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LOCATING DAM SITES FOR WATER HARVESTING: CASE STUDY OF NAJAF PROVINCE, IRAQ

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The Middle East is considered as an arid area. Iraq was an exception due to the presence of the Tigris and Euphrates Rivers. After 1970, the flow of these rivers started to decrease due to climate change and building of dams in the upper parts of the catchments of the rivers. Now, Iraq is experiencing water shortage problems. Rain water harvesting will definitely minimize the effect of water shortage problems. In this research an arid area was selected (al Najaf) to find out the best sites for water harvesting using GIS techniques. The good agreement between the results from a simple GIS model and observations in cases such as al Najaf Sea is indicating a promising future for GIS application in hydrological modeling. The present study proposed a function formula of estimating suitable dam site using existing geographic information map such as the digital elevation maps. It is expected that it will save time, cost and work force. Finally, through the contour map of the study area, the lowest three elevation values at the governorate level were observed (20, 40, 60m). Based on these values, three possibilities were suggested to select the dam sites.

INTRODUCTION

Water is a vital material for all usages and requirements of human beings. It is a renewable but finite resource that is fundamental to human existence and human activities through its' direct relationship with drinking, agriculture, sanitation, and economic development. This is more important in arid areas. Iraq which is located in the Middle East (Figure 1) is experiencing water shortage problems now due to climate change and building of dams in the upper parts of the catchments of the Tigris and Euphrates Rivers (Al-Ansari, 2016, 2019, Abbas et al, 2016 a,b,c,d,e, Osman et al., 2017 a,b,c). To minimize the effect of water shortage problems in Iraq, rain water harvesting can be used. To check the validity of this technique, it should be tested in an arid area. Al Najaf governorate was selected because it is located in the southwestern part of Iraq and it has an arid climate (Figure 1). According to the precipitation characteristics of al Najaf governorate, climate change trends show that annual rainfall characteristic has fluctuated, so it is difficult to predict and manage water resources including water use and flood prevention. The dam mainly consists of reservoirs built over the path of water flow to store water, and it provides a great benefit to humankind (Raheem and Khan, 2002, Ghazal1 and Salman, 2015, Directorate of Urban Planning, 2007, Hashim and Hadi, 2014, Al Jubaely et al, 2016, Iftikhar et al, 2016).

There were many studies in this field which developed the functional formula to determine suitable dam sites using the weighting method and overlapping for each parameter (Tai et al, 2017). Ghazal1 and Salman (2015) according to the analysis of their results suggested one site to be located in 46^{o} 4' 11" E longitude and 32^{o} 46' 29" N latitude as the best site in the studied area. Hashim and Hadi (2014) introduced a study about the same problem, by developing a model for selecting an optimum water harvesting dam location among available locations in a watershed. This was achieved using an integrated GIS-VBA (Geographical Information System – Visual Basic for Application). Al Jubaely et al (2016) proved the outcomes of locating dams within the study area and indicated that the developed criteria were sensitive to physical, hydrological environmental and economic settings on the study area. Water resources are secured through the dam by effective operation, and a dam has an important function to supply the water in case of drought season. Therefore, the present study proposed a function formula for estimating suitable dam sites using existing geographic information map digital elevation maps. It is expected that it could save time, cost and workforce.

STUDY AREA

The governorate of Najaf is located in southwestern Iraq and has borders with Saudi Arabia. It also shares internal boundaries with the governorates of Anbar, Kerbala, Babil, Qadissiya, and Muthanna (Figure 1). Desert plains dominate the landscape of the governorate. A ribbon of irrigated farmland runs along the course of the Euphrates River, which intersects the governorate near its eastern border. Najaf has a typical dry desert climate. The summers are hot and dry, while precipitation is very low and limited to the winter months. The governorate receives an average amount of the only 99 mm of rainfall annually. Its area is 28,824 km^2 with an estimated population of 1,220,145 inhabitants (Figures 1 and 2). The main hydrological features are the perennial Al Kufa River which represents the main source of agriculture and drinking water.

MATERIALS AND METHODS

The digital elevation model of the al Najaf governorate was used (Figure 3). A number of important properties from the model (such as gradient direction and the Earth's shadow) were derived, which

represent the input data to extract the hydrological characteristics such as determining the flow direction. It was also used to calculate the flow accumulation, producing the output map of streams to determine the valleys in the region, and the production of basin map to determine the basin of nutrition. Finally, the locations of the small dams can be selected using Arc GIS (ver. 10.5) (Geographic Information System Programming, 2002, GIS manual Laboratory, 2017).

