Using Remote Sensing Technique (NDVI) for Monitoring Vegetation Degradation in Semi-Arid Lands and its Relationship to Precipitation: Case Study from Libya

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Abstract

Most of Arabic countries are located within the arid and semi-arid zones, which are characterised by the scarcity and the high spatial and temporary variability of rainfall .The influence of rainfall patterns on natural vegetation cover is significant and can be monitored and assessed using NDVI indices derived from remote sensing data. The literature stresses on the wide use of NDVI to study the changes in vegetation cover, because of the sensitivity of vegetation to the Red and Infra-red spectrum.
In this paper the SPOT Apparent Green Cover Percentage data and MODIS Vegetation index are used to monitor the vegetation cover change in North western Libya.

The aim of this study is to establish the spatial and temporal changes in vegetation cover and their relation to the rainfall pattern.
The data and method:

The utilized data for research included multi-temporal remotely sensed data (Spot, MODIS, and Landsat ETM), climatic data (ground stations and satellite data) and digital maps (DEM, slope, flow direction and basins).

The satellite images were firstly pre-processed. This included the importing of different format images into a standard format of the ERDAS IMAGINE 9.1. Then the dataset were geometrically corrected into the WGS84 latitude/longitude geographic co-ordinate system. The study area was then subseted using a vector file representing the area boundary (AOI). The multi-bands were stacked to create time series, the NDVI equation was used to convert the DN values into NDVI values.

Introduction

Understanding the complex relationships between climate and vegetation dynamics is a major component of earth system science research. The power and utility of remote sensing and GIS have, in the past twenty years, gained widespread recognition in many fields, due to the advantages of their application. Ball & Babbage (1989) note the datasets for natural resource monitoring, such as vegetation, can be obtained by remote sensing. Remote sensing and GIS together form a powerful information acquisition and analysis tool for monitoring environmental changes (Albert *et al*. 2006). Remote sensing data enable collection of information about land cover and land use. Modelling studies can now select from several different remotely sensed land use/cover products that provide land surface parameter information.

Satellite remote sensing and GIS technology are now widely used for environmental monitoring and mapping the distributions of land surface biophysical parameters that have an important effect on climate (Henderson and Sellers, 1990). During the past 20 years, the Normalized Difference Vegetation Index (NDVI) has been widely used for vegetation mapping and monitoring land-cover change in semi-arid regions. This is because these satellite-derived datasets provide spatially continuous data (not sampled at individual points) and yield time series signatures from which temporal patterns, changes and relationships may be extracted (Nicholson, et al, 1994).

Most of Libya is desert, but semi-arid lands occupy many parts in the north, near the Mediterranean Sea, where rainfall is sufficient to support growth of vegetation but insufficient to produce reliable cultivated crops. Because primary production is determined through rainfall, which is often erratic and variable, the effect on natural vegetation and agricultural production is also highly variable from year to year. Remote sensing of vegetation cover is needed to understand the relationship between climate variability and Vegetation degradation. This research paper focuses on this relationship.

The overall aim of this research paper is to use remote sensing technique (NDVI) for monitoring vegetation degradation in semi-arid lands and to identify the relationship between climate and NDVI especially rainfall: case study Tarhuna Region in Libya, also to see how can be delineated by integration of satellite, meteorological and other ancillary data.

Abbreviations:

NOAA: National Oceanic and Atmospheric Agency, NDVI: Normalized Difference Vegetation Index, AVHRR: Advanced Very High Resolution Radiometer and MODIS: Moderate Resolution Imaging Spectrometer

Using remote sensing and GIS for vegetation studies

NDVI data derived from the Advanced Very High Resolution Radiometer (AVHRR) on board the National Oceanic and Atmospheric Administration (NOAA) series of satellites have been widely adopted for vegetation studies. These data have been demonstrated to be highly correlated with green biomass. According to Box and Kalb (1989) NDVI is a measure of vegetation vigor, which provides an effective measure of photosynthetically active biomass, and it is calculated as follows:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where NIR and R are the spectral reflectance values in the near infra red and visible red band passes respectively. The data are normalised by equation 2.1

to be within the range -1 to +1, to facilitate comparison between images collected under different illumination conditions.

The spectral reflectance of green vegetation is strongly wavelength dependant. Recent developments in hyperspectral remote sensing (imaging spectrometry) enable much higher spectral resolution studies using the visible, NIR and shortwave infrared part of the electromagnetic spectrum. In the visible range of the electromagnetic spectrum, chlorophyll absorbs mostly blue and red radiation (0.45-0.65 micrometers), known as Photosynthetically Active Radiation (PAR).This uptake is important in the process of photosynthesis and necessary for plant growth. However, when conditions are not favourable for the growth of vegetation or when the plant is producing reduced chlorophyll, then there is less absorption in the visible part of the spectrum. Therefore, the plant leaves appear yellow or red., as we see in Autumn as senescence occurs. Decrease in chlorophyll production results in higher reflectance in the blue and red bands.

In the near infrared (0.8 to 1.1 microns), the plant absorbs less than 50% of incident infrared radiation. Instead, radiation at these wavelengths is strongly scattered in the spongy mesophyll layer (the part of the leaf, which provides structural support). The total amount of reflection in this part of the spectrum is about 85%. In the shortwave-infrared part of the spectrum, foliar moisture absorption bands at 1.4 and 1.9 microns limit reflection in these wavelengths. (Thomas *et al*, 2004). However, these features are of little use in remote sensing, as the atmosphere is nearly opaque at these wavelengths, due to the presence of water vapour.

NDVI-rainfall relationship

Climate is the most important element for the growth of vegetation because it exerts a major control on the environment at the Earth's surface (Sager and Ibrahim 2005). Land degradation is a widespread problem in many parts of Africa (World Bank Group, 2004). In semi arid lands, where livestock farming is prevalent, degradation from overgrazing often results in decreased vegetation cover (Pickup and Chewings, 1994), or changes in vegetation community composition and reduced rain-use efficiency (Diouf and Lambin, 2001; Li *et al*., 2004).

Some scientists have attempted a more sophisticated analysis of the relationship between NDVI and climate, using concepts such as growing degree-days, in arid and semi arid areas where rainfall is the limiting factor for vegetation growth (Nicholson, *et al*, 1994; Schmidt and Karnieli, 2002). These studies result in large uncertainties due to the lack of detailed ground information and absence of significant variation in the environmental conditions in these areas.

Rain fed pastoral lands in semi-arid environments are characterised by sparse vegetation cover. One of the most distinct features of this environment that affects plant growth is the seasonal (intra-annual) and year-to-year (inter-annual) variation of rainfall. In semi-arid areas with a single rainy season, there is usually a short growing period followed by a long-lasting dry period (Zhou *et a*l., 2005).

The above studies indicate that vegetation mapping is becoming increasingly important for monitoring changes and identifying areas affected by land degradation (Taylor, 2003,; Li *et al.,* 2004).

Study area

The Tarhuna Region is located in the northwest of Libya. It lies between 13, 15′ E to 14°, 15′ E and between 32°, 1′ N to 32° 38′ N and covers a total area of 3820 sq km (Ministry of Planning,1979) (Figure 1).

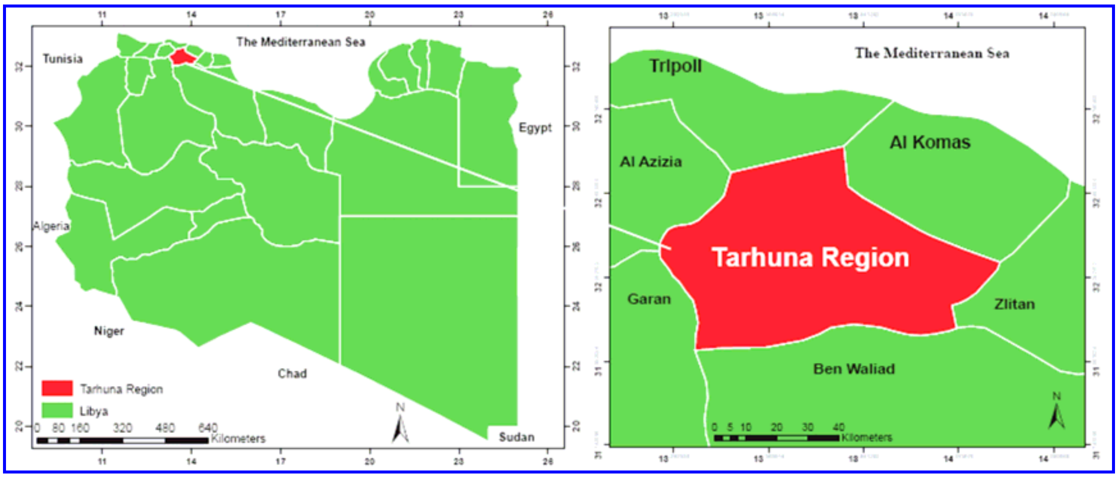


Figure 1: Location of the Tarhuna Region
Source: prepared by the researcher from Libyan Natural Atlas.

In Summer, the mean annual maximum temperature in Tarhuna reaches 35°C to 40°C in August but sometimes the temperature rises to 50°C. In Winter, the temperature ranges between 4°C to 17°C but it rarely drops to 0°C. Daylight occurs for seven hours a day in Winter and eleven hours a day in Summer. Consequently, the ground surface receives insolation of an estimated average of 310313 watts per sq metre. (Libyan Meteorological Department, 2005).

Rainfall usually occurs in Winter (December to February), with some in Autumn and Spring (September to November and March to May) but the Summers (June to August) are always very dry. As is common in dry land regions, rainfall is not only low, but also highly variable and unpredictable over time and space. In summary, the climate of the study area is classified as semi-arid with mild, cold Winters and hot, dry Summers.

