998 corresponding to the Wadi Ar Rumah zone. However, low values of NDVI correspond to the dry years of 1997 and 1999.

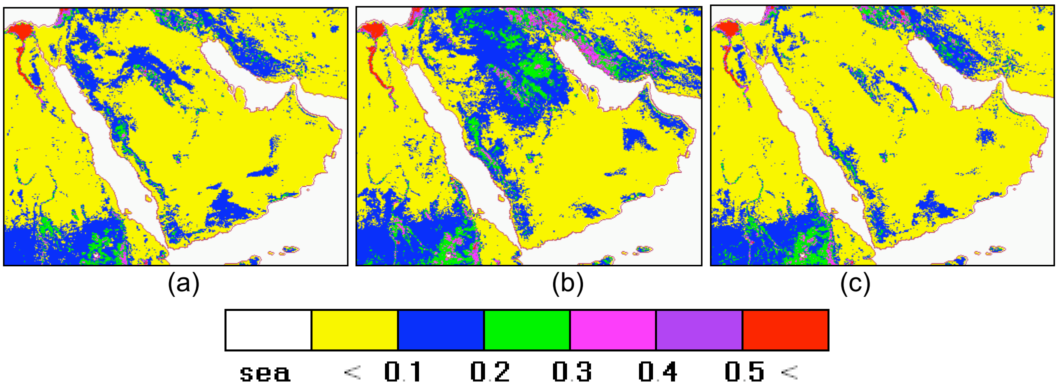
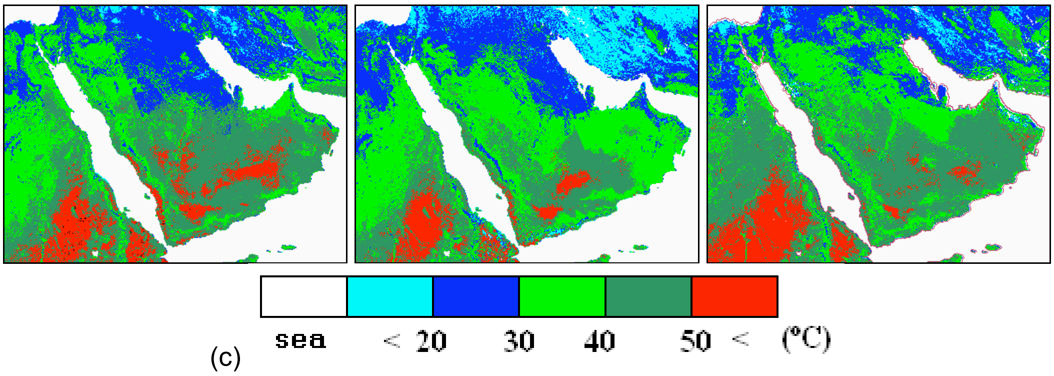


Figure 5. NDVI corresponding to (a) 1997, (b) 1998, (c) 1999.

Figure 6 shows the LST corresponding to the month of February for the years of 1997, 1998 and 1999. A surface temperature increasing gradient of about 20 ºC is clearly shown from north to south of the peninsula. In what concern Wadi Ar Rumah zone, a decreasing gradient of about 10 ºC is also shown from the upstream area (A) to the down stream area (D).



(c)

Figure 6. LST corresponding to (a) 1997, (b) 1998, (c) 1999.

To carry out a more comprehensive and detailed statistical analysis along Wadi Ar Rumah, several regions among the four areas (A,B,C,D) has been chosen (see Fig. 7). Each region is 2x2 pixels distributed in a homogenous way along the wadi landform.

