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Remote Sensing Techniques for Ground Water exploration in South Darfur State - Sudan

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Abstract

In recent years much progress has been made in the application of remote sensing techniques to ground water. Exploration procedures can ideally adopt remote sensing as the first step to be followed by field geological studies, geophysical prospecting and test drilling. The advent of Geographical Information Systems (GIS) has added new vistas in the field of ground water resources mapping and management. It helps to integrate remotely sensed derived data with ancillary data to have more precise and correct information about various factors involved in the ground water resources management. The main objective of this study was to detect the groundwater potential in South Darfur state using Remote Sensing. In computation of the potential recharge locations, the Spatial Analyst tools in GIS software was used to generate the final recharge map of study area from integration of geology, slope, rainfall, fracture and density layers as inputs. It was determined that the alluvial deposits in the study area contain a large amount of potable water. The integration of GIS of data extracted from satellite imagery with traditionally gathered geological knowledge of the area under investigation provides a powerful tool in groundwater search.

Keywords: GIS, remote sensing, ground water

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Introduction

Ground water constitutes a major portion of the earth's water circulatory system known as hydrologic cycle. Ground water occurs in permeable geologic formation known as aquifer, i.e. formation having structure that can store and transmit water at rates fast enough to supply reasonable amounts to wells. Exploration procedures can ideally adopt remote sensing as the first step to be followed by field geological studies, geophysical prospecting and test drilling. This helps in concentrating the field efforts in areas where greater potential exists and eliminating other zones, thus reducing the cost and time involved in exploration procedures. The advent of Geographical Information Systems (GIS) has added new opportunities in the field of ground water resources mapping and management. It helps in the integrating remotely sensed derived data with ancillary data to have more precise and correct information about various factors involved in the ground water resources management. Studies are being targeted in this direction by many authors (Roy1993, Murthy 2000 and Alain 2005).

The ground water regime is a dynamic system wherein water is absorbed at the surface of earth and eventually recycled back to the surface through the geological strata. In this process, various elements like relief, slope, ruggedness, depth and nature of weathering, thickness and the nature of deposited material, distribution of surface water bodies, river/stream network, precipitation, irrigation through canals, land use-land cover etc; also influence the ground water regime, besides the geologic frame work. Thus, the frame work in which the ground water occurs is as varied as that of the rock types, as intricate as their structural deformation and the geomorphic history and as complex as that of the balance among the litho logical, structural geomorphic and hydrologic and meteorological parameters.

Groundwater cannot be seen directly from the earth surface, so a variety of techniques can provide information on its potential occurrence. Existing methods of identifying potential groundwater areas using geophysical instruments are time consuming and costly. New technologies based on using remote sensing and Geographical Information System (GIS) was used in this study to identify potential groundwater areas, in mainly alluvium soil, almost all alluvial plains have a high potential of groundwater occurrence.

Remote Sensing and Geographic Information System has become one of the leading tools in the field of hydro geological science, which helps in assessing, monitoring and conserving groundwater resources. It allows manipulation and analysis of individual layer of spatial data. It is used for analyzing and modeling the interrelationship between the layers.

As a result of conflict, Darfur has unprecedented conditions of population, imposing high localized demand on water resources, which takes place in an area where rainfall last for only four months in the year and the prevailing geological conditions are unfavorable for groundwater storage. This situation is very clear in South Darfur State where the location and physical characteristics of rainfall, soils, topography, geology, and the high consumption rates led to depletion in groundwater resources.

Water is increasingly becoming a scarce resource while its demand continues to grow due to increased socio-economic activities coupled with the ever increasing population. The study area face shortage of water in dry season, the surface water only occurs during and shortly after the rainy season in intermittently flowing wadis.

The main objective of this study is to detect the groundwater potential in the study area using Remote Sensing data.

The specific objectives of this study were to:

1- Produce digital thematic maps for south Darfur state

2- Determine the characteristics and zones of potential groundwater in south Darfur state by integrating of remote sensed data and GIS techniques

Materials and Methods

Study area

Location

The study area lies within South Darfur State, between latitude 12 – 12.82 N and longitude 24– 25.2 E, it covers about 14685 km² (Fig 1). Rainfall in the region is unimodal occurring during the summer period between May and October every year. It is patchy, erratic and fluctuates considerably around the mean. Part of the precipitated rains return directly to the atmosphere due to high evaporation rates. A considerable part of the remaining water forms surface runoffs that partially replenish the groundwater. The limited storage capacity of the aquifers combined with the fact that there is almost overuse of groundwater, particularly in the IDPs (internally displaced persons) areas, suggest a shortly existence of no balance condition in the water budget.

