

WATER HARVESTING SEARCH IN NINEVAH GOVERNORATE USING REMOTE SENSING DATA

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ABSTRACT

In the framework of the methodological approach provided to the water harvesting search programme, for the Ninevah Governorate, a comprehensive remote sensing methodology was develop to identify potential sites for water harvesting exploitation. To over come the problem we must find solutions or some resources which if it managed properly can enhance our supply and reduce the pressure on our limited water resources, specially after Iraq is being classified as one of the Arab countries which is of critical water resources.

Complete coverage of the Ninevah Governorate by the landsat imagery has been analyzed, to determine major and minor landform characteristics, and its relation with water harvesting search concept. Landsat7 imagery proved particularly useful for revealing landforms within Al-Jazeera Region. Some of these landforms were known or suspected from ground studies, but the majority was revealed for the first time during the landsat investigations. These data were superimposed on the landsat image and kept as background data.

Water harvesting concept can be carried out in different ways and can be stored in different methods too. In this study, the author looks into two different methods for rain water harvesting. These methods are compatible with the best management practice in agriculture or domestic use. In order to reach the fundamental basis of this study, the hydrological systems were monitored in Al-Jazeera Region. The emphasis was on ephemeral stream valleys, and alluvial fans, which located within the gently sloping surfaces of Al-Jazeera Region. By drawing some hydrogeomorphic maps and conducting analyses and measurments, a suitable site was determined to construct a surface run off collection dams and or converted channels on two main valleys (Wadi Al-Tharthar and Al-Ajij). Best locations to construct barriers and stony ditches on the main flow of alluvial fans were determined, to recharge the aquifers beneath these surfaces, which located in both flanks of Sinjar Mounatin. These data were utilized to draw thematic hydro-geomorphological maps to improve landuse and vegetation cover in the study region as a whole which suffers from deficiency in this concern.

البحث عن حصاد المياه في محافظة نينوى باستخدام معطيات التحسس النائي

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المستخلص:

في إطار تقديم مقترحات عملية إلى برنامج حصاد المياه لمحافظة نينوى، تم إعداد دراسة منهجية شاملة باستخدام معطيات التحسس النائي لتحديد مواقع محتملة لاستثمار حصاد المياه. وللتغلب على هذه المشكلة، يتطلب إيجاد حلول أو بعض المصادر بحيث إذا استخدمت بشكل صحيح سوف تساهم في توفير المصادر وتقليل الضغط عن مصادرها المائية المحدودة، خاصة بعد أن تم تصنيف العراق واحدا من الأقطار العربية ذات المصادر المائية الحرجة. تم تحليل المرئيات الفضائية الحديثة التي تغطي معظم محافظة نينوى وذلك لتحديد خصائص مظاهر الأشكال الأرضية كافة وعلاقتها مع فكرة حصاد المياه. إن مرئيات راسم الخرائط الموضوعي للقمر الاصطناعي الأمريكي لاندسات كانت ذات فائدة كبيرة في تحديد هذه الأشكال الأرضية في إقليم الجزيرة. إن بعض هذه الأشكال كانت معروفة من الدراسات الميدانية ولكن معظمها قد اكتشف للمرة الأولى من خلال نتائج تحليل المرئيات الفضائية. تم وضع وحفظ هذه المعطيات كقاعدة معلومات مع المرئيات الفضائية يمكن تنفيذ مفهوم حصاد المياه بطرق مختلفة و تخزينها أيضا بأساليب مختلفة. في هذه

الدراسة تم الإمعان في أسلوبين مختلفين من حصاد مياه الأمطار مصاحباً ذلك بتحليلات هايدرو-هندسية. ولأجل التوصل إلى المبادئ الأساسية لفكرة حصاد المياه المتبعة تم مراقبة الأنظمة الهيدرولوجية في إقليم الجزيرة، إذ كان التركيز على كل من مجاري الوديان الموسمية سريعة الجريان وسطوح المراوح الفيضية في الأراضي المنحدرة لإقليم الجزيرة. تم إجراء التحاليل والقياسات وإعداد الخرائط الخاصة لتحديد المواقع المثلى لإقامة السدود الصغيرة أو تحويل الوديان المقترحة لكل من وادي الثرثار والعبيج. فضلاً عن تحديد أفضل المواقع لإقامة الحواجز والقواطع الحجرية على المجرى الرئيس للمراوح الفيضية وذلك لتعزيز الخزانات الجوفية تحت سطوح هذه المراوح والمتواجدة على طرفي جبل سنجار. استخدمت هذه المعطيات في إعداد خرائط غرضية هايدرو-جيوغرافية لتساهم في تطوير استخدامات الأرض والغطاء الأرضي في عموم منطقة الدراسة والتي تعاني قصوراً في هذا المجال.

INTRODUCTION:

As a resource, rain water harvesting system is gaining increasing importance in the supply of water to sub-districts in the drier regions of Iraq, where surface water are very scarce or absent for agriculture or domestic use. The combination of population growth, economic and agriculture development and an arid to semi-arid climate results in over exploitation of the water resources in many remote areas of Iraqi territory (Rafeek et al., 2000).

The present landscape of Ninevah Governorate located in the northwestern part of Iraq, between longitudes 41° 30' – 44 ° 30' and latitudes 35° 00' – 37 ° 00', represents one of the most varied and complex geomorphic landscapes in Iraq (Fig. 1), in which geomorphic agent represents the main factors in the special distribution of soil types, lithological escarpments and the existing landuse and landform patterns (Al-Dagastani, 2007).