Data and Methodology

PAL NDVI Images

The Pathfinder AVHRR Land (PAL) archive provides global NDVI data in 8km by 8km cells at 10-day intervals. NDVI derived from AVHRR images are useful for analysing spatial vegetation patterns and for assessing vegetation dynamics (Prince 1991). PAL data covering the twenty-five years from July1981 to December 2006. 918 PAL images (25.5 x 36 dekadal images per year) have been used to construct a vegetation time series for the area.

The Pathfinder data were used for time series analysis of vegetation dynamics due to its long-term periodicity, global coverage and availability.

SPOT Apparent Green Cover Percentage data

SPOT Apparent Green Cover Percentage data, are created from VEGETATION data .This was specifically designed for desert locust monitoring, but it can also be used for topics like food security, desertification, etc. The product can also be used for year-to-year comparison of vegetation status in arid and semi-arid North Africa. The product is based on an empirical transformation of the NDVI into apparent fractional cover at 1km^2 resolution. Again, a 10-day maximum compositing approach is used to reduce cloud contamination and other variation (water vapour, etc). Dekadal data covering the period January 2002 (when the product became available) to December 2006, (216 images) were used .

MODIS Vegetation index

The moderate resolution imaging spectrometers (MODIS) a component of the TERRA and AQUA Mission payloads provide a global and improved source of information for the study of land surfaces with a spatial resolution of up to 250 x 250. The MODIS Vegetation Index data from the TERRA Mission (MOD13, L3 V005 format); these data are 16-Day composites resampled to a 500m grid. Data for the period January 2001 (when the database started) to December 2006.

Landsat Image

Two Landsat 7 Enhanced Thematic Mapper (ETM+) images (188/37 and 188/38) covering the area; they were used to create a land cover map of the study area.

Images processing

Many intermediate steps were used for processing the satellite data; the images were processed in the following manner to produce the vegetation estimates:

1- Importing into ENVI 4.4 and ERDAS IMAGINE 9.1.
2- Geometric correction
   All the images of the study area (PAL, SPOT, MODIS and Landsat) have been referenced as latitude/longitude geographic co-ordinates and Datum: WGS84.
3- Subset of the study area is estimated.
4- Layer stacking to create time series.
5- Converted DN to NDVI values.

All the image pixels digital numbers (DN) were converted to ASCII then they exported into Excel and Gen Stat to obtain actual values of NDVI using statistical equations for comparison with other climate data.

Climate data

Data for northwest Libya were obtained by personal collection from individual Libyan meteorological stations. In total, monthly rainfall data were obtained for 100 stations in the North West of Libya. The record obtained for other climate measurements was less complete.

Statistical analysis

To obtain, the patterns of NDVI summary statistics was computed by using the following expressions:

1. Average NDVI (M) = (B1 + B2 +B3)/ 3 (Jan)
2. Average NDVI (S) = (B12+B1+B2)/3 (winter)
3. Agricultural year of NDVI = (B25+B26 + ---------+B24)

Mean NDVI was computed by using the following expressions:

1. Mean NDVI PAL = (Average NDVIy1+ Average NDVIy2+…...+ Average NDVIy25)/ 25
2. Mean NDVI Spot = (Average NDVIy1+ Average NDVIy2+…...+ Average NDVIy5)/ 5.
3. Mean NDVI MODIS = (Average NDVIy1+ Average NDVIy2+…...+ Average NDVIy6)/ 6.

The vegetation index data were compiled to cover growing seasons, and the agricultural years were identified, beginning with the vegetation index minima in each year. This was done because studies of primary productivity are usually based on the agricultural, or growing-season year, rather than the calendar year.

In order to determine the appropriate lag to account for the response time of vegetation to rainfall, Pearson's correlation coefficients were computed for zero, 1, 2 and 3 month Lags was used.
Sharf's aridity index used to identify the aridity index in the study area, which is given by:

$$A = [P/ (T+9)]$$

where, P = mean annual precipitation (mm), t = mean annual temperature (°C) was applied to classify the climatic regions in Tarhuna area, as well as to elaborate the trends of aridity index in the area, (Ibrahim, 2005). The trend is the basic tool for describing and analysing the changes of climate parameters (Shada, 1997)

Therefore, a simple linear regression (Equation $Y = a + \beta^* x + \varepsilon$) was used to detect climatic trends over time series. Also a simple linear model and multiple linear regression models (Equation $Y = a + \beta 1^* x + \varepsilon + \beta 2^* x + \varepsilon$) were used to model the relationship between vegetation patterns and climate factors (Shada, 1997, pp-370-411).

TINDVI was computed by using the following Equation:

$$\int_a^b f(x)\,dx$$

where the indefinite integral of f(x) with respect to x Thus, f(x) dx is a collection of functions. The function f that is being integrated is called the integrand, and the variable x is called the variable of integration. F is continuous on the closed interval [a, b].

This integrated equation was used to find the area between a graph curve and the 'x' axis, between two given 'x' values. This area is called the 'area under the curve.

Spatial Analysis

Geostatistics techniques were applied to estimate values at locations where data were not available, using Arc GIS 9.1 geostatistical tools. Ordinary Kriging was used to produce monthly maps of rainfall, temperature and evapotranspiration.

Results

Annual temporal variation of rainfall

Figure 2 shows a general decline in the mean annual rainfall in the study area especially in recent years. It was found that 25 years (54.3%) had less than the mean annual rainfall and 13 years (28.3 %) had more than the mean annual long term rainfall while 8 years (17.4 %) had rainfall equal to mean annual long term rainfall; In addition, there was a high variation of rainfall over the study period. The mean standard deviation of all the study period was 91mm. Moreover, the coefficient of variation (CV 36%) of data, the slope estimates also are negative (-1.57).They may support statistically this view.

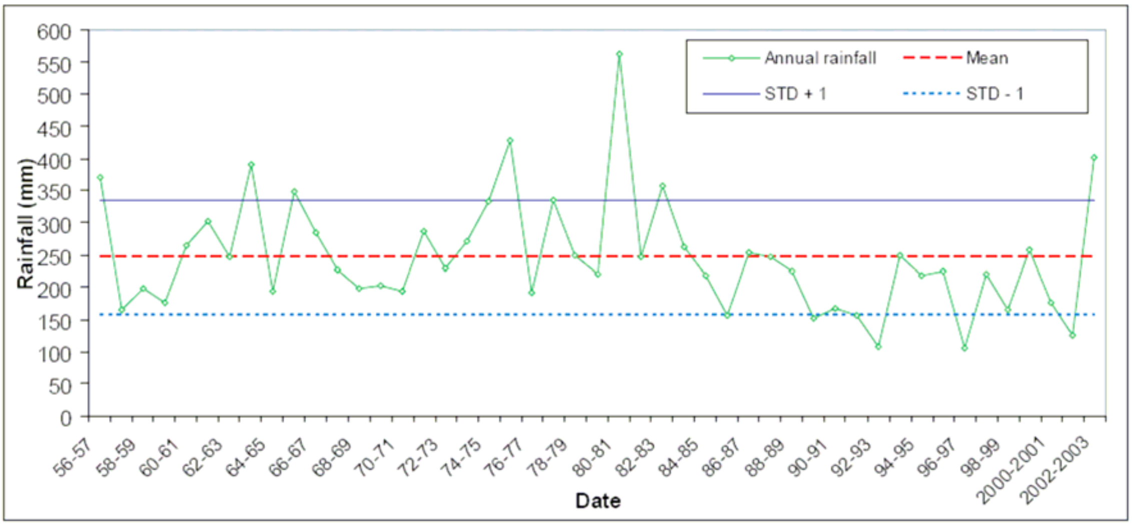


Figure 2: Variation of the annual rainfall at Tarhuna region (1956-2003)
Source: prepared by the researcher

Monthly temporal variation of rainfall

The warmest period of the year can occur in June to August (summer with on precipitation), whereas, autumn occurs from September to November and then winter is prevailing from December to February. It has followed by spring (March to May). This climate is continental with very hot summer. Following the variation of humid and arid months it may be considered as a major climatic characteristic, hence climatic diagrams developed by Bagnols & Gaussen (UNESCO, 1977)) method make an easy definition of arid and humid months; diagram is based on the following equation :

P / T □□2N

where P = mean monthly precipitation (mm) T = mean monthly temperature (°C)

Diagram of humid and arid months in at the Tarhuna region (Figure 3) shows the variation of the mean temperature and mean Precipitation during 1956 to 2003. It has presented the dry and wet periods when the precipitation falls under the temperature curve and vice versa respectively.

The figure shows that the period spanning from May to October is usually dry, while November through March were more frequently wetter.

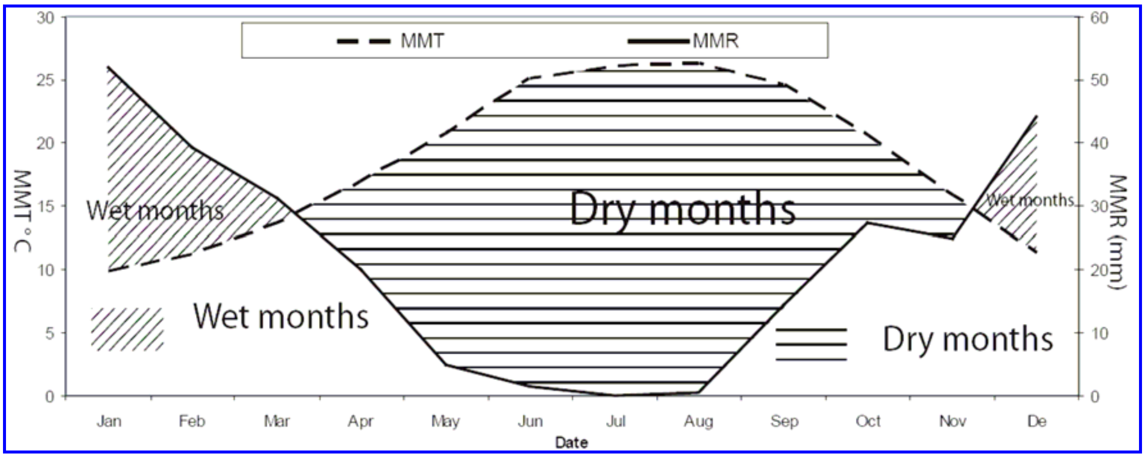


Figure 3: Number of humid and arid months in at the Tarhuna region
Source: prepared by the researcher

General trend of rainfall

The annual precipitation total has changed during the last 47 years. The statistical analysis of reliable instrumental data was demonstrating marked changes of precipitation at the area over the period 1956-2003 (Figures 4).