Climate and Rainfall

The climate in South Darfur consists of a rainy season lasting approximately from May to October and dry season covering the rest of year. In south the rainy season starts earlier and ends later. Ninety percent of the annual precipitation (100-200 mm) falls during the rainy season and ten percent during May and October.

Temperature is lowest in December – January and highest in April – May. (Average value in Nyala is about 16°C and 39°C respectively. During dry season northerly winds prevail which especially during April and May often cause the traditional dust storms or Haboobs. In rainy season, winds are usually from the South West. Annual potential evapotranspiration is between 2000 and 3000 mm.

The water sources in Darfur region is mostly expressed by seasonal rivers, wadis and temporal ponds. A small portion of the flow is gathered and conserved in artificially excavated Ponds called Hafirs.

Runoff

The main drainage system in the state consist of wadi Azam and wadi Tiwal in west drain towards Lake Chad wadi Ibra in centre and Bahar al Arab in East, centre and South. Run off in the state is seasonal with exception of a few perennials stream in Jebel Mara area.

Water Resources

Generally, surface water only occurs during and shortly after the rainy season in intermittently flowing wadis. The most important aquifers are the medium to coarse grained parts in the 10-30m thick alluvial deposits. The clastic of Bagara basin form the second important aquifer. The volcanic and the fractured parts of the basement complex that are close to wadis (recharge) from aquifers of minor potential.

There are tow productive aquifers in south Darfur:

1-Alluvial deposits and the Baraga basin aquifer

Alluvial deposits are embedded in Basement complex and consist of rapidly alternating gravels, sand and clay ranging in thickness from 10-35m

2- Bagara basin aquifer consist of sand stone and Umm Ruwaba series

Geology

The flowing five rock types can be distinguished in south Darfur

1-Basement complex – Precambrian

2-Nubian Sand Stone –Cretaceous-Tertiary

3-Jebel Marra Volcanic –Tertiary-Quaternary

4-Superfical Deposits –Pleistocene-Recent

Data used and tools

The data used in this study included the Following:

The study area covered by four scenes (Land-sat Enhanced Thematic Mapper (2000) ETM-17951, ETM-17851, ETM-17751, and ETM-17651. The Land-sat ETM+7 data have the spatial resolution of 30 m for the six multispectral bands and 15 m for the panchromatic band, where the thermal band has been ignored in this study for its different characters and specifications. The data has been collected from the Remote Sensing Authority-Sudan.

The geological map of Sudan, rainfall data and boreholes data were used in the study.

Digital processing and GIS tasks were performed on a PC-based system using ERDAS Imagine 9.1, Arc-View 3.3 and Arc-GIS 9.1 (ESRI products) as GIS software.

As a rule, the investigations of the ground water identification using remote sensing techniques should be based mainly on the visual interpretation with a color viewer.

Data processing

1-satellite Image Mosaicing

Image mosaicking is the process by which several images are stitched together to create one large, cohesive image. Image files that need to be mosaicked must have the same spatial and spectral resolutions and the same number of bands. The study area consists of four pieces (four scenes). Mosaic four scenes (ETM-17951, ETM-17851, ETM-17751, and ETM-17651.) which cover the study area.

Enhancement Image processing package has been utilized, linear contrast Enhancement to make the image more interpretable and features better discernible. Directional edge detection techniques have yielded useful hydro-geomorphic information. Then subset of study area was performed. Image enhancement was processed through contrast stretching technique for the color composite images of triplet bands (7, 4, 1) and (4, 3, 2), beside the contrast stretching for the panchromatic band. Image fusion, by using the IHS transformation technique of the RGB images of triplet bands (7, 4 and 1); and (4, 3 and 2) with the panchromatic band in order to enhance the spectral and spatial characteristics of the images. In order to demarcate the groundwater potential zones of study area different thematic maps were prepared from remote sensing data, topographic maps, and rainfalls data. Fig. 2 shows the methodology chart.