The interest of local authorities in Ninevah Governorate in rain water harvesting search, development and management, is

mainly to find solutions or some resources which if it managed properly can enhance our supply and reduce the pressure on our limited water resources. The aim of this study is to look into two methods of rain water harvesting applied to the Iraqi northwestern Al-Jazeera Region (Fig. 2), which suffers from deficiency in this concern using remote sensing techniques.

These methods are used to develop general principles for the production of local thematic maps leading to preparation of water harvesting search programme for the drier regions in Iraq. These methods are compatible with best management practice in agriculture or domestic use.

GEOLOGY, PHYSIOGRAPHY, HYDROLOGY AND CLIMATE OF THE NINEVAH GOVERNORATE

Geology:

The fundamental framework of the structure and stratigraphy of northern and northwestern Iraq are part of the Taurus-Zagros Belt developed during the collision

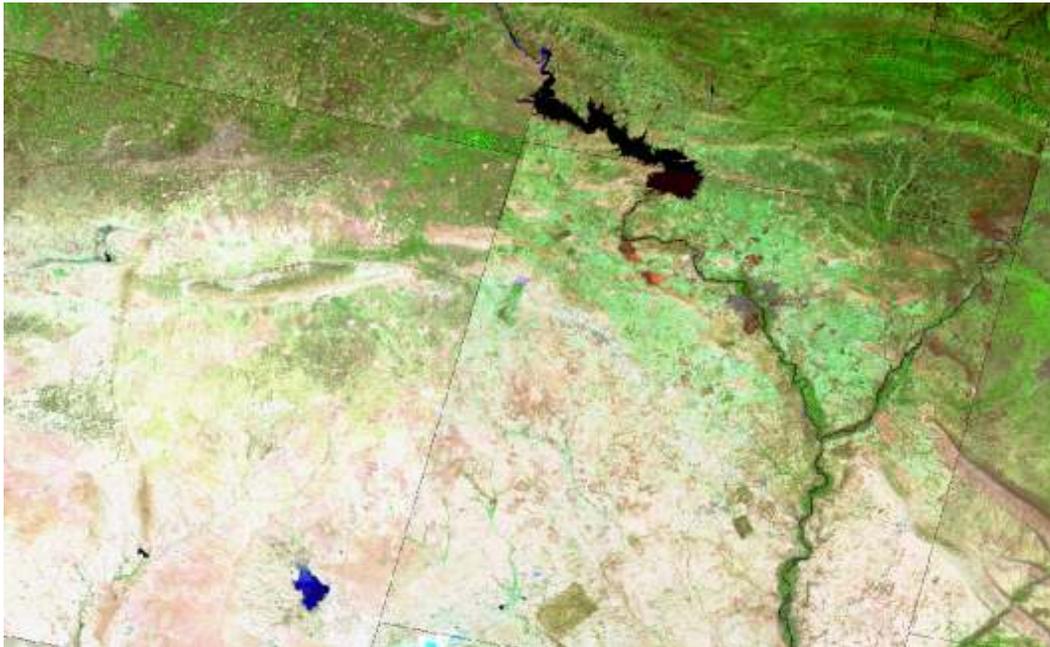


Fig-1: Coverage of Ninevah Governorate by normal color Landsat imagery.

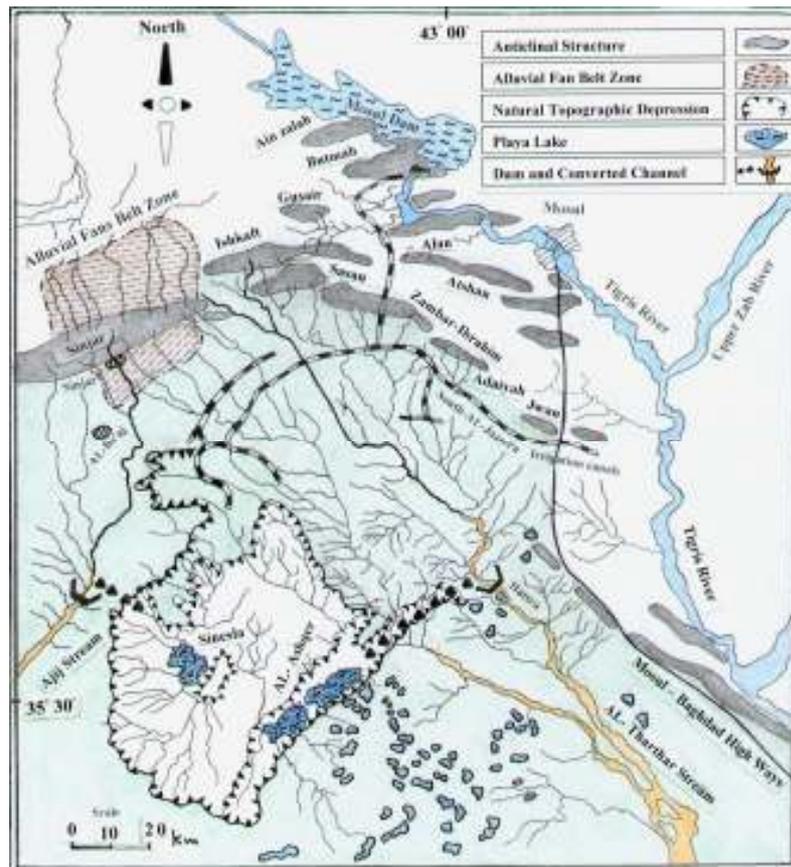


Fig.-2: Locations of rainwater harvesting methods applied to Al-Jazeera Region.

of the Arabian Plate with the Turkish and Iranian plates (Eurasian Plate) that culminated in the Miocene-Pliocene (Senger and Kidd, 1979; Daly, 1989; Numan, 2001; Jassim and Goff, 2006). Some major faults and lineaments trends parallel to the fold axes and other cut diagonally across the axes. These faults are very significant in ground water movements.

