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DETERMINATION OF WATER HARVESTING REGIONS IN IRAQI WESTERN DESERT USING GIS SYSTEM

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Abstract:

Water resources is one of the most important criteria for societies building and their development. Evaluation, planning, and management of water resources are rasid to be one of important subjects in the humans life, particularly in arid and semiarid region like Iraqi western desert, since precipitation is extremely limited and spatially distributed, with poorly available ground water supply.

Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions.

This paper examines the effects of different variables on the water harvesting in Iraqi western desert like catchments area, bed slope geometric and topographic properties. By using unit hydrograph theory, the volume of harvesting water was calculated, and by frequency and statistical analysis to determine maximum harvesting water for return period (5, 10, 25) years, with geographic information system (GIS) we make a number of maps for the region of optimum harvesting water which can use for design of agriculture and irrigation project in Iraqi western desert. The study show there is a potential ability for using the harvesting water in Iraqi western desert.

تحديد المناطق الواعدة لحصاد المياه في المنطقة الغربية من العراق باستخدام نظم المعلومات الجغرافية (GIS)

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المستخلص:

تعد الموارد المائية واحدة من أهم متطلبات بناء المجتمعات المدنية وتطورها، فالتخطيط وتقدير وإدارة الموارد المائية أصبح واحدا من أهم المواضيع في حياة البشرية، خاصة في المناطق الجافة وشبه الجافة مثل منطقة الصحراء الغربية العراقية، بسبب محدودية الأمطار الساقطة وتوزيعها مع قلة المتوفر من المياه الجوفية.

من هنا كان موضوع إيجاد مصادر للمياه مع استغلال المتوفر بالطريقة المثلى يعد من الأهمية بمكان، حيث يمثل حصاد المياه أهم وأقدم التقنيات المعروفة في هذا المجال.يعرف حصاد المياه بأنه عملية أو طريقة (تجميع ،خزن،وحفظ) مياه الإمطار الساقطة على منطقة معينة لإغراض الري والزراعة في المناطق الجافة وشبه الجافة.

في هذا البحث تم دراسة العوامل المؤثرة على حصاد المياه في المنطقة الغربية من العراق من خلال دراسة تأثير المساحة المجمعة، ميل قاع قناة الوادي، الخصائص الهندسية والطبوغرافية للوديان وتأثير كل هذه العوامل على كمية المياه القابلة للحصاد.

تم استخدام طريقة المخطط المائي القياسي لحساب كميات المياه التي يمكن حصادها، كما تم استخدام الطرق الإحصائية ودراسات التكرار لحساب أعلى كميات مياه لفترات تكرار (5,10,25) سنة ومن ثم استخدام تقنيات نظم المعلومات الجغرافية (GIS) لوضع خرائط تحدد المناطق الواعدة لحصاد المياه في المنطقة الغربية يمكن الاستفادة منها في عملية وضع التصاميم وإعداد الدراسات الخاصة بمشاريع السدود واستغلال مياه السيول في المنطقة حيث بينت الدراسة إمكانيات كامنة هائلة لحصاد المياه وتطوير الزراعة والري في المنطقة.

1.Introduction:

Water resources is one of the most important criteria for societies building and their development. Evaluation, planning, and management of water resources are rasid to be one of important subjects in the humans life, particularly in arid and semiarid region like Iraqi western desert, since precipitation is extremely limited and spatially distributed, with poorly available ground water supply.

Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions.

The problem of water shortage in arid and semi-arid regions is one of low rainfall and uneven distribution through out the season, the average annual rainfall in (Iraqi Western Desert) area is about 115mm, which makes rainfed agriculture a risky enterprise (Ministry of Agriculture, 1998). Therefore new interest came up in recent decades to evaluate traditional water management techniques most of them being simple, sure to implement and of low capital investment.

The classical sources of irrigation water are often at the break of overuse and therefore untapped sources of (irrigation) water have to be sought for increasing agricultural productivity and providing sustained economic base. Water harvesting for dry-land agriculture is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of world.

This old technology is gaining new popularity these days. As the appropriate choice of technique depends on the amount of rainfall and its distribution, land topography, soil type and soil depth and local socio-economic factors, these systems tend to be very site specific. The water harvesting methods applied strongly depend on local conditions and include such widely differing practices as bounding, pitting, micro catchments water harvesting, flood water and ground water harvesting (Prinz 1996, Critchley and Siegert 1991).

Until the last few years, GIS applications to hydrology, flood routing and water harvesting modeling have been relatively limited. With the rapid advances in GIS in the 1980s, GIS began to be used to represent the flow of water on the land surface.

Incorporating hydraulic and hydrologic model results into a GIS environment has improved rainfall-runoff analysis in recent years.

