The Use of Remote Sensing and Geographic Information System for Soil Salinity Monitoring in Libya

Bashir Nwer, Hamdi Zurqani, Ezzdein Rhoma

Abstract—Remote Sensing (RS) and Geographic Information System (GIS) have become important tools for detecting, mapping and monitoring degradation problems including their spatial variation and effect with time. The combination of RS and GIS can be considered as a high tech method that is cost, time and labour effective to assess the change in soil salinity. In addition, traditional soil survey methods covered only the time of measurements and did not address the dynamic nature of degradation process. The aim of this paper is to monitor soil salinity spatially over period of time using RS and GIS a combined by site observation. So that a contribution can be made to the effort to develop an efficient methodology to map, detect and monitor soil salinity in Libya. The ultimate goal is to support the decision makers in their attempt to anticipate degradation and conduct proper and timely interventions to adjust management practices or undertake suitable reclamation and rehabilitation measures. Land Sat Satellite images data were acquired for 3 different years to assess the pattern of soil salinity change. The result revealed that RS and GIS can be used to map and detect soil salinity which proved to be a promising approach to monitor land degradation. However, the results should be taken with care because some features cannot be detected by RS. For example, the area of saline soils in the study area decreased as a result of eolian sand movement and coverage on the surface which prevent Sabkhas detection using remote sensing.

Index Terms— Libya, GIS, Remote Sensing, Soil, Soil Salinity, Sebkha.

I. Introduction

The use of remote sensing and Geographic information system techniques has become increasingly important in describing a variety of satellite-derived data sets and their application to understand changes in landscape [5].
The potential to detect, map and monitor degradation problems including their spread and effects with time are the main recommended advents of remote sensing [4], [9].

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The detection of soil degradation by conventional means of soil surveying become expensive and time-consuming, but remote sensing data and techniques offer the possibility for mapping and monitoring these processes more efficiently and economically. However, to assess the accuracy of the ability of satellite images to map and monitor salinity, it is necessary to validate the output with field measurements of salinity. Remotely sensed data has great potential for monitoring dynamic processes, including salinisation. Mapping and monitoring salinity is vital to keep track and anticipate further degradation and essential for proper and timely interventions to adjust management practices or undertake suitable reclamation and rehabilitation measures. To map and monitor salinity, firstly, identifying the areas where slats concentrate; secondly, detecting the geographic variations over time in this occurrence [11]. Satellite data have been used for detection and mapping of saline soils using different techniques such as principal component analysis [7],a combination of spectral classification and physiographic maps [9], and spectral correlation and classification [1]. GIS is now a very important tool for land use planning. This is due to the capacity of such systems to provide different functions, which benefit land use planning. These capabilities include database management (data integration), cartographic analysis and modelling functions [8] .
The combination of remote sensing with GIS is very promising, especially for the monitoring of soil salinisation. Remote Sensing and GIS techniques can be an excellent tool for mapping saline and waterlogged soils [2]. The integration of remote sensing data, in the form of satellite imagery, with the GIS has boosted up the ability of delineating and mapping soil salinity.
The monitoring of land degradation especially soil salinity in arid and semi-arid regions is of a high importance to aid the decision making process and policy formulation to intervene where is necessary to achieve sustainable development.
Remote sensing image data sets were used to show the spectral classes and the corresponding areas of the different land uses covering the region, and to delineate and map those areas that are salt-affected, and finally to monitor the changes in salinity in terms of its severity and real extent for the period under investigation.

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II. The Study Area

A. Location

The study area is an extensive area of coastal salt flats, locally known as“sabkha" which is situated between the longitudes (12 ° 15-11 ° 33) and (32 ° 30-33 ° 10) north. . It is a large area with total area of about 221689 hectares. It is a part of Jefara plain which is considered to be the most important agricultural area in the country.

As shown in Fig (1) the study area is located on the north west of Libya alongside the coastal area to the west of Tripoli. It is bounded to the north Mediterranean sea, Bir Algnem from the south and on the east the city of Ajeelat stretching west to the Tunisian border.