Triassic and Pliocene formations crop out in the Simple Folded Zone, and consist mainly of sedimentary rocks, with a predominance of limestone, dolomitic limestone, sandstone and gypsum. These formations are very significant because of both intensive karst phenomena and the large volume of potential ground water storage. Recent Quaternary deposits fill the valleys and the footslopes and also cover the older Tertiary formations in the plains (Buday and Jassim, 1987).

Physiography:

Ninevah Governorate can be divided into three main physiographic zones, namely:
Structurally controlled folded topography.
Internal gently sloping polygenetic plains.
Sloping surfaces of upper Al-Jazeera plain.

The north-northeastern part of the study area (Fig. 2) is characterized by an en echelon anticlinal system (the Low and High Folded Zone), which gives to a relief with a general orientation NW-SE and E-W respectively (Al-Kadhimi et al., 1996). Heights up to 1460 m a.s.l. are reached in Sinjar Anticline. Wider synclinal system occurs in this zone, which are strongly influenced by tectonic control. Vegetation coverage is rather sparse at high anticlinal system (e.g. Sinjar and Bashiqa) and widespread in the synclinal plains, constituted of both seasonal winter crop lands and mixed crops and pasture lands.

The central part is dominated by low alluvial plains of the Tigris River and its tributaries,

surrounded by gently sloping fluvial river terraces at low and high levels. Vegetation cover is widespread constituted

of both seasonal vegetables and irrigated lands. Average altitude is between 250-400 m a.s.l.

The western part is dominated by a smoother morphology of the upper Al-Jazeera, the area being characterized by seasonal dry valleys, depression salt areas (playa lakes), karstic landforms with sinkholes and with some aeolian sand deposits without distinct dune forms, so that it becomes possible to evaluate the rain water harvesting selection systems in this zone.

Significant surface water resources occur in the Ninevah Governorate. The major perennial rivers are the Tigris (which runs at the middle in a NW-SE orientation) and the Upper Zab (which runs at the eastern border in a NNE-SSW orientation), and have their origins outside Iraq.

Ultimately, on both sides of Tigris River, all tributaries (wadis) are ephemeral and dry out regularly by the end of spring time. The main wadis in the west (Al-Jazeera Region) are wadi Al-Tharthar and Al-Ajjij. The main wadis in the north are Al-Khosser and Al-Khazir, however, wadis runoff reduces towards the southwest. One dam controls the Tigris River (Mosul Dam) in the

northwestern part, and their main purpose is to generate hydropower and for traditional irrigation schemes (e.g. North Al-Jazeera irrigation project).

Climate:

According to the data recorded by the Iraqi Meteorological Organization (1990-2002), Ninevah province has extremely hot summers, with mean temperatures ranging from 22.20 to 33.64 °C. Winter is wet and cold with mean temperatures between 5.90 and 12.50 °C. The average annual precipitation in the district is 357 mm. (Table 1A and B). In the winter, the region is invaded by Mediterranean cyclones moving east to north-east over the region (Ministry of transport, 2002).

Arabian sea cyclones moving northward and passing over the Gulf usually carries great amount of moisture which causes a large amount of precipitation (Stevanovic and Markovic, 2004).

Typical arid to semi-arid climatic conditions prevail throughout the northwestern Al-Jazeera Region. Precipitation occurs from October to May, and decreasing from the NE to SW. The total annual rainfall registered at Al-Ba'aj station was 311.56 mm.

Table-1 A: Mean precipitation in the study area (from 1990-2002).

Station	Sinjar	Ba'aj	Mosul
Jan	67.77	57.78	63.40
Feb	63.44	44.54	56.08
Mar	64.76	47.63	72.70
Apr	45.29	23.99	41.05
May	23.11	21.09	25.20
Jun	0.72	2.50	2.40
Jul	0.00	0.00	0.50
Aug	0.00	0.00	0.00
Sep	0.50	0.24	0.24
Oct	12.18	10.82	9.70
Nov	37.08	37.90	37.90
Dec	67.58	65.16	68.85
Mean Annual mm	382.43	311.65	378.0

Table-1 B: Mean temperature in the study area (from 1990-2002).

Station	Sinjar	Ba'aj	Mosul
Jan	6.54	5.90	7.66
Feb	8.37	7.20	8.72
Mar	12.02	11.10	12.40
Apr	17.06	17.50	18.01
May	23.70	22.20	22.20
Jun	29.80	28.80	32.05
Jul	33.50	32.20	34.13
Aug	33.05	31.70	33.64
Sep	29.19	28.30	28.43
Oct	22.55	23.00	22.03
Nov	14.70	12.50	14.20
Dec	8.54	10.00	9.39
Mean Temp. ° C	19.92	19.20	20.24

Satellite Data:

In the view of the water harvesting objectives, landsat7 data were selected as acquired in both the dry and wet seasons, to evidentiate features like (vegetation, soil moisture, springs, sinkholes and drainage patterns) related to the occurrence of water.

Landsat7 provides eight co-registered spectral channels, this permitted a large spectrum of band combinations, useful in both visual and digital interpretations of different features for landscape, drainage and lineaments analyses (Lillesand and Kiefer, 2000). Band 5 was preferred among the other spectral channels, due to the fact that, as an infrared band, contrast of light and shadow is enhanced to detect karstic landforms and playa lakes in Al-Jazeera Region. False colour composites bands 453 were also used, especially to detect drainage, sinkhole and springs by means of riparian vegetation or soil moisture in low areas.

