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Temporal and spatial variation of Groundwater level in Barnaty plain districts using GIS and RS data -Case Study: in Erbil City, Iraq

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ABSTRACT: Water is one of the most valuable resources for agricultural production and human life in arid and semi-arid climates. This study will monitor groundwater fluctuations in the Baranati area, around 500 km2 and located in the north of Erbil city, about 30 km away. The Baranati area is bounded by the Bastora river in the east and the Great Zab in the north. According to the Ministry of Agriculture, approximately 627 wells are available in the study area that the Ministry has recorded, and the agriculture ministry has permanently monitored seven wells since 2001. . In addition, the author visited 25 water wells in the study area to meet and discuss with the farmers in order to know the water levels in the area. In the study area, three metrological stations are available (Ankawa, Bastora, and Khabat). One accurate way to identify and monitor the water wells is through remote sensing (RS) and Geographic Information Systems (GIS). Baranati area, like many other areas in Iraq, has a lot of wells mostly due to population growth after 2016. Massive amounts of water, particularly groundwater, are consumed by the growing population and agricultural and industrial projects. Previously lacking well-organized urban planning systems and principles, the area has seen uncontrollable urban growth with adverse environmental impact. To classify the land use of area, the study employs three different types of satellite imagery: Landsat-8 OLI from 2013 to 2021, Worldview imagery from 2021, and Quick Bird 2006. This study looked at wells to see if the water was enough for irrigation and agriculture. In addition, to determine the causes of the decreasing groundwater level in the study area. As a result, from 2001 to 2006, the average of groundwater level was reduced to 1.85 m, and from 2006 to 2011, the groundwater level was reduced to 4.05 m. The water level decrease was reduced to 11.81 meters between 2011 and 2016, and to 24.09 meters between 2016 and 2021.

Keywords: Remote sensing (RS), Geographic Information Systems (GIS), Satellite image, irrigation, groundwater level.

INTRODUCTION

Groundwater is one of the most critical water sources for human activities, including drinking water, agricultural and industrial uses, and other household needs g. During the twentieth century, the urban population increased more than tenfold, with most of this growth occurring in low and middle-income countries. With changing patterns and rates of recharge, this urbanization trend impacts the use of fresh water and the quantity and quality of groundwater (Vahid, 2013; Eassa et al., 2013; Josiah, 2011; Kanagalakshmi et al., 2013). Cities housed less than a third of the world's population before 1950. However, cities have housed more than half of the world's population since 2008. Before 1950, cities housed less than a third of the world's population. Since 2008, cities have housed more than half of the world's population. According to research, the global population will increase by up to 60% before 2030, similar to increased urbanization (Haque et al., 2012; Ray et al., 2012; Vahid, 2013). For this reason, water resource assessment, monitoring and estimation aid in efficiently and equitably allocating water to competing needs (Majumder & Kale, 2021). Urbanization and population increase have contributed to natural resource destruction through surface flow increase and groundwater recharge reduction (Thangarajan & Singh, 2016). Changes in land cover have an immediate impact on recharge distributions and reduce recharge amounts (Josiah, 2011). However, sewers and water pipeline leakage will infiltrate this recharge. Groundwater abstraction, on the other hand, will decrease groundwater levels, groundwater levels, and groundwater levels, reduce groundwater levels, and reduce system flows (Tellam et al., 2006; Tilahun et al., 2009; Ibrahim, 2015).

The interaction between groundwater and urban expansion is the main issue with urbanization, particularly in cities and towns located on shallow unconfined aquifers. As a result, groundwater abstraction directly impacts the quantity and level of groundwater. Therefore, groundwater pollution, its impact on building engineering and integrity, and fluctuation in groundwater levels are all significant issues associated with urban expansion (Almahawis, 2018).

Human activities reduce groundwater recharge in some areas. For example, urban expansion reduces groundwater infiltration due to the impermeability of catchment areas due to the construction of parking lots and roads (Environment Agency, 2018). Numerous studies have been conducted in recent years to investigate the potential impact of climate change and land-use change on groundwater quality and quantity. For example, Randall et al. (2013) used the MIKE SHE model ('MIKE SHE' is an advanced integrated hydrological modeling system) to estimate how climate change affects the urban groundwater table. The MIKE SHE model used evapotranspiration, precipitation, and temperature data.

The study found that climate change impacts the urban groundwater level. For example, Maimone et al. (2011) used the DYNFLOW (DYNamic workFLOW) model to estimate if the city planned to convert 40% of its permeable area to an impermeable area, the future groundwater level would be more than 1.5 m higher than it is now. According to Thakur, Singh & Ekanthalu, 2016, the use of geographic information systems and remote sensing provides useful tools for dealing with the spatial and temporal variability of dynamic features when studying the impact of urban growth on quantitative and qualitative groundwater and remote sensing is significantly increasing water resource use and hydrological developments (Thakur, Singh, & Ekanthalu, 2016).