2.Area Under Study:

The Iraqi Western Desert is located approximately between the longitude 34^{o}-39^{o}. which occupies all the south western part of the Euphrates River. The desert extends at much upper altitude to the west to Syria and Jordan, and to the south, and south west in to Saudi Arabia (fig.1). The total area of it is about 220 000 km^2.

Most of these area is composed of bare soils which where found suitable for agriculture.

The rainy season begins from September to the last of May. The average annual rainfall in this region is 115mm of about 49.5% occurs in Winter, 36.3% in Spring and 14.8% in Fall.

The average annual evaporation is 3200 mm, the dryness coefficient in this region (Evaporation/rain) is (25-35).

The hottest month is July and the coldest is January. The mean annual temperature is 20.6^{o} C.

The minimum annual mean appears in Rutba (19^{o} C) and this increases toward Euphrates River, where the elevation decreases in conformity with the increasing rainfall. The relative humidity is between 19%-82%. The ground water level of the area is deep enough so as to not give any recharge to the surface runoff, and it forms an artesian conditions represented by some wells constructed in these area, (Kamel 1999) .

3.Factors Affected Water Harvesting:

The knowledge of rainfall characteristics (*intensity and distribution*) for a given area is one of the pre-requisites for designing a water harvesting system. The availability of rainfall data series in space and time and rainfall distribution are important for rainfall-runoff process and also for determination of available soil moisture.

In this study we choose six wadies to determine the best location or regions for water harvesting in the Iraqi western desert, (Horan, Ghdaf, Ubaiydh, Tubel, Amij, Awaj).

The area of these wadies different from 13340 km^2 for Horan Wadi to 1246 km^2 for Awaj Wadi, the geometric characteristics are explained in (table-1).

To study the rainfall-runoff relation in the region, we use the investigation and measurements for the Iraqi western desert block-7, from Iraqi Ministry of water resources. The measurements were made for rainfall in four stations (Muhaiwer, 160 km, Qasra, Nukhaib) for one year. The rainfall data for Al-Rutba station we got from Ministry of transportation in Iraq for the period 1929-1998.

To develop the relation of rainfall distribution between Rutba station and other station we can use the distribution factor which can get it by the following:

$$D.F=(DRS)/(DRR)\ldots\ldots\ldots\ldots(1)$$

DRS =depth of rainfall in a station
DRR =depth of rainfall in Rutba

Because of the limited available poor data, the recorded information about storms are taken from the metrological station at Rutba because it provide to be the most representative and reliable station with longest observation period.

For other station we can determine the rainfall data by using the (D.F).

Useful rainfall factors for the design of a rain- or floodwater harvesting system include: (1)- Number of days in which the rain exceeds the threshold rainfall of the catchments.

From the available data for the stations in the region, (table-1) explains that the station at 160 km, Rutba, and Muhaiwer have the high intensities compared with Qasra and Nukhaib stations.

This means the rainfall increases from south to north and west to east, the reason may be because the ground level of the region decreases from south and west to north and east respectively.

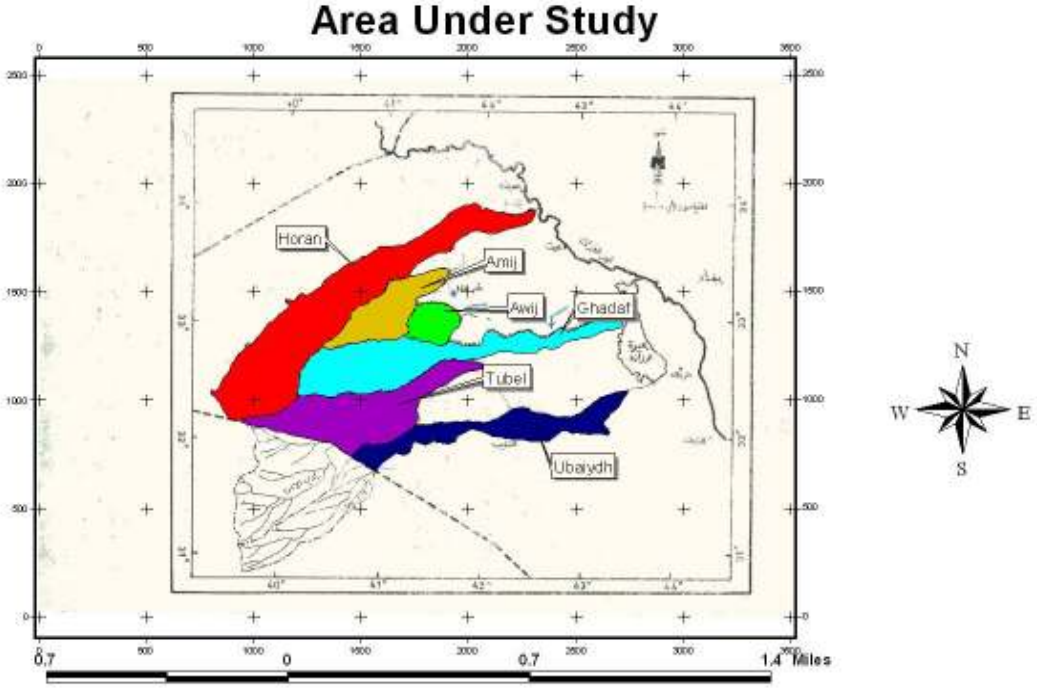

Figure.1: Study Area

(2)-It is very important for rainfall-runoff relation and then the amount of harvesting water to determine the losses of rainfall like evaporation, depression storage and infiltration.

