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ESTIMATING OF GROUNDWATER RECHARGE IN NORTH, CENTRAL, AND SOUTH BASIN OF ERBIL

Jwan Sabah MUSTAFA -PhD student, University of Salahaddin , College of Engineering, Civil Engineering Department, Erbil, Iraq, e-mail: juan.sabah@yahoo.com or jwan.mustafa1@su.edu.krd

Dana Khider MAWLOOD -Prof. Dr., lecturer, University of Salahaddin , College of Engineering, Civil Engineering Department, Erbil, Iraq

Abstract: Groundwater recharge is the most important element in water planning and management in Erbil basin. The rapid grow in population and development causes to increase their requirement to water demand and consumption. The most important steps in aquifer system is accurate estimation of groundwater recharge. There are many approaches to estimate the recharge. In this study, it is focused on water level method then compare with calculated recharge by empirical equations. The method provides a point value of the recharge calculated from the water level rise in a well multiplied by the specific yield (Sy) of the aquifer. Based on the assumptions that the water-level rise is caused by recharge arriving at the groundwater table (GWT), and also assume that the Sy is constant. The main aim of this study is to estimate the amount of change in groundwater levels over time and the recharge calculation for the study area. The study concluded that the change in groundwater levels between years (2021-2022) is (-0.09, -7.74 and -17.42) m for the Kapran, central and Bashtepa sub-basins respectively. Similarly, the difference between water levels in (2004-2022) are (-32.72, -50.87 and -54.58) m for the same mentioned sub-basins as well. It means that the average decreases during (2021-2022) is (-8.42) m, however, the average change in water levels in all three sub-basins in (2022) with (2004) declined by amount of (-46.06) m. The continuous lowering groundwater levels will cause to damage the aquifer system and drought problems in Erbil basin.

Keywords: Erbil basin, change in groundwater, groundwater level, recharge, aquifer system

1. Introduction

Usually, rainfall in the mountains, hills, plains and rivers infiltrate gradually into deep aquifers lead to recharged groundwater. In the Kurdistan region northern part of Iraq, groundwater is the main source of water supply and human activites. The groundwater is abstructed by drilling wells. This study conducted on Erbil groundwater basin, which is divided into three main sub-basins: the Northern (Kapran) sub-basin, the Central sub-basin, and Southern (Bashtepa) sub-basin. This study is based on data obtained from the field observation and previous archieved data that collected by Groundwater Directorate in Erbil basin (GWD) to evalaute the existing illegal wells within Erbil basin, also to present their impact on groundwater levels, and decreasing Recharge as well. The total number of drilled legal and illegal wells in Erbil basin is much higher than its legally permitted number of wells. Previous studies has shown that the selected basin water table has suffered the most declination. For these reasons, people in this region are facing to water shortage, and many wells have dried up in Erbil basin. The studies that conducted on Erbil basin area: the study on Hydrogeological conditions of the central part of Erbil sub-basin [1], then the study on the Urban Hydrology and hydrogeological conditions of Erbil City [2], later the study on the Hydrogeology and Iraq aquifer system [3], Groundwater Chemistry of the Erbil Hydrogeologic Basin [4], after those the study on the Future of the World when the Climate is changed [5], then the another study which is on the water harvesting in Erbil Governorate by using the geographic information system (GIS) and remote sensing [6]. Then, the study of the Prediction of the most suitable sites for artificial groundwater recharge using integrated GIS and AHP techniques in Erbil region in Kurdistan region of Iraq [7]. The study of Groundwater Degradation and Sustainability of the Erbil Basin, Erbil, Kurdistan Region, Iraq [8]. Another study is on the Calculation of the Groundwater Recharge by using both Meteorological Water Balance and also Water level Fluctuation in Khan Al-Baghdadi Area [9]. The study on Estimation of water balance in all Iraq using meteorological data [10]. Then also the study on Estimation of water balance for the central part of Erbil basin [11]. Later, the study on Estimating Groundwater Balance by using the Climate Change Impact for Erbil basin which is Semi-Arid Area [12]. Later, the study on Sustainability of Aquifer and Ground Water Condition in Erbil Basin, Iraq [13]. After those, the study of Assessment of sustainability and management for groundwater source in Erbil city [14]. Then, another study on Groundwater Recharge Potential Zone in Erbil Basin which is Determined by Using Fuzzy-Analytical Hierarchy Process (AHP) in North, Iraq [15], Water budget analysis and the groundwater depletion in Kapran sub-basin, Erbil, Iraq [16], However, the study on the impact of climate change on groundwater recharge in the western desert of Iraq [17]. The aim of this paper is to explain the main problems in Erbil basin, Meanwhile, it resommends main points to take into account to develope and keep the sustainability of this vital resources in the study area, and to all those region having similar conditions.