Significant spatial data management is required to deal with the large amount of data generated by utility remote sensing technologies, necessitating an efficient system. Large and complex databases are efficiently managed by providing appropriate alternatives through GIS technology. Over time, satellite data has become increasingly important in environmental research (Mohammad et al., 2021). Remote sensing technologies routinely provide multi-temporal, multi-spectral, and multi-sensor information about the earth's surface. The validation and predictive ability of remote sensing data is the most powerful tool for hydrological studies and monitoring processes, as remote sensing has a phenomenal ability to generate information in spatial and temporal areas, contributing to a more successful analysis (Ibrahim, 2015).

Remote sensing and GIS can demonstrate trends and rates of change in areas like Erbil city. This research looks at the impact of irrigation systems on Groundwater Levels and analyses the findings. It intends to:
- Track Agriculture land and changes occurring between 2001 and 2021 in Barani land.
- Create land use and land cover maps of the study area over the target periods

The main aim of this study was to identify the type of irrigation system that impacts groundwater levels using ArcGIS and ERDAS techniques. The following objectives will be used:
- Use three sets of satellite imaging to generate basic data and identify any changes of cover in the urban area.
- Using geo-spatial tools to solve the farmer's problem in the study area.

Research Question
1. What type of irrigation impacts the groundwater level in the study area?
2. What rate of land-use change took place in Baranati land in Erbil City between 2006 and 2021? Is there an increasing number of people impacting groundwater levels during the period?
3. How will the amount of rainfall in the study area affect groundwater levels between 2001 and 2021?
4. Increasing the number of wells impacts the groundwater level in the study area?
5.

MATERIAL AND METHODS

2.1 Study area

Erbil is one of the oldest continuously inhabited cities in the world and has an urban life that could be dated back to at least 6000 BC (UNESCO, 2010 & Hamad, 2016). Erbil is one of the governorates of northern Iraq. Baranati area is a small area located in Erbil, which covers 500 km2 in Nort Erbil city centre. The location of the Baranati area is between the latitudes and longitudes is 36.327490 43.864667. The amount of rainfall is 395mm per year (Kalid 2014) and its fastest growing city (Kalid 2014) and its fastest growing city, the plains in the south of Erbil governorate, are important parts of the agricultural production. 73.12 % of crops depend on rainfall and only 26.87 % of the land is irrigated. Erbil City, according to Köppen's climate classification system, is located in a climate zone between the Mediterranean climate (Csa) and the Arid climate (Bwh) (Abdullah et al., 2020).

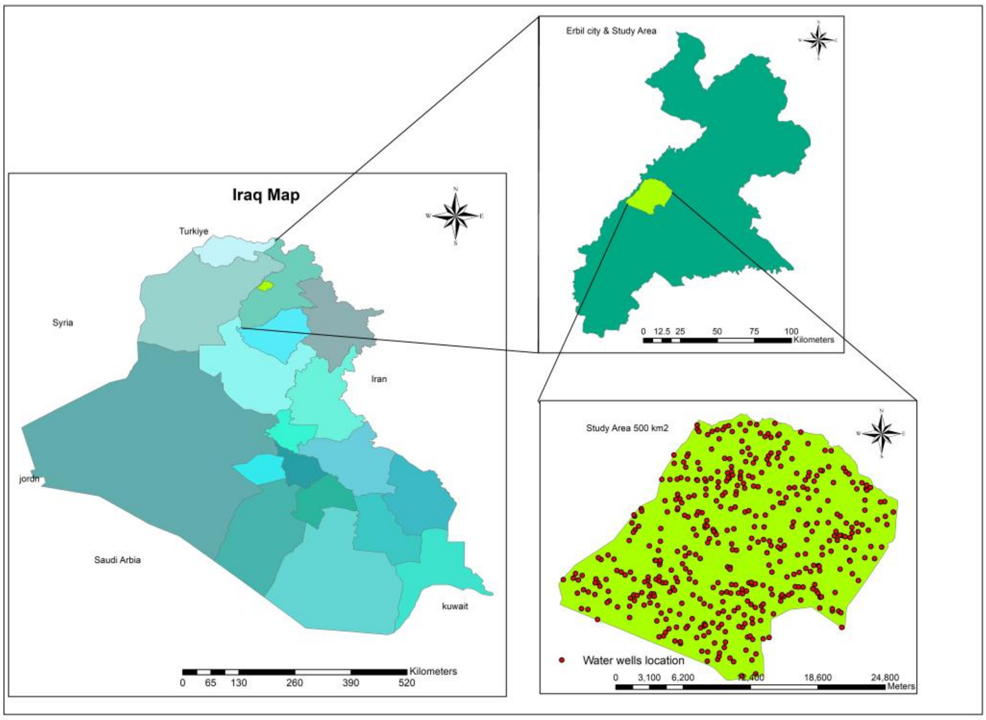


Figure 1: Location of the study area

Table 1: Slope classification by Winnaar, 2007**.**

No	slope Class	Slope %
1	flat	< 2
2	Undulating	2 - 8
3	Rolling	8 - 15
4	Hilly	15 - 30
5	Mountainous	> 30

2.1.1 Slope map of the study area

The slope is generated from a topographic ratio, which represents the ratio of the elevation difference between two points divided by the straight horizontal distance between the two points Figure 2 (Hamad, T. (2016). The slope is derived from the Digital Elevation Model (DEM), and classified into five slopes. Table (1) percentage classes according to the FAO slope classification (Winnaar, 2007).

