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# Rainwater Harvesting at Koysinjaq (Koya), Kurdistan Region, Iraq

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## Abstract

Macro Rainwater Harvesting (RWH) has been tested at Koysinjaq (Koya) District, Kurdistan region of Iraq, due to its limited source of water.The studied area consists of four basins with total area of 228.96 km2. The estimating volumes of harvested runoff for the four selected basins together for the study period (2002-2011) were calculated using the Watershed Modeling System (WMS) which is based on Soil Conservation Service Curve Number (SCS-CN) method.In this research, a comparison between maximum and minimum rainfall seasons was conducted to give better understanding for the events that is governing the harvested runoff collection.The results show that, the total harvested runoff ranged from14.83 to 80.77(*106 m3) from the four selected basins together. This indicates that the technique of Macro RWH can be considered to provide a new source of water to contribute to reduce the problem of water scarcity.

**Keywords:** Macro Rainwater Harvesting, , Koysinjaq, Kurdistan region, Iraq.

## 1 Introduction

All population gatherings different cities and villages, including those which do not suffer from water scarcity, use water balances to guide water management. Thus the water balance should include the local natural catchment areas that contribute water to the cities and villages, as well as the water downstream of these areas [1].
On other hand, rainwater harvesting (RWH) is one of the oldest-most recent techniques that collect water from natural catchment areas to augment available water for certain area. Humans have used RWH about 9000 years ago as a traditional technique [2, 3, 4, and 5]

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in order to supply drinking water for people and livestock as well as the agricultural purpose, as far as there is a limited amount of available water. In recent decades, and due to water scarcity, different researchers at different part of the world focused on RWH. The goal is to establish a new water source. There are several definitions for RWH but the shortest and most comprehensive definition is the collection of runoff for its productive use [6]. RWH systems have proven to be an effective technique in an arid and semi-arid region to achieve new water source that can be used for several purposes [2].

The most important factors that affect practicing water harvesting are the intensity and distribution of rainfall, runoff properties of the catchment area, soil water storage, reservoir's capacity, agricultural crops, available technologies and socio-economic conditions [7].

The rainfall-runoff relationship of watershed had been studied with different approaches such as water balance, agricultural non-point source, kinematic wave storms runoff, and Soil Conservation Service Curve Number (SCS-CN). However, SCS-CN method having advantages over other methods [8].

In general, there are several kinds of RWH system, depending on the size of the catchment area, such as micro RWH for small catchment area less than 1000 $m^2$ , and macro RWH for large catchment area more than 1000 $m^2$, other kind like traditional macro-catchment RWH system (Tabias). The performance of these kinds of RWH systems was been studied by [9, 10, 11,12, and 13]. Their goal was to save water for agricultural purposes; they concluded that they had good results to augment the crop yield. The traditional macro-catchment water harvesting system of Tabias, was been studied by [14] in Tunisia. They conclude that, this system minimized flood risks by decreasing the local surface runoff that was collected from hill slope, which lead to reduce soil erosion hazards. The harvested water that was stored behind the Tabias requires not more than three days to supply (by infiltration) the soil water storage to allow planting vegetables during the following months. Even deep soil water storage will be utilized by the roots of fruit trees.

Adekalu et al. (2009) [15] studied both macro and micro RWH combined with supplemental irrigation that gave good benefits of reducing the impacts of dry periods that affect the crop to the half, which lead to the increase the yield.

Mzirai and Tumbo (2010) [16] concluded that the crop yield in semi-arid areas can be increased by using RWH systems; they noticed that water use efficiency can be increased up to more than 20 kg $ha^{-1}$ $mm^{-1}$ compared to a rain-fed system where water use-efficiency can hardly reach 3 kg $ha^{-1}$ $mm^{-1}$.

Iraq , Government and people, face a big challenge with water shortage's problems due to reduction the discharges of Tigris and Euphrates Rivers, effect of climatic changes, i.e. rising temperatures, rain retention, in addition to the bad planning and management of the water resources. Accordingly, huge farm's lands were converted to desert areas [4, and 17]. The water shortages problem is becoming more serious with time [5, and 18]. Despite this fact, practically, RWH might be one of the good solutions for this problem.

Water shortages cannot be objectively analyzed nor adequately addressed without a thorough consideration the main overwhelming consumer of water across the region, i.e. human, animals, the goals both of agricultural and industrial activities. Certainly the agriculture is the largest consumer [3, 5, and 19].

In Iraq, number of regions with a specific conditions have a chance to establish a new source of water if these regions significantly supported by Macro RWH technique, based on availability of a surface reservoir of small earth dam [20, 21, and 22]. Environmental and hydrological conditions indicate, through this work, that the Kurdistan region of Iraq is an adequate area for RWH and can play a vital role in the augmenting water for various purposes in order to achieve self-sufficiency.

This required a series of studies of Macro RWH technique for different areas , rainfall and time conditions. Such studies include recorded and forecasting rainfall data scenarios similar to those conducted on Sinjar District- northwest of Iraq, which is largely similar in its environment to Koysinjaq which located in Erbil - Kurdistan region of Iraq. In addition Koysinjaq has an advantage in producing more harvested runoff due to environmental, hydrological and geographical conditions.

These series of studies of Macro RWH technique conducted by [20, 21, 22, and 23] aimed to study a macro RWH to exploit harvested runoff for supplemental irrigation system in order to increase the wheat crop yield of the rain-fed farms by increasing the irrigated area under different rainfall conditions and for both recorded and forecasted rainfall depths. These researches conducted on south; north and east Sinjar District respectively using (NRCS-CN) curve number method with the watershed modeling system (WMS) to estimate the direct harvested runoff from an individual rain storm in suggested reservoirs. The results indicated that there was a considerable amount of annual harvested runoff. The harvested runoff used for supplemental irrigation process was satisfying the increase of the irrigated crop area. East Sinjar location has four basins, with catchment's area of 63.32, 65.81, 151.7, and 154.2 ($km^2$), the maximum volume of harvested runoff was been produced during the season of 2000-2001 of annual rainfall of 415.5 mm. The volume of harvested runoff that stored in the reservoir No. 1 through No. 4 were 3.53, 4.02, 9.22 and 11.41(*106 $m^3$) respectively. The minimum runoff volume had been achieved during the season 1999-2000, where the annual rainfall was 182 mm. For this value, the volume of stored water in the reservoirs was 0.005, 0.005, 0.003 and 0.10 (*106 $m^3$) respectively [21].

The aim of this research is to test the Macro RWH in Koysinjaq (Koya) District, Kurdistan region of Iraq to discover the capability of the region for rainwater harvesting in order to save significant runoff water for different purposes then to contribute solving the problem of water shortage of Iraq.

## 2 Methodology

Digital Elevation Model (DEM) of Koysinjaq (Koya) district was used with Global Mapper model in order to find suitable location for the harvested dams. Topographical criterion of harvested dams was investigated where the location should satisfy first, crosscut with the final main runoff trajectories of the catchment area. Second minimum dams cross section that lead to a minimum ratio of reservoir's surface area to its storage volume in order to minimize the dams constructions cost as well as to minimize the losses water by evaporation processes from reservoir's surface area. Then Watershed modeling system (WMS) was used with Koysinjaq's DEM, its land use, soil type and rainfall data, firstly, to figure out the selected basins and their properties then to estimate the runoff volumes based on SCS-CN method. The details of land use and curve number will be explained later.

The methodology used for this research is well documented by Zakaria et al. [20, and 21] and Al-Ansari et al. [22].