2. Materials and Methods

2.1. Study area description

Erbil basin is one of the major groundwater basin in the Kurdistan region of Iraq. The basin boundery is cover the area about 3,200 Km^2. The study area is bounded by two rivers which are the Greater Zab from the northern part and the Lesser Zab from the southern part of the basin it also lies between coordinate of 36º 08' 30" and 36º 14' 15" north, and 43º 57' 30" and 44º 03' 20" east. The area of the study is described as arid or semi-arid region [1]. The Description of the location of the study area is shown in (Fig.1):

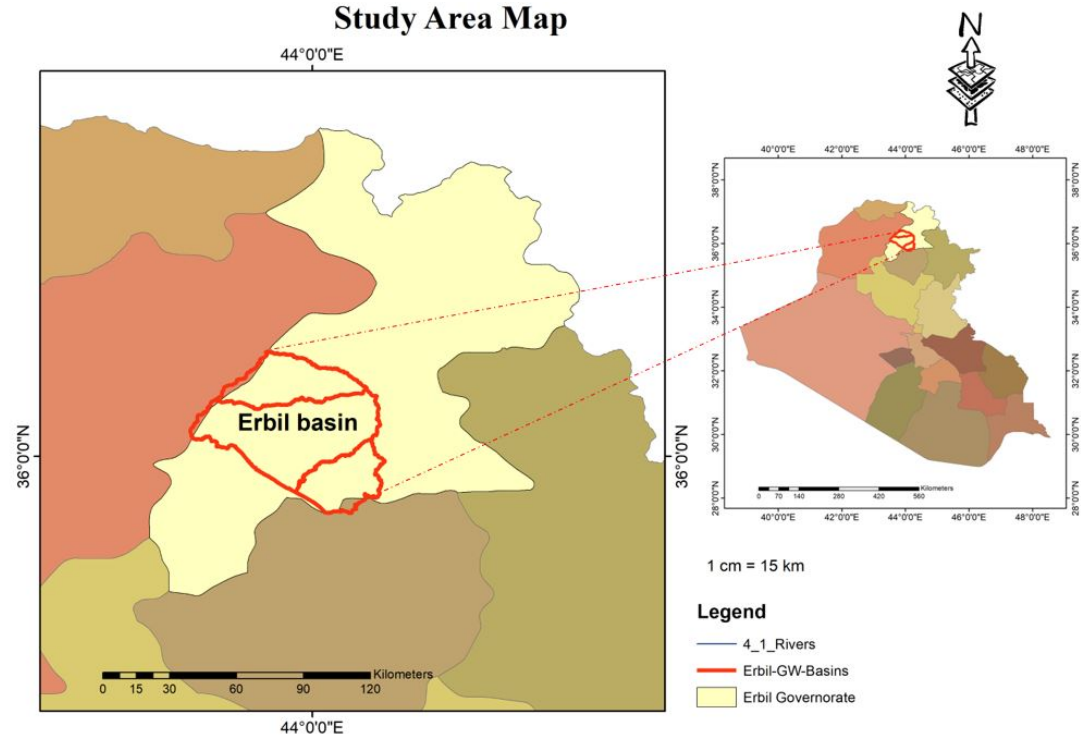

Fig.1 location of the study area (Erbil basin)

2.2. Hydrogeological conditions of Erbil basin

The Erbil Basin is is located in the Low Folded Zone in Northern part of Iraq, and it is in the syncline formed by the two main anticlines that are: the Kirkuk anticlinal structure in the south-west and the Permam Dagh anticline in the north-east. It is bounded by the Greater Zab and from the north and the Lesser Zab from south. Generally, the groundwater flow in the basin from north-east to south west direction [1, 2]. According to the data available in groundwater directorate most of the new drilling wells having depth about 500 meters or more with variable groundwater levels over all the basin, because the topographics of the aquifers in Erbil basin are variable, and this variability impacts on depth to groundwater.

The geological formations of the study area are mostly composed of (Alluvium, Mukdadiya and Bai Hassan Bakhtiary) formations. While, the Bai Hassan Bakhtiary Formation is the main formations in the Erbil basin. It is composed mainly of gravel, sand, clay, and conglomerate strata. In addition, the Mukdadiya Formations consist of thin beds of gravel, sand, or conglomerate. However, the Alluvium is also very common in compositions of the study area, and the composition of it is similar to compostion of Bai Hassan Bakhtiary formations. However, in the Alluvium aquifers there is silt between the other layers instead of multiple clay layers [8]. To see the map of geological cross-section in Erbil basin see Fig. 2:

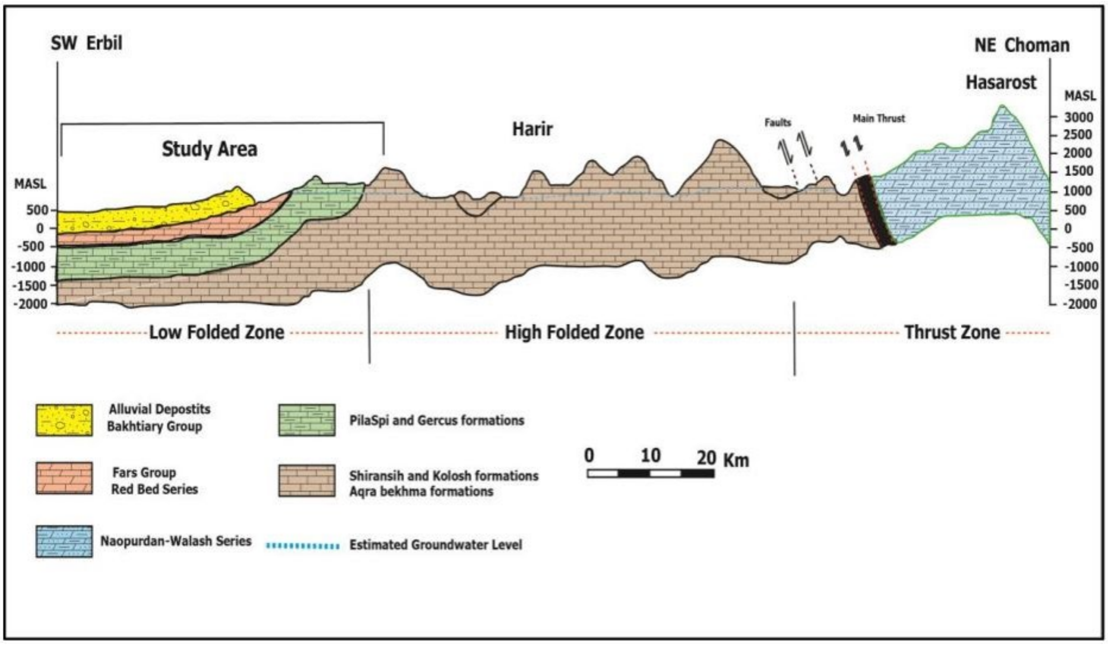

Fig. 2. The geological formation profile of Erbil basin [8]

2.3 Hydrological conditions of Erbil basin

Generally, the climate of the Kurdistan region is comprised of cool snowy winters and warm dry summers. The plain is in the south have semi-arid climate conditions. Erbil basin is located in plain area of the Kurdistan region, the climate of Kurdistan region of Iraq is characterized by high precipitation rates in the northern, and mountainous parts, while dry weather is governed in the plains and in the southern parts, the rainfall starts from (October to May). Moreover, according to the study of the study shows the climate change effect on water balance in Erbil basin [11]. Table 1shows the rainfall data obtained from (2006-2020):

Table 1

Mean monthly rainfall data in Erbil meteorologiacl station (2006-2020)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	sum
Rainfall (mm)	30.9	36.7	66.2	68.3	64.5	72.1	46.5	18.1	1.6	0.0	0.1	3.7	408.6

From above table the maximum mean monthly rainfall is (72.1 mm/year) and the minimum is (0.1 mm/year). Thus, the mean annual precipitation in Erbil meteorological station is about (408.6 mm) during the last 14 years (2006–2020).

2.4. Erbil basin soil types and Curve number

According to the study of [6] who presented that Curve Number (CN) is used to characterize the runoff properties for a certain soil and land cover/land use. The soil conservation service (SCS) runoff equation uses the CN value as input parameter. As well as, the study is also estimated CN per pixel for the study area, via the land cover map and soil map that was reclassified into Hydrologic Soil Groups and hydrologic condition. The curve number value for each hydrologic soil group and corresponding land cover class are presented in Fig. 3:

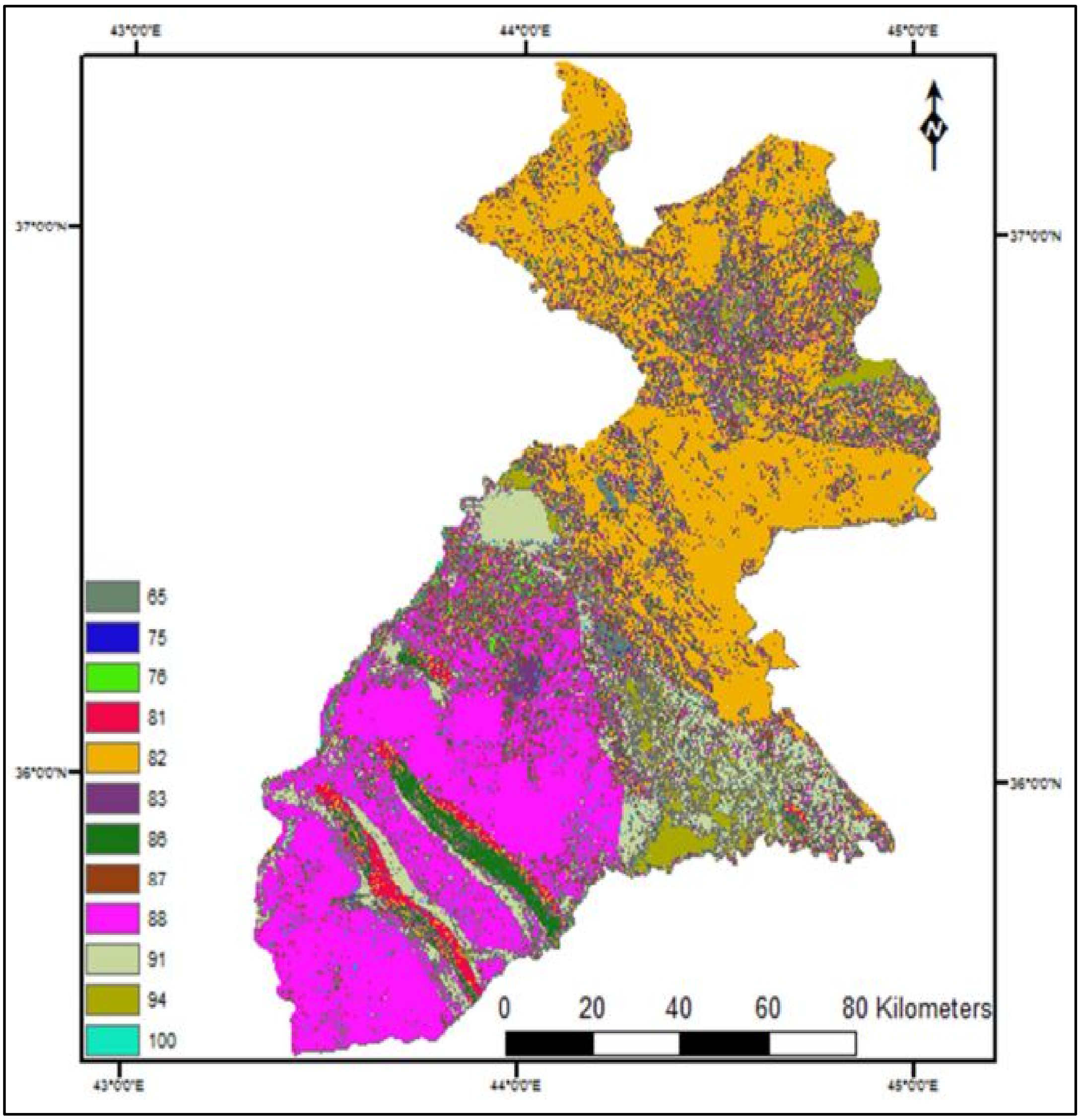

Fig.3- Classification of CN for Erbil governorate [6]

In addition, soil type map prepared for Erbil basin depending on the global hydrology soil group from USGS, the map created by both Watershed Modeling System (WMS) and Arc Map as presented in Figs. 4, 5:

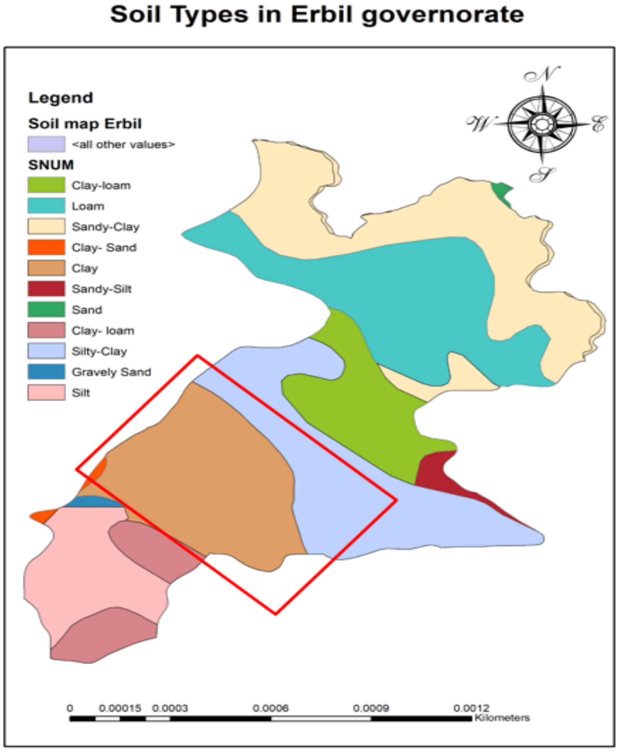

Fig.4. Soil types of the Erbil governorate by [Arc Map 10.8]

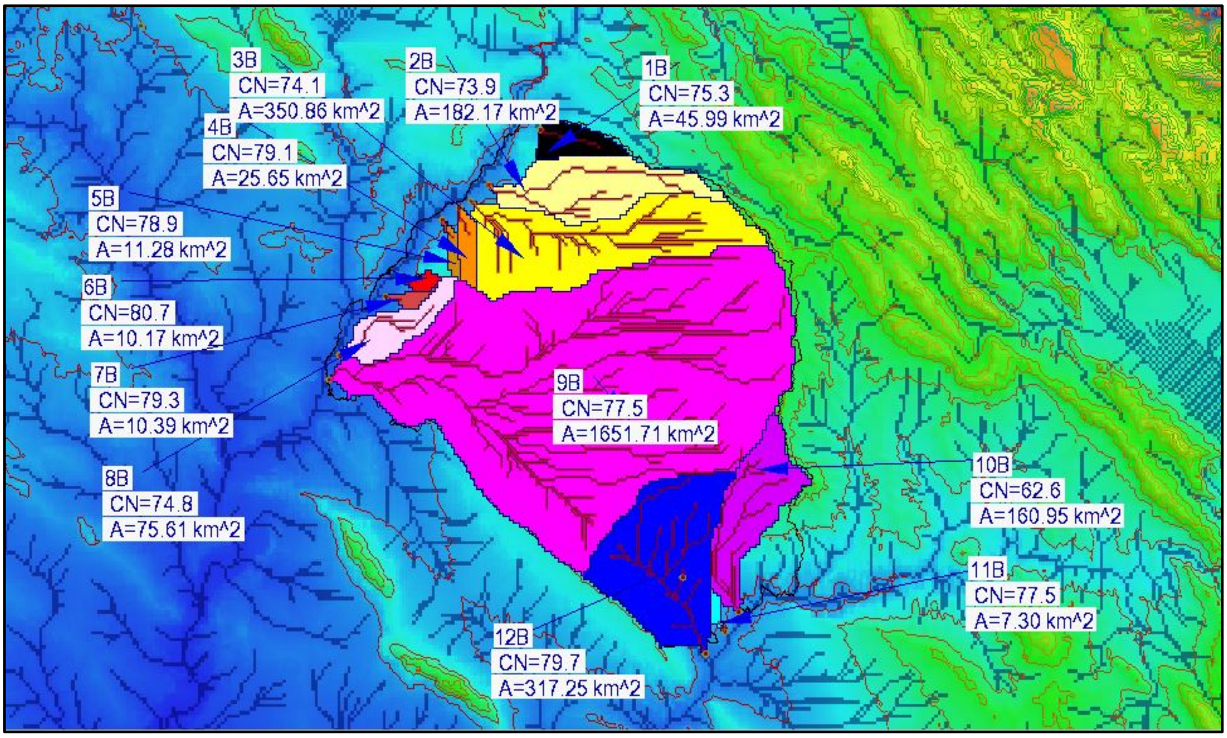

Fig. 5. Soil types of the Erbil basin using WMS software (v.11)