In the current study we used the Φ-index to determine these losses from the detailed data available about storms take place through one season, because a very poor data for the region under study. (Table-2) show the Φ-index for this region. This index depends on soil characteristics, slope of wadi channel and catchments area properties.

(3)-the amount of rainfall represent a good indicator for any water harvesting project. As mentioned before, in this study the depth of rainfall was taken from four rainfall stations (Muhaiwer, 160 km, Qasra, Nukhaib) for one year, the result is showed in (figure-2).

(4)-the average annual water harvesting was estimated for years 1992,1993, 1994, and 1995. the volume of water harvesting was calculated by determine the effective rainfall from the following equation:

ER=R-Φ……..(2)

Where:

ER: effective rainfall R: rainfall intensity

Φ: losses include (infiltration, evapotranspiration, and depression storage).

Then by using unit hydrograph which is estimated according to field measurement (from Ministry of Irrigation), the volume of runoff (water harvesting) can be determined. (Table-3) show the results of water volume which can be harvested, and the (figure-4) show the average water harvesting for these years.

Table-1: No. of rainy days in western desert during season 1975-1976.

No.	Station	No. of rainy day	No. of day <5mm/hr	No. of day >5mm/hr	No. of day >10mm/hr	No. of day > 20mm/hr	Total Rainfall (mm)
1	160 km	36	29	7	5	2	134
2	Muhaiwer	31	24	7	4	1	147
3	Qasra	32	28	4	1	-	78
4	Nukhaib	36	31	5	2	-	86.1
5	Rutba	34	27	7	5	1	144

Table-2:average rainfall losses (Φ)

No.	Region	(Φ) index (mm/hr)
1	Ubaiydh	4.0
2	Ghdaf	2.65
3	Horan	3.25
4	Amij	3.9
5	Awaj	4.1
6	Tubel	4.5

Table-3: volume of water harvesting in western desert.

	Wadi	Water harvesting (million cubic meter)			
		1992	1993	1994	1995
1	Horan	4.7	108.28	459.9	12.7
2	Ghdaf	5.62	62.96	232.16	9.5
3	Ubaiydh	-	2.22	11.01	0.07
4	Amij	-	3.2	16.53	0.17
5	Awaj	-	1.17	6.57	0.02

4.Frequency and Reoccurrence Studies:

Hydrologic systems are sometimes impacted by extreme events, such as severe storms, floods, and droughts. The magnitude of an extreme event is inversely related to its frequency of occurrence, very severe events occurring less frequently than moderate events. The objective of frequency analysis of hydrologic data is to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions. The hydrologic data analyzed are assumed to be independent and identically distributed.

The accuracy of analysis depends on the period of observation, when the period of observation be long (more number of observations) the analysis is more accurate and vise- verse.

There are two methods now commonly used for frequency analysis;

- The statistical analysis of past floods with extrapolation to estimate the magnitude and probability of occurrence of future floods, and;
- The estimation of probable maximum precipitation on to the particular catchments under the worst meteorological conditions likely to occur over the catchments, followed by an estimation of the run-off that would result from such a storm.

In this study we use the method and procedure was used by (Kamel ,1999), to analyze the frequency and probabilities for hydrologic events in Iraqi Western Desert.

The hydrologic data employed should be carefully selected so that the assumptions of independence and identical distribution are satisfied, in his study this is achieved by selecting the annual maximum rainfall for the Rutba station because it has the longest period of observation with the expectation that successive observations of this rainfall from year to year will be independent.

In this study, the analysis was made with reoccurrence period (5, 10, 25, and 100) years for studied area. The result of analysis is showed in (figures5, 6, 7, and 8).

The results of frequency analysis can be used for many engineering purposes: for the design of dams, bridges, culverts, and flood control structures.

5.Geographic Information System

Geographic Information System (GIS) is defined as computer systems capable of assembling, storing, manipulating, and displaying geographically referenced information (USGS, 1998). Originally developed as a tool for cartographers, GIS has recently gained widespread use in engineering design and analysis, especially in the fields of water quality, hydrology, and hydraulics. GIS provides a setting in which to overlay data layers and perform spatial queries, and thus create new spatial data. The results can be digitally mapped and tabulated, facilitating efficient analysis and decision making. Structurally, GIS consists of a computer environment that joins graphical elements (points, lines, polygons) with associated tabular attribute descriptions. This characteristic sets GIS apart from both computer-aided design software (geographic representation) and databases (tabular descriptive data).