METHODOLOGY:

There are many practical examples around the world for rain water harvesting (Arar, 1993; Appan, 1997; El-Mowelhi and Salem, 1997; Fok, 1998; David and Yusi, 1999; Hachum et al., 1999). Following the positive experience gained in the Sinjar district (Rafeek et al., 2000), a comprehensive remote sensing methodology was developed, to identify potential sites for water harvesting exploitation.

The approach used was a development of the traditional standard sequence of selected layers of the data base depending on previous geomorphological studies, such as drainage networks, landform assemblages, land use and land cover characteristics, lineaments and faults analysis in the study region. These observations have been used to locate those geologic formations and morphological sites most suitable for water harvesting search. By applying the interpretation procedure on the basis of the above considerations, the sites were indicated on the final thematic map for water harvesting and ground water assessment by the field team.

The rain water harvesting system that author going to explore is very simple to implement and maintain achieved by a minimum cost compared with the large irrigation project, and mainly it consists of:

A collecting area; such as small dam site, stony ditches, barriers, converted channel etc. Storage area; such as fan surfaces, small reservoir, natural topographic depressions, artificial recharge groundwater aquifer.

Hydrologic information; the rate of water losses through different ways (evaporation, leakage, infiltration etc.) and the intensity and duration of rainfall.

From the four selected layers of the data base as mentioned above, the final map (scale 1:250,000) were produced, for the entire study area. Based on a comparison between collected field data and the visual interpretation of the landsat images, the final thematic map was finalized following the scheme devised by the ITC Textbook (Zuidam and Zuidam, 1979). These observations have been used to develop rain water harvesting method within Al-Jazeera Region to improve scarce water resources. The final output can easily be stored in a GIS for further practical applications.

First: Geomorphic Landforms Analysis:

The study area consists of three main genetic groups of landforms based on units of tectonic, fluvial and denudation landform types, subdivided into 14 sub-units (Fig-3).

Detailed study of individual geomorphic units and landforms from dynamic, tectonic and morphochronologic aspects have been studied by mapping the distribution of the various geomorphic landscapes (Al-Daghastani, 2007).

These are important step forward in hydro-geomorphological management, because it allows the identification and quantitative assessment of several landform characteristics throughout the study area. These landforms assemblages have been used to locate those morphological sites must suitable for rain water harvesting search in Al-Jazeera Region.

Group one: Landforms of Tectonic Origin

- 1-Structurally controlled high folded topography.
- 2-Structurally controlled low folded topography.
- 3-Structurally controlled denudational hills.

Group two: Landforms of Fluvial Origin

- 4.Tigris River Valley and its tributaries.
- 5.Seasonal dry valleys .
- 6.Fluvial river terraces at low levels.
- 7.Fluvial river terraces at high levels.
- 8.Basin of Mosul Dam lake .
- 9.Depression salt areas and playa lakes.

Group three: Landforms of Denudational Origin

- 10.Stable accumulation glacis on sloping foothills surfaces.
- 11.Mixed erosional glacis on sloping foothills surfaces .
- 12.Active erosional glacis on gently sloping surfaces .
13. Karstic landforms with sinkholes and subsurface valleys.
- 14.Aeolian sand deposits without distinct dune forms.

Second: Land Use And Land Cover Analysis:

The vegetation cover in the study area, as well as the land use, is heavily influenced by varying climatic conditions, lithological escarpments, soil fertility and former land uses. The final land use and land cover thematic map (Fig. 4) shows the whole of the apparent activities up to the third level according to the USGS system (Anderson et al., 2001) and 27 classes (Table 2) have been shown in the final map (Al-Daghastani, 2008).

For water harvesting studies, the occurrence and types of natural vegetation and their spatial distribution may provide useful information. However, very little natural vegetation is present in Al-Jazeera Region.

All hills and plains of the study area being mainly covered by seasonal grass rangeland, dry in the period of landsat acquisition. Furthermore, areas of green grasses indicated increased soil moisture or the

occurrence of water, providing further inputs in the selection of promising sites for groundwater and water harvesting search.

Third: Lineament Analysis:

Landsat imagery proved particularly useful for revealing lineaments within the study area. Lineaments observed are almost entirely confined to the basement and Cenozoic covering strata, and were classified as major and minor, based on their relevance.

Many of the major lineaments are known faults predominantly oriented in an east-west to northwest-southeast directions (Fig-3).

The second set Fig4: Lineaments and land cover of Nineveh G. The northeast-southwest direction, is visible in imagery (Al-Daghastani, 2007).