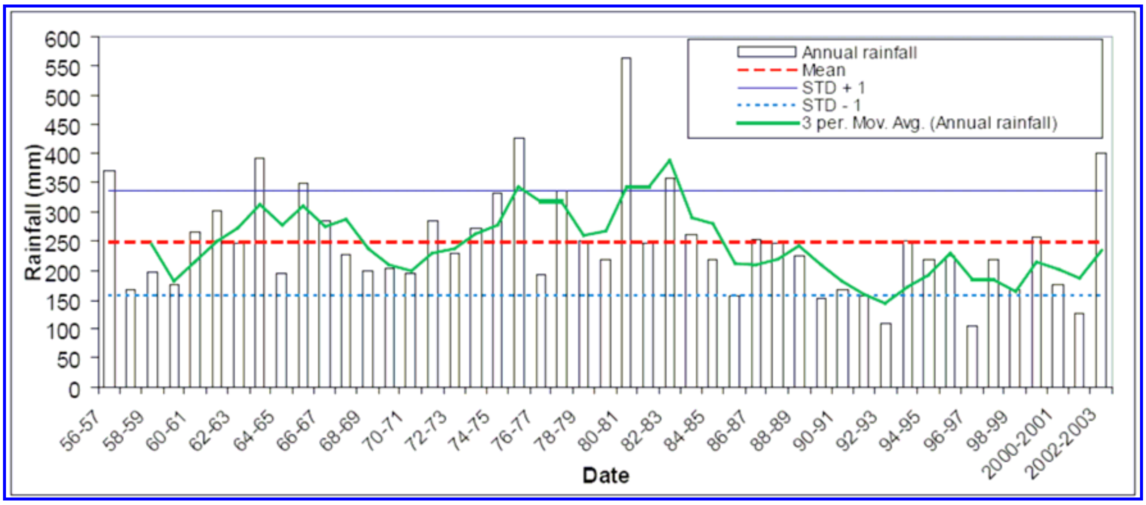


Figure 4: Annual mean of the rainfall, three-year moving mean of the rainfall and STD (- +1) at Tarhuna region.
Source: prepared by the researcher

The trends of annual precipitation total over all- Tarhuna regio were negative because, the trend of rainfall in the Tarhuna region has tended to decline in recent years.

This does not mean that rainfall in the study area exhibits a steady, monotonic decline, rather the precipitation varies year on year in an unpredictable fashion. However, over the past 47 years there has been a slight decrease in annual precipitation. Using the mean value of rainfall only may be a misleading descriptive measure of rainfall in Tarhuna Region. The Standard deviation (+1 & -1) has also been computed for the deviations of above and below-average annual rainfalls plotted in Tarhuna region.

It is clear from the data by calculating the 3-year moving averages of rainfall that the area experienced irregular cycles of dry periods and wet periods.

Overall, according to the Figure 4 it can also be noticed that trend of precipitation total was negative especially at recent years.

Aridity

Tarhuna region was classified into climatic regions according to the De Martonne climate classification based on the duration of the aridity period over the year, which modified by Sharf (1985) .The aridity index is defined by:

A = [P/ (T+9)] .where P is annual precipitation total (mm), T is mean annual temperature (°C).

According to the Sharf aridity index climate can be identified by the following types as desert (0-5), Steppe (5-10), Sub-humid (10-20), Humid (20-30) and Very humid (>30). Based on precipitation and temperature data (1956-2003), arid index was computed at Tarhuna region as illustrated in (Figure 5), which shows that Tarhuna region is mostly occupied under Steppe climate type.

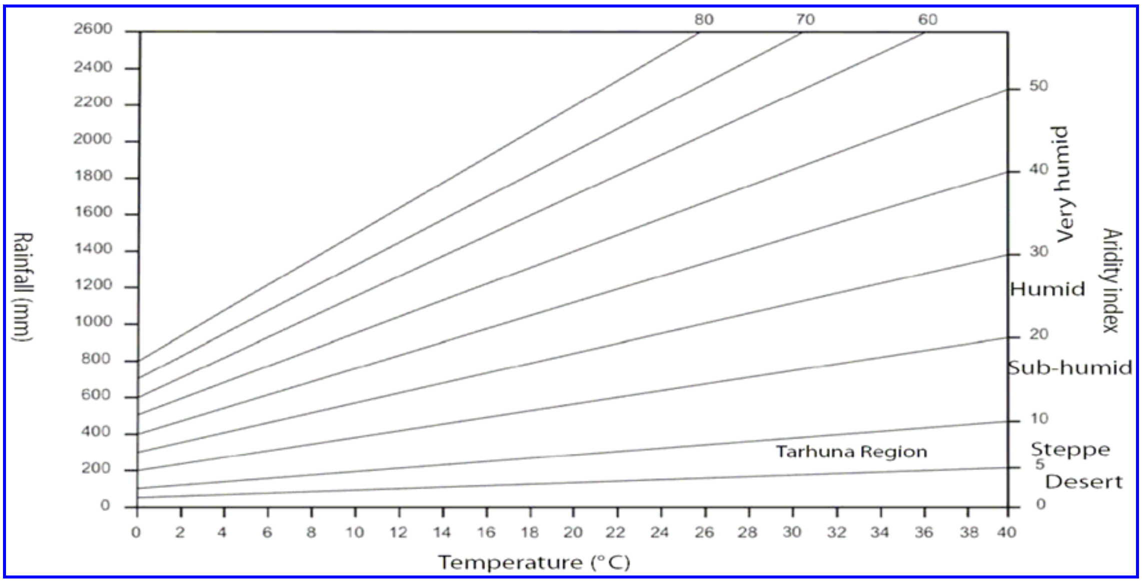


Figure 5: Climate type in Tarhuna region, after the Sharf climate classification Schemes
Source: prepared by the researcher

Due to erratic and highly variable of precipitation were noticed in the area, particularly in recent years, it affects without any doubt, rain fed agriculture and pastoral lands which might be the main cause of vegetation degradation in the area.

Modelling spatial patterns in climate parameters

While the climate data are point measurements, the satellite values are averages over pixel sized areas. Thus, to establish a relationship between these two types of data, the climatic measurements are interpolated using geostatistical technique of interpolation. The layers were obtained on latitude/longitude geographic co-ordinates and Datum: WGS84.

In order to spatially distribute data from climate stations for spatial modelling,

Ordinary Kriging was used. The technique is based on modelling the variogram describing the spatial dependence of semi-variance, and a large number of data points are needed to produce a stable variogram; at least 100 points are recommended (Webster and Oliver, 2001). Typically, 100-200 data points are needed to produce a stable variogram.

The reliability of the experimental variogram is affected by the distribution, the size of the sample (or its inverse, the density of data), and the configuration or design of the sample.

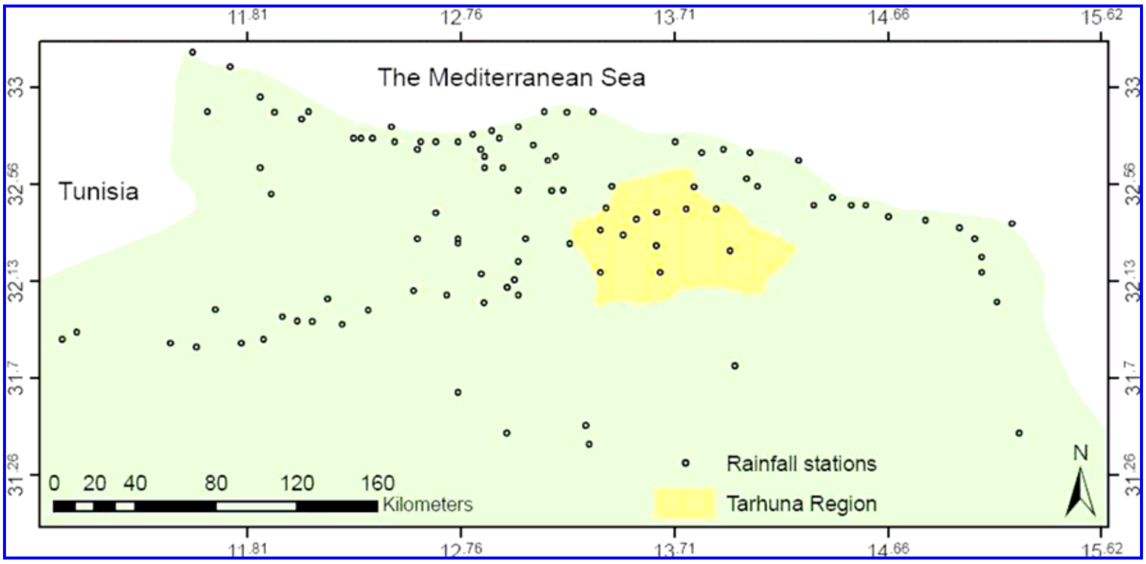


Figure 6: Rainfall Stations in Northwest Libya
Source: prepared by the researcher

The larger the sample from which the variogram is computed, the more precisely is it estimated (Webster and Oliver, 2001).
Since there are a limited number of data (12 climatic rainfall stations) within the area of investigation, other data are taken from stations around the study area (see Figure 6), to provide 100 stations.