GIS provide a common link between different types of information. The GIS assimilates large amounts of data within a short time frame and supplies the spatial data in a format that can be input to deterministic or statistical models. GIS also provides the power to analyse spatial watershed data such as land use types, slope, and soils that can then be used as inputs for hydraulic models.

5-1.Arc View GIS

The Arc View GIS software package, developed by the Environmental Systems Research Institute, was used as the computer development environment for this research. In the past several years, Arc View has emerged as the industry leader in

desktop GIS software. All activities within Arc View are organized with a project, which may consist of a number of views, tables, charts, layouts and scripts (Maidment, 1999). Files created in Arc View are called projects and are denoted by an ".apr" file extension. Vector and raster data files in Arc View are called shape files. The functions of Arc View include: displaying shape files in a view, viewing and editing the related attribute tables of this view, plotting charts to display spatial information, and creating layouts of the view and related tables and charts. Specialized Arc View software, called extensions, is required to manipulate and analyze raster and TIN data. The Arc View spatial analyst extension is designed for creating, querying, mapping, and analyzing raster data, whereas the 3D Analyst extension is intended for creating, analyzing, and visualizing TINs and three-dimensional vector data (ESRI, 1999). GIS data in Arc View can be manipulated using avenue, a customization and development programming language embedded in the software package.

For this study, we use the aerial photo to make the map for the area under study. Then by using Arc View we make the maps for rainfall distribution, losses and infiltration, and the expected rainfall for (5, 10, 25, and 100) years reoccurrence period, (figures 5, 6,7, and 8) show these maps.

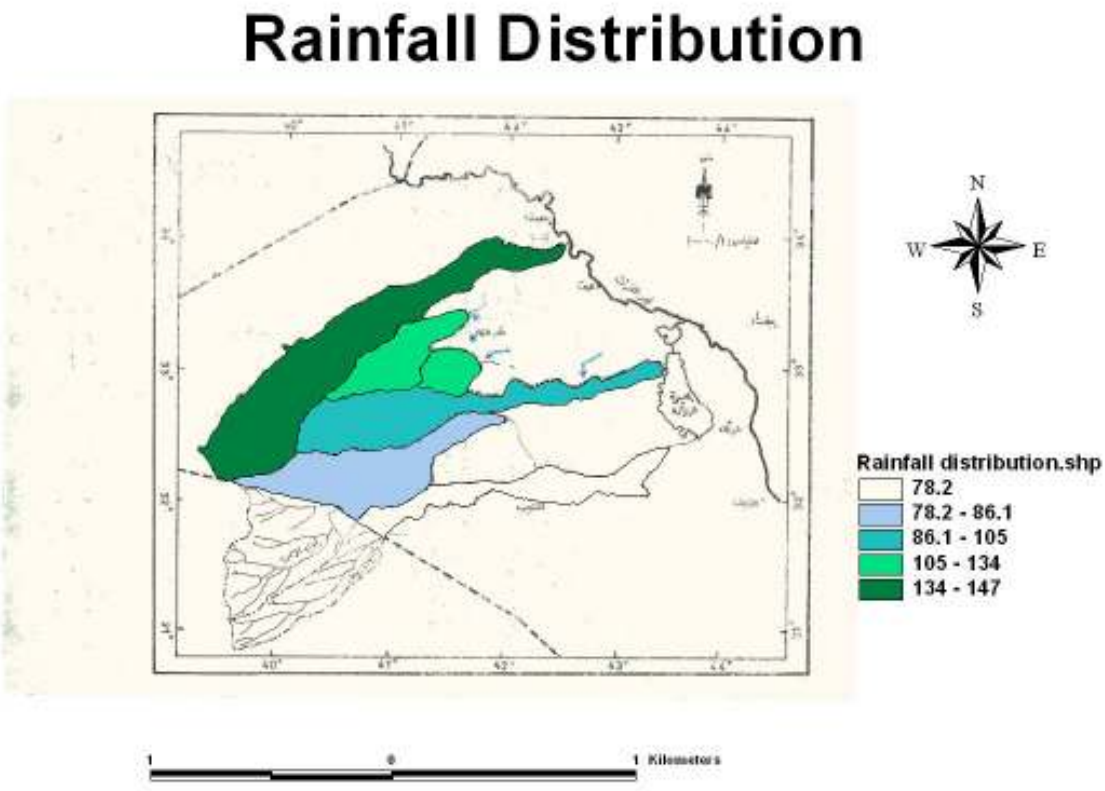

Figure-2: rainfall distribution in western desert.