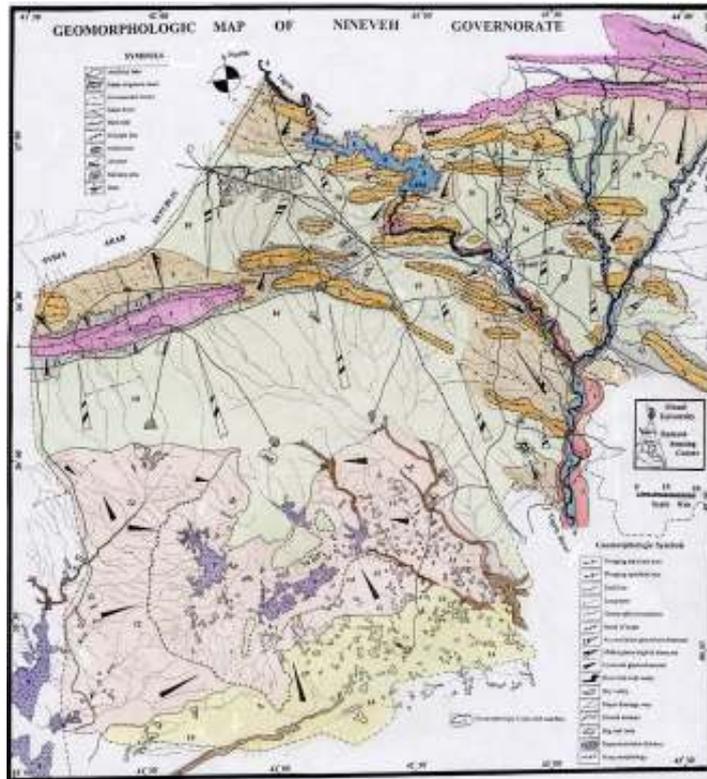


Fig-3. Geomorphologic map of Nineveh Governorate as interpreted from Landsat imagery (Al-Daghastani, 2007).

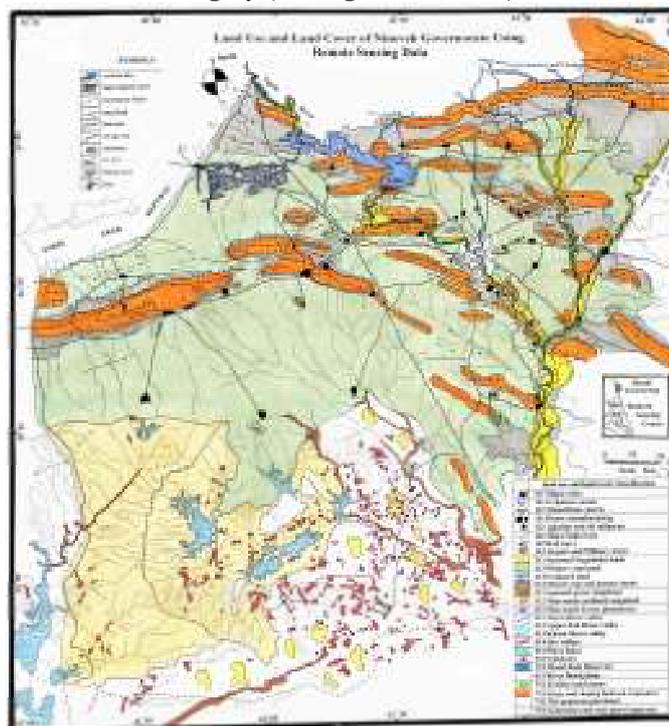


Table-2: USGS land use and land cover classification system for Ninevah Governorate.

Level I	Level II	Level III
1/ Urban or build up land	11 Residential	111 Major cities
	12 Commerical and survice	121 Irrigation canals 122 Mosul Dam resorts
	13 Industrial	131 Heavy manufacturing 132 pipeline and oil refineries
	14 Transportation	141 Major high ways 142 Rail ways 143 Airport and Military areas
2/ Agricultural land	21 Cropland and Pasture	211 Seasonal Vegetables lands 212 Winter crop lands 213 Irrigated land 214 Mixed crop and pasture lands
3/ Rangeland	31 Herbaceous rangeland	311 seasonal grass rangeland 312 Man made confined rangeland
4/ Forest land	43 Mixed forest land	431 Man made Forest plantations
5/ Water	51 Streams	511 Tigris River valley 512 Upper Zab River valley 513 Khazir River valley 514 Dry valleys
	52 Lakes	521 Playa lakes 522 Sinkholes
	53 Reservoirs	531 Mosul Dam Reservoir
6/ Wetland	62 Nonforested wetland	621 River flood plains
7/ Barren land	73 Sandy areas	731 Aeolian sand sheets
	74 Bare exposed rock	741 Steep and sloping bedrock exposures 742 Flat gypseous pavement
	75 Strip mines, quarries, and gravel pits	751 Limestone and river gravel quarries

Forth: Drainage Network Analysis:

The three physiographic regions occurring in the Ninevah Governorate largely influence the drainage network (Fig. 3). The drainage systems are strictly dependent on the slope, nature and attitude of bedrock and on the regional and local fault patterns (Huggett, 2003; Jensen, 2007)

Locally, control of drainage segments by faults or geomorphic lineaments is clearly recognizable; for example the main tributaries of the Al-Ajij and Al-Tharthar, which have parts of their course clearly oriented along NE-SW and NW-SE directions respectively. Frequent cases of antecedence were also observed; for example Al-Khazir, Al-Shor where streams cross an anticline in deep gorges (Al-Daghastani and Al-Daghastani, 1996).

Morphotectonic analysis has confirmed the tectonic control of stream channels in those zones, which greatly contributed to making the stream network rather complicated.

WATER HARVESTING CONCEPT:

In the present study, planning of water harvesting system can be defined as the orderly consideration of a project from the original statement of purpose through the evaluation of the alternatives to the final decision on a course of action. It includes all the work associated with the design of a project except the detailed engineering of the structures. Because each water harvesting project is unique in its physical and economic setting, it is impossible to describe a simple processe which will inevitably lead to the best decision (Appan, 1998; Dillon, 1999).

In this study, two different methods for rain water harvesting have been carried out. The aim of the first method is the study of the morphometry and hydroengineering for two ephemeral stream valleys located in Al-Jazeera Region, to locate a suitable sites for a small surface runoff collection dams (Fig. 2). The aim of the second method is the study of the geomorphology and hydrology of alluvial fans, which located in both flanks of Sinjar Mountain, to recharge the aquifers beneath these surfaces and or to the lithological formations must suitable for artificial ground water recharge (Fig-2).