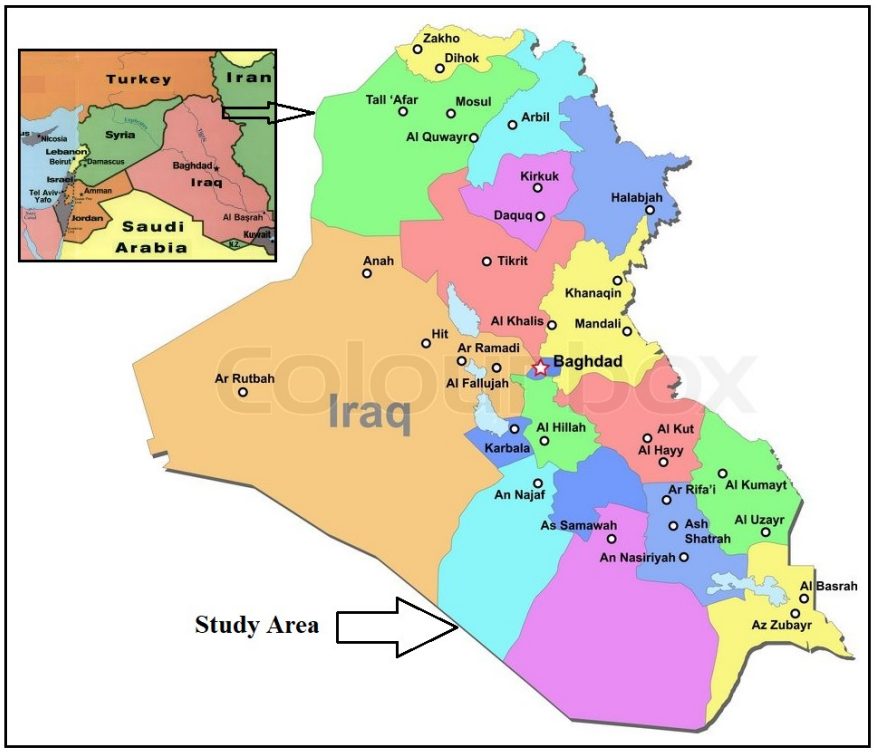

Figure 1. Map of Iraq and the location of the study area.

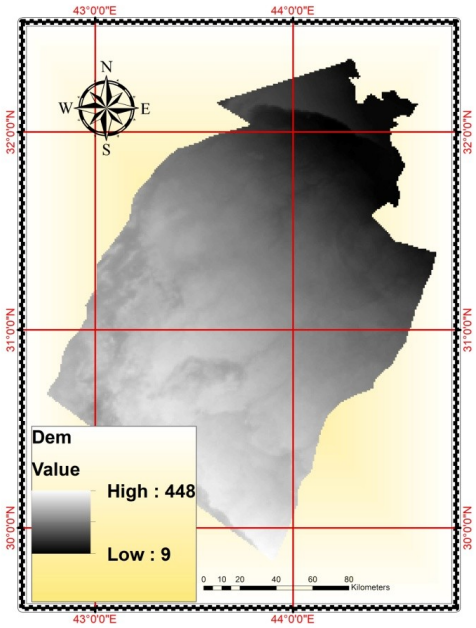

Figure 2. Land Digital Elevation Model (DEM) of study area [4]