## 2.1 Study Area

Koysinjaq (Koya) district (Figure 1)is located within Erbil Governorate in northeast. According to Iraqi statistics of 1987, the Koysanjaq population is about 39484 people. Koysinjaq (Koya)geographically is a mountainous area with different uphill at the north, while at the south and southwest, fertility plain extends to the border of Erbil with Kirkuk city, which represents the historical alluvial plain of the Tigris River. The intensive farming of wheat and barley are distributed at the plain of Erbil south of Koysinjaq (Koya)districts. Accordingly, the average depth of the soil increases from the north to the south to reach up to 1.3 meters [24].Koysinjaq (Koya), northeast of Iraq, and Sinjar District are characterized by what locally Known by Kahrez which is a subterranean aqueducts that collect groundwater by subsurface tunnel to surface canals then the water provided to the residential locations and farms. Most kahrezs in Iraq are passing through an alluvium of porous, water-bearing beds. The longest kahrez in Iraq is found in Sinjar District. Other Kahrezs can be found in the area between Shaqlawa and Koysinjaq in addition other locations of Kurdistan region of Iraq [25].

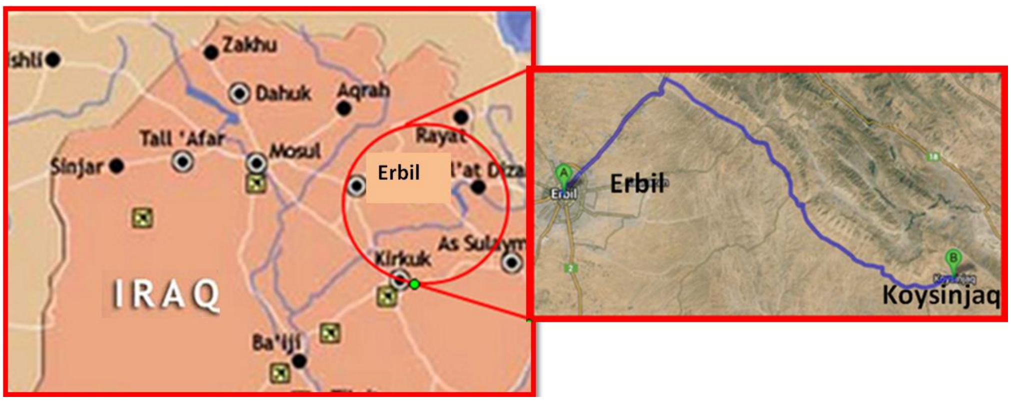



Figure 1: Location of Koysinjaq area according to the Erbil city at Kurdistan region of Iraq, (source: flickr.com and Googol map)

Buringh (1960) described the soil of study area (Figure 2) as a brown soil medium and shallow phase over Bakhtiary gravel. People at Koysinjaq (Koya) depend on rain and groundwater for agriculturalprocesses.

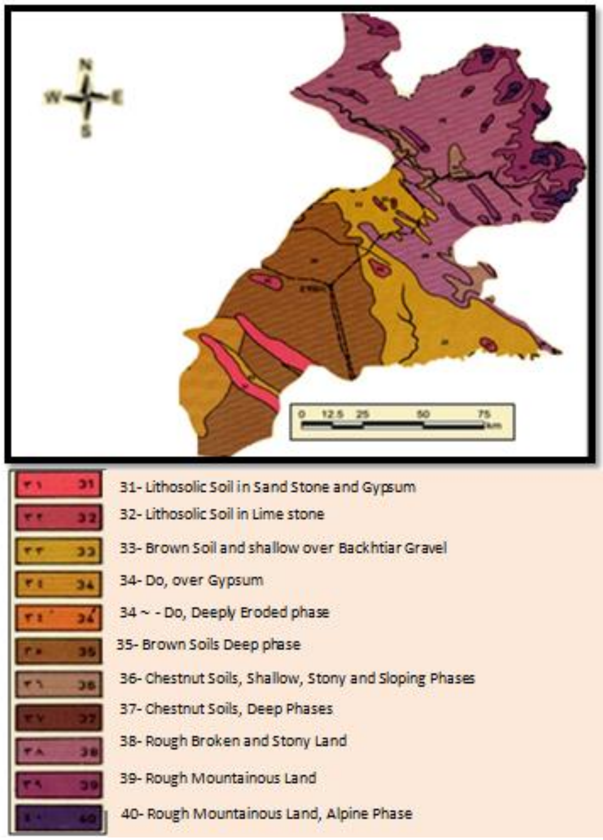



Figure 2: Soil map of Erbil Government, (source: Buringh ,1960)

## 2.2 Koysinjaq Rainfall

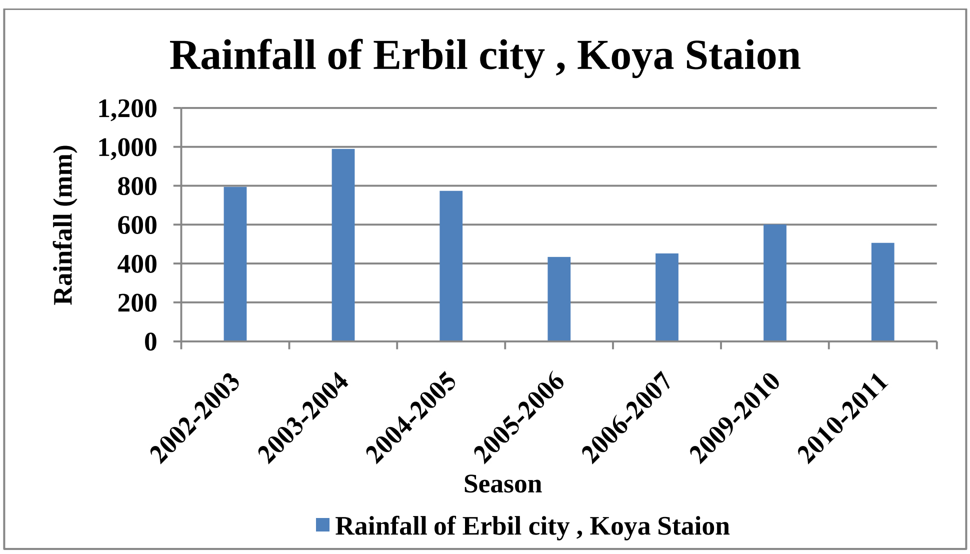



Figure 3: Annual rainfall depths on Koysinjaq area for the period (2002-2011)

Figure 3 shows annual rainfall depths for the period (2002-2011) as provided by Koysinjaq (Koya)Meteorological station. Two seasons (2007-2008 and 2008-2009) where neglected due to missing data. The rainy season extends from November to May.
Despite the fact that, annual rainfall depth (433-989) mm varies largely on the study area (Koysinjaq (Koya)) during the study period (2002-2011), was above 600 mm apart from three seasons (2005-2006, 2006-2007 and 2010-2011) which reached about 433, 452 and 506 mm respectively. However, according to the historical rainfall record, the average annual rainfall depth on Koysinjaq (Koya)area exceeds 650 mm. With this depth of rainfall, Koysinjaq (Koya) area cannot be consider as an arid or semi-arid region [26].
Four basins were been selected to estimate the runoff during the rainy seasons for the study period. For each basin, the runoff is to be collected from the catchment area of the basin toward the outlet of the basin where an earth dam is to be located.

## 2.3 Land Use/Land Cover

The Land use/land cover (LULC) map provides information on the types of features found on the earth's surface (land cover) and the human activity that is associated with them (land use). It is an important indicator for the calculating the curve number for the suitable sites for the catchment is of rainwater harvesting. In this study, the LULC was derived from satellite imagery, Landsat 8, that provided by the National Aeronautics and Space Administration (NASA).The image was acquired on June 15, 2013 which has 11 bands with a 30 m spatial resolution. It is registered using the Universal Transverse Mercator (UTM) Projection Zone 38 North with a World Geodetic System (WGS) 84 datum. Moreover, the image is atmospherically corrected using the darkest pixel method which is also known as the histogram minimum method. This method provided a reasonable correction, at least for cloud-free skies. Figure 4show the following maps:(a) Map of Iraq, (b) Location of Erbil governorate,and the area of interest (Koysinjaq) is masked up from the image (figure 4 (c)).