The above figure created by Watershed Modeling System (WMS) software, it is divided the Catchemnt area of Erbil basin into 12 small subcatchments, then based on the soil type groups and land cover of the surface, it computed values of Curve number as shown in the Figure 5. Thus, based on the soil types described in WMS software of the Erbil basin, it consists of clay and loam which is type D soil. Thus, most of the area is low permeable area and most of the rainfall will be runoff.

2.5. Erbil basin Land use/ Land cover (LULC)

Land cover was downloaded from Sentinel-2 with 10 meter resolution land cover time series of the world, it displays a global map of LULC for the year 2021, which is produced by ESRI, the maps prepared by Arc Map software and it shows the main cover of the surface area by; water, vegetation, built up area, bare ground, and etc., for more explanation see Fig. 6:

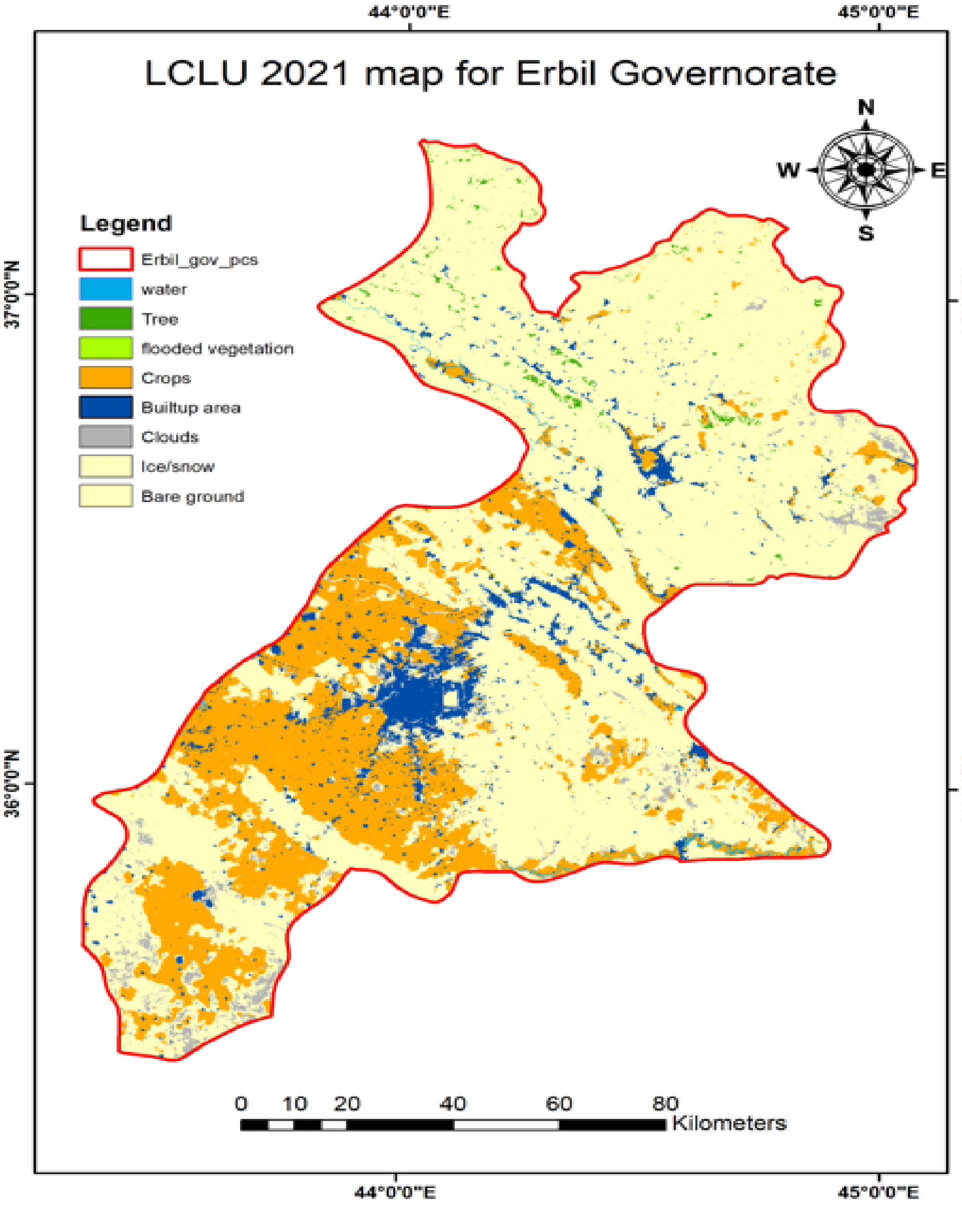

Fig. 6. Map of Erbil government Land use/ land cover using for year (2021) created by [Arc Map 10.8]