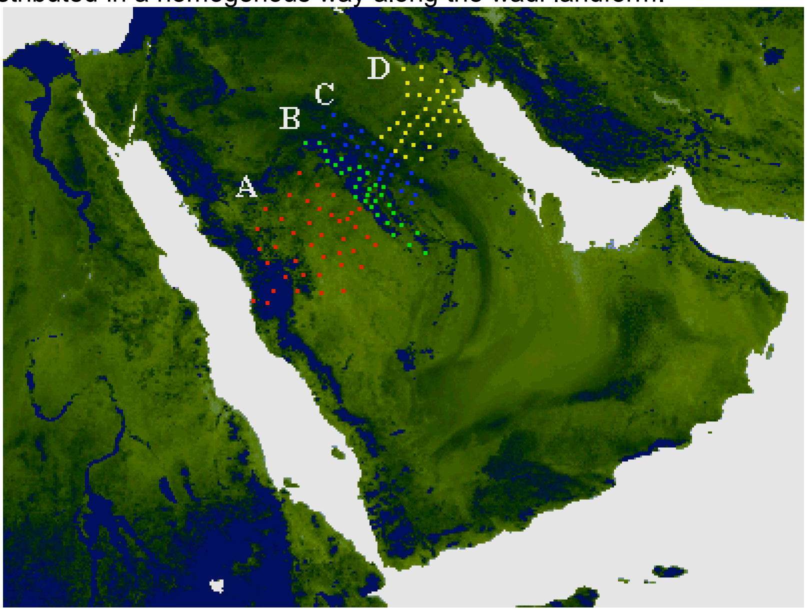


Figure 7. Selected areas (A,B,C,D) and corresponding study regions along Wadi Ar Rumah.

Figure 8 and Figure 9 present respectively the results of the analysis corresponding to the annual comparison of NDVI and LST for each area and the comparison among areas for each year.

Starting with the analysis of Figure 8:

Area A: The dry years 1997 and 1999 present an NDVI in general lower than 0.1 with LST values between 25ºC and 45ºC. For the wet year 1998 the NDVI increased up to 0.25 with LST values around 35ºC and 40ºC.

Area B: A correlation between LST and NDVI is shown for the three years, because of the vegetation nature of the area. More the NDVI increases the LST decreases. Also for the wet year 1999 the area present the highest values of NDVI from 0.15 to 0.5 with LST respectively from 40ºC to 25ºC.

Area C: The NDVI is lower in this area with values around 0.1 for dry years 1997 and 1999. For the wet year a relative increasing in NDVI is shown with values from 0.1 to 0.25. The LST is varying from 25ºC to 40ºC.

Area D: A similar behavior is shown for dry years 1997 and 1999, with NDVI values between 0.01 and 0.1 and LST values between 25ºC to 30ºC for 1997 and from 27ºC to 35ºC for 1999. For the wet year 1998, the NDVI increases and present a values from 0.1 up to 0.3 with a LST around the 25ºC.

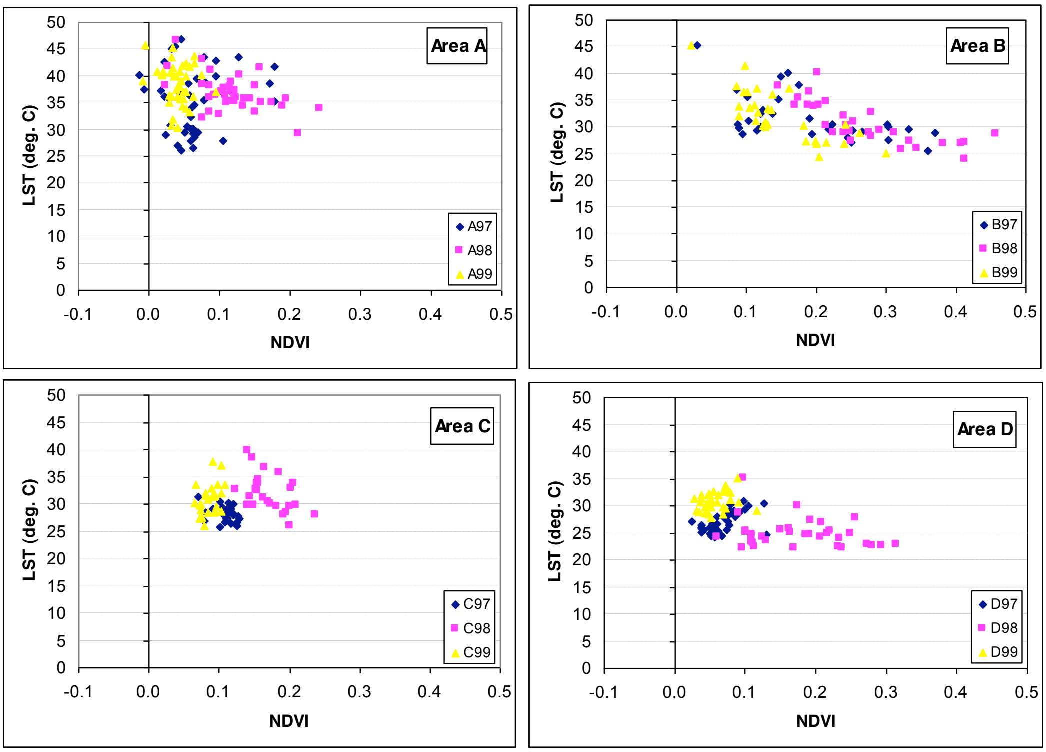


Figure **8**. Comparison of LST vs NDVI for each area during years 97, 98 and 99.