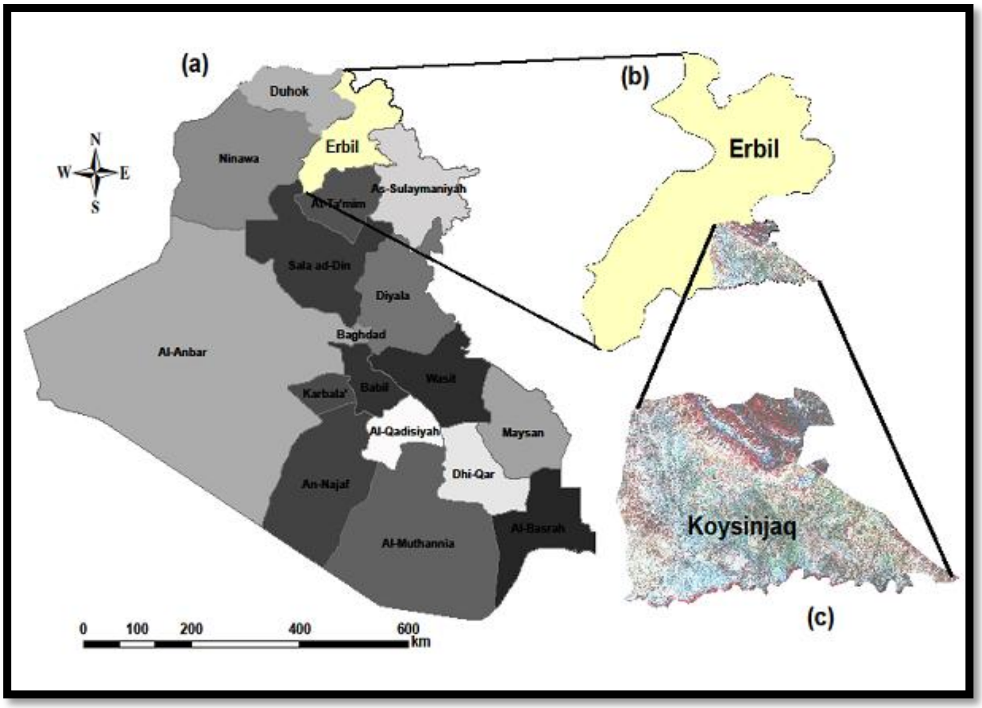



Figure 4: (a) Map of Iraq. (b) Location of Erbil governorate. (c) Location of study area (Koysinjaq)

Thematic mapping of different LULC classes was achieved through supervised classification using a maximum likelihood approach. The training data (sites) for the classification purpose were obtained using Google earth and the false color composition of three bands 5, 4, 3 (Figure 5).This is achieved due to the lack of the field data information. The data processing and classification were conducted using ENVI (V. 4.7, ITT Visual Information Solutions Group (ITT VIS), formerly known as Research Systems Inc. (RSI), Boulder, CO, USA). Using the study area, the land covers classified into five classes (type). They were: building up,vegetation, bare soil, rock, and water (Figure 6).

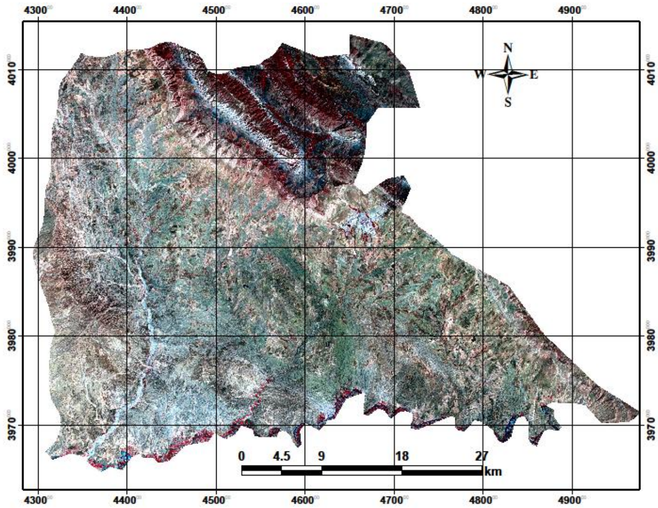



Figure 5: Color composite satellite images (Landsat 8) of the study area

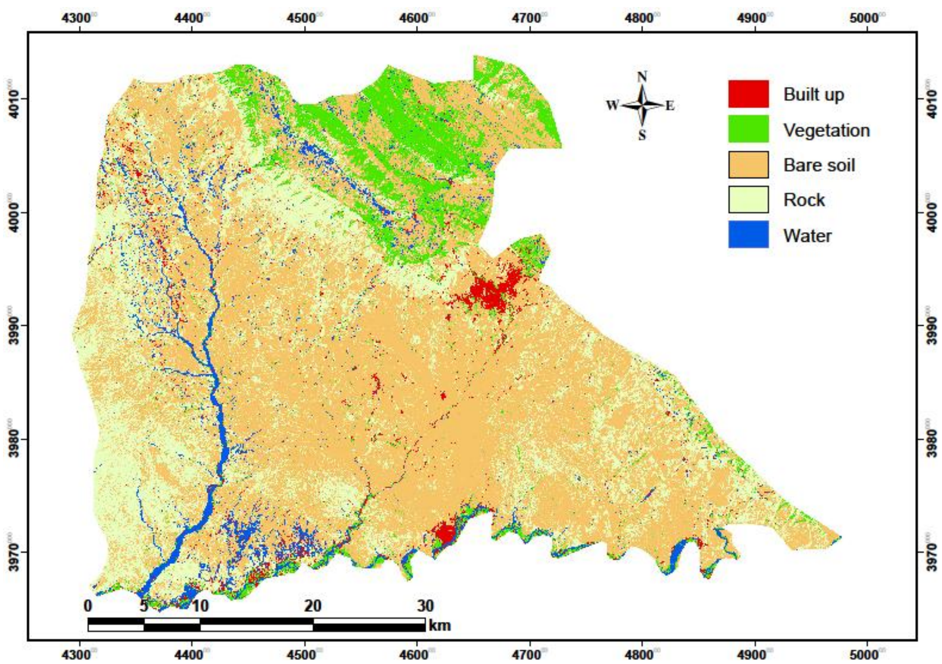



Figure 6: LULC map for Koysinjaq districts

The built up area is shown in red color, and blond color refers to the bare soil area, including spares grass. The water areas are shown in blue, olive color respectively, while green color refers to the vegetation area including trees and grass. The land use data for selectedbasins (Figure 7) was usedin order to identify thecurve number for each basin, then based on percent of area for each sub-area (build up, vegetation, bare soil, rock, and water) the weighted average curve number was estimated to be considered in the runoff model.

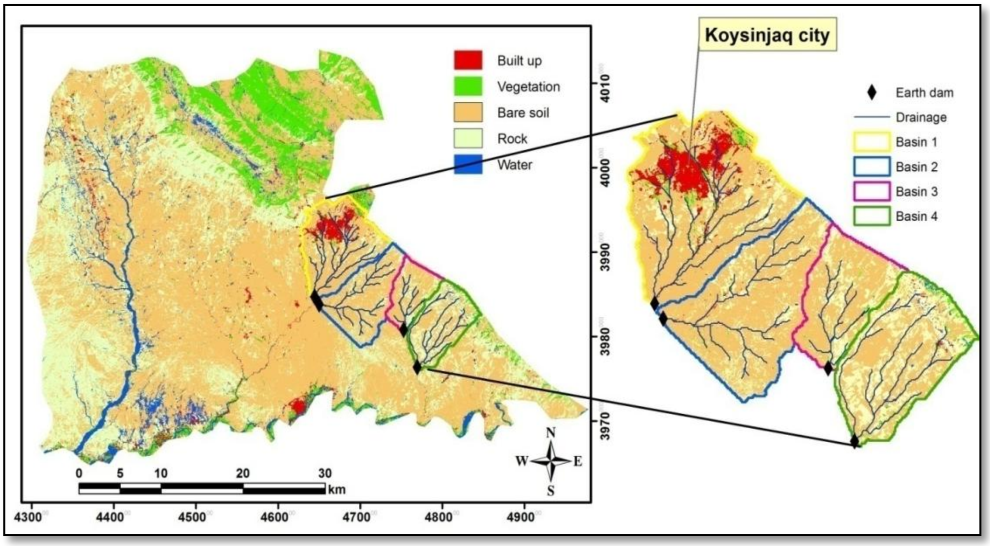



Figure 7: LULC map of the selected four basins area

## 2.4 Curve Number

The weighted average CN values for the four basins at Koysinjaq (Koya)District (Table 1) were estimated depending on area of specific land use as a percent of total basin area and calibrated based on antecedent moisture condition (AMC) for dry, average, and moisture conditions for the total antecedent rainfall depth (antecedent five days).