Case study:

First: Al-Ajij Valley Basin:

The Ajij ephemeral stream valley and its tributaries form the major drainage basin in the extreme northwestern Al-Jazeera between latitudes ($35^{\circ} 20' - 36^{\circ} 25'$) north and longitudes ($41^{\circ} 10' - 42^{\circ} 00'$) east. The Ajij stream rises in the southern flank of Sinjar Mountain at 1460 m a.s.l., flows southward across the stable accumulation glacia to Al-Ba'aj city, then westward to the Syrian territory (Fig. 2). The main channel length is about 119.5 km in Iraq and 56.5 km in Syria, draining a total area of about 5057 km².

Morphometric analyses were performed on this basin (Al-Taeé, 2002) to determine the basin area, drainage density, order and stream length, network shape, relief and slope and other formal features of the Ajij Basin (Table-3).

Based on observation of individual geomorphic units and landforms from morphogenetic aspects, the basin was divided into six geomorphic surfaces (Fig-3). A land use and land cover map was also prepared within

three levels of classifications by using USGS system (Fig-4). The first level contained six classes and the third twelve classes.

Depending on these observations, some suggested sites were determined to be the most suitable places for constructing a small dam on the Ajij valley. A special purpose thematic map was drawn with the proposed sites marked (Fig-5). By using the contour lines and determining the positions and quantities of the water storage with calculation of soil volumes for each of the five proposed sites (Table-4), it was concluded that the second site was the best suggested site.

Second: Al-Tharthar Valley Basin:

The upper Al-Tharthar catchment covers an area of 5332 km² and is defined by the surface catchment boundaries of the Al-Tharthar stream and its tributaries, and form the second major drainage basin in the extreme northeastern Al-Jazeera between latitudes ($35^{\circ} 35' - 36^{\circ} 30'$) north and longitudes ($41^{\circ} 55' - 43^{\circ} 00'$) east (Fig. 2). The study reach is about 120.5 km long and extends in a southeasterly direction from the main divides of Sinjar, Sasan and Shaikh Ibrahim Mountains to its main junction near Hattra city.

Morphometric analyses were performed on the upper basin (Al-Moula, 2002) to determine the drainage density, order and stream length, network relief, slope and shape and other formal features of the upper Al-Tharthar basin (Table-3).

Based on observation of individual geomorphic units and landforms from morphogenetic aspects, the upper basin was divided into seven geomorphic surfaces (Fig-3). A land use and land cover map was also prepared (Fig-4). The third level contained fourteen classes.

Detailed examination of the geomorphic features across the primarily suggested dam sites were determined (Fig-6).

Table-3: Morphometric analyses of Al-Ajij and Al-Tharthar streams (Al-Taeé, 2002 and Al-Moula, 2002).

Stream Name	Basin Area Km ²	Total stream length (Km)	Basin Form Factor	Circumferences Consistency Ratio	Area Consistency Ratio	Total Stream Number	Relief Ratio (m/Km)	Longitudinal Drainage Density	Numerical Drainage Density
Al-Ajij	5057	5819.4	0.281	1.547	0.418	2963	9.635	1.151	0.586
Al-Tharthar	5332	6599.4	0.367	1.436	0.485	3825	10.141	1.237	0.733

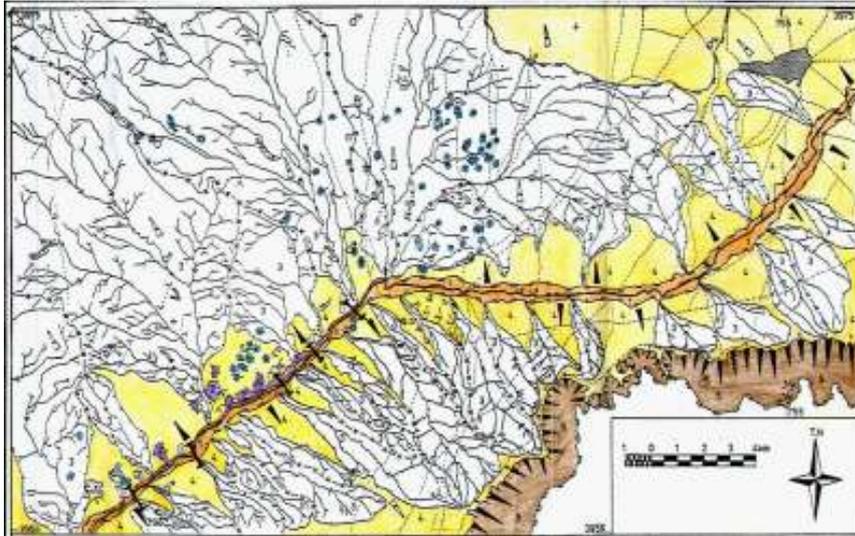


Fig-5: Thematic map showing perfect dam sites on Al-Ajij Stream (Al-Tae'e', 2002).

Table-4: Best location of the proposed dam sites on the Al-Ajij stream (Al-Taeé, 2002).