2- Maps preparation

The thematic maps on Alluvial Deposits and lineaments were prepared using Land-sat data by visual interpretation. The drainage map was prepared from topo-sheet & satellite data. Also the Rainfalls map was prepared from rainfalls data (fig3). Using the thematic map of geology delineate from Geological map (fig4) of Sudan, slope map was generated from DEM (Fig.5). All primary input maps were digitized in Arc/View, GIS software package version 3.3 (ESRI products). The digitized maps were then edited to suite as an input variable in GIS analysis. This whole process has given an output of digital maps required for the study.

Ground water recharge computation

Precipitation in study area = 400 to 600 mm/y

Average Rainfall = 500 mm/y

Area of study region = 14685.10^9 km^2

Total amount of rainfall = area * average of rainfall

$= 500\ mm/10^3 * 14685\ km^2 * 10^6 = 7.3425 * 10^9\ m^3$

(Alain 2005)

A grid of rainfalls data points was used to compute theoretical water quantities on each watershed and determine the Rainfalls/Surface ratio (R/S) which represents the efficiency of each watershed linked to average rainfalls.

R/S of study area = 7342.5/14685 = 0.5

Computation of the potential recharge locations

The Spatial Analyst tools in the GIS software was used to generate the final recharge map of study area from integration of geology, slope, rainfall, fracture (fig6) and density layers as inputs (Fig 7).

Results and Discussion

The stream system can be considered as an outcrop of groundwater flow system if there is excess rainfall.

Alluvial water quantities are directly linked to rainfalls which determine runoff. The actual potential groundwater zones resulted from this analysis were found to be three types of zones

1-Very high potential zones (Recent Deposits & Umm Rowaba Series).

2-High potential zone (fractures)

3-No potential zone (Basement)

Results from study of the potential alluvial aquifer indicate that the alluvial deposits contain large amount of potable water. Very high groundwater potential zones was found in favorable biophysical environment –agriculture land use and water bodies located in flat rolling terrain having underlying alluvium and very low to moderate drainage density. Zone of no groundwater potential is however characterized by unfavorable conditions – very low to moderate annual rainfall, forest, urban and cleared land. Results were checked against the bore wells data which reflects the actual groundwater potential.

The wadi alluvial deposits play major role in superficial groundwater distribution. Alluvial water quantities are directly linked to rainfalls.

Most natural recharge to the aquifers occurs as precipitation that falls directly on the alluvial deposits, infiltration of runoff from adjacent slopes, and infiltration from the streams that cross the deposits.

1- Generation of thematic layers which include alluvial deposits, rainfalls, lineament &drainage.
2- Integration of thematic layers through GIS In the present study: groundwater prospects map has been generated by integration of geology, Lineament, rainfalls and slope layers.

The delineation of groundwater prospects zones was made of the integrated layers into different prospect zones. This provides a broad idea about the groundwater potentiality of the study area. From estimation of total amount of rainfall, sufficient quantities of groundwater resources were indicated; alluvial deposits fed by an upstream. Remote sensing method seems to be efficient in investigating water resources. With this method, researcher can get easily general information about features of topography, geomorphology, geology in order determine ground water aquifer for different purposes.

Table 1. Watershed hydro-geologic characteristic,Rainfall and Watershed (Alain, 2005)

Watershed	Surface in km^2	Rainfall in mm^3 /year	R/S
Wadi kaja	24.850	16.848	0.39
Wadi Azum	36.960	23.871	0.65
Wadi Sund	4.49	3.063	0.68
Wadi Ibra	15.180	8.713	0.57
Wadi Nyala	8.389	4.078	0.49
Wadi Alku	28.00	10.395	0.37
Wadi Howar	12.211	2.656	0.22