Table 1 : Curve number (CN) values for the selected Basins at Koysinjaq districts, Kurdistan region of Iraq

| | Curve Number Condition | | |
|---|---|---|---|
| **Basins** | **Normal** | **Dry** | **Wet** |
| **1B** | 79.95 | 62.61 | 90.17 |
| **2B** | 76.63 | 57.93 | 88.29 |
| **3B** | 78.68 | 60.78 | 89.46 |
| **4B** | 82.78 | 66.88 | 91.71 |

These antecedent rainfall depths were identified based on daily rainfall data of the region. The antecedent moisture content considered dry if the total five days rainfall depth was less than 35mm and wet if the depth is greater than 53mm. For the Soil Conservation Service, 1972 (SCS) method of rainfall abstractions,the tabulated curve number is equal to CNII, for average condition and modified for dry and wet conditions, by the following equations [27]:

$$CN_I = \frac{4.2 * CN_{II}}{10 - 0.058 * CN_{II}} \qquad (1)$$

$$CN_{III} = \frac{23 * CN_{II}}{10 + 0.13 * CN_{II}} \quad (2)$$

In which:
$CN_I$= Curve number for dry condition. ;
$CN_{III}$=Curve number for wet condition.

## 2.5 Properties of Basins, Reservoirs, and Dams

Watershed modeling system (WMS) is an efficient tool to estimate runoff for a specific catchment area. It has ability to provide the propertiesof the selectedbasins, (area, length, elevation and slope),(Table 2) depended on data elevation model (DEM) of the region.

Table 2: Properties for the selected Basins at Koysinjaq

| **Basin** | **Area ($km^2$)** | **Average Length (km)** | **Average Basin slope (m/m)** | **Average Elevation (m)** |
|---|---|---|---|---|
| 1B | 81.45 | 12.7 | 7.70% | 580.5 |
| 2B | 62.76 | 12.05 | 6.40% | 551.0 |
| 3B | 32.41 | 8.7 | 6.10% | 598.0 |
| 4B | 52.34 | 10.8 | 9.80% | 617.4 |

Furthermore, WMS can support the calculation to estimate the properties of the reservoirs and dams (Table 3). However, the elevation of dam 3 can support to minimize losing water when accrue by converted the harvested water to the nearest reservoir by some channel.
The main trajectories of the harvested runoff to the outlet of the selected basins at Koysinjaq (Koya)District are some valleys distributed in the study area, and theyare characterized by narrow, deep andV-shape. The dimensions of the cross section of these valleys give short lengths for the selected dams with a relative increase in their heights.

Table 3: Properties for the reservoirs and dams at Koysinjaq

| **Reservoir** | **Max. surface Area ($km^2$)** | **Max. storage ($*10^6$ $m^3$)** | **Dam height (m)** | **Dam length (m)** | **Dam elevation (m)** |
|---|---|---|---|---|---|
| 1B | 0.401 | 0.378 | 6.0 | 110.0 | 421.5 |
| 2B | 0.633 | 0.685 | 6.0 | 233.3 | 425.5 |
| 3B | 0.098 | 0.083 | 6.0 | 092.0 | 470.5 |
| 4B | 0.330 | 0.363 | 6.0 | 123.6 | 409.5 |

However, the predominant factors are the short length which givesa minimum cost when constructing these dams.
For this research, dams of 6 m height were selected, and according to the selected height,

the length of the dams, total capacity of the reservoirs as well as their surface areaswere estimated (Table 3), the relationship between reservoirs storage capacity and the elevation were illustrated in figure (8- a,b,c and d) and then linearization relationship of Surface area- Storage capacity of four selected reservoirs(Figure 9). This relationship is very important to estimate the loses of the water by the evaporation process (the calculations of the losses water from the surface reservoirs are not included in this work).