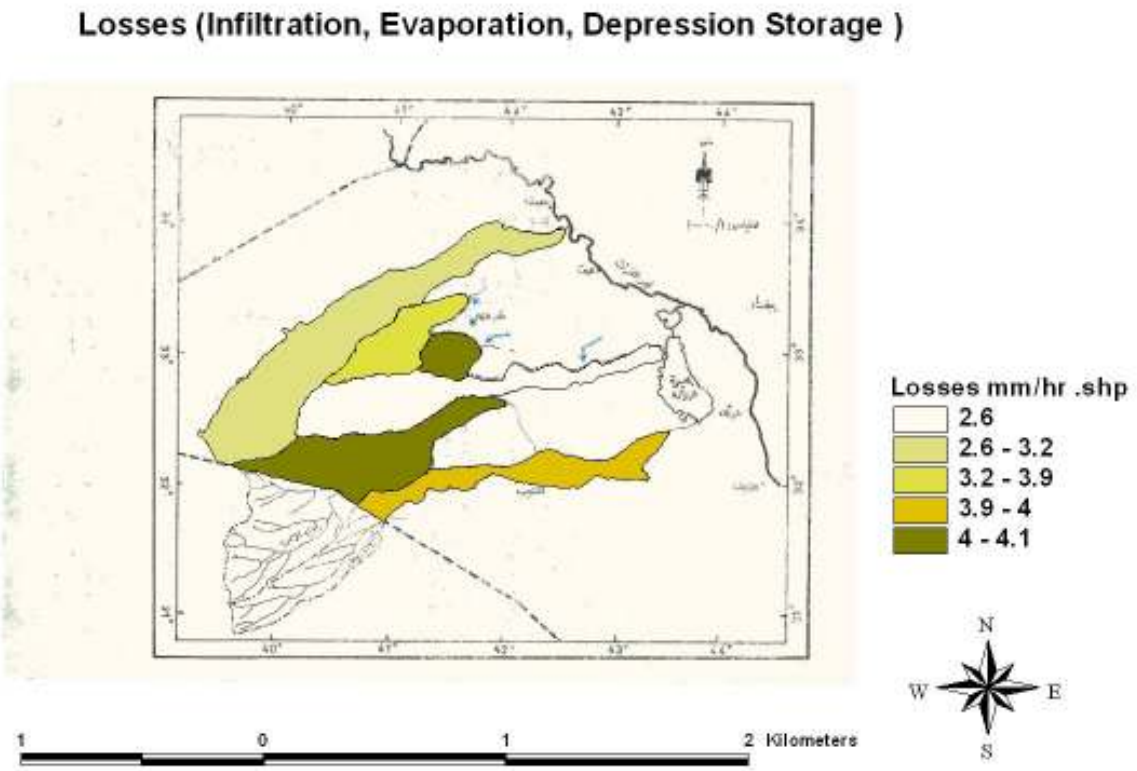

Figure-3: average Φ losses index for western desert.