A major issue in Kriging is the choice of the most appropriate model to fit to the observed variogram (see Figures 7 A & B) an example of model variogram for mean rainfall and temperature in January. The spatial patterns in mean of January for precipitation and temperature are shown in (Figure 7 A & B).

The model selected in each case was the one with the lowest prediction error.

As well as mean monthly precipitation, maps of mean monthly temperature and mean monthly ETO were produced, along with maps of standard error.

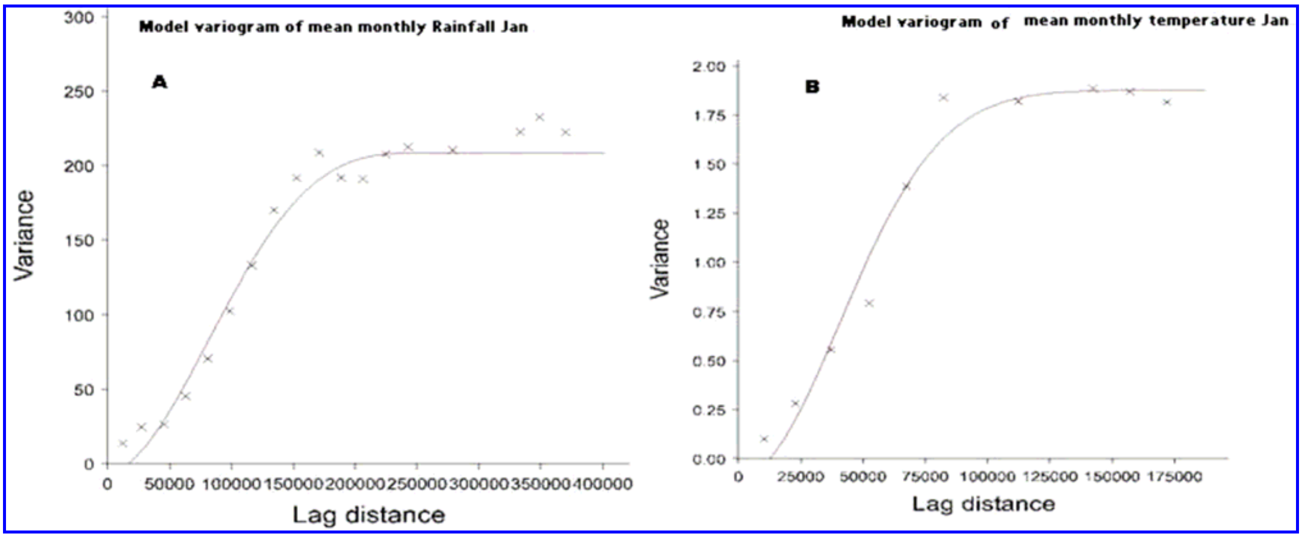


Figure7: Predicted model variogram of rainfall (A) and temperature (B) for January in Tarhuna region using GenStat
Source: prepared by the researcher

1. An example map of precipitation of January (Figure 8 rainfall) shows that most of the rainfall occurs in the north and decreases as one moves south. More rainfall occurs in the north than the south.
The result of regression analysis of annual total rainfall and latitude in North West Libya was <0.001. This supported the predicted rainfall maps, which showed that most of the rainfall occurs in the north and decreases as one moves south. Therefore, multiple linear regression analysis was used to detect climatic trends over time series at all stations before collecting a model variogram.
2. An example mean temperature map of January (Figure 8 MMT) shows that it is far warmer in the south, and as you go north the temperature decreases.
3. An example evapotranspiration map of January (Figure 7 ETO) shows higher values in the south than the North, due to the greater temperature.

Monitoring of vegetation distribution in the Tarhuna Region

As Figure 9 A shows, there are six types of land cover in the area (irrigated land, rangeland, urban, bare land, rain-fed arable land and forest).
They were created by supervised classification of Landsat Thematic Mapper images. The main land cover types: rangeland and rain -fed arable lands, which cover 93.7 % from all the area, make up most of the study area, and this project focuses on them.

The classified monthly and yearly maps of ‘September to August’ were used for spatial and temporal trajectory analysis.

The stable classes of land cover types from Tarhuna land cover map were overlaid with the PAL NDVI Grid pixels map (figure 8) to determine sample pixels representing each land cover type the because not all the PAL NDVI Grid pixels of Tarhuna region were used.

Time-series data from the PAL NDVI archives (spatial resolution of 8 km) were used to estimate the spatial and temporal patterns of vegetation.

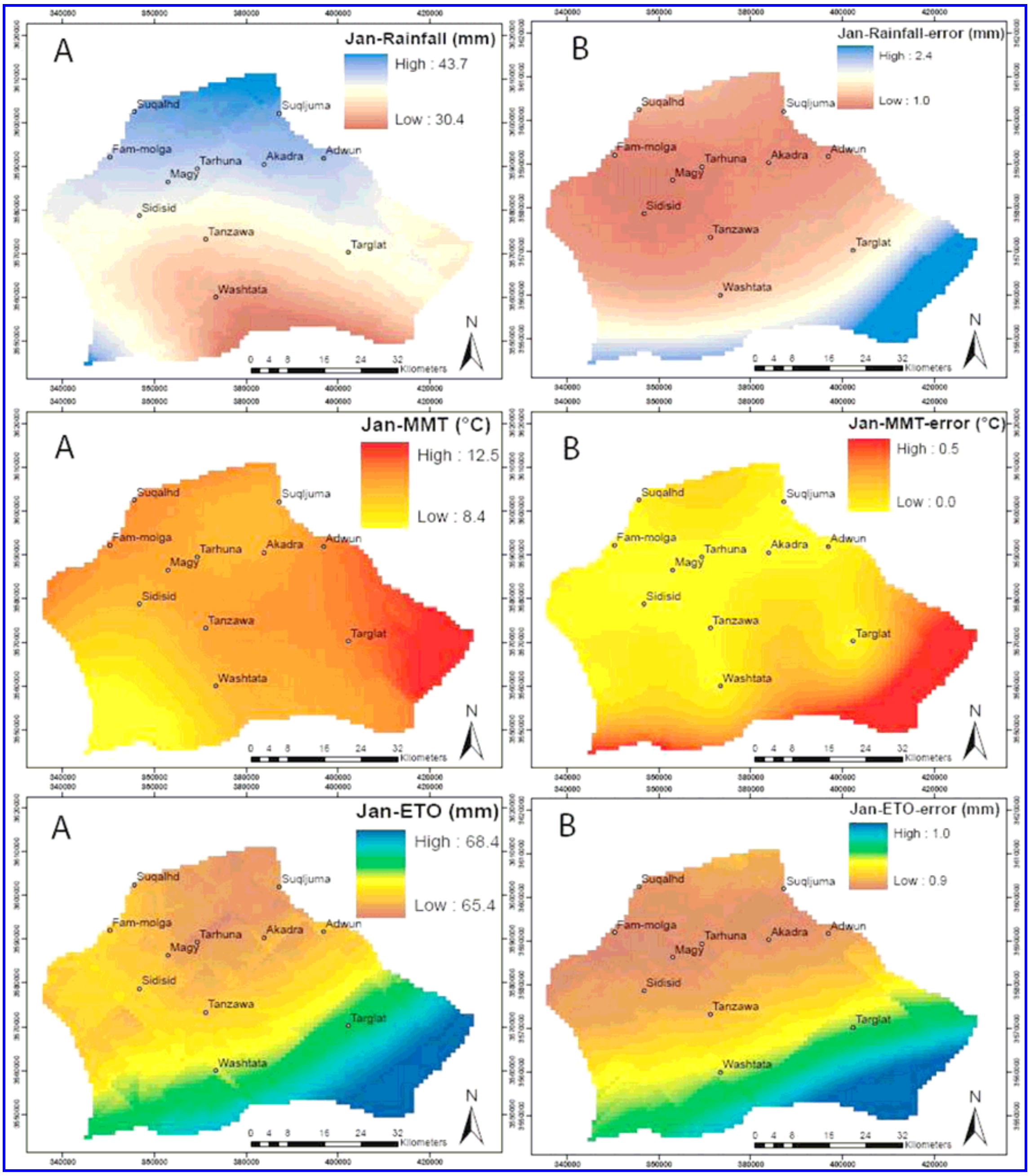


Figure 8: Predicted mean monthly maps of rainfall, temperature and ETO (A) and prediction of standard error (B) for Tarhuna region using Ordinary Kriging Source: prepared by the researcher from climate data

The PAL database includes dekadal data for the 25.5 years from 1981 to 2006. The PAL data were partitioned according to land cover.