For the comparison analysis among areas for each one of the three years in Figure 9 it is observed that:

For the dry years 1997 and 1998, the behavior is similar:

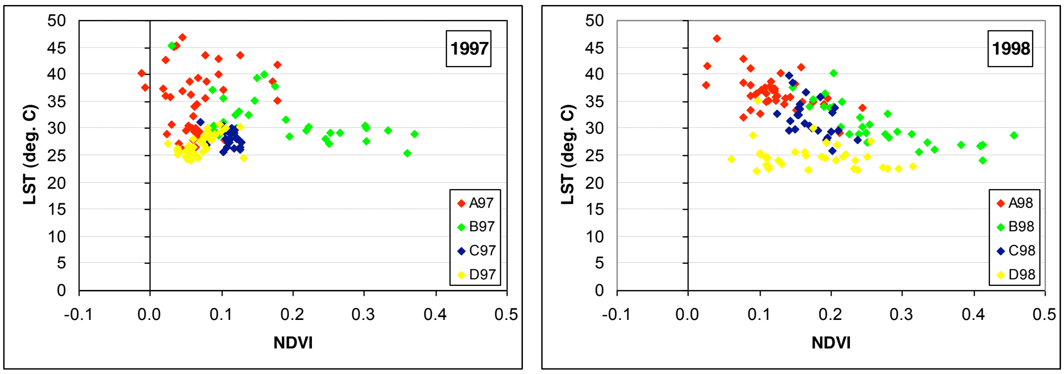
i) area A, presents values of NDVI lower than 0.1 and LST from 30ºC to 45ºC,

ii) area B, presents a clear decreasing tendency between NDVI and LST with maximum NDVI of about 0.35 and minimum LST of 25ºC and minimum NDVI of about 0.1 and maximum LST of about 45ºC,

iii) area C, presents NDVI values around 0.1 for both years and LST values from 25ºC to 30ºC for 1997 and from 25ºC to 40ºC for 1999.

iv) area D, presents NDVI values lower than 0.1 with LST values from 25ºC to 30ºC for 1997 and from 27ºC to 35ºC for 1999.

For the wet year 1999, a decreasing tendency between NDVI and LST is shown for areas A, B and C. Higher LST values correspond to lower NDVI values and vice versa. For area D, the NDVI values increase reaching values of 0.3 with a low and stable LST values of about 25ºC.



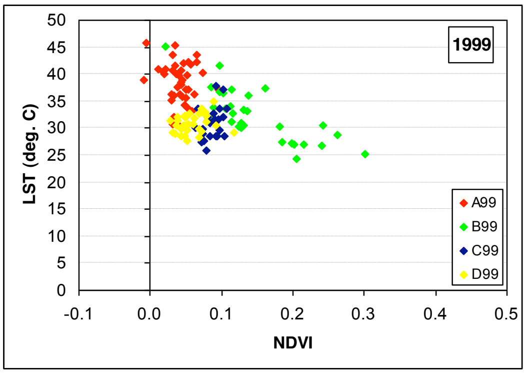


Figure 9. Comparison of LST vs NDVI among areas (A,B,C,D) during years 97, 98 and 99.

5. CONCLUSIONS

This work proved the wadi drainage system from up-stream in Hijaz Mountain in the west to Shut El Ar Rab river and Al Basrah city in northeast as the longest dry revir in our plant. A study on watershed system analysis for Wadi Ar Rumah in the Arabian Peninsula has been carried out. The analysis is based on the combination of NDVI and LST. This permits characterizing the behavior for each one of the integrated areas along the wadi watershed network. For wet conditions, a relationship between NDVI and LST is clearly shown along the wadi watershed boundary. Independently of the dry or wet conditions, area B that corresponds to Al Qassim zone presents always this tendency due to the seasonal vegetation agriculture. The thermal factor in terms of land surface temperature and its relationship with the natural and planted vegetation is a practical tool to understand the phenomenon of the drainage system, physical features and desert vegetation.

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