3. Data analysis and Recharge estimation

Based on the above figure it is clear that the Land cover of Erbil area is differe from land cover of the same area before 10 years ago, this can be described as the rapid increasing of the population in the area. The main concern in water reduction, change in water availability and decrease in groundwater level is not mainly depend on annual rainfall in the catchment area. there are many points and might to be important point is that the water availability and source which is development of the city and increasing density and population play the major role in the area and also indirect relation between density and increasing the temperature by having less green area surrounding the catchment area. on the other hand, if the number of wells increased the efficiency and drawdown are decrease and the user is increases, all those reasons lead to decline groundwater level. Also, it is clear that every 15 years the population growth is became double [8] then, their demand to water is cause to decreases in the groundwater level in the area. The change of groundwater levels in 2020, 2021, 2022 calculated and compared with change on the same wells data in 2004 to see the comapred values based on Specific yeild equations as below:

Specific yeild Sy= Recharge (R)/ Change in head (dh) (1)

$Sy=R/dh_{rise}$

Thus:

R =Sy X dh

Where :

Sy - specific yeild

R - is recharge

dh - is chnage in groundwater head

Table 2

The calculated values of groundwater levels and recharge amount for three Erbil sub-basin

Sub-basin name	Northern (kapran)	Central	Southern (Bashtepa)	Average
Depth to groundwater (m) 2004	34.71	33.87	24.94	31.17
Depth to groundwater (m) 2020	66.03	69.18	49.64	61.62
Depth to groundwater (m) 2021	67.35	77.00	62.10	68.81
Depth to groundwater (m) 2022	67.44	84.73	79.52	77.23
change between (2020-2021) dh in (m)	-1.31	-7.82	-12.46	-7.20
change between (2021-2022) dh in (m)	-0.09	-7.74	-17.42	-8.42
change between (2004-2022) dh in (m)	-32.72	-50.87	-54.58	-46.06
Area x10^6 (m^3)	772	1742	585	
Specific yield (Sy)	0.26	0.24	0.23	0.24
volume of water m^3/yr (2020-2021) X 10^6	-263.50	-3267.94	-1676.83	-1736.09
volume of water m^3/yr (2021-2022) X 10^6	-18.44	-3235.37	-2344.20	-1866.00
volume of water m^3/yr (2004-2022) X 10^6	-6568.18	-21265.73	-7343.74	-11725.88

The values of the specific yield was estimated for each basin according to [13]. The values of change in head are in minus, this is the main indication to that the groundwater table is contionously decreases over time. Therfore an empirical equation is used such as described below to estimate the recharge based on rainfall data:

Recharge empirical equations such as described in study [2]:

$R=0.87(P-50)$, $P> 50$ (2)

Where:

R: is Recharge in (mm/year)

P: is average monthly rainfall (mm/year)
In addition, another empiricalequation such as described in[18]

$$R=0.3P \quad , \text{for } P < 456 \text{ mm/year} \qquad (3)$$

Where:

R: is Recharge in (mm/year)

P: is annual rainfall (mm/year)

Table 3

Recharge rate estimated in mm/year for annual rainfall (2006-2020)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	sum
Rainfall (mm)	30.9	36.7	66.2	68.3	64.5	72.1	46.5	18.1	1.6	0.0	0.1	3.7	**408.6**
R=0.87(P-50)	0.0	0.0	14.1	15.9	12.6	19.2	0.0	0.0	0.0	0.0	0.0	0.0	**61.9**
R=0.3 P	9.3	11.0	19.9	20.5	19.3	21.6	14.0	5.4	0.5	0.0	0.0	1.1	**122.6**

The above tables are shown that the total of calculated recharge by equation 2, is (61.9 mm/year), however, the estimated recharge by equation 3 is equal to (122.6 mm/year). These values can be more explained in the barchart to see the raltion of rainfall with recharge values, see Fig.7:

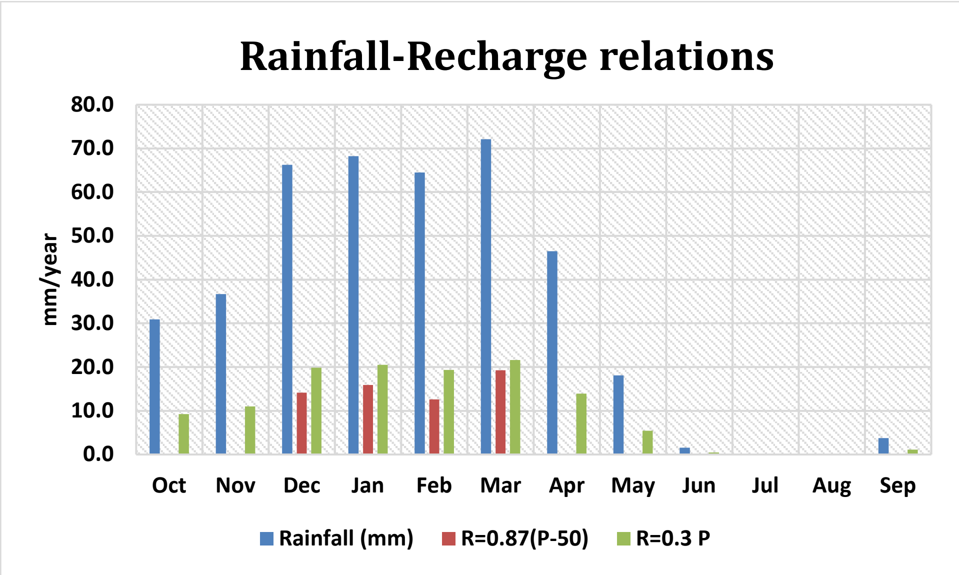

Fig.7 Rainfall- Recharge chart for the periods of (2006-2020)