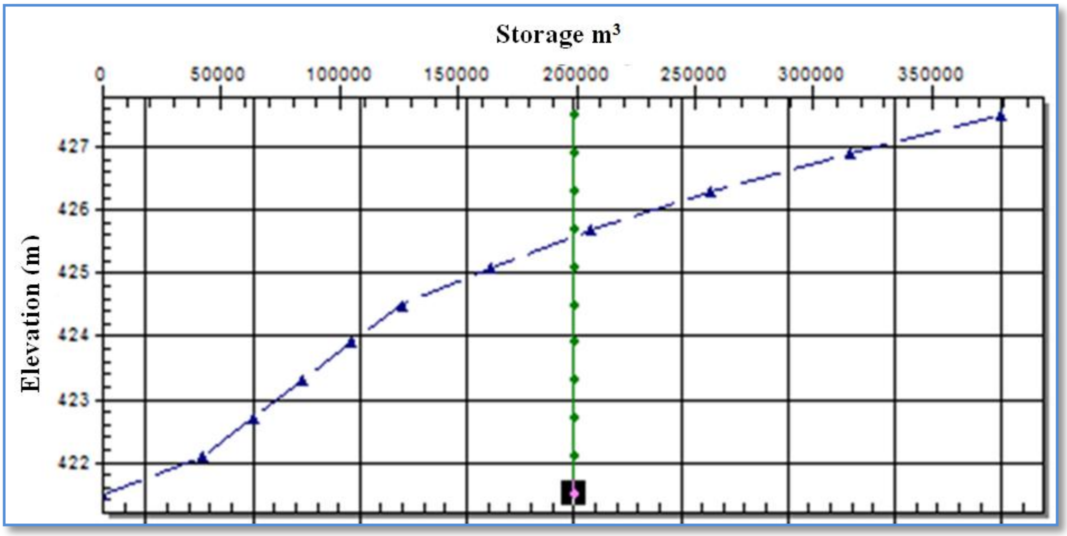



Figure 8-a: Storage-Elevation curve for Reservoir No. 1

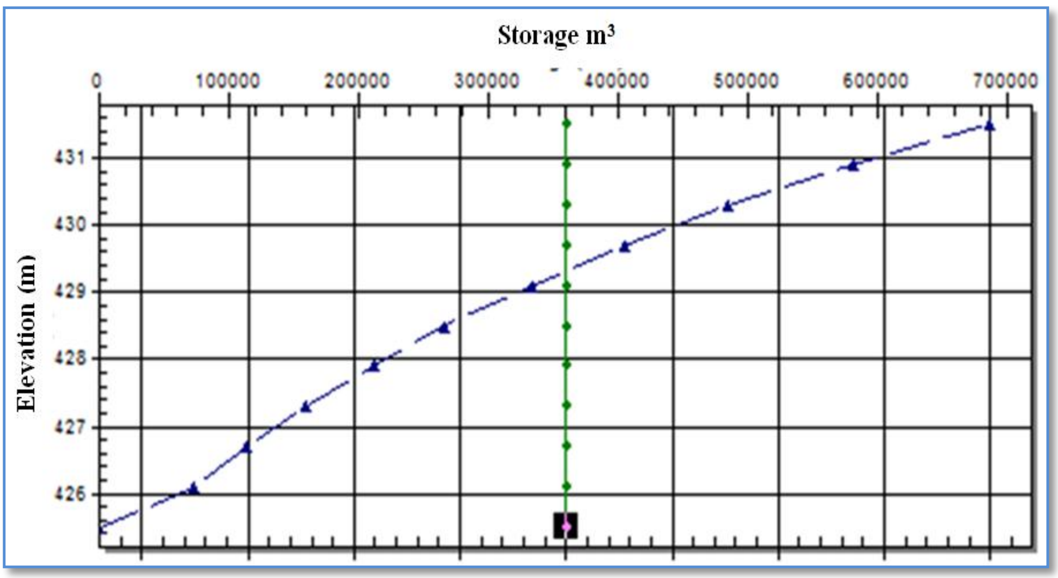



Figure 8-b: Storage-Elevation curve for Reservoir No. 2

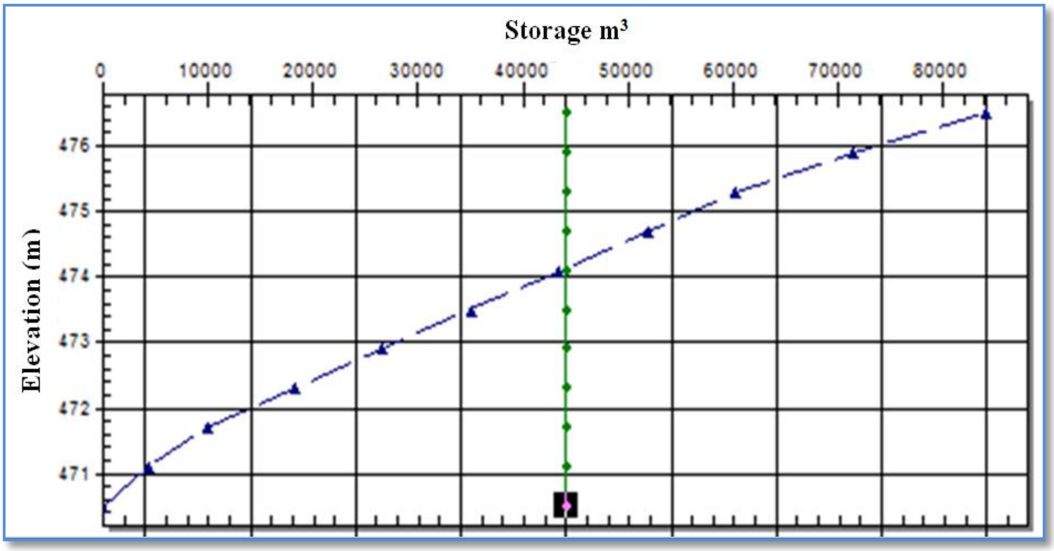



Figure 8-c: Storage-Elevation curve for Reservoir No. 3

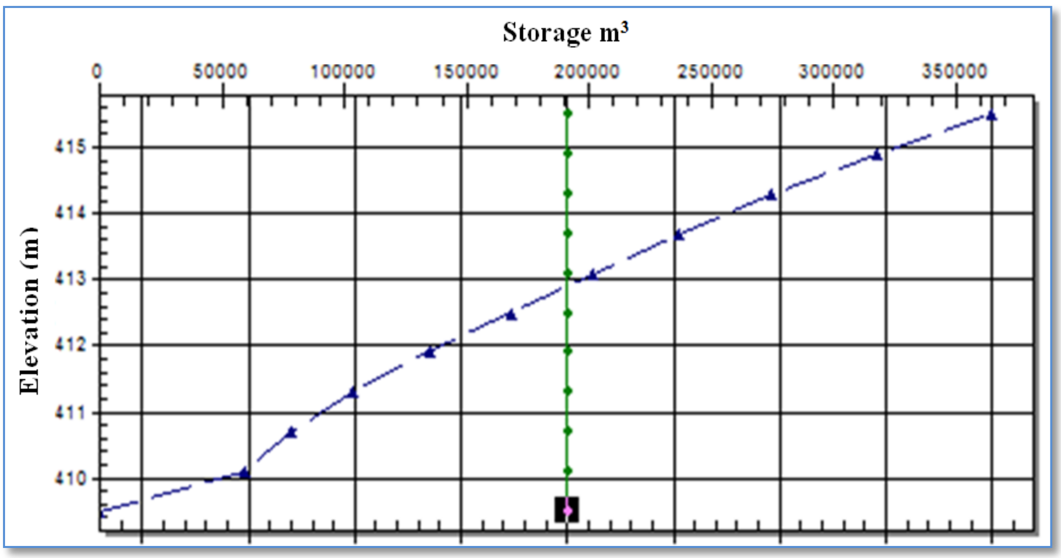



Figure 8-d: Storage-Elevation curve for Reservoir No. 4

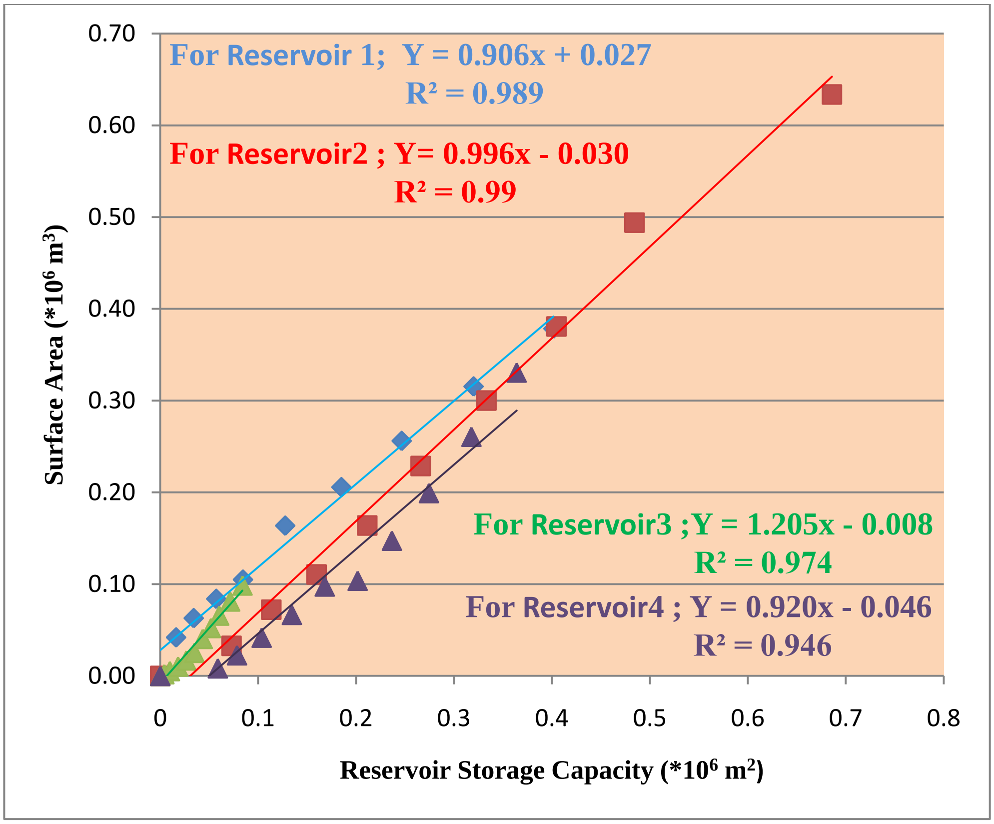



Figure 9: Linearization relationship of Surface area- Storage capacity forthe four selected reservoirs.

## 3 Results

The harvested runoff from the four individual basins that might be stored at the outlet of each basin to form reservoirs of different capacities using an earth dam are shown in figure 10 andtable 3. The harvested runoff volumes were calculated using WMS.