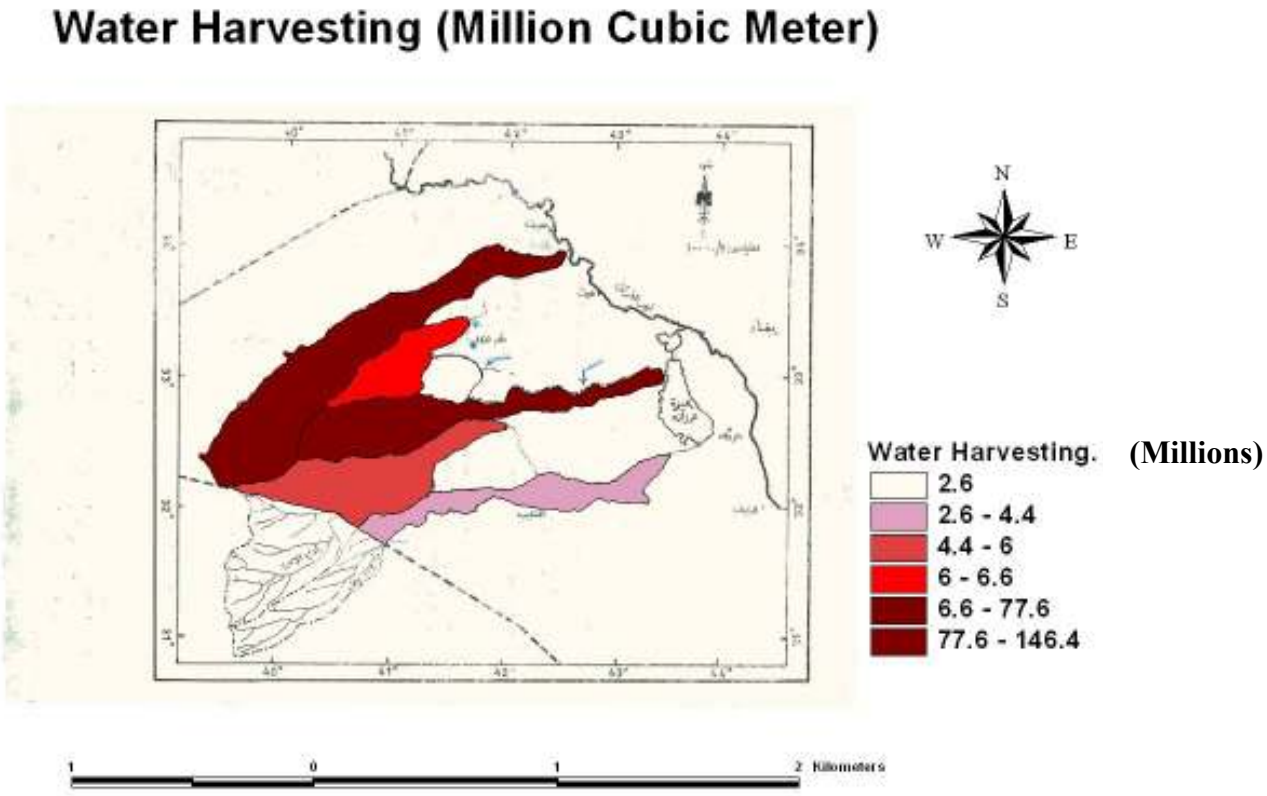

Figure-4: average water harvesting

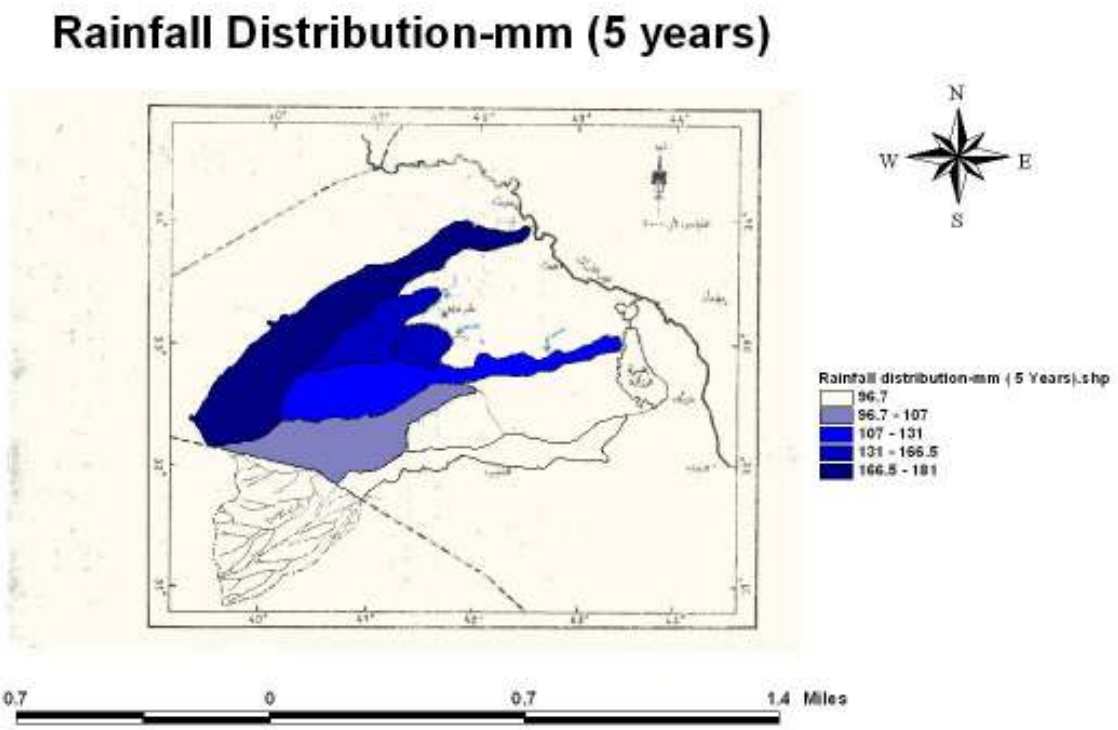

Figure-5: rainfall distribution (5-years).