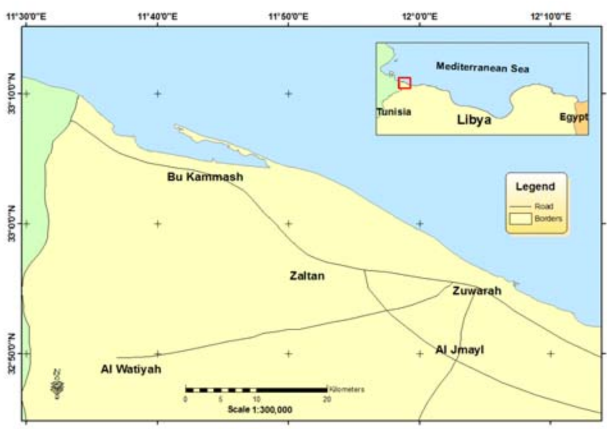

Fig (1) Location of the study area .

A. Climate

The Climate in the study area is the influenced by Mediterranean climate (Xeric), which is characterized by rainfall in the winter and almost no rainfall period in the summer which is the most heat and drought period of the year. The southern part of the study area is under Torric moisture regime .The maximum temperatures ranging from 18.3C° in January to 32C°. The minimum temperatures are ranging from 8.0 C° to 23.9 C° .The average monthly temperatures range from 13.2 C° to 27.9 C° with an annual level of 20.7 C°. The soil temperature regime in the study area is Thermic. The average annual rainfall varies from region to region according to the geographic position and the topography. Rainfall occurs during the winter months (October to March), but great variability is observed over space and time (year to year). For example, the rainfall in Zora is 226 mm whereas it is 186 mm in Aljmeal [6].

B. Soils

Soils and their characteristics in the study area are effected to great extent by the nature and conditions in which these soils were formed. Generally, aridity is the main characterises of such soils. Most of these soils are undeveloped or partly developed. Soils in the study are classified in accordance with US Soil Taxonomy as shown in Fig (2). Aridisols and Entisols are the main soil orders in the study area. The salt effected soils are widespread in the study area such as , Salic Haplocambids, Typic Aquisalids, Typic Haplosalids,Typic Haplocalcids, Lithic Haplocalcids, Typic Torriorthents.

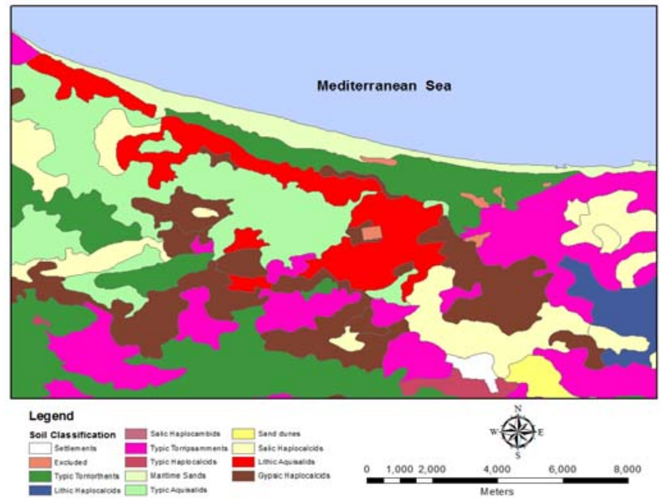

Fig (2) Soil Map of the study area

Fig (2) representative soil profile for Typic Aquisalids

C. Soil salinity

Soil salinity problems in Libya started to be noticed after the extensive agricultural activities, coupled with increasing population, through the use of lands suitable for farming and overdraw of fresh groundwater to an extent of causing seawater intrusion. In addition, the nature of harsh climate featuring low amount of rainfall ranges, and high temperatures are also contributes to the soil salinity problems. Saline soils in Libya cover around 12 % of the north region, 16.5% of the west region and 23.4% of the middle region [4]. Mapping and monitoring salinity is vital to keep track and anticipate further degradation and essential for proper and timely interventions to adjust management practices or undertake suitable reclamation and rehabilitation measures. To map and monitor salinity, firstly, identifying the areas where slats concentrate; secondly, detecting the temporal and spatial changes in this occurrence [8].

III. MATERIAL AND METHODS

The assessment of the salinity has been structured under two main phases: salinity detection using remote sensing data for 29 years (1972, 1987 and 2001) and site observations (ground truth). Figure (2) shows the steps of the assessment conduction.