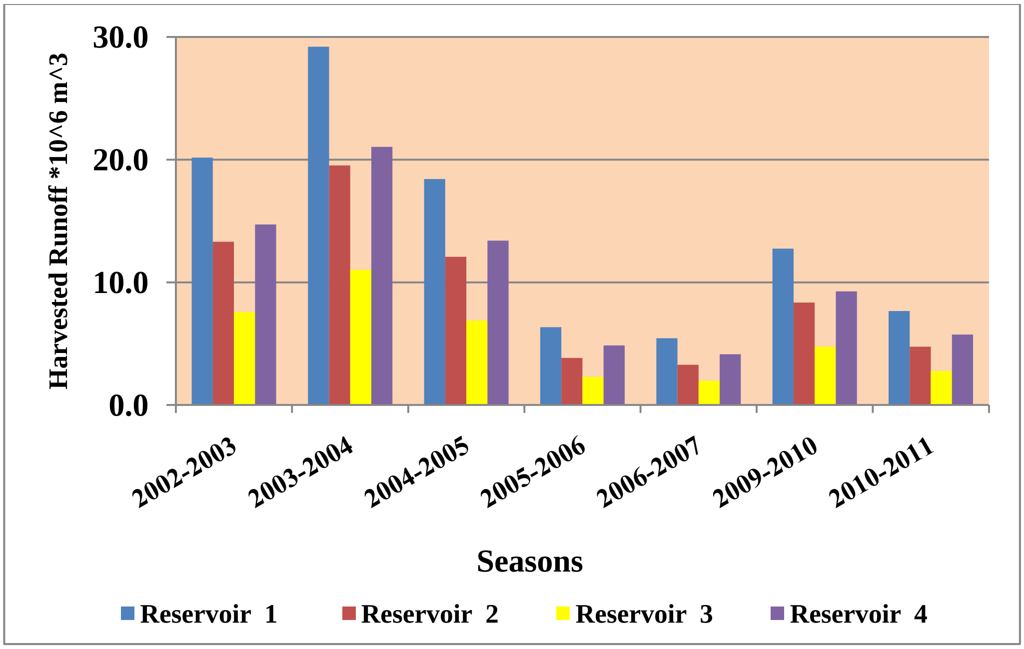



Figure 10: harvested runoff volumes in the individual four reservoirs for the study period (2002-2011)

The results showed that, the maximum accumulated harvested runoff reached up to 29.19, 19.52, 11.01, and 21.04 ($*10^6 m^3$) that was captured from catchment areas of basin No1 to No 4 and stored in the reservoir No. 1 to No.4 respectively during maximum rainfall season 2003-2004 of total rainfall depth of 989.2 mm.

While the minimum accumulated harvested runoff reached up to 5.44, 3.29, 1.97, and 4.14 ($*10^6 m^3$) that was captured from catchment areas of basin No1 to No 4 and stored in the reservoir No. 1 to No.4 during the minimum runoff season of 2006-2007.

It should be noted that, it is not necessarily that the least rainy season produces less amount of runoff, as the determining factor in that firstly, is the distribution of rainfall and then its quantity. However, Figure 11 shows the maximum total harvested runoff from the four basins together that reached up to 80.77 ($*10^6 m^3$) during maximum rainfall season 2003-2004, while minimum total harvested runoff from the four selected basins together reached 14.83 (($*10^6 m^3$) during the minimum runoff season of 2006-2007.

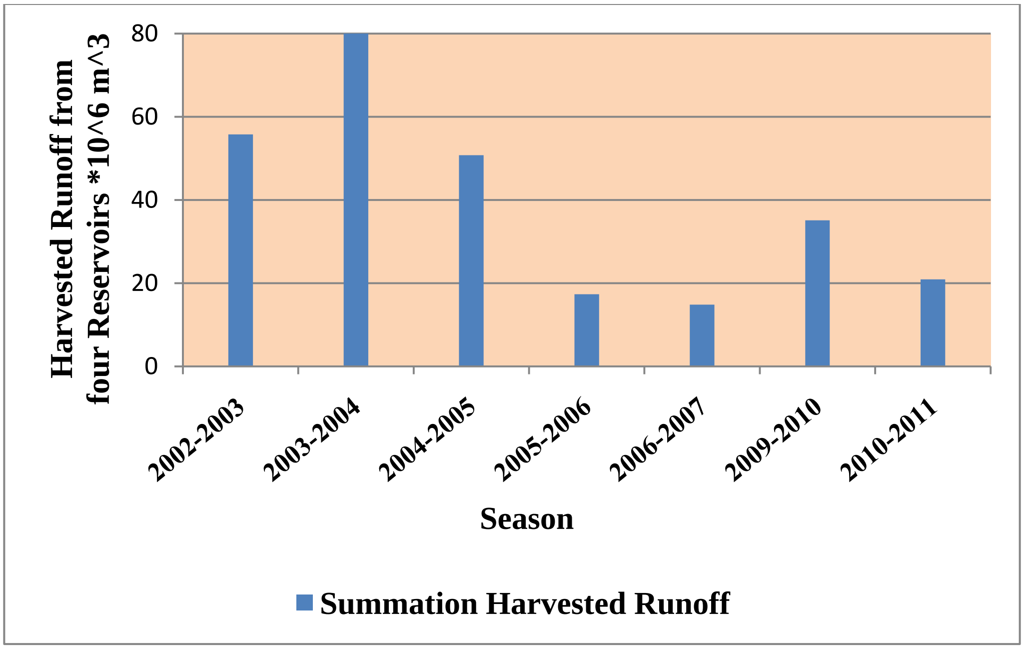



Figure 11: Total harvested runoff volumes from the four reservoirs for the study period (2002-2011)

Heavy rainfall storm, not less than 12.5 mm for the normal condition, may produce a runoff wave that had been directed by gravity and the effect of the basin slop to the outlet of the basins to face small earth dams and then to conform reservoirs.

Rainfall is the most important factor influencing the amount of runoff, especially its distribution and amount, in addition, to some other factors that will be mentioned later.For better understanding of the mechanics of runoff, a comparison between the maximum (989.2 mm) and minimum (433.9 mm) rainfall seasons that occurred during 2003-2004 and 2005-2006 respectively for the study period of 2002-2011will be shown. Figure 12, shows the distribution and amount of the rainfall on the whole catchment area of the four basins for the maximum and minimum rainfall seasons (2003-2004 and 2005-2006).

For all selected rainy seasons, the seasons begin on the first of November. During the rainfall season of 2003-2004, there were twenty-six rainfall's storms that produced runoff, the first rainfall depth was (25 mm) and last one was (41mm) occurred during 10 and 182 days after start the rainfall season of 2003-2004. The duration between these rainfall storms were ranged from 0 to 44 days, and the maximum rainfall depth was 70.0 mm.

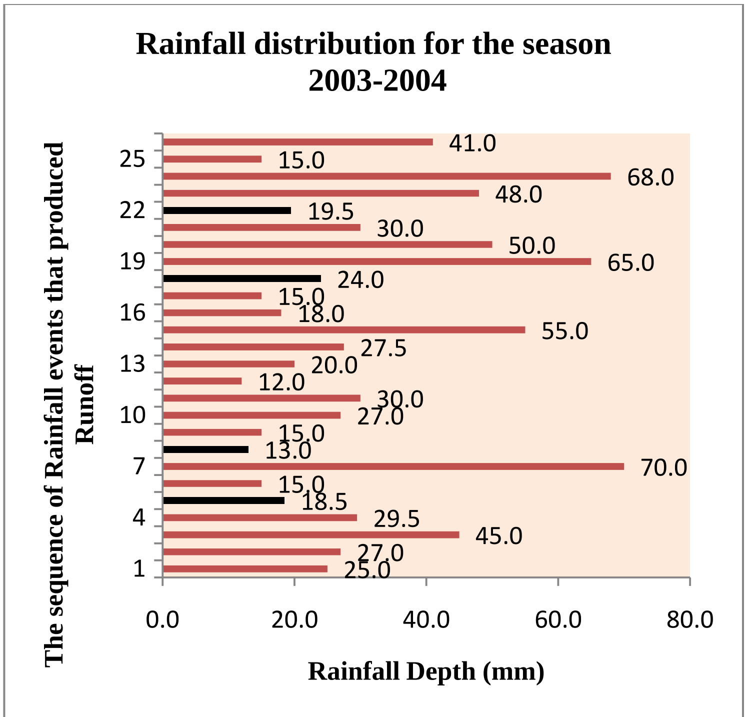
Wet antecedent moisture condition (AMC) was satisfied during all these rainfall storms, except four events of 15, 13, 24 and 19.5 mm of rainfall depth, which are marked in black line in Figure 12, where these four events occurred under normal antecedent moisture conditions. Other rainfall storms which occurred during season 2003-2004, did not produce runoff due to low rainfall depth i.e. less than 12.5 mm. During the rainfall season of 2005-2006, there were fifteen rainfall storms that produced runoff. The first was with rainfall depth 13.0 mm and the last one with depth of 22.5 mm, all of them had occurred between the 22 and 177 days after the start of the rainfall season 2005-2006. The durations between these rainfall storms were from 0 to 47 days.