Map Of Study Area

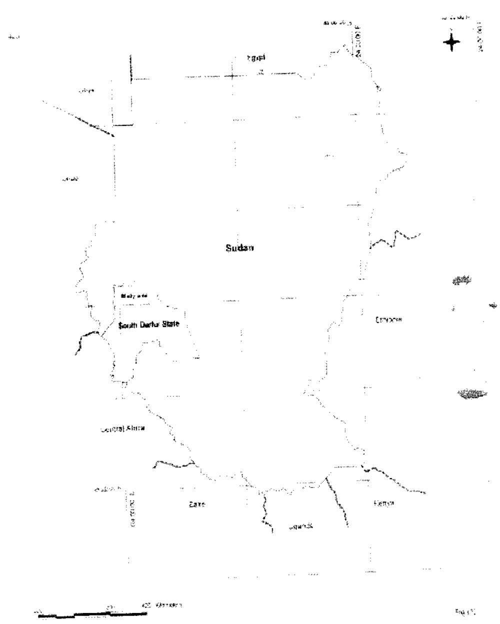

Figure 1. Location of the study area

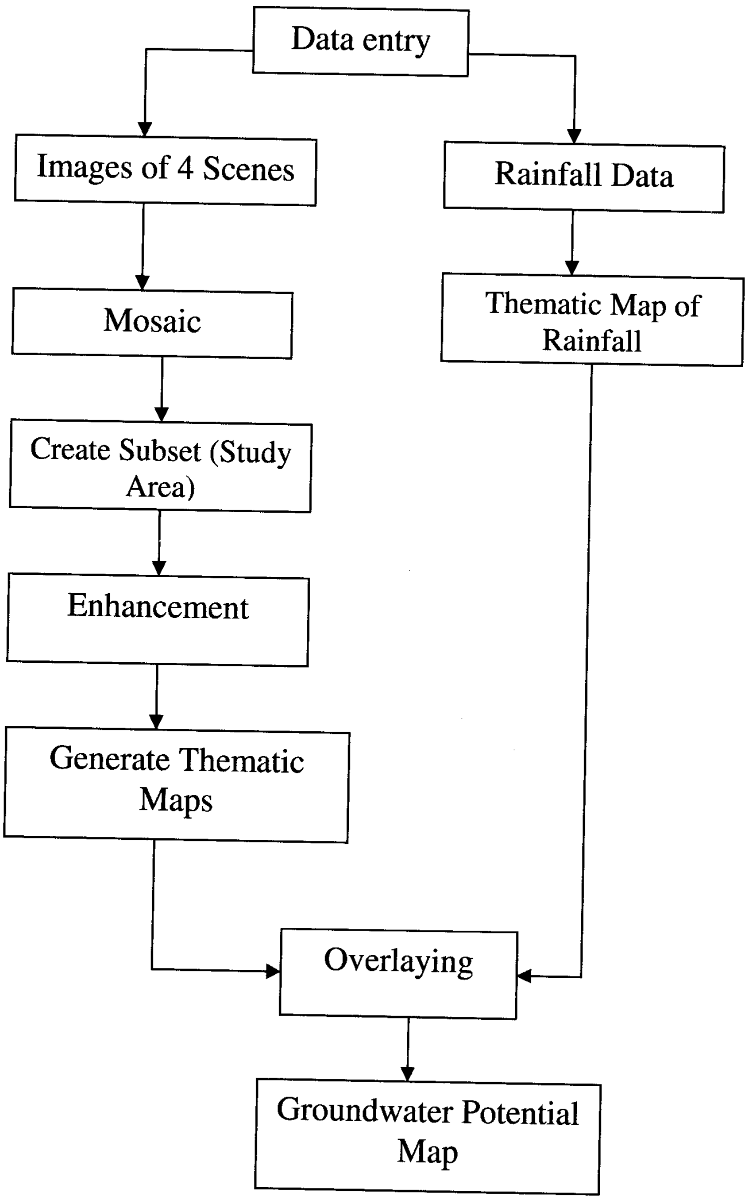

Figure2. Research plan flow chart

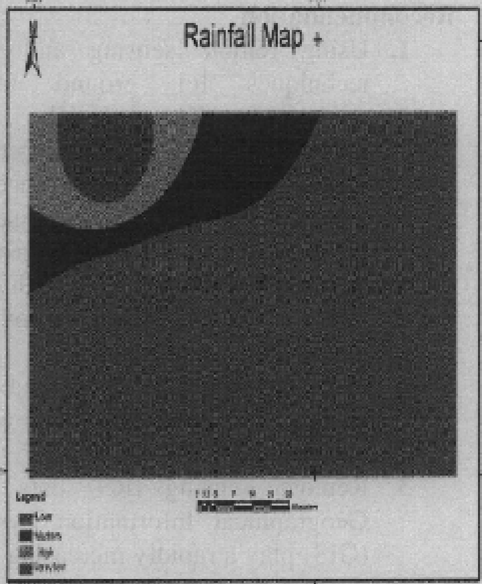

Figure3: rainfall map

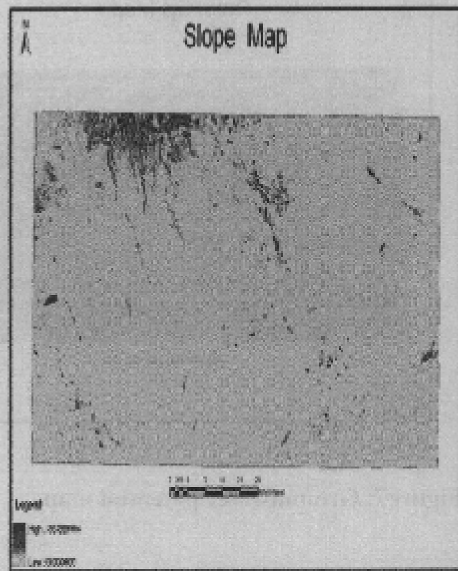

Figure5: slope map

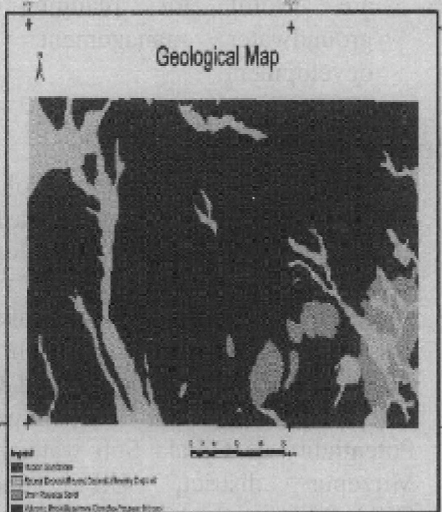

Figure 4: Geological Map

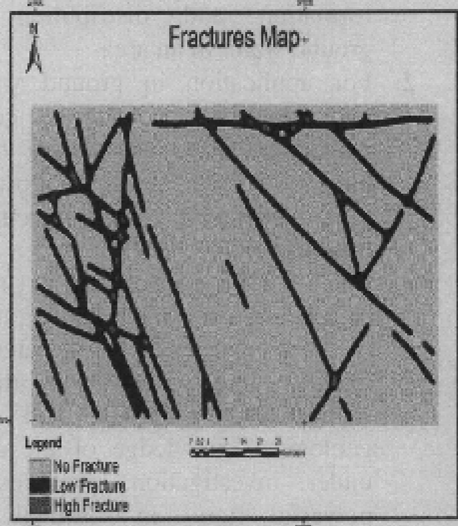

Figure6: fracture map

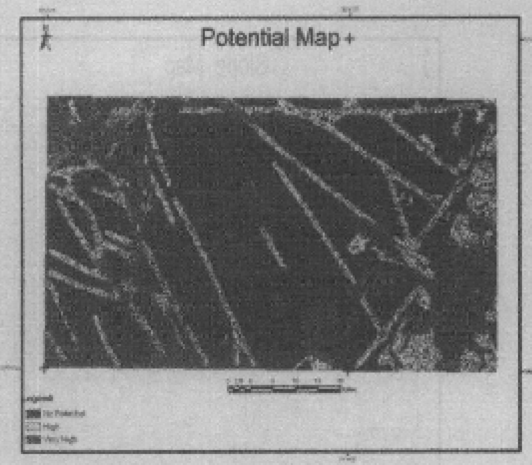

Figure7: Groundwater potential map

Conclusion

1. Remote sensing techniques are an important tool for investigating the ground water of hydro geological phenomena and found to be reliable indicators for identifying the formation and distribution of ground water in an area.
2. For application in ground water investigations, false color composites have advantages over black-and-white images, allowing more detailed and accurate interpretation.
3. This study undertaken in area clearly indicates that the integration of data extracted from satellite imagery into a GIS with those traditionally gathered, and the geological knowledge of the area under investigation, provides a powerful tool in groundwater search.
4. Geographic information systems provide an opportunity for integrating a great variety of data sources to assist in integrated cross-discipline decision making during groundwater exploration work.
5. Climactic data, particularly rainfall patterns in the region, was of significant importance to the study.

Recommendation

1. Using remote sensing and GIS techniques for ground water exploration are Quick and inexpensive technique for getting information on the occurrence of ground water, aids to select promising areas for further ground water exploration thus reducing field work and provides information on prospects.
2. It also minimizes the need for costly, time-consuming, and often hazardous ground surveying.
3. Remote Sensing (RS) data and Geographical Information System (GIS) play a rapidly increasing role in the field of hydrology and water resources development.
4. Integration of GIS & RS with the field investigation are good tools to produce relatively cheap, fast change detection maps, these maps are useful for planning of groundwater management and development.

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