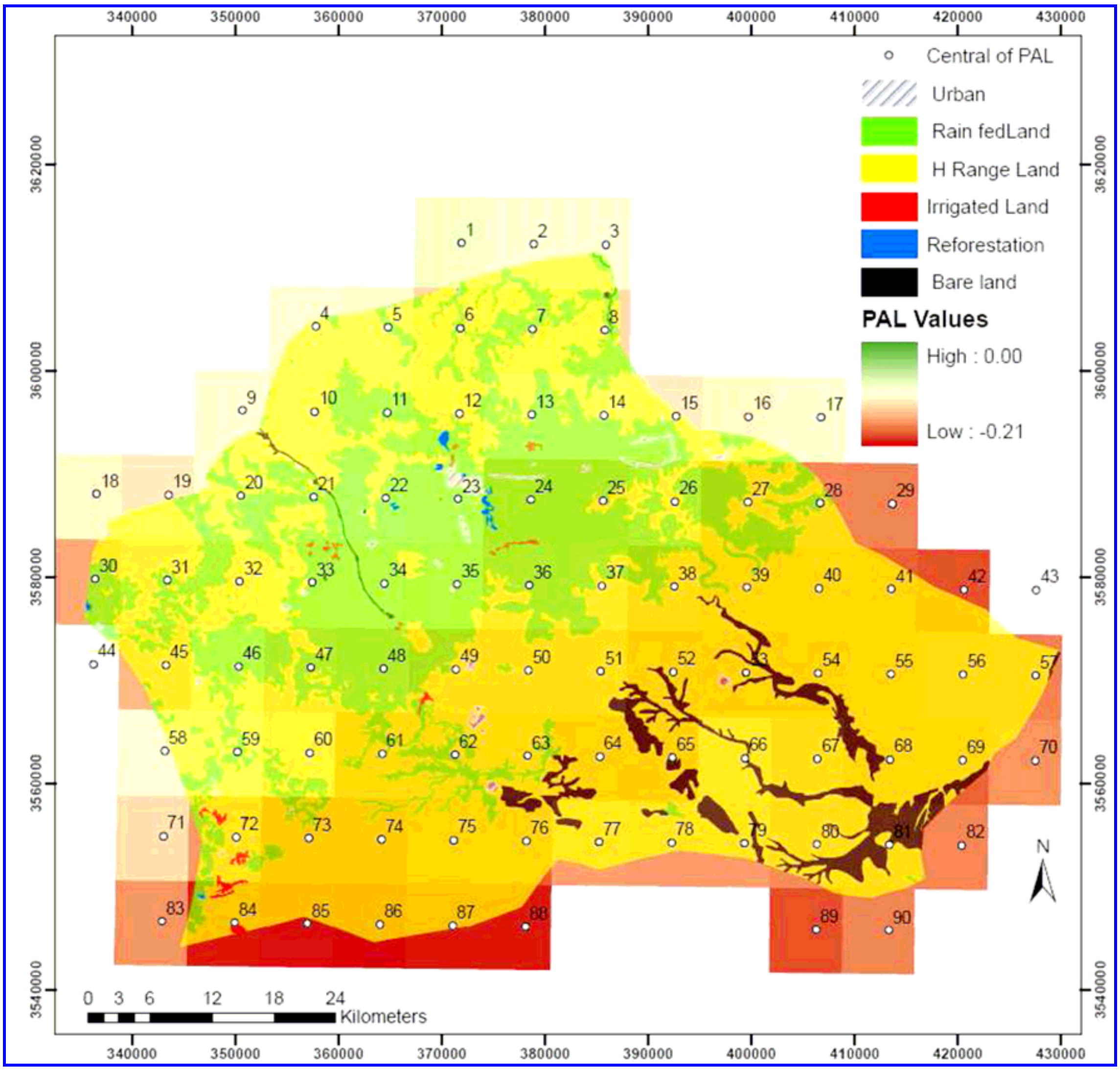
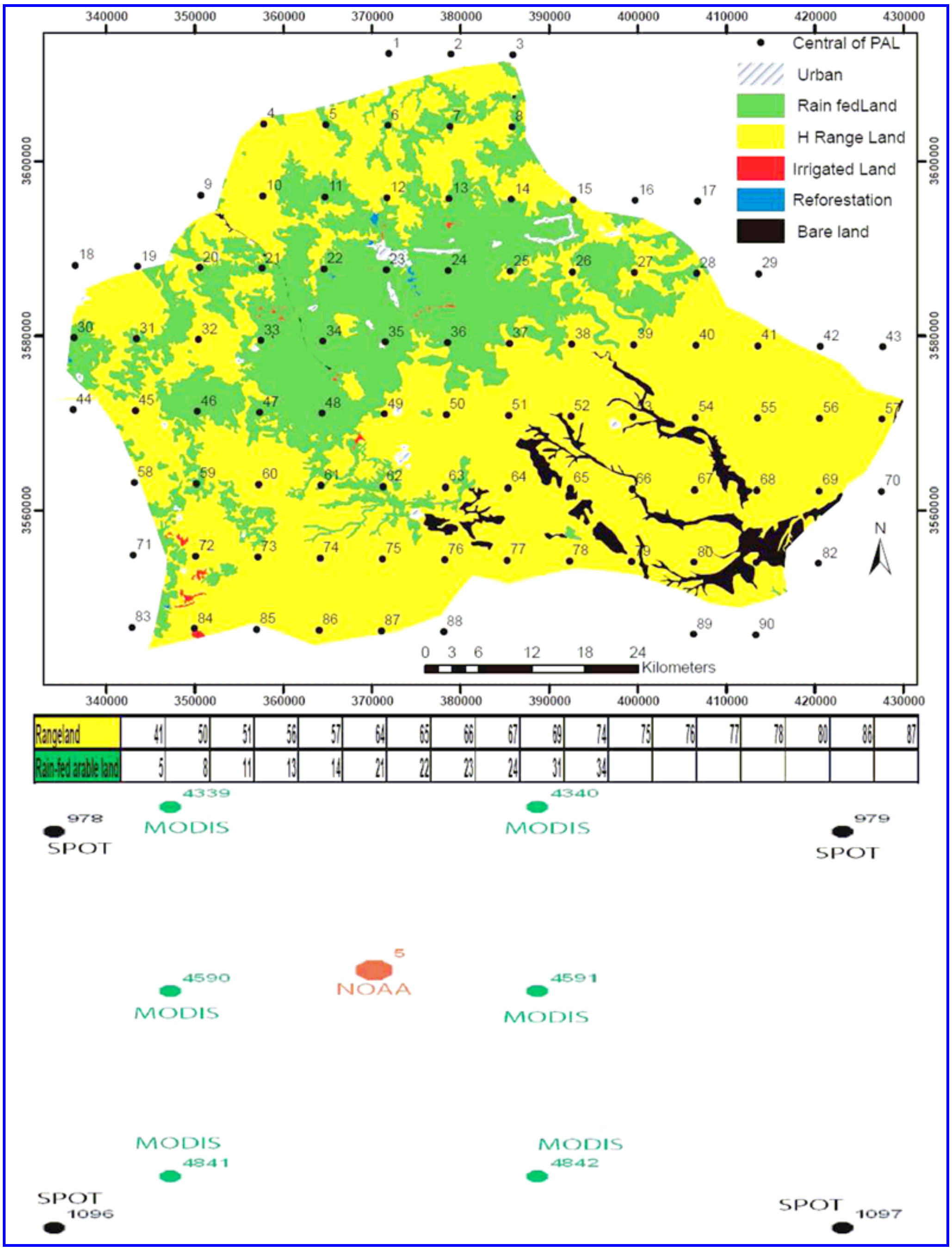


Figure 9: Tarhuna land cover map overlain by PAL pixels
Source: prepared by the researcher

Figure 10 shows the strategy sampling method was used for data collection in this area, where the area was divided into two land cover types, and then sampling was applied based on these land cover types.

Most of the PAL NDVI of rain-fed arable land and range Land were chosen depending on land cover map classes using ArcGIS software. The number of points was chosen to represent land cover classes and the entire study area. The points were used also to extract simple values for Spot & MODIS.

Sample pixels representing rain-fed arable land and rangeland were selected which consist of at least 80% of the appropriate cover type, according to the land cover map.



Rangeland	41	50	51	56	57	64	65	66	67	69	74	75	76	77	78	80	86	87
Rain-fed arable land	5	8	11	13	14	21	22	23	24	31	34							

Figure 10: Strategy followed in sampling biomass of Rain-fed arable land and Rangeland at the level of central PAL, SPOT and MODIS imagery of the study area Source: prepared by the researcher

Temporal patterns of rainfall and vegetation variability

The advantage of using the high temporal NDVI data for change detection analysis is its ability to monitor changes of vegetation (Lunneta, 1999).

The NDVI data were extracted from the selekted pixels representing rangeland and rain-fed arable land. The dekadal data were summed to monthly values for comparison with the monthly climatological data.

