Determining the Optimum Site of Small Dams Using Remote Sensing Techniques and GIS

Nawal K. Ghazal[1], Salman Rasool Salman[2]

University of Baghdad, College of Science, Iraq

Abstract: ***The dams regarded as an appropriate way for harvesting and storing water. The main aim of this research is to study the use of remote sensing and geographic information system (GIS) to locate the best site of small dam in the east part of Iraq, east Alkut city. Satellite image of Landsat 8 were used to extract the lineament structures of the studied area by using the Geomatical2014 software, the extracted lineaments were identical in lengths and number to the lineaments in the geological map of studied area. Digital elevation models (DEM) were used to draw the drainage pattern and slope map of the studied area by using ArcGIS software. The drainage pattern was dendritic of e6^{th} order and the slope of studied area was ranging from 0^o to 61^o, where the zero degree refers to the flat area. Finally, according to the analysis of the previous results, one site was suggested in 46^o 4' 11'' E longitude and 32^o 46' 29'' N latitude to be the best site in the studied area.***

Keywords: Determining Dam Site, Remote Sensing, GIS, DEM

1. Introduction

Water is a vital material for the existence of human beings, not only of drinking but also in other usages and requirements of human beings [1]. Dam is one of the ways to store water to use it whenever needed. Dam site selection in order to store water in the rainy seasons and use it in the drought seasons is an effective task to make the proper use of water in Iraq's situation. The most important point in the study of dams is the selection of the best spot of the basin in order to lower the costs and increase the benefits [2]. Remote Sensing and GIS technologies are well-established tools and are routinely used in applied hydrology, forestry, land use dynamics analyses, etc. Abilities of remote sensing technology in hydrology are to measure spatial, spectral, and temporal information and provide data on the state of the earth's surface. It provides observation of changes in hydrological states, which vary over both time and space that can be used to monitor hydrological conditions and changes [3]. Remote sensing data are fundamentally different, they incorporate spatial information. The rapidly developing GIS technology is a powerful tool to organize process and visualize spatial data. Thus, remote sensing and GIS can complement each other and enable hydrological models to be more physically based and more efficient [4]. Application of remote sensing and GIS techniques in hydrology is today one of the most effective approaches. Recently, remote sensing has provided valuable datasets to examine hydrological variables and morphological changes over large regions at different spatial and temporal scales. Many researchers over the past 20 years have focused on satellite imagery applications in hydrology [5].

2. Data and Software Used

1. Geological Map of soil type.
2. Digital elevation model (DEM) of 30m resolution.
3. Landsat 8 Satellite image of 30m resolution.
4. ArcGIS 10.2, PCI Geomatica 2014.

3. Describing of Studied Area

The studied area is a basin located in the east part of Iraq east of Alkut City, which is bounded from the east by the international Iraq-Iran boundaries. The basin represented by longitude (46^o9'20" N-46^o16'44" N) and by latitude (33^o4'37" N-32^o55'30" N) covering an area of (2098 km2) as shown in figure (1). The north-east part of the basin which is originated from Iran has higher elevations. About (98 km2) of this basin is locate in Iranian lands.