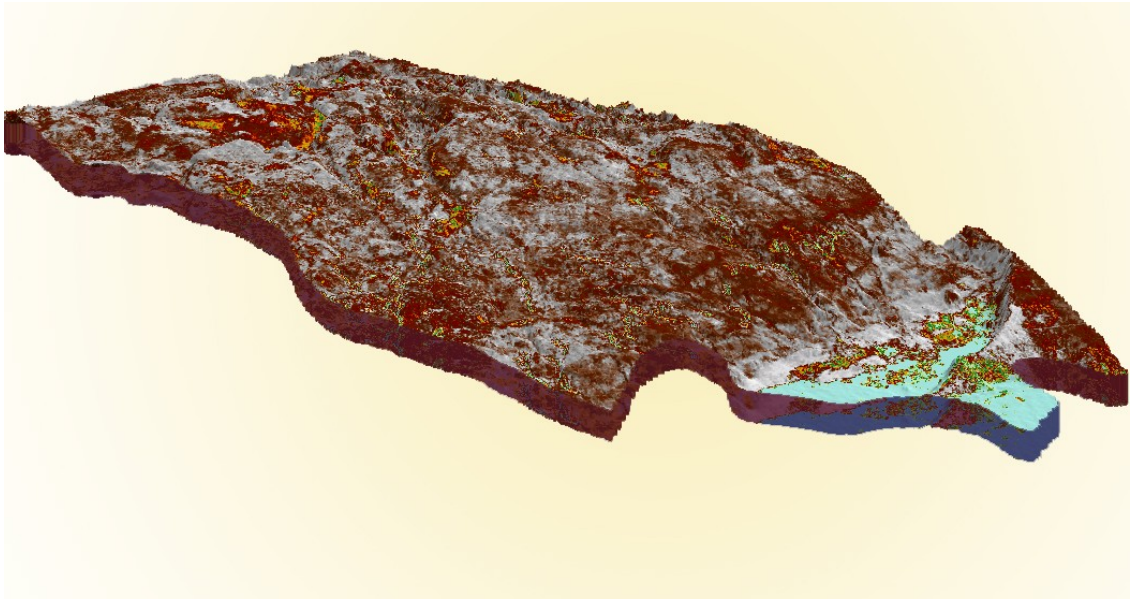

Figure 3. 3D stereoscopic shape of the study area.

RESULTS AND DISCUSSION

Analysis of the hydrological properties of a surface of the Earth means a group of properties. These are responsible for controlling the movement of rain and surface water on the ground into a basin called drainage basin. It is one of the most important applications of the ground surface analysis. The shape of the earth's surface determines the direction of the water flow. It is possible to automatically delineate a drainage system and quantify its characteristics using a digital elevation model (DEM) as an input. The following graphics illustrate the steps involved in calculating the watershed and stream network from a DEM map. The hydrologic modeling tools in the ArcGIS Spatial Analyst extension toolbox provide methods for describing the physical components of a surface. This includes identifying stream order (Figure 4), flow direction (Figure 5), calculating flow accumulation (Figure 6), and delineate watersheds. It extracts the information about where water comes from and where it is going across each cell of a raster data. Besides, DEM hydrology analysis model can be used to identify the extension of a flood, location of the sources of pollution of a river. It also forecasts how changes in that area may affect the flow. This is useful in many fields, such as regional planning, agriculture, and forestry. As far as the study area is concerned, Figures 4, 5, and 6 show the stream order, flow direction and accumulation depending on GIS programming.

Aspect

The aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction. The values of numeric elements range from (0 to 360) indicating the direction where the Earth is facing, while the value (- 1) is used to indicate the flat Earth. Figure 7 shows the aspect map.

Slope

The slope is the first derivative of a DEM. It represents the rate of change of elevation for each digital elevation model (DEM) cell over a certain distance. The slope map of this study was extracted from the DEM using the slope tool in ArcGIS software. This tool expresses the change in elevation in

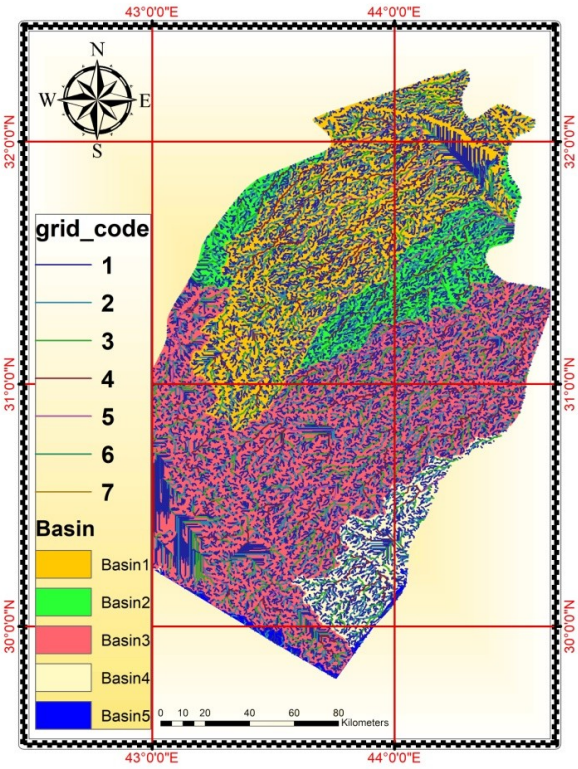

Figure 4. Stream order within the study area.