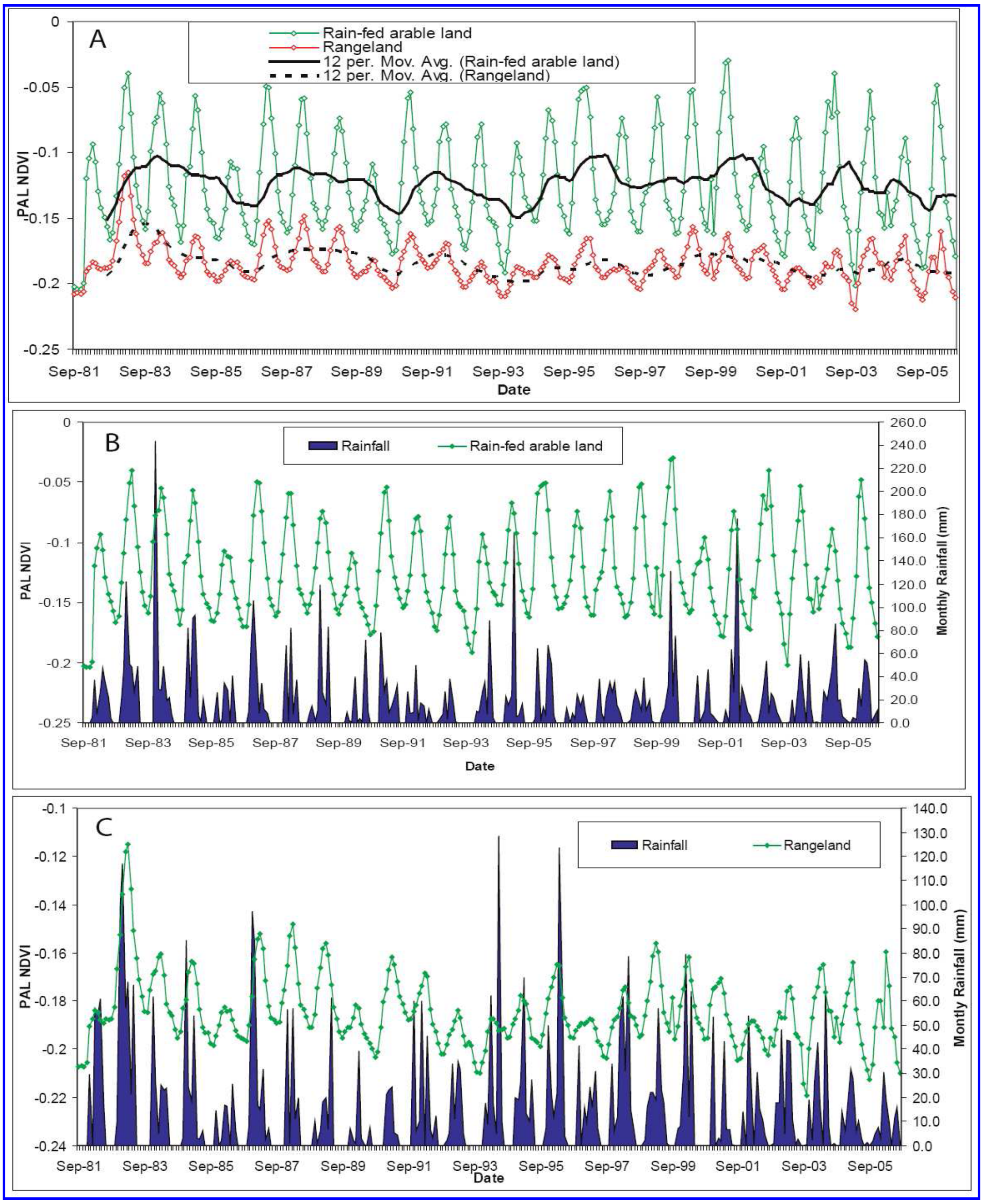


Figure 11: Time-series and annual moving average of PAL NDVI (A, B & C) response to rainfall at rain-fed arable land (RF) and Rangeland (RL) in Tarhuna region

Source: prepared by the researcher

The results (figure 11) show positive relationship between rainfall and PAL NDVI. This was particularly in agreement with Telesca and Lasaponara (2006) who found that in the Mediterranean environments, high NDVI could be associated with high vegetation productivity and high precipitation, while the low NDVI values could be associated with low precipitation. This was clear behaviour of area land cover classes, which dominated by arable (no irrigated) land because they are rain-fed arable land and rangeland (precipitation dependant). Similar behaviour of NDVI is due to Winter and Autumn rainfall in the Mediterranean area, most of the NDVI profiles were having a down-welling pick on summer and beginning of an Autumn each year. For example, Most of the low PAL NDVI values were found in the southern part of the area, because of low precipitation throughout the year.

One of the problems in NDVI based agricultural applications is the time lag between precipitation and vegetation response. The relationship between precipitation and PAL NDVI were calculated for a 0 lag, 1 month lag, 2 month lags and a 3 month lags (Table 1). Simple linear model was used, in this model, the two variables to be related are y, the dependent variable (NDVI), and x, the independent variable (Rainfall). To studying relationships between vegetation distribution and rainfall, one bases on the calculation on the assumption, that at each point of the study area this model is absolutely representative and the quantified relationship is constant.

Table 1: Coefficient correlations (r) for lags month (0, 1, 2, and 3) between rainfall and NDVI for Rain-fed arable land (RF) and Rangeland (RL) in Tarhuna Region

Land cover type	Rain-fed arable land (RF)	Rangeland (RL)
Lags month	r	r
0	0.24	0.20
1	0.45	0.39
2	0.50	0.48
3	0.41	0.47

Source: prepared by the researcher

Table 1 and Figures 12 & 13 show the results of coefficient correlations (r) and linear regression of the relationships between precipitation and NDVI for rain fed arable land and rangeland (1981- 2006) In Tarhuna area with different lags (0, 1, 2 and 3 Months).There is a positive relationship between NDVI and precipitation data, this was evident in Figures (12 and 13).

The results show that the strongest relationship between NDVI and rainfall occurs for a 2 months lag (0.50 & 0.48). This lag value was adopted in all subsequent modelling.

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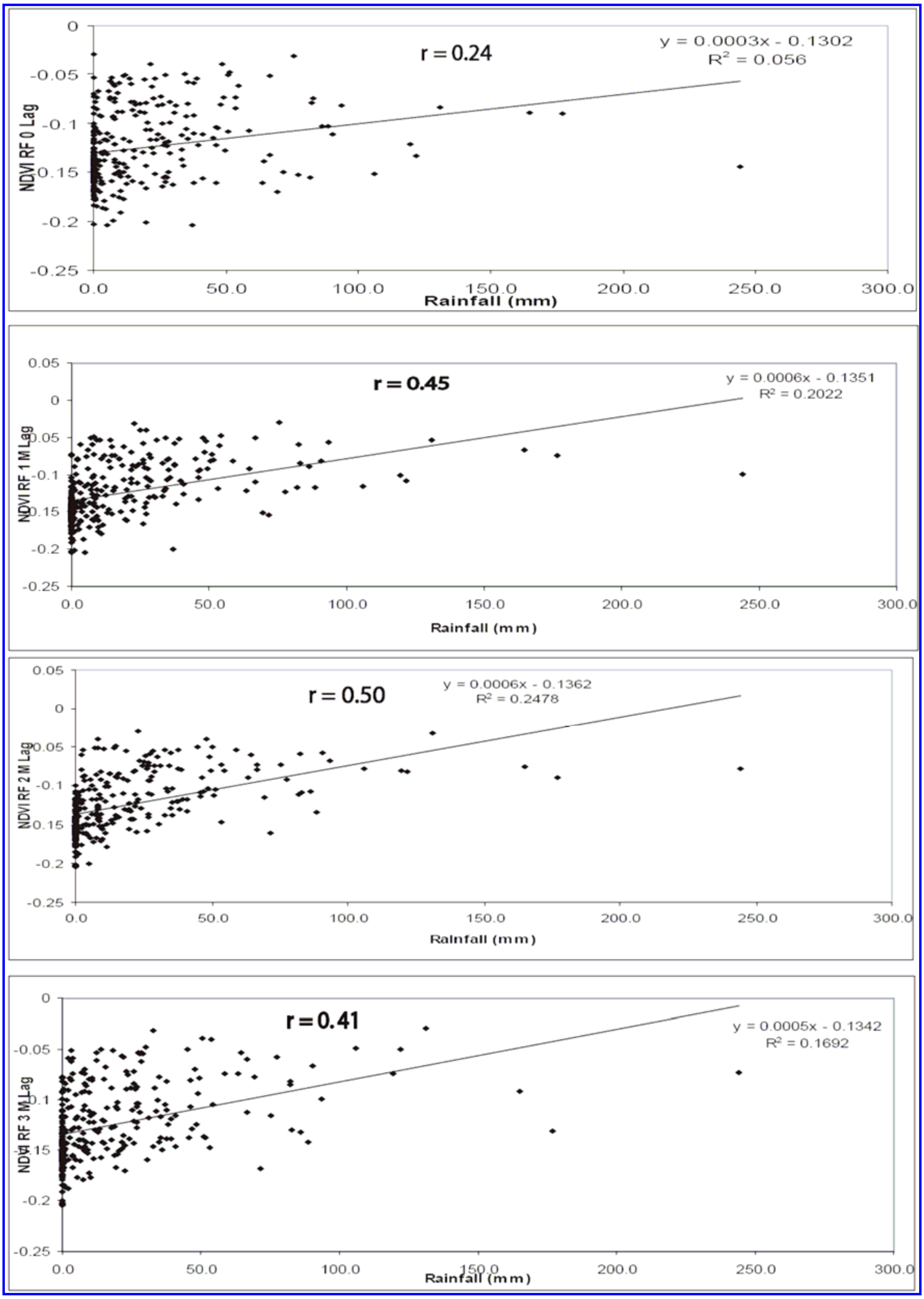

Figure 12: Linear regression of the relationships between rainfall and NDVI for rain fed arable land (1981- 2006) In Tarhuna area with different lags (0, 1, 2 & 3 months)