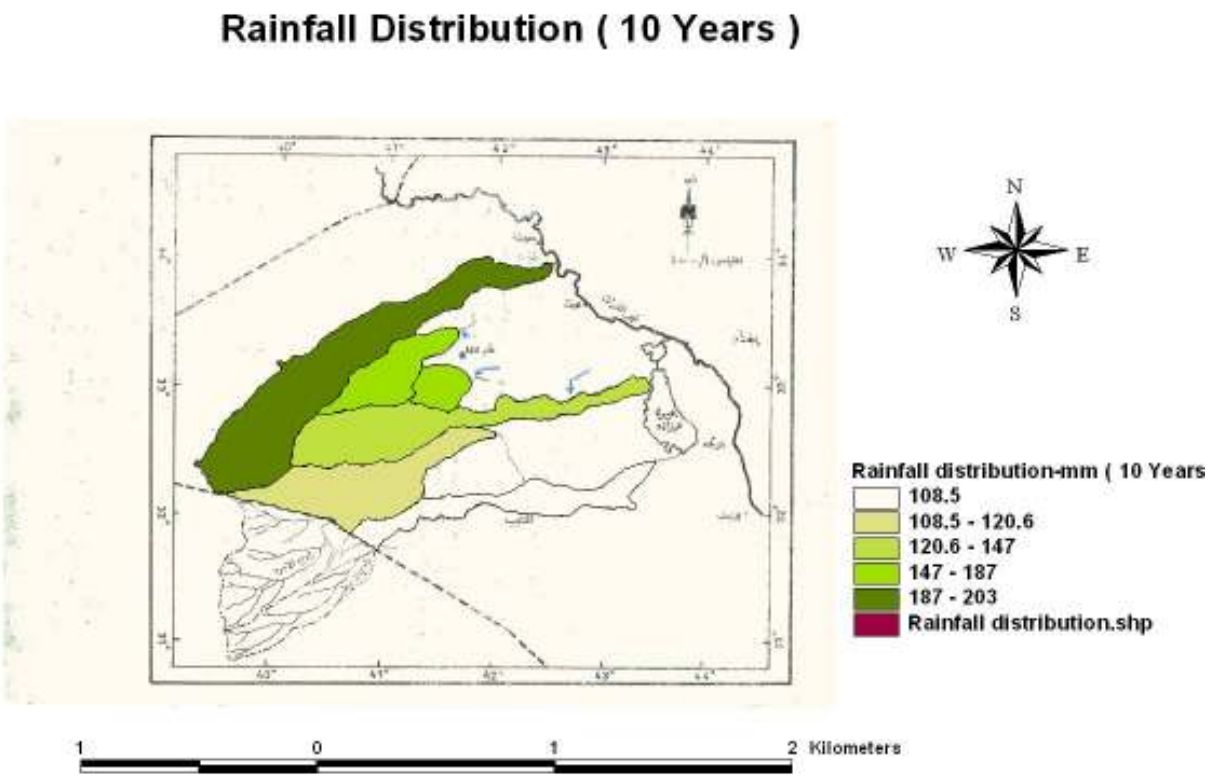

Figure-6: rainfall distribution (10-years).