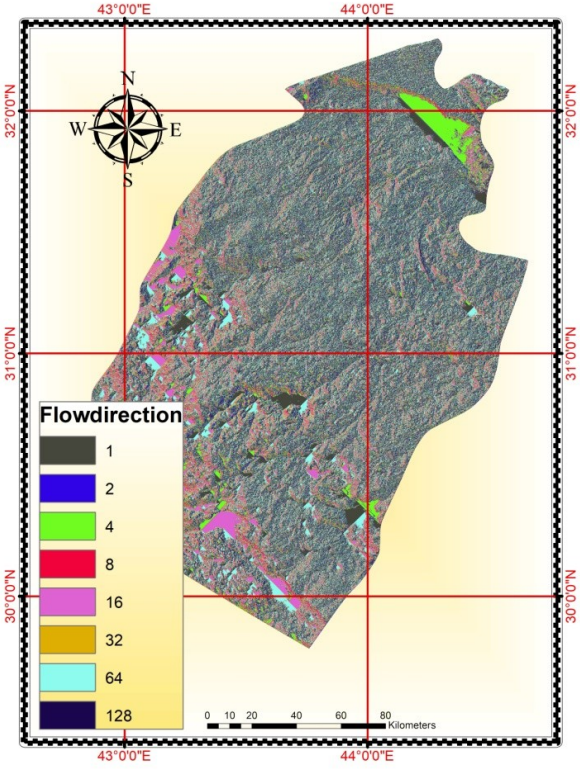

Figure 5. Flow direction within the study area.

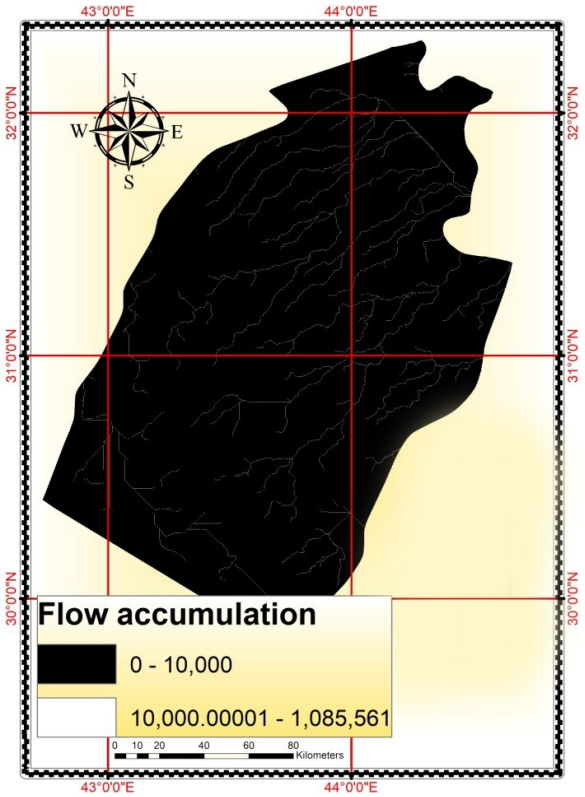

Figure 6. Flow accumulation within the study area.

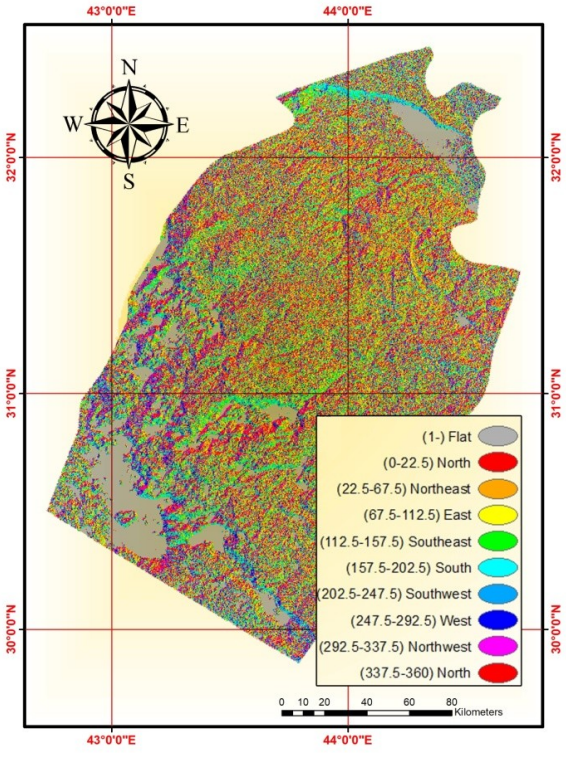

Figure7. Aspect map of the area.