Source: prepared by the researcher

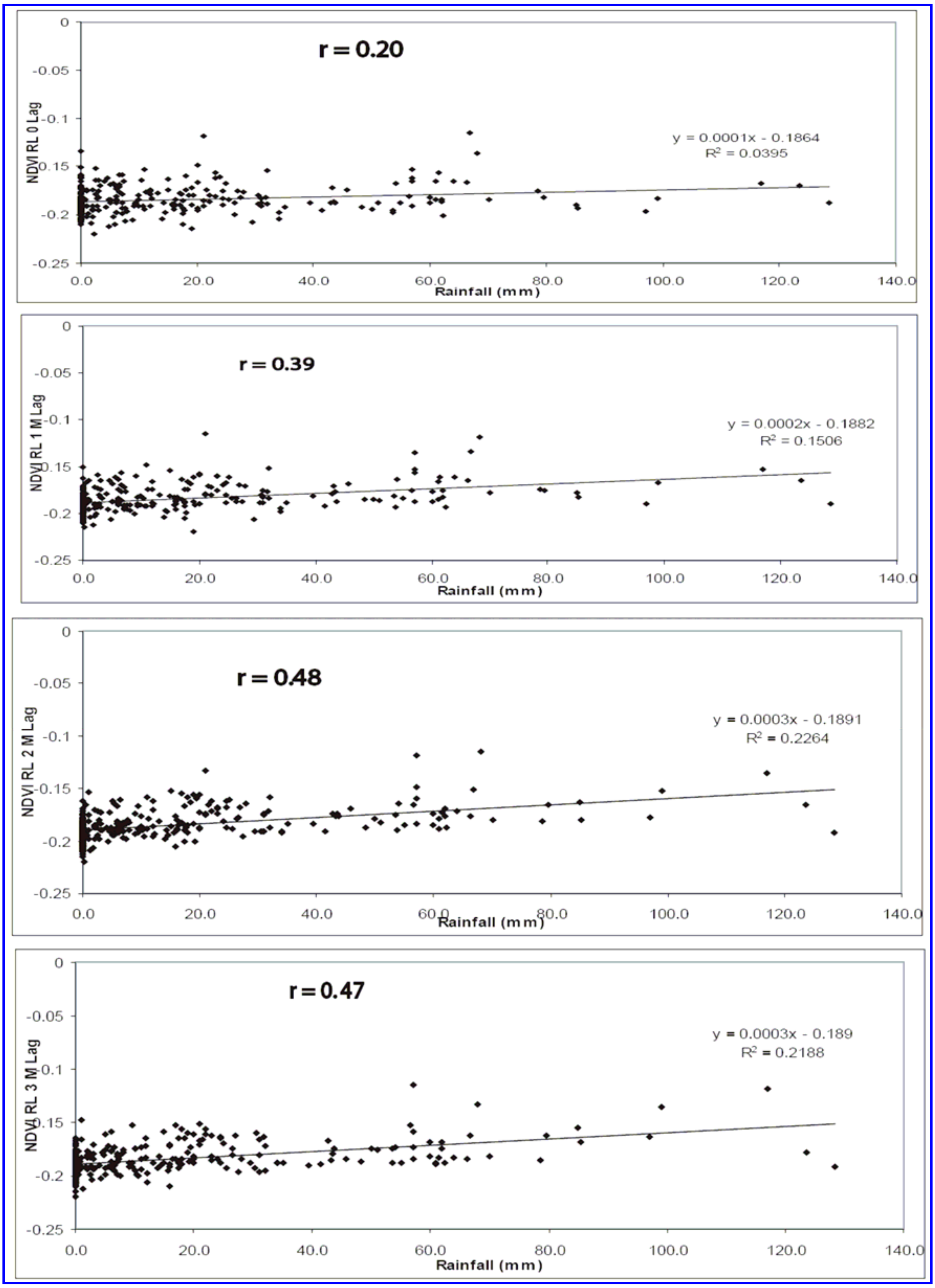

Figure 13: Linear regression of the relationships between rainfall and NDVI for rangeland (1981 - 2006) in Tarhuna area with different lags (0,1, 2 & 3 months)

Source: prepared by the researcher

Spatial distribution of annual mean of PAL NDVI, SPOT Percentage NDVI and MODIS NDVI in Tarhuna region

As figure 14 shows that the highest NDVI values occur in the north and decreases as one moves south. It agrees with spatial distribution of annual mean of rainfall figure 8. This shows that rainfall has a great impact on the vegetation condition figures 12 and 13. At places with good amount of rainfall, vegetation shows a good response and NDVI values at these places is high as compared to low rainfall areas.

These maps showed a high degree of spatial variation with clear decreasing in NDVI values. This temporal and spatial decreasing in NDVI values is an indicator of the general regional vegetation degradation .since NDVI is a good surrogate for net primary productivity. However, further analysis is required to determine whether these patterns translate an indicator of agricultural production.

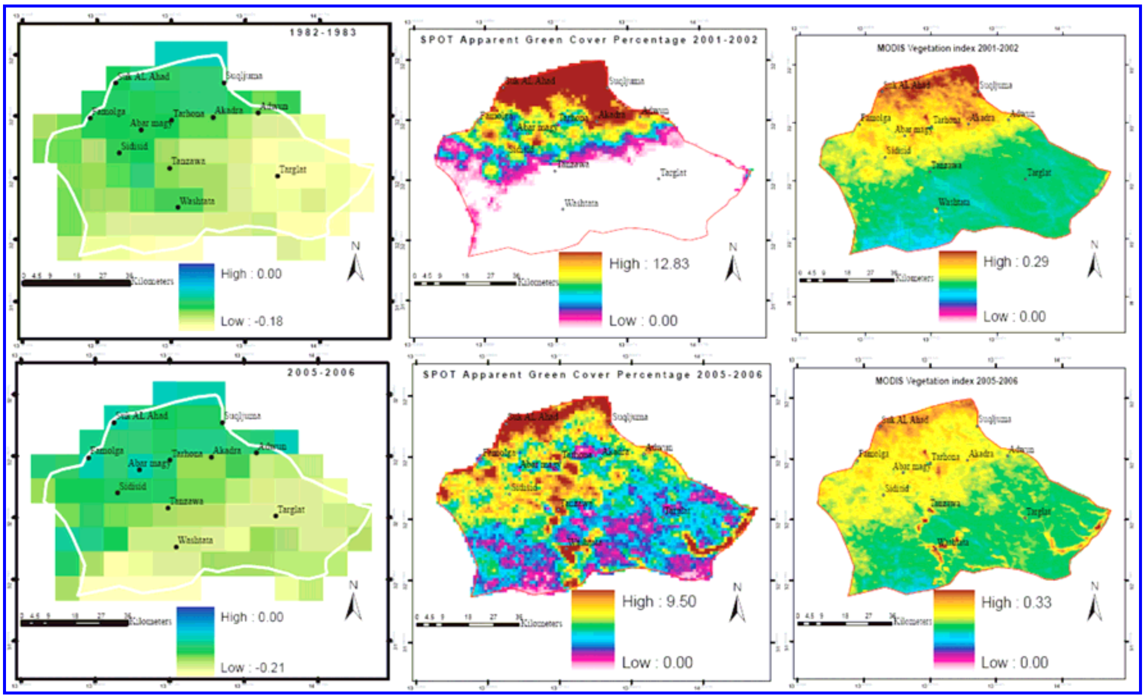

Figure 14 Spatial distribution of annual mean of PAL NDVI (1982-2006), SPOT Percentage NDVI and MODIS NDVI (2001-2006) in Tarhuna region.

Source: prepared by the researcher

The relationship between productivity of NDVI and rainfall

The pattern of relationship between productivity of PAL NDVI and rainfall in this research was examined by calculating the time series of 26 years over the Tarhuna Region, using time integration of NDVI (TINDVI). TINDVI is derived by calculating the area under each agricultural year curve and uses the baseline as the beginning point of integration. TINDVI is a potential surrogate for net primary production because it measures the amount of greenness across the agricultural year (= productivity) of one year. The classification was based on temporal and spatial patterns of integration NDVI metrics as for rain-fed arable land and rangeland. The analysis covered the total productivity for each agricultural year (TINDVI) from 1981 to 2001, since census data was only available to coincide with rainfall metrics for this period. Figure 14A & B shows, the linear regression of the relationships between TINDVI as vegetation productivity, across the rainfall years. Based on the curve produced from TINDVI, a strong relationship can be seen between the TINDVI and annual mean of rainfall. This productivity of NDVI was directly correlated to rainfall. In addition, the TINDVI were higher with years having more rainfall and lower in years having less rainfall. It can be concluded that metrics from TINDVI could be routinely and transparently used for retrospective assessment of rainfall conditions and changes in vegetation responses and cover. Overall, the relationship between rainfall and amount of TINDVI over the period 1981-2001 showed a high response particularly in rain fed arable land and moderate response in rangeland (Figure 15).