There are several production wells within Erbil basin used to monitor goundwater levels every months to measure the depth to grounwater tablein Erbil basin area, It is obvoius that all wells decreses the groundwater levels and it continous over times, to present the location of the wells used to monitoring puposes the following map is created, see Fig 8:

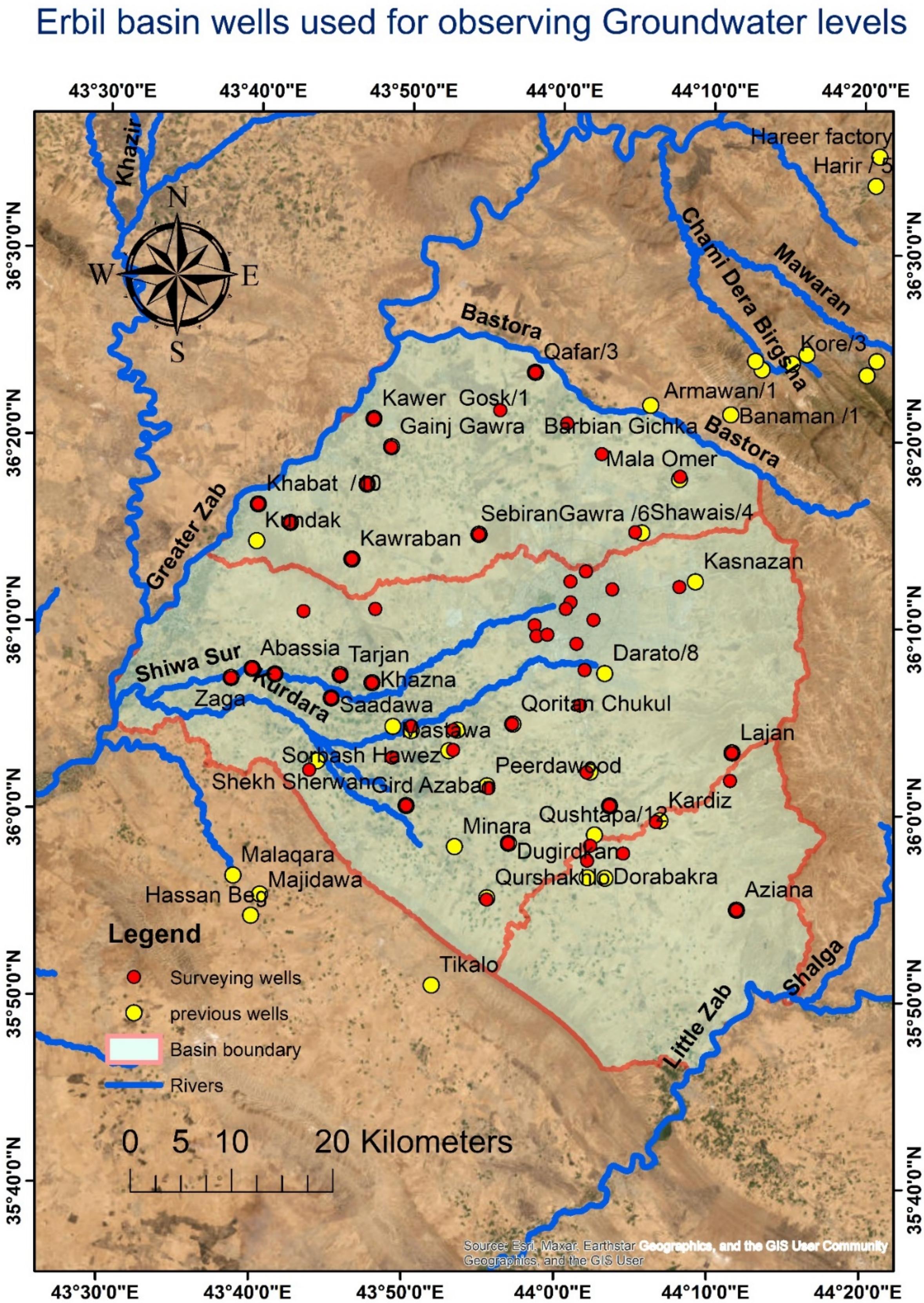

Fig. 8 Map and location of the production wells used for measuring groundwater levels [Arc Map 10.8]

Morever, to describe the groundwater levels in the Erbil basin the map of Erbil groundwater table is created as it is shown in Fig.9:

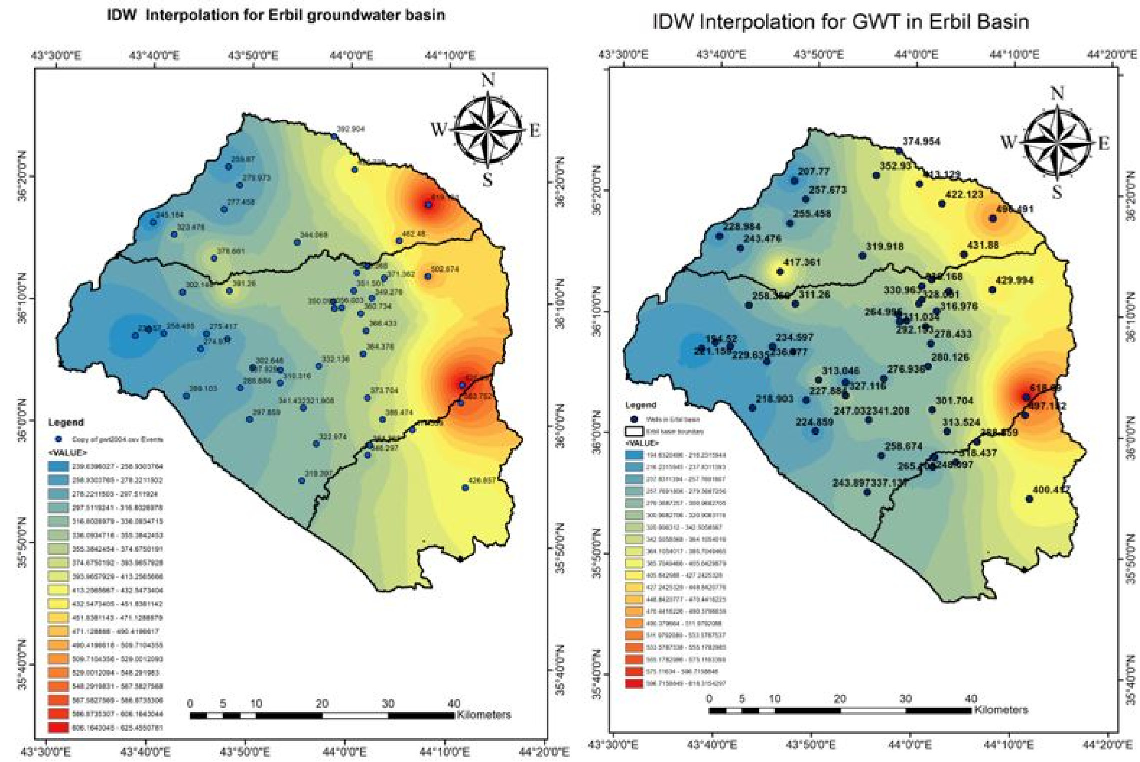

Fig. 9. Groundwater table map in two different years (2004) and (2022) in Erbil basin [Arc Map 10.8]

The above figure shows that the groudwater levels in the year 2004 is much higher than in 2022, the map created by Arc Map 10.8 with inverse distance weighing (IDW) interpolation methods, it seems that the rapid increasing in population growth in increasing their requirement for water consumption. the study also determine the main problems and causes of lowering water wells levels are related to poor managing aquifer recharge and there are a cluster of illegal and legal wells that continous drilling inside the basin without any control [8].

4. Results and discussion

From the results of this study that explained in Table 2, it is noticed that the change in groundwater levels between years (2021-2022) is (-0.09, -7.74 and -17.42) m for the Kapran, central and Bashtepa sub-basins respectively. Similarly, the difference between water levels in (2004-2022) are (-32.72, -50.87 and -54.58) m for the same mentioned sub-basins as well. It means that the average decreases during (2021-2022) is (-8.42) m, however, the average change in water levels in all three sub-basins in (2022) with (2004) declined by amount of (-46.06) m. It is obvious that the wells in the early time near to ground surface, meanwhile, the wells data in (2022) is deeper. This change increases with time consuming and also the depth of drilled wells in (2004) is less than 200 meter, whereas, the wells in (2022) reach to 450 meter and in some places reaches to 600 meter, all the information about groundwater levels are provided from the Erbil groundwater directorate. Hence, for sustainable management development it is necessary to predict future investigations and keep the groundwater reservoir as important resources for the next generation. On the other hand, the wells tapped in Erbil basin should control and manag according to the global aquifer stoarge and recovery principle, because if the amount of recharge is less that the amount of abstraction of water from the aquifers, the area will face to droght and water shortage in the near future, and for sure will lead to damge the aquifer system. Therefore,based on the results of this study it is important to assessed the Erbil basin aquifers, because the groundwater subjected to over-exploitation. As well as, the study estimated that the amounts of recharge is not as much as possible, because the values are in minus which is indication to continous decreasing groundwater table in Erbil basin.

5. Conclusions

The study described the impact of the land developemnt and population grwoth may cause to sudden drawdown in water levels in the study area, also the land use and land cover on the ground surfaces on recharge area of the aquifers, this caueses to avoid penetrating surface water into the recharge zones and increses the groundwater level in Erbil basin. The main concern in lowering the water levels, the decrease in groundwater level is not mainly depend on annual rainfall in the catchment area. there are many points and might to be important point is that the water availability and source which is development of the city and increasing density and population play the major role in the area and also indirect relation between density and increasing the temperature by having less green area surrounding the catchment area. on the other hand, if the number of wells increased the efficiency and drawdown are decrease and the user is increases, all those reasons lead to decline groundwater level. Also, it is clear that every 15 years the population growth is became double then, their demand to water is cause to decreases in the groundwater level in the area. The study highly recommended to develope the groundwater subject in the area to provide the good managment of the aquifer system in Erbil basin. To keep this vital resources as sustainble elememnt for future.

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