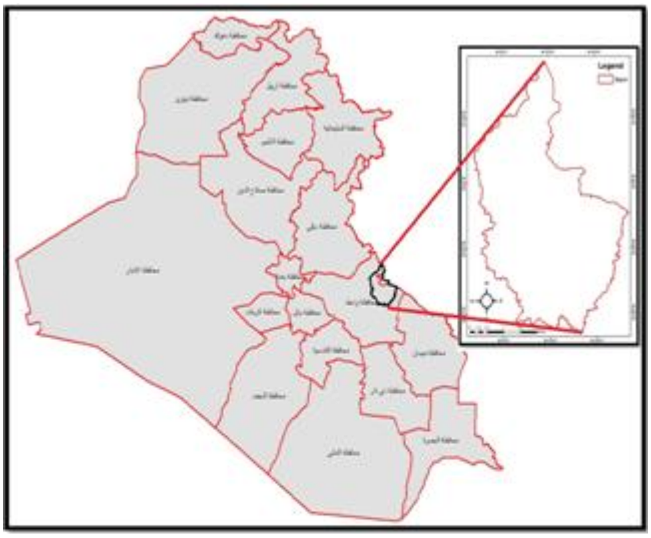

Figure 1: Location of studied area

4. Methodology of Work

1. Enhance the digital elevation model (DEM) to draw the drainage pattern and slop map utilizing the ArcGIS software.
2. Make the Geo reference process to the geological map by using ArcGIS software.
3. Using Landsat satellite image to extract the lineament structures utilizing PCI Geomatica software and comparing the results with lineaments in the geological map.
4. Select dam site according to the data that acquired from previous steps.

5. Drainage System

Drainage system is the pattern formed by streams, rivers and lakes in a drainage basin. As an indivisible part of the land, drainage system is an important component in GIS and in terrain analysis [6]. With the passage of time, a drainage system achieves a particular drainage pattern where its network of stream channels and tributaries is determined by local geologic factors. Drainage patterns are classified on the basis of their form and texture according to slope and structure. Their shape or pattern develops in response to the local topography and subsurface geology [7]. Drainage pattern can be extracted from the DEM using Arc Hydro extension within ArcGIS (Hydrology tools). The main steps include sink filling, identification of flow direction, calculation of flow accumulation and stream definition. The Hydrology tools are used to model the flow of water across a surface. Information about the shape of the earth's surface is useful for many fields, such as regional planning, agriculture, and forestry. These fields require an understanding of how water flows across an area and how changes in that area may affect that flow. When modeling the flow of water, we may want to know where the water came from and where it is going. The Hydrology tools can be applied individually or used in sequence to create a stream network. Drainage pattern can be drawn from digital elevation model (DEM) and by using ArcMap software as in figure (2) which illustrates the main steps for drawing drainage pattern.

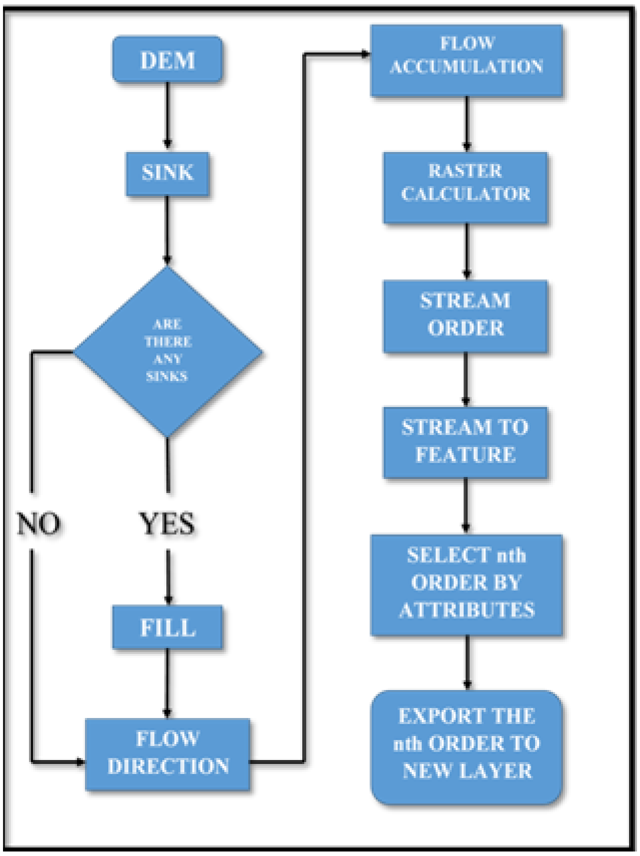

Figure 2: The main steps for drawing drainage pattern.

By applying these steps on a DEM of studied area it is found that the drainage pattern of studied area is a dendritic consists of six orders as shown in figure (3).