degrees, where the large value refers to a high slope, and the small refers to the small slope. After applying the Slope tool, the result shown in Figure 8. The slope is useful when designing canals, channels and when choosing the appropriate places to expand urbanism. It also plays an important role in defining and extracting geomorphologic phenomena from models of Digital Altitude

Hill shade

It is used to change the illumination angle when applying a shaded hillshade to a digital elevation model (DEM). It is the result of the sun at a height of 45^0 and an angle of azimuth 315^0 and its value ranges from (0 - 255). Zero does not face the light of the sun while 255 directly face the light of the sun. Digital product map is shown in Figure 9.

Contour map

Through the contour map of the study area, the lowest three elevation values at the governorate level were observed (20, 40, 60) (Figures 10 and 11). Based on these values, three possibilities were suggested to select dam sites as shown in Figure 11. In this Figure, green star, red and pink are the first, second and third choices respectively.

CONCLUSIONS

In view of the water shortage problems in Iraq, water harvesting technique can minimize the effect of this problem. To validate the effect of water harvesting, an arid area was chosen to find the best locations of dams for water harvesting. Al Najaf governorates was chosen as an arid area. GIS tools

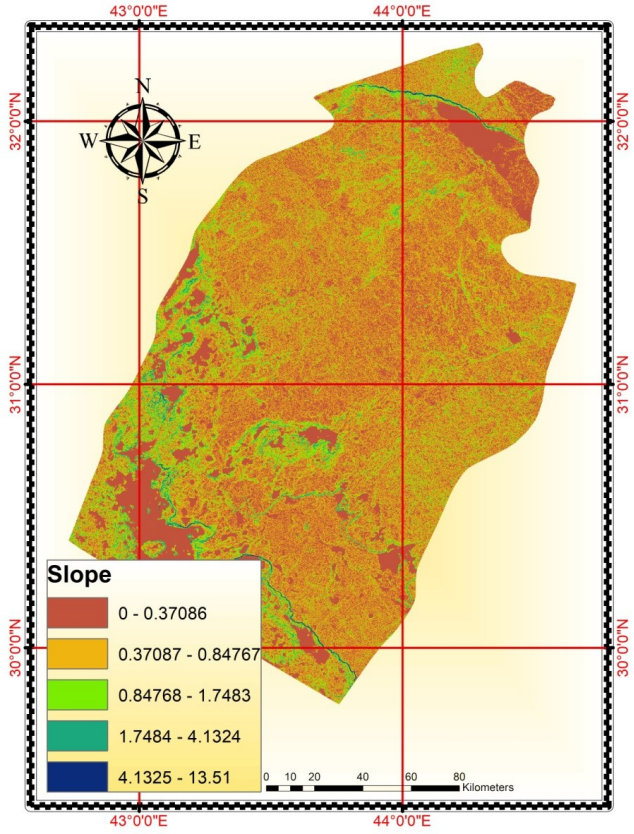

Figure 8. Slope map of the area.