In summary, the rainfall storms approached each other and moved away from the beginning and the end of the season more than what happened in the season of 2003-2004. In addition, during 2005-2006, there was one extra storm for normal condition and three days more for the maximum duration of rainfall, and the maximum rainfall depth was 40.0 mm.Wet antecedent moisture condition (AMC) was satisfied during all these rainfall storms, except five events of 13.0, 13.5, 22.0, 20.5 and 23.0 mm of rainfall depth, which are marked as black lines in figure 12,where these five events occurred under normal antecedent moisture conditions.

Other rainfall storms which occurred during 2005-2006, did not produce runoff due to low rainfall depth.

Chow, et al. [27], explained the classification of antecedent moisture conditions (AMC) for the Soil Conservation Service, 1972 (SCS) method of rainfall abstractions for the dormant season according to the total 5 days antecedent rainfall depth as follows: The condition of AMC is dry if total 5 days antecedent rainfall depth is less than 0.5 inch (12.7 mm), and the condition is normal if total 5 days antecedent rainfall depth ranged between 0.5 to 1.1 inch (12.7 to 27.94 mm), while the condition will be wet if the total 5 days antecedent rainfall depth is more than 1.1 inch (27.94 mm).

The main factors that affect the harvested runoff volume are the size of the catchment area, its type of soil, the distribution and amount of rainfall, the time period between the rain storms, curve number (CN) values, the antecedent moisture condition (AMC), the size of the reservoirs. It should be noted that, not all rainfall storms produce runoff, the weak rainfall storm that does not produce runoff is very important for estimating the SCS curve number where it affect the corresponding value of CN and change its value from dry to wet and this is very sensitive for runoff calculations. This may be explained by figure 13 (AMC during the seasons 2003-2004 and 2005-2006), which shows, through the twenty-six rainfall storms that produced runoff during the rainfall season of 2003-2004, the antecedent moisture condition (AMC) drop to less than 27.94 mm just four times at 23.2, 19.0, 24.0, and 19.5 mm. Accordingly, normal antecedent moisture condition (AMC) was satisfied during these four rainfall storms. During the rainfall season of 2005-2006, the antecedent moisture condition (AMC) drop to less than 27.94 mm just five times at 13.0, 24.5, 25.0, 23.5 and 23.0 mm.. Accordingly, normal antecedent moisture condition (AMC) was satisfied during these five rainfall storms. Through time producing runoff, dry condition didn’t satisfy during seasons 2003-2004 and 2005-2006, due to the fact that the rainfall did not stop during these seasons for enough periods to satisfy dry condition.