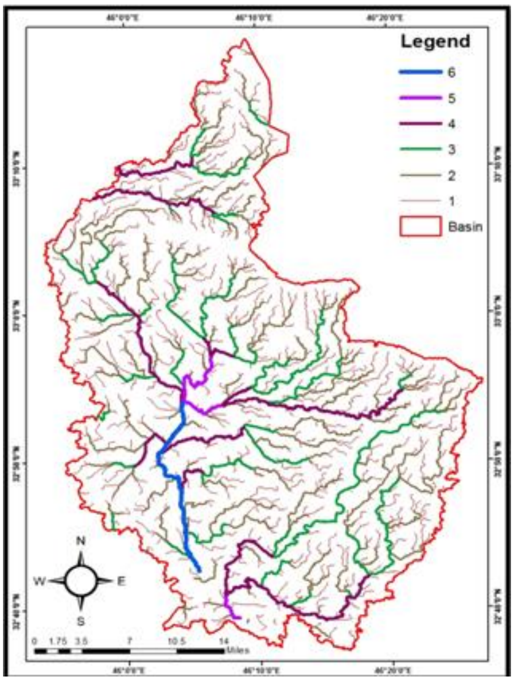

Figure 3: Drainage pattern of the studied area

6. Lineaments Extraction

Lineaments are defined as mapable linear surface features, which differ distinctly from the patterns of adjacent features and presumably reflect subsurface phenomena. The subsurface effect is valid if the origin of the lineament is controlled by geological structures such as faults and fractures. Other types of lineaments resulted from morphological effects (stream channels or drainage divides) or human effects (roads, field boundaries) can also exist in the region [8]. Lineament mapping is considered as a very important issue in different disciplines to solve certain problems in the area. For example, in site selection for construction a dams, bridges, roads, etc., for seismic and landslide risk assessment, for mineral exploration, for hot spring detection and hydrogeological research the nature and the pattern of the lineaments should be known [9]. Satellite images and aerial photographs are extensively used to extract lineaments for different purposes. Since satellite images are obtained from varying wavelength intervals of the electromagnetic spectrum, they are considered to be a better tool to discriminate the lineaments and to produce better information than conventional aerial photographs [10]. The lineament structures were extracted automatically by using Lineament Extraction algorithm in PCI Geomatica software, where this algorithm extracts linear features from an image and records the polylines in a vector layer. Although this module is designed for extracting lineaments from radar images, it can also be used on optical images to extract curve-linear features. 6th band of Landsat 8 satellite image of less than 10% clouds were used. The result of extraction is shown in figure (4) which shows the distribution of the lineament structures through the studied area.

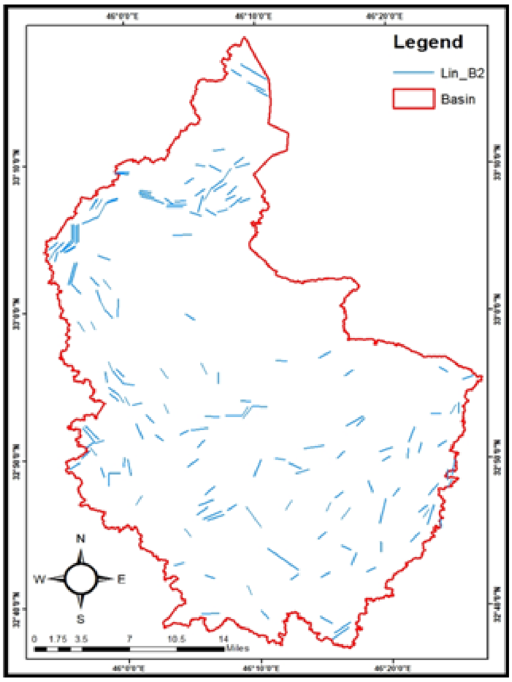

Figure 4: Lineament structures extracted from Landsat 8 satellite image

These lineament structures were extracted from 6th band of Landsat 8 satellite image because this band is useful for distinguish the geological features such as rocks types and minerals. Since the lineaments are appear in geological map geological map were used to compare between the lineaments in geological map and that extracted from satellite image and they were identical in lengths and numbers.

7. Slope Map

The slope map retrieves the change in elevation over a certain distance. The slope map of studied area extracted from the DEM by using Slope tool in ArcGIS software. This tool expresses the change in elevation in degree, where the large degree refers to high slope and the small degree refers to the small slope. After applying Slope tool the result shown in figure (5) is got.