Proposed Dam Site	Contour Line (m)	Total Dam Height (m)	Total Dam Length (m)	Total Dam Storage (million m ³)	Top Dam Width (m)	Bottom Dam Width (m)	Total Soil Volume (m ³)
First	250	2.5	530	0.021	1.37	15.12	6039.46
	255	7.5	1270	3.114	3.01	44.26	117001.51
	260	12.5	1860	27.130	4.44	73.20	562261.10
Second	250	3.0	180	0.109	1.55	18.05	2612.00
	255	8.0	580	5.466	3.16	47.16	52584.40
	* 260	13.0	1120	40.307	4.58	76.08	24649.96
Third	245	2.5	60	0.003	1.37	15.12	618.37
	250	7.5	330	0.662	3.01	44.26	20916.97
	255	12.5	870	8.482	4.44	73.20	149554.05
	260	17.5	1460	53.179	5.80	102.10	526282.25
Forth	245	6.0	400	0.805	2.55	35.55	17526.00
	250	11.0	740	7.135	4.02	64.52	128169.80
	255	16.0	1280	33.555	5.40	93.40	468682.50
	*** 260	21.0	1440	118.634	6.72	122.22	1007343.70
Fifth	240	3.0	110	0.061	1.55	18.05	1617.00
	245	8.0	220	2.406	3.16	47.16	23587.50
	** 250	13.0	820	14.824	4.58	76.08	117260.30
	255	18.0	1840	55.254	5.93	104.93	491664.35
	260	23.0	2700	170.607	7.24	133.72	1463548.30

The contour maps were used to calculate the size of the water reservoir and the earth works of the three final selected sites for constructing the dam (Table-5). The analysis showed that the first site was the best suggested site. A special purpose thematic map was also drawn with the proposed sites marked (Fig-6).

Detailed examination of the geomorphic features, valley morphology and topographic depressions of Al- Ashqer and Sinesla playa lakes located west of Al-Hattra city was made to identify the best location to convert the main channel flow (Fig-2). A detailed survey using aerial photo interpretations was made, and the altitudinal relationships of the converted channel and the present floodplain of the Al-Tharthar and Aliji streams have been projected onto a thematic map (Fig-2).

The mechanism for complete re-alignment to a new channel in the lower Al-Tharthar reach during and following the most active period of rain storm will recharge the two topographic depressions mentioned above. The clearest features in the land use map (Fig-4) were primarily the extensive seasonal grass rangeland, and the two playa lakes in Al-Jazeera Region. This information is needed to identify

future development pressure points and areas, and to implement effective plans for regional development in this area, by recharge these two seasonal lakes.

Further studies are needed, because in the closed basin or depression, the additive of water may temporary deplete the concentration of total dissolved solids, then the evaporation mechanism causes enrichment of salinity concentration.

Third: Alluvial Fans Belt Zone:

Sequence of multi-stage of alluvial fans exist where a distinct boundary occurs between the Sinjar Mountain and its surrounding plains and stretching for more than 25 km in the northern plain (Fig-1 and 2). These fans belt zone vary considerably in morphology and extent because of varying characteristics of catchment areas and different local base levels.

Quantitative morphometric analysis was carried out (Al-Shakergee, 2002) on the surface discharge basins of four selected fans on the northern flank which gave the spatial, form and topographic characteristics and consequently the determination of the typical and appropriate basins to apply the concept of water harvesting (Table-6).

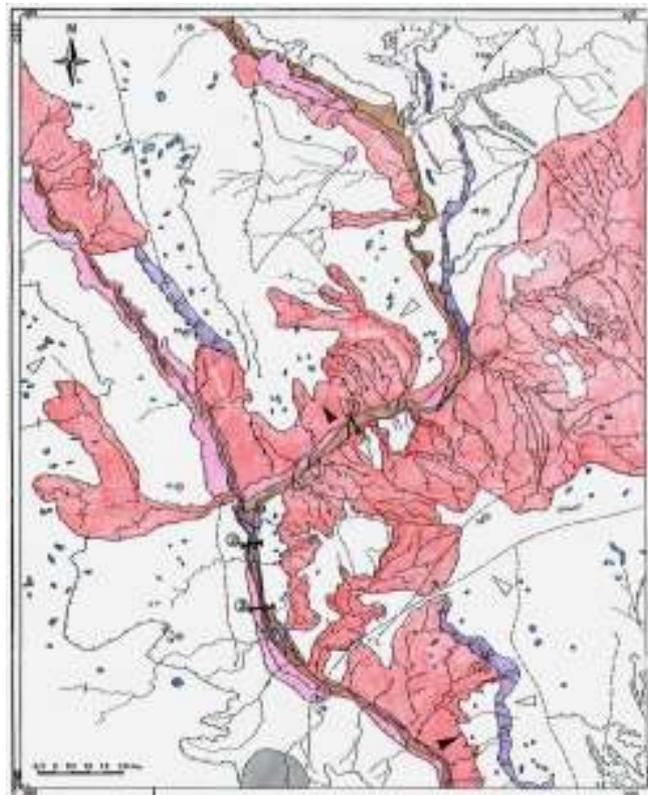


Fig-6: Thematic map showing perfect dam sites on Al-Tharthar Stream (Al-Moula, 2002).

Table-5: Best location of the proposed dam sites on Al-Tharthar stream (Al-Moula, 2002).

Proposed Dam Site	Contour Line (m)	Total Dam Height (m)	Total Dam Length (m)	Total Dam Storage (million m ³)	Top Dam Width (m)	Bottom Dam Width (m)	Total Soil Volume (m ³)
First	170	6.0	275.0	0.888	2.5	35.5	13794.0
	175	11.0	540.0	10.691	4.0	64.5	101583.5
	* 180	16.0	970.0	50.376	5.4	93.4	331375.2
Second	170	12.0	397.5	5.540	4.3	70.3	57964.2
	175	17.0	772.5	27.328	5.7	99.2	232720.6
	180	22.0	1200.0	90.709	7.0	128.0	611347.5
Third	170	12.75	400.0	9.045	4.5	74.6	84122.8
	175	17.75	880.0	36.239	5.8	103.4	284684.4
	180	22.75	1520.0	111.001	7.2	132.3	774119.8

Table-6: Morphometric analysis of four selected fans on the northern flank of Sinjar Mountain (Al-Shakergee, 2002).