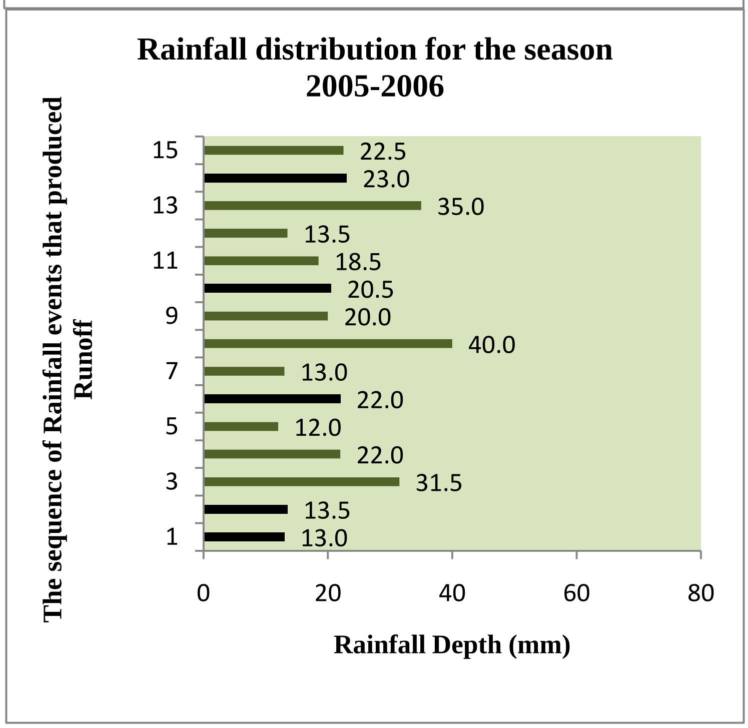




Figure 12 : Rainfall distribution for the maximum and minimum rainfall seasons

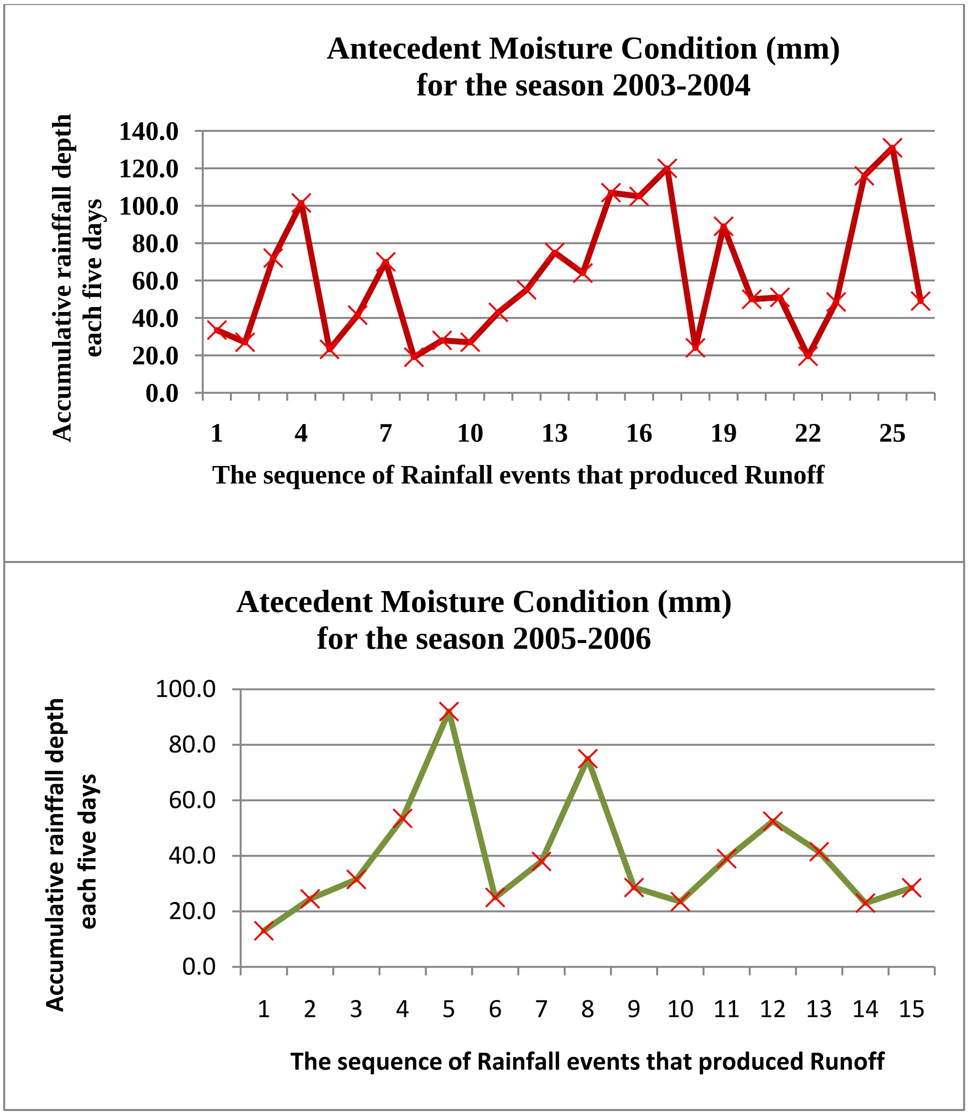



Figure 13: Antecedent Moisture Condition (total 5 days antecedent rainfall depth) during the seasons 2003-2004 and 2005-2006

Dry condition didn't satisfy during both seasons of 2003-2004 and 2005-2006,that is due to the fact that the rainfall did not stop during these seasons for enough period to satisfy dry condition. However, for both rainfall seasons 2003-2004 and 2005-2006 the change of antecedent moisture conditions (AMC) among dry, normal, and wet will reflect on the values of curve number and thus will effect on the runoff volumes and so on for other selected seasons. However, some factors like the size of the catchment area, its type of soil, the distribution and amount of rainfall, the time period between the rain storms, curve number (CN) values, the antecedent moisture condition (AMC), and weak rainfall storm that does not produce runoff, all these factors participate together to produce the amount of runoff as explained in figure 14 that shows runoff behavior during the seasons 2003-2004 and 2005-2006.

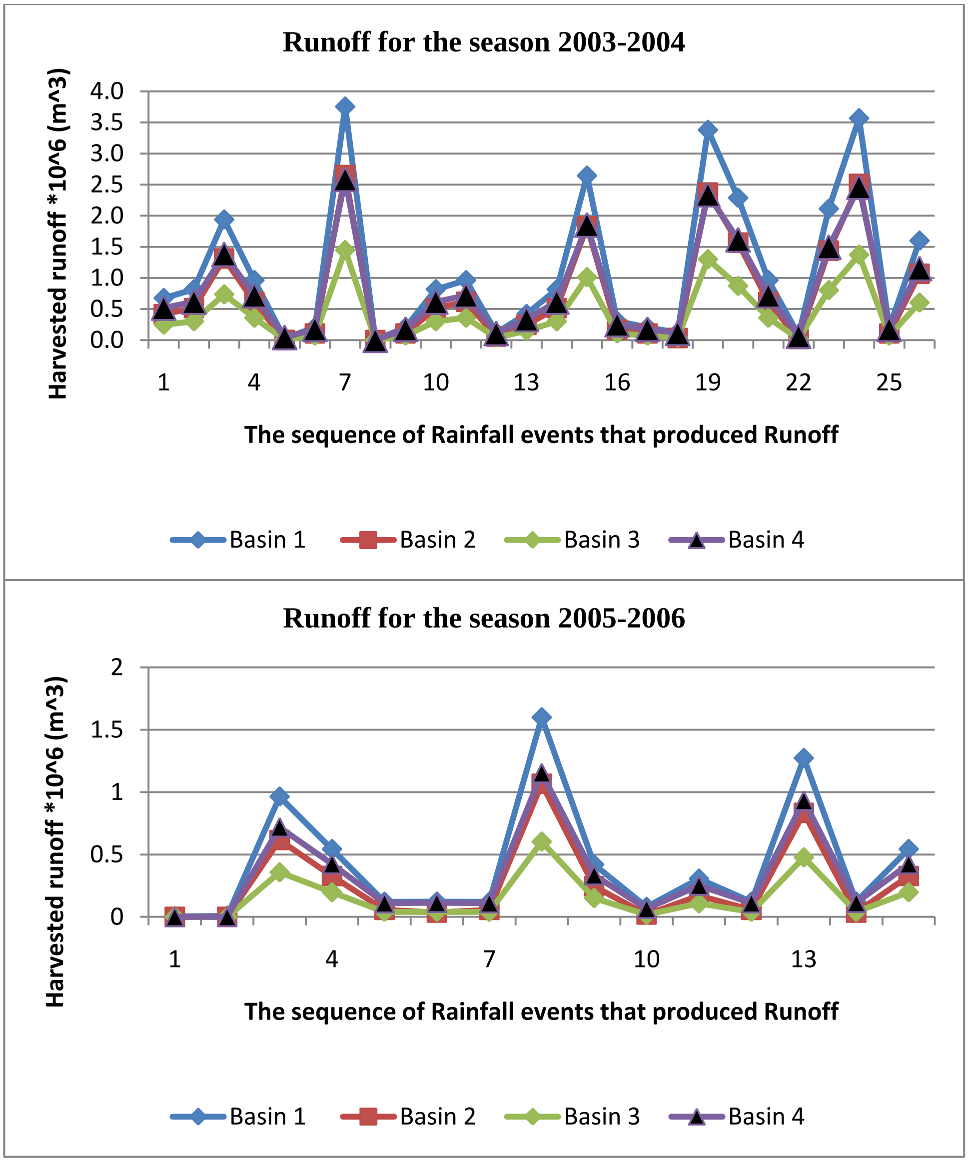



Figure 14 : Runoff behavior during the seasons 2003-2004 and 2005-2006

For the season 2003-2004, the results show that the maximum harvested runoff was always achieved from the catchment area of basin number one, which has the biggest area (81.45 $km^2$) compared with other basins.

The maximum harvested runoff from basin one reached 3.755 ($*10^6 m^3$). The resultant amount of this harvested runoff is due to the 7th rainfall storm out of 26 that produced runoff. This storm reached 70 mm, where it strongly with other effective factors produced the above maximum runoff. On another hand, the minimum harvested runoff was always achieved from the catchment area of basin number three, which has the smallest area (32.41 $km^2$) compared with other basins. The minimum harvested runoff from basin three reached 0.017 ($*10^6 m^3$). The resultant amount of this harvested runoff is due to the 22$^{nd}$ rainfall storm out of the 26 that produced runoff. This 22$^{nd}$ rainfall storm reached 19.5

mm, where with other effective factors produced the above minimum runoff.
Same events occurred during the season 2005-2006, but with less values due to less rainfall depths, where the maximum runoff reached up to 1.598 ($*10^6 m^3$) that was harvested from basin number one by the 8th rainfall storm out of 15 that produced runoff which reached 40.0 mm. While the minimum runoff reached up to 0.0177 ($*10^6 m^3$) that was harvested from basin number three by the 10th rainfall storm that reached 20.5 mm. These runoff quantities can be employed in various fields, especially for the development of cities.

## 4 Conclusion

Koysinjaq (Koya) District, at Kurdistan region of Iraq has limited water resources and is rapidly developing. The area might face a big problem of water shortage due to its limited water resources in addition to the lack of good planning and management of the water resources. Water shortages problem can affect the vocabulary of day life in its various forms, agricultural, industrial and then to varying degrees the economic activities.Rainwater harvesting is not widely used in Iraq. Such technique can be used to save a huge amount of water for various purposes. Therefore, the technique of Macro RWH has been tested in Koysinjaq District, to discover the capability of the area for rainwater harvesting. The results show that, the application of Macro RWH will provide a new source for water. The annual volume of water that can be harvested from all selected basins ranged 14.83 to 80.77 (*106 m3) for the study period (2002-2011). This indicates that the technique of Macro RWH can be considered to provide a new source of water to the area and then to minimize the water shortages problem.

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