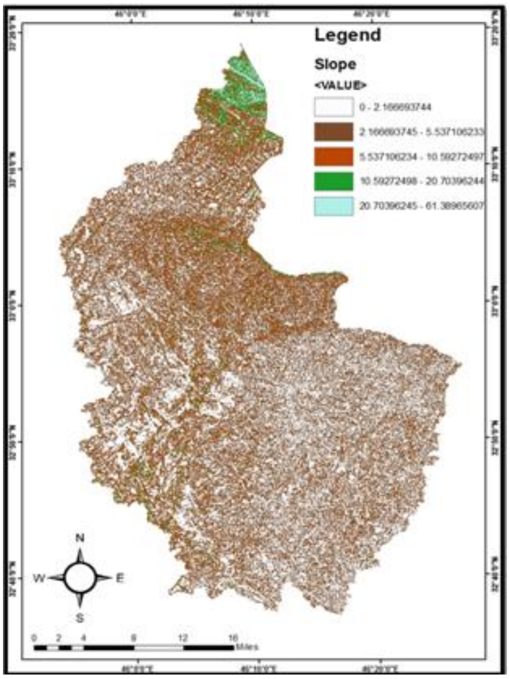

Figure 5: Slope map of studied area

As shown in figure (5), the slope of studied area ranging from 0^{o} to 61^{o} where the zero degree refers to the flat area. It is needed to get the low slope areas only, so that Raster Calculator tool were used to extract the areas that are flat by using the following expression in the tool ("slop map == 0") and the result is no data if the area has a slope as shown in figure (6).

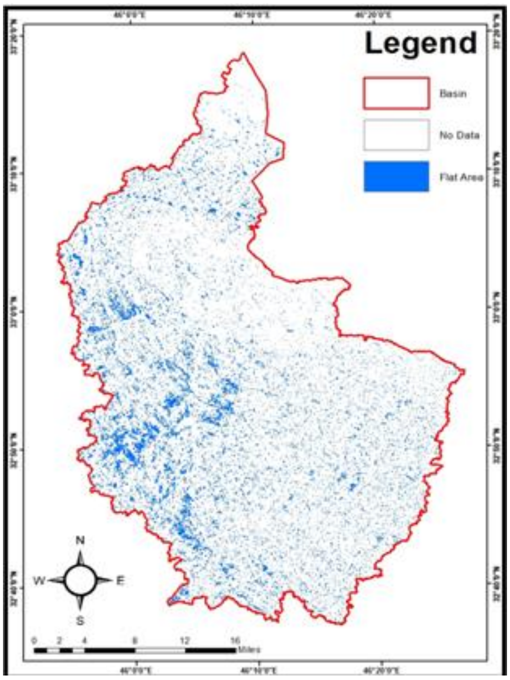

Figure 6: Flat areas

8. Results and Discussion

Lineament structures regarded as one of the impediments that affect the choosing of the dam site because it is a fault generated due to the underlying of geological structure. So that in determining dam site, lineaments or lineaments intersection must be avoided because it cause the collapse of the dam. The dam site must be in flat area or in area of small slope to facilitate the calculation of the amount of water collected by the dam. Also the dam site must be located on stream of high order to collect large amount of water. Due to the previous considerations three layer were combined, 6th order, lineaments, and flat area layers as shown in figure (7).