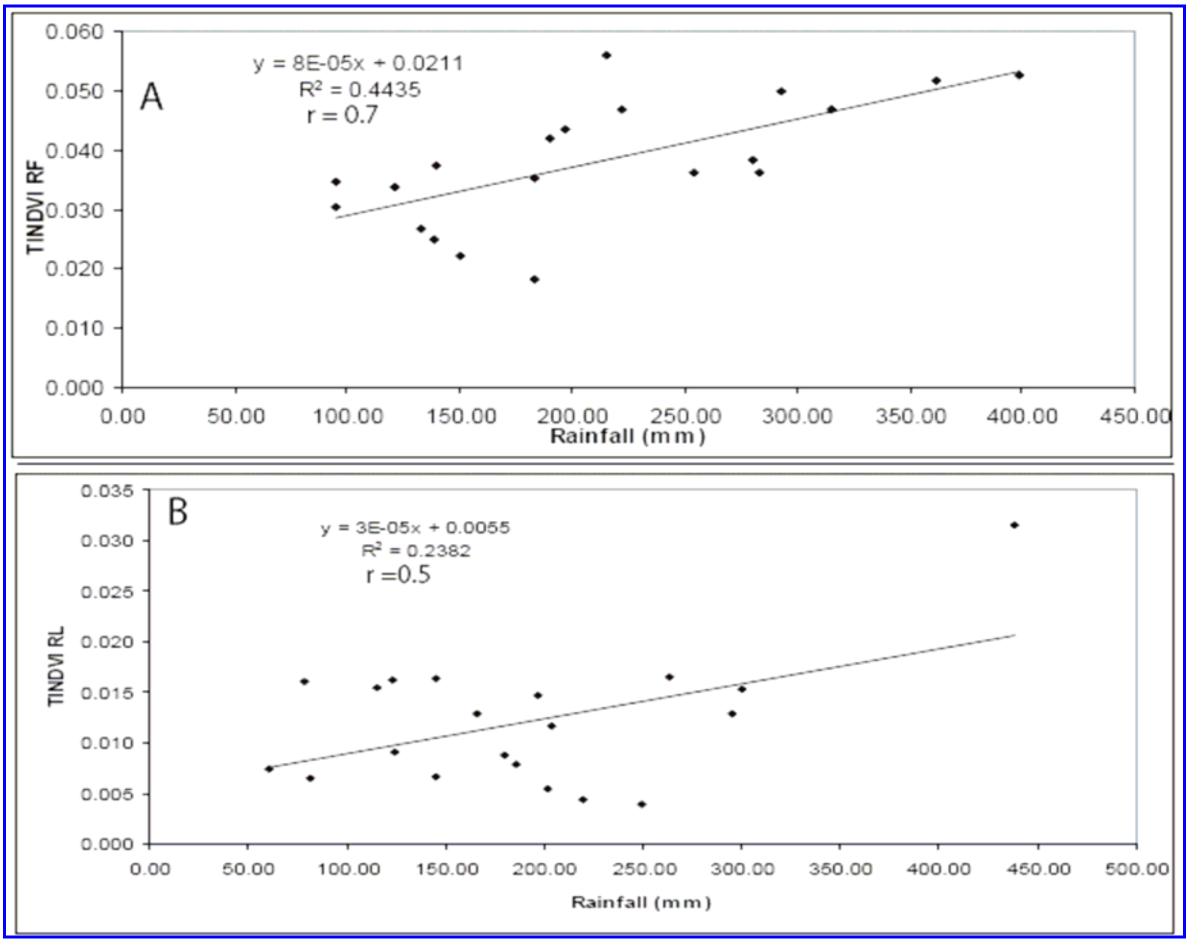

Figure 15: Linear regression of the relationships between rainfall and TINDVI as vegetation productivity for rain fed arable land A and rangeland B (1981 - 2001) in Tarhuna area.

Source: prepared by the researcher

In view of these results, it is suggested that the dominant cause at the spatial and temporal scales are the structure of the rainy season (distribution, concentration) with other causes such as population increase, livestock farming and government planning and their effects in vegetation degradation. The output can be used to provide basis for mapping spatial and temporal vegetation productivity to understand vegetation degradation.

Manifestations of the Deterioration of Vegetation in Tarhuna Region

Vegetation degradation is a manifestation of desertification, which is among the important consequences resulting from climate change in arid and semi arid lands.

Desertification differs from drought; drought is a temporary phenomenon occurring when precipitation falls below normal or when near normal precipitation is made less effective by other climate parameters such as high temperature, low humidity and strong winds, (Ibrahim,2005).

Unlike desertification, there is no universally accepted definition of drought because droughts are a recurrent feature of the climate, varying in intensity, duration, and frequency. Therefore, its definition depend on region specific, reflecting differences in climatic characteristics as well as incorporating different physical, biological and socioeconomic variables, it is usually difficult to transfer definitions derived for one region to another, (Ibrahim, 2005).

However, the most widely used definition of drought is that introduced by the U.S. Weather Bureau (1953). Desertification is a more deadly enemy than drought because it threatens the whole ecological basis of production in the affected lands (Kassas, 1995).

The high variability in precipitation accompanied with deterioration of vegetation cover leads to an increase in surface albedo and, in turn, affects the atmospheric energy budget in a way that intensifies subsidence and hence increases aridity.

Dry years lead to the drying of soil, vegetation degradation and fall in the productivity, thereby increasing the rate of desertification, so one of the main things to consider is occurrence of periods of successive dry years, the cumulative impact of which might be drought-induced desertification, (Kassas, 1995).

These periods of prolonged drought and variabilities of precipitation were noticed in Tarhuna region and can be the main cause of vegetation degradation. High summer temperatures and hot dry sandstorms (Figure 15) called Gibli winds leads to increase in temperatures e.g. In 1995, 1996, 1999 and 2003 measured temperature exceeded 53 °C in the area (Ibrahim,2002).

These have direct and indirect implications on contributed to the severe negative consequences on vegetation cover arising from the absence of rainfall.

Most of the Tarhuna region is in rain-fed arable land and rangeland, which are particularly susceptible to drought years, resulting in the death of thousands of apple and almond trees in the area particularly in recent years (Figure16).

There is a higher monthly variation in rainfall, where the most of rainfall in the study area is concentrated in winter, which in turn, limits its utility for vegetation growth.

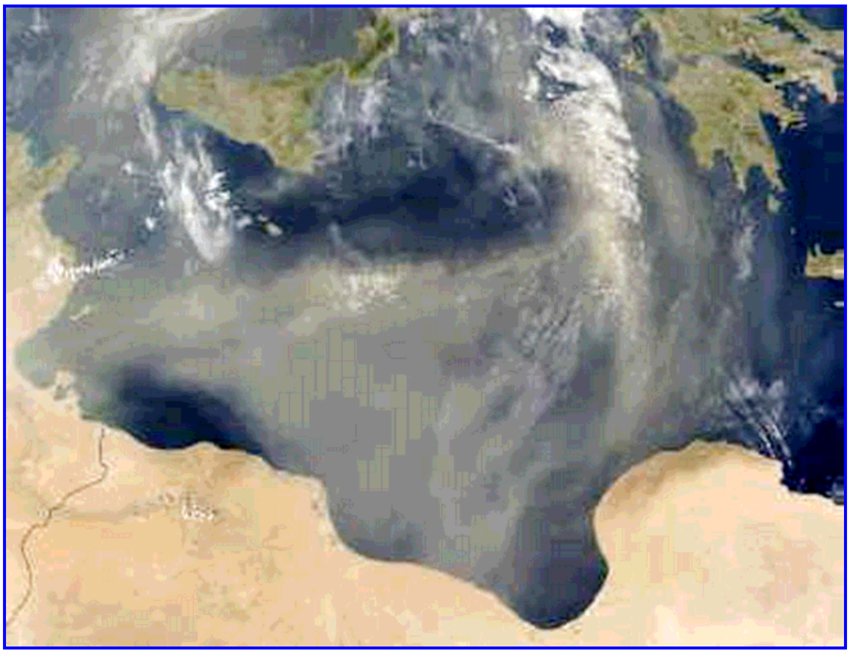

Figure 16: Gibli dust in Libya
Source: http://visibleearth.nasa.gov/view

Figure 17: Affect of drought years in the study area
Source: Researcher

The concentration of rain, 51%, in the coldest month January (Ibrahim, 2002) has a direct impact on vegetation and there are several attributions for that:

At this period, moisture is not the only limiting factor for plant growth, where the temperature is more likely to be a limiting factor, hence it reduces the efficiency of moisture use. In addition, the root system of the annual plants at this period is still at early stage of development, with low soil contact surface, which in turn limits the efficiency of plans moisture use (Ibrahim, 2005). The plant needs moisture at a later stage in the growing season. Autumn rains are good for germination of seeds; effective spring rains are needed for flowering; concentration of rainfall in the coldest month (January) may be one of the factors promoting vegetation degradation in the study area. Vegetation is primarily affected by climatological variables; uneven precipitation distribution and increasing drought, which lead to significant declines in vegetation productivity (Schafer, 2001).

Unfortunately, most of the Tarhuna region experiences a stress on its natural resources for example soil erosion (Sarif, 2005). In recent years the region is already troubled by crucial imbalances in vegetation degradation as a result of general decline in the mean annual rainfall (Figures 4 & 13).This alongside with the rapidly developing population growth puts more pressure on the stressed natural resources. There was a sharp fluctuation in vegetation productivity, for example, a large area of natural vegetation was cleared in Tarhuna region for the Man-Made River Projects (Figure 17) to be substituted by cereal crops such as Wheat or Barley cultivation to match the needs of rapidly growing population in Libya, but these activities affected the natural vegetation (Ibrahim,2002).

Figure 18: Farm Molga project in Tarhuna region
Source: Researcher

Conclusions

The conclusion is not easy to explain the trend in NOAA NDVI for 25 years because a huge data need to be used. Furthermore, an integrated NDVI data of semi dry lands with climate data appears to be a useful tool to understand vegetation degradation and desertification.

The objective of this paper was to demonstrate the use of satellite derived indices from PAL NDVI, SPOT Apparent Green Cover Percentage data and MODIS Vegetation index satellite data for monitoring the Vegetation degradation with integration of both climate data.

The climate data analysis indicates that the study area has a highly variable rainfall. Rainfall appears to have decreased over the period of study. 54.3% of the past 47 years had less than the long term mean annual rainfall, leading to increased occurrence of drought and a greater risk of desertification. Also 51% of the rainfall in the study area was concentrated during the coldest month January when there is less demand from vegetation. In addition, the slope estimates are negative (-1.57), the trend of annual precipitation was negative especially at recent years.

Tarhuna region is mostly occupied under Steppe climate type; it affects without any doubt, rain fed agriculture and pastoral lands, which might be the main cause of vegetation degradation in the region. Rangeland and rain -fed arable lands are the main land cover types; they make up 93.7 % from all the study area.

There is a positive relationship between rainfall and PAL NDVI. The maximum values of NDVI occur in the rainfall season from October to May, whereas the minimum values occur in the dry season. The highest NDVI occurred in the North of the study area where the relatively high rainfall promoted vegetation growth and cover.

There is a positive relationship between NDVI and precipitation occurs for a 2 months lag (0.50 and 0.48).

There is a positive relationship between rainfall and amount of TINDVI over the period 1981-2006. Vegetation productivity was directly dependent on rainfall.

There was a sharp fluctuation in vegetation productivity; for example, a large area of natural vegetation was cleared in Tarhuna region for the Man-Made River Projects, which have affected on natural vegetation.

The availability of information base is very important for putting policies and action plans to mitigate climate change and combat desertification.

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