A. Soil Salinity Detection Using Remote Sensing and GIS

Remotely sensed data, multi–temporal Landsat-7 ETM image (Enhanced Thematic Mapper) acquired in 1971, 1987 and 2001 has been used to detect coastal saline areas. Remote sensing data was intensively used to identify and map salt-affected areas. The main factors affecting the reflectance are the quantity of salts, soil moisture, soil color and terrain roughness. Salts influenced surface features are crusts without or with only little evidence of salt, thick salt crusts and puffy structures. A visual interpretation of the processed satellite image data was carried out to delineate boundaries of the saline areas.

ERDAS imagine and ArcGIS were used to produce thematic maps. Raster and vector GIS datasets were used to create different maps. Area calculation were preformed to quantify the change on saline soils overtime. A number of saline maps for three years 1971, 1987 and 2001. Then three different areas were selected to assess the pattern of change. The selection were based on the distance to the sea and the pattern of change in these areas.

B. Site Observations

Soil samples were collected to validate the output from the interpretations of data derived from satellite images. In addition, to understand the spatial and temporal variation of soil salinity patterns. The soil samples were gathered from the study in two different sites (Site A and Site B). Sites were selected depending upon the distance to sea and the area were found to spatially change in terms soil salinity. The site observations also were used as verifications tool and searching for reasons behind decrease on the area of saline soils.

IV. RESULTS AND DISCUSSIONS

A. Detection Using Remote Sensing Data

ERDAS imagine and Arc GIS were use to detect soil saline areas. Visual assessment were conducted for satellite images data for the years 1972, 1987 and 2001. The results show that in 1972 the soil saline area covered about 43639 hectares whereas it is decreased to 40898 hectares in 1987 and 38043 hectares in 2001 (Fig 3,4).

B. Soil Salinity Monitoring in the study area

Salinity process has a dynamic nature which require that any salinity assessment should take into consideration the time and spatial aspects of salinity changes. . The results from data processed and visual assessment for 29 year (1972, 1987 and 2001) indicated that there is a decrease in the area covered by saline soils (Sehbkha). The area of saline soils has decreased through the last 29 years. The results revealed that the area of the marshes is in clear decline over time. For instance, in a period of 15 years (1972- 1987), the area of saline soil decreased by 6.28 % . The total Sebkha's area in the period of 29 years (1972 to the year 2001) has decreased at a rate of 12.82%. Fig (4) and Fig (5) show the pattern of this decrease in the area. In Fig (5) the spatial distribution of the area show the decrease in terms of time scale. However, it was necessary to explain the causes of the decrease in saline soils area.