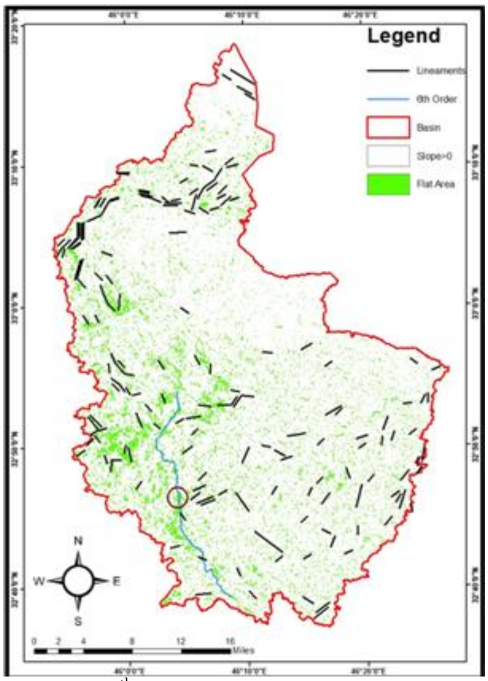

Figure 7: 6th Order, lineaments, and flat layers

As noticed from figure (7) that the encircled area has no lineaments, no slope, and located on the higher stream order so that this area studied by taking many profile across the stream (The Profiles is a 3D analyst tool show the change in elevation of a surface along a line). One dam site was suggested to be the best site and has the profile shape illustrated in figure (8).

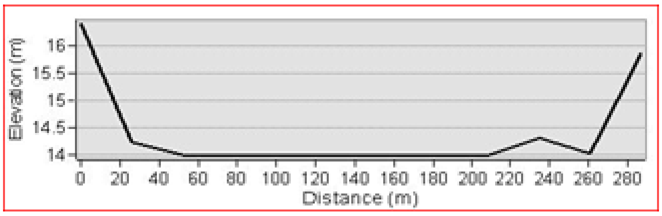

Figure 8: Cross sectional profile of the suggested dam site

This site is located on (46^o 4' 11" E and 32^o 46' 29" N) as illustrated in figure (9).

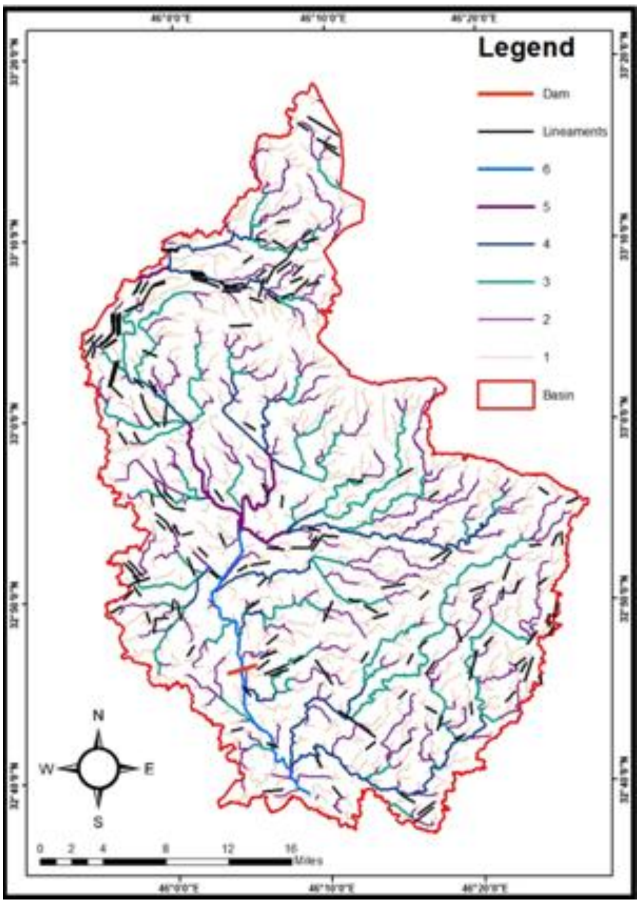

Figure 9: Suggested dam site

9. Conclusions

1. The GIS can be utilized in two ways. First, to input, store, organize and analyze the available data. Second, the spatial analysis, visualization and query capabilities of GIS can be employed in selecting the dam site for a precondition set of criteria.
2. GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage system delineation.
3. Depending on the size of the DEM, processes like Filling Sinks and Flow accumulation can take from few minutes to up to one hour or more.

4. The first stage in any hydrology processing is to fill any pits in the DEM using the fill tool to ensure that water can flow over the surface without becoming 'stuck' in an erroneous hole in the DEM.
5. In order to check the reliability of the automatic lineament extraction, manual lineament extraction is referred as a reference.
6. Profiles can help in studying the change in elevation of a surface along a line.

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Authors Profiles

Salman R. Salman, M.SC Student in Physics Department, College of Science, Baghdad University. His research interest includes the**,** Remote Sensing and GIS.