Fan Name	Basin Area Km ²	Total stream length (Km)	Total Stream Number	Basin Form Factor	Circumferences Consistency Ratio	Area Consistency Ratio	Relief Ratio (m/Km)	Longitudinal Drainage Density	Numerical Drainage Density
Dahuna	34.25	115	199	0.07	2.0	0.25	41.8	3.36	6.17
Mustawfi	46.88	117.9	195	0.11	2.1	0.23	35.07	2.51	4.16
Kersi	48.0	155.6	240	0.07	2.8	0.13	29.6	3.24	2.8
Quaisy	35.94	108.5	184	0.14	1.9	0.27	48.41	3.0	5.11

A land use and land cover and geomorphological analysis of selected alluvial fans at the Dahuna village was carried out. The fan profiles are slightly convex, and lateral coalescence is common. Rills and minor gullies can be seen, and these develop by surface runoff during or after showers (Fig-7).

Techniques of rain water harvesting which was appropriate of application in the alluvial fan belt zone was chosen. Best locations to construct barriers and stony ditches on the main flow of Dahuna Valley were determined (Fig. 7). Results of hydrological balance of the study area showed the lossing of adequate quantities of the

surface water due to rainfall is (17650) m³/km² annually lost in forms of surface runoff outside the Iraqi territory (Al-Shakergee, 2002).

Other methods of rain water harvesting according to surface landforms of these alluvial fans near the exposed structural ridges on the slopping foothills surfaces were also determined (such as terraces, small stony ditches surround trees, and barriers on main valley), to artificial recharge the aquifers beneath these surfaces and formations which located in both flanks of Sinjar Mountain such as Jaddala, Avana, Serikagni, Jeribe and Injana formations.

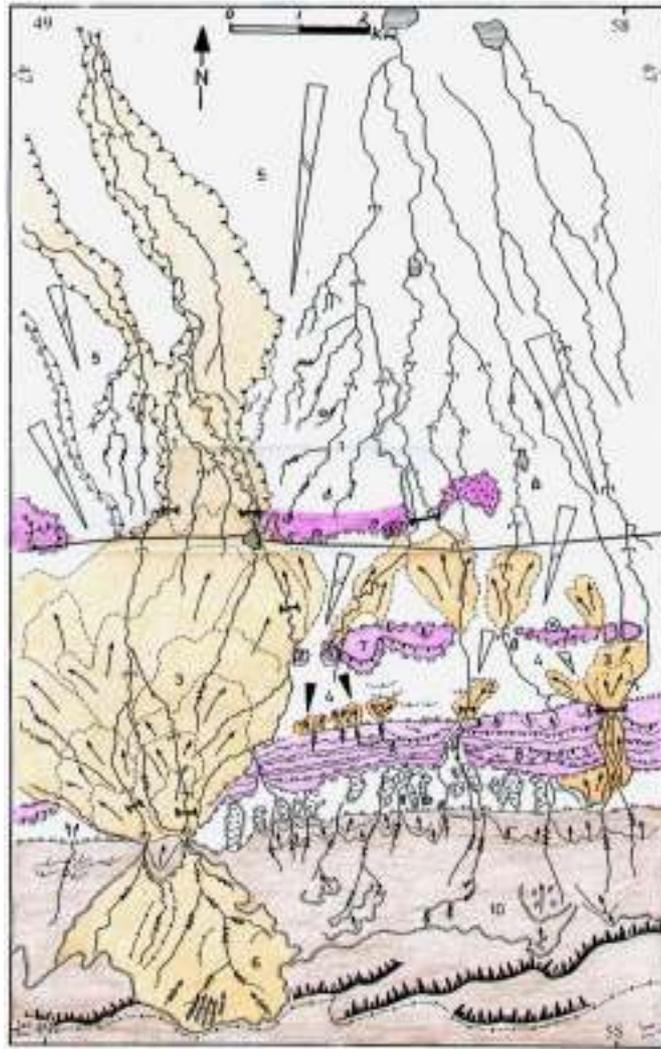


Fig-7: Thematic map showing perfect dam sites on Dahuna fan (Al-Shakergee, 2002).

- 1- A special purpose geomorphic-engineering map for small dam construction was drawn with the proposed sites marked of both Al-Ajj and Al-Tharthar ephemeral streams, which located within the gently sloping surfaces of Al-Jazeera Region, using remote sensing techniques.
- 2- The analysis showed that the second proposed site of Al-Ajj, and the first proposed site of Al-Tharthar, is the best site since it achieves the highest water storage, the least amount of soil volumes and the shortest length to height of the projected dam with a minimum cost.
- 3- This paper presents an outline of a technique that can aid in the integration of the ephemeral stream resources with the water harvesting method in the two natural topographic depressions (Sinesla and Al-Asker). This technique consists of lowering the salinity of these natural basins by diverting a number of stream valleys to artificially recharging them by rain water.
- 4- Suitable methods of rain water harvesting were applied to the belt of alluvial fan surfaces located on the sloping foothills surfaces on both flanks of Sinjar Mountain to recharge the aquifers beneath these surfaces after showers.
- 5- One of the prime pre-requisites for better use of land in Al-Jazeera Region is information on existing land use patterns and possible changes in land use through time. Knowledge of the present distribution of rain water harvesting

projects as well as information on their distribution proportions is needed by planners and state or local governmental official to determine better land use policy in this semi arid region. A new hydrogeomorpho-logical map for Al-Jazeera Region is acquired from this study.

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