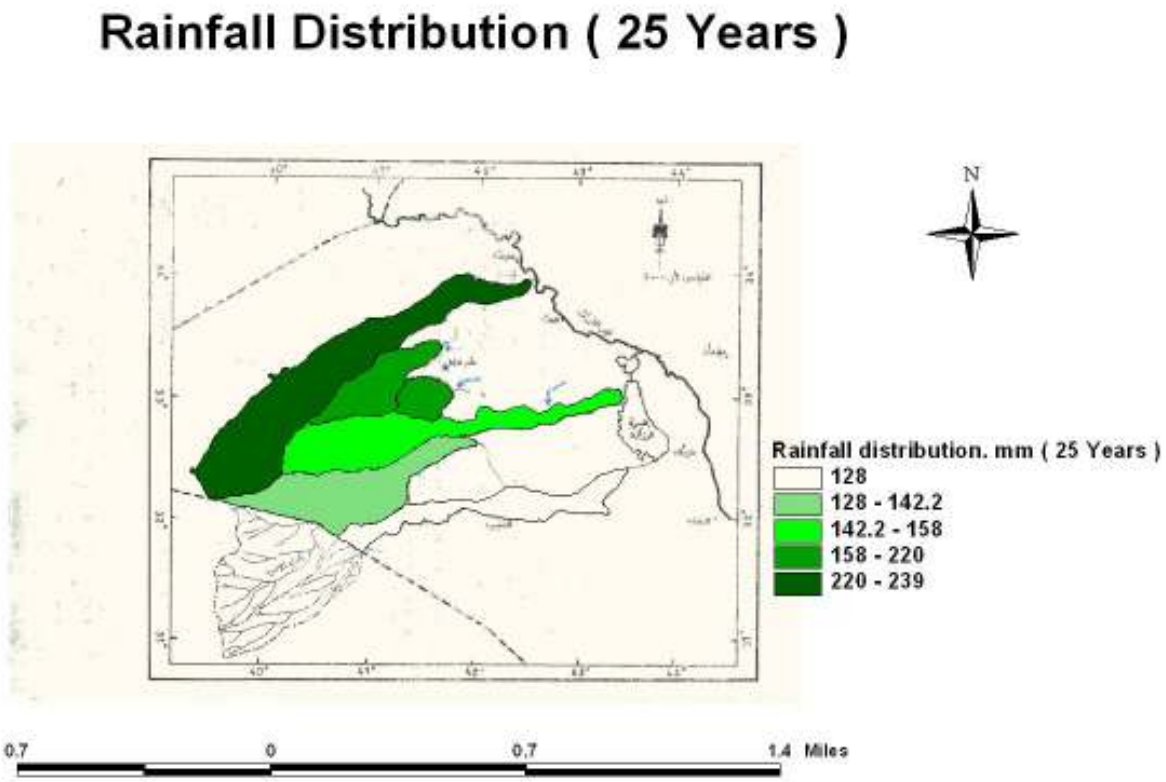

Figure-7: rainfall distribution (25-years).

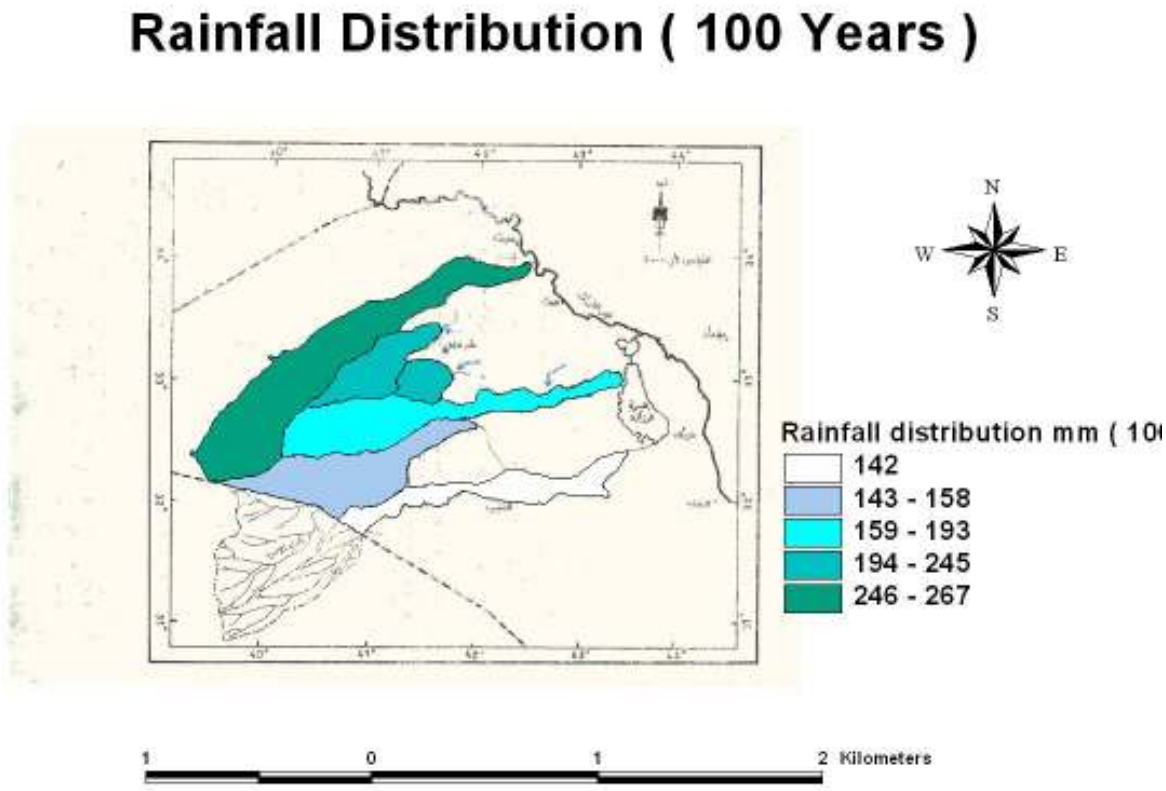

Figure-8: rainfall distribution (100-years).

Conclusions:

1- Planning, management, and evaluation of water resources requires a well and long-term hydrologic investigation, which are too limited in Iraqi Western Desert. Data base from using GIS in this study is necessary to quantify it.

2- There is a good chance to harvest water in Wadi Amij, Wadi Awaj, and Wadi Ghadaf, while the water of Wadi Horan is harvested anywhere because this Wadi is end in the Euphrates River. Wadi Ubaiydh is more poor with water resources compared with other wadies therefore; the dams projects and other water harvesting water must be achieved in Wadi Ghadaf and Amij because a good average rainfall with a low losses and these wadies end in desert and lake of al-Razaza.

3-Region is very poor with metrological stations, to update our data base for water resources in the western desert we need to setup more metrological stations to cover all western desert.

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