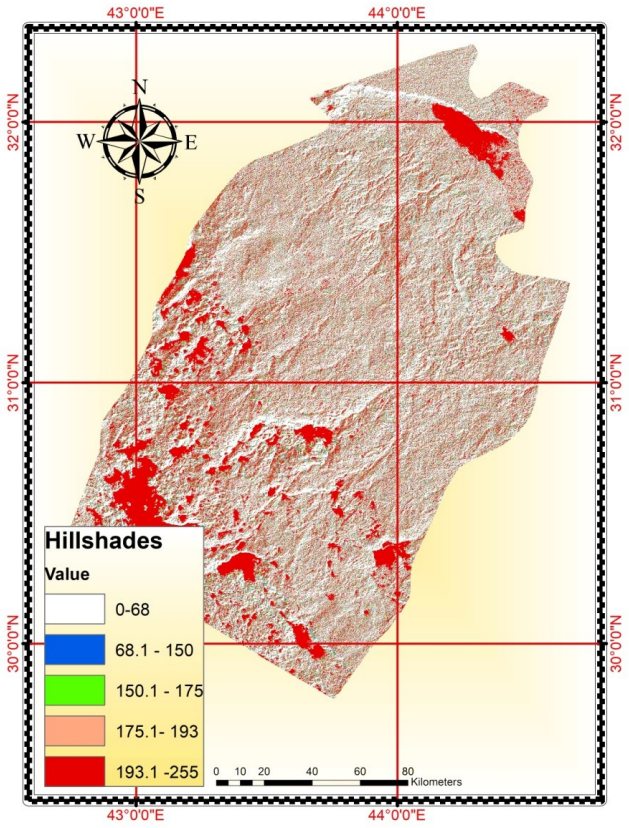

Figure 9. Hill shade of the studied area

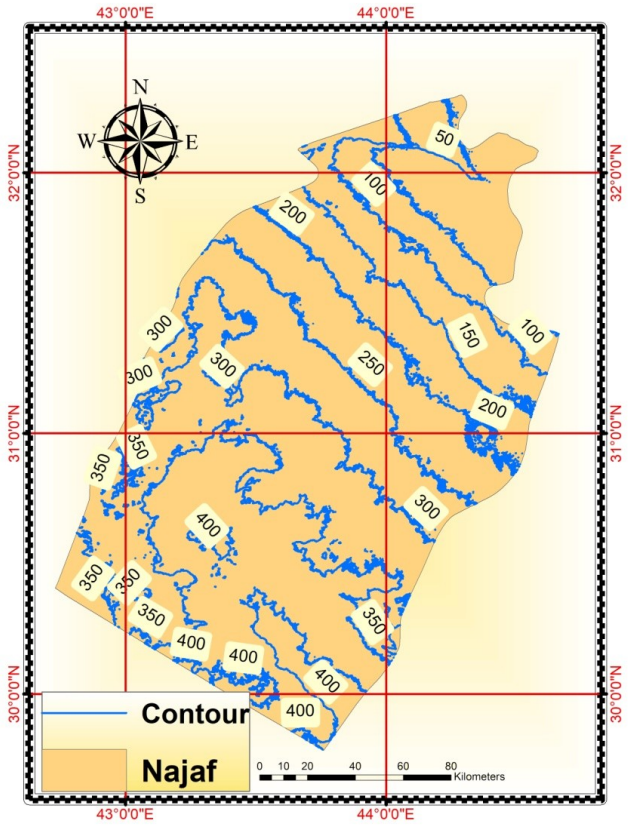

Figure10. Contour map of the area.

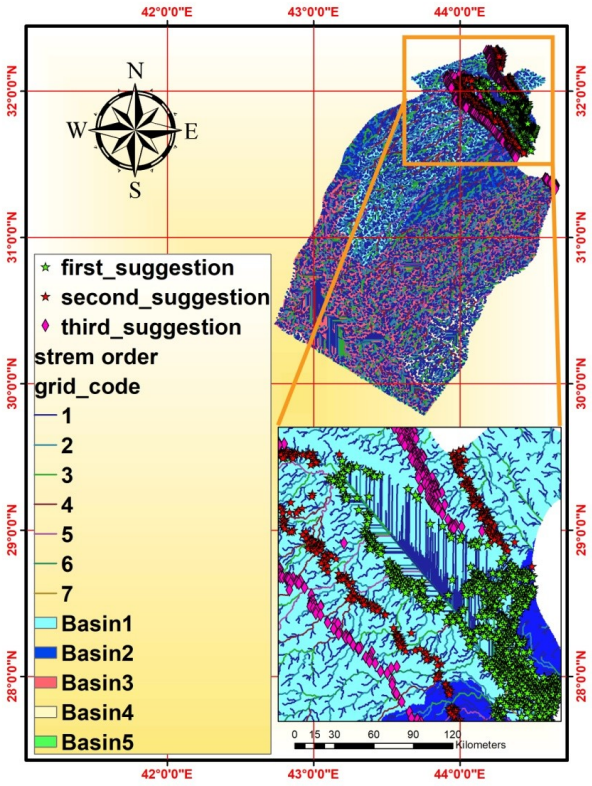

Figure 11. Location of suggested water harvesting dams.

were used for this purpose. The GIS program is one of the most modern technologies used in most scientific research, which is used as an effective research tool. Using the digital elevation model (DEM) we can identify many of the hydrological characteristics of the Earth's surface. Knowing the hydrological characteristics of the Earth's surface enables us to know the location of the valleys in the study area, the basins and the direction of flow. By knowing the locations of the basins in the study area, GIS applications enable us to propose possible locations of dam sites. Using this technique, three suggested locations for the suggested water harvesting dams were located.

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