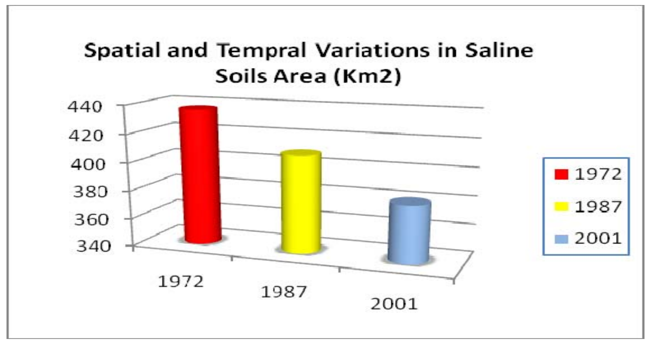

Fig (4) Soil Salinity Variations in the Study Area (1972, 1987 and 2001

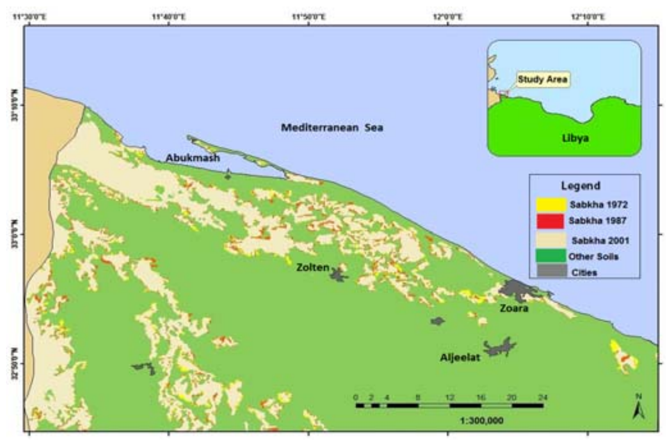

Fig (4) Soil Salinity Variations in the Study Area (1972, 1987 and 2001

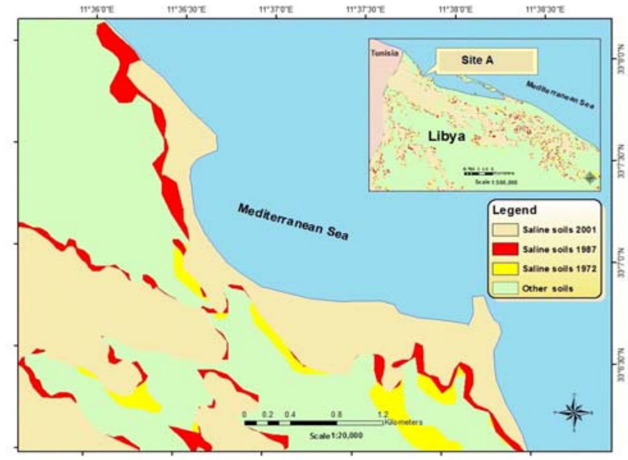

Fig (6) Soil Salinity Vartiotions in the study area Site A (1972, 1987 and 2001)

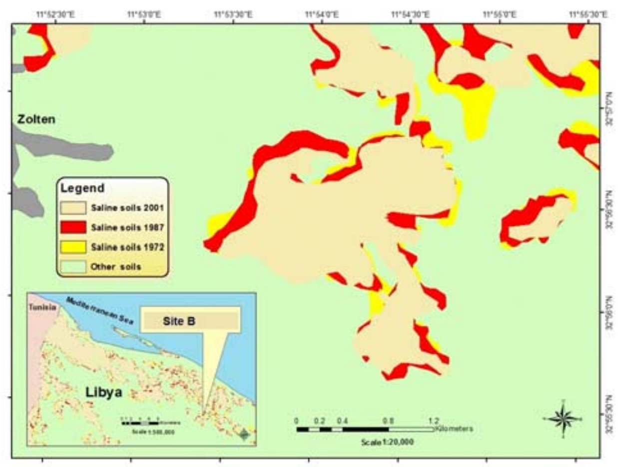

Fig (6) Soil Salinity Vartiotions in the study area in Site B (1972, 1987 and 2001)

The decrease of the salt affected areas (Sabkhas) in the study area could be explained as a result of Eolian sand movement and coverage on the surface which prevent Sabkhas detection using remote sensing. These thickness of the sand material range from 20 – 30 cm.

The results revealed most of the study area soils are saline soils. Aridisols are the main soils in the two sites. Table (1) shows classification of saline areas at great group level of USDA Soil Taxonomy. The outputs from the data analysed from remote sensing or concluded from soil samples results show that there were a decrease in the area covered by saline soils.

TABLE (1) SOIL CLASSIFICATION FOR THE STUDY AREA (USDA SOIL TAXONOMY)

Soil Classification (USDA Soil Taxonomy)	
Site (A)	Site (B)
Calcic Aquisalids Calcic Petrocalcids Natric Petrocalcids	Calcic Haplosalids Xeric Haplocalcids Calcic Haplosalids Lithic Haplosalids

V. CONCLUSION

The use of RS and GIS has increasingly become an important tool in soil degradation monitoring specially soil salinity. Soil salinity is considered as an important factor in desertification in arid regions and semi-arid regions such as Libya. Several studies and research projects, using traditional or more advanced methods like GIS, related to soil and water salinity monitoring, assessment, and mapping were conducted in Libya. However, they covered only the time of measurements and did not address the dynamic nature of salinity process and its coverage of large areas in Libya. Hence, remote sensing analysis has been introduced and proven to be a new, cheaper and faster technique than the traditional ones in delineating and mapping soil salinity. Although some efforts have been done in using remote sensing tools for this purpose, more researches are needed in this direction for instance developing a model integrate remote sensing and GIS techniques with site observation to optimize the accuracy of the outputs to be used in rehabilitations programs of saline soils.

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