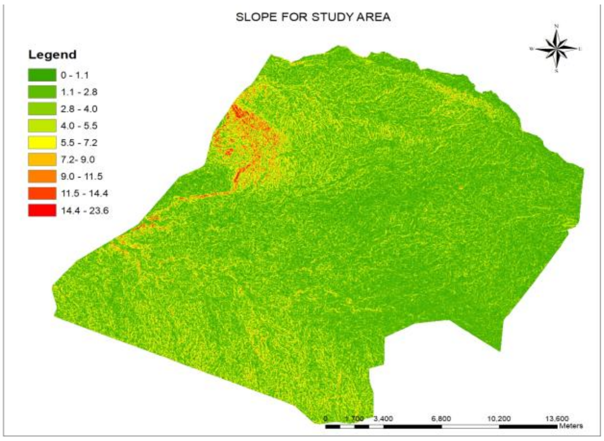


Figure 2: Slope map of the study area

2.1.2 SOIL

Soil is one of the critical resources in achieving food security through direct association with agricultural production—the depth of the soil changes over the study area. The soil in the mountain areas, located in the north and northeast, is shallow. The soil in the mountains has been created from the original rocks and has a low potential for agriculture, but it is rich in natural rangeland (Hussein, 2020). *Leonardi, C. 2005 in* FAO Organization, determined the types of soil in the study area, which contains the following bellow Figure (3)

Vc: Chromic Vertosols
3: Fine Textures
a : Flat (0-8% slope)
Xk: Calcic Xerosols
2: Medium Texture
B: Undulating (8-30% slope)

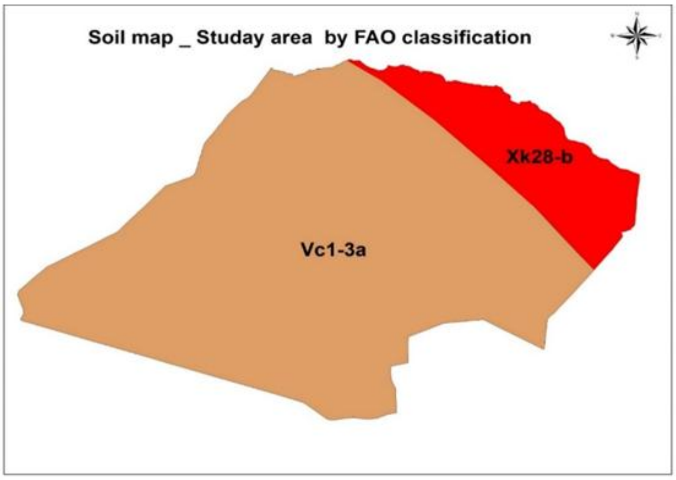


Figure 3: The soil type of the study are

Statement of problem

Rapid population growth due to economic and political changes has resulted in Erbil city expanding in size. Size has increased significantly over the last seven years, particularly in the Baranati area, but not in a planned manner; the number of wells has increased in recent years, as has the depth of wells. Ngan and Khaleel Ismael (2010) and (Mohammad 2021). This has a significant impact on the environment as well as the land itself. Furthermore, farmers must spend more money and use much electricity to obtain water for their agricultural products. In these circumstances, planning time and maintaining a keen awareness of all factors is vital. GIS and Remote sensing techniques can provide useful information and a close look at the study.
This study examines the relationship between groundwater irrigation and off-farm employment.

2.2 DATA AND METHODS

2.2.1 DATA

The study employs three different types of satellite imagery: Landsat-8 OLI from 2013 to 2021, to find out the Normalized different vegetation index (NDVI) within the area of research. Worldview imagery from 2021 and Quick Bird 2006 for classification of the study area. The data was collected from the United States geological survey (USGS) website and the other imagery was bought by Geoland Company. Geo-referenced data for UTM Zone 38, WGS 84. The images were taken on 18 Jun 2006 and on 06 July 2021. Secondary data sources were collected from various sources, including traditional local government census data, written works, academic textbooks, and associated maps from Erbil Municipality and the Ministry of Agriculture.

2.2.2 Interpolation and Statistical Analysis

The interpolation was done in ArcGIS 10.8 using the IDW method to plot the parameter distribution for the wells. IDW spatial interpolation assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variations in the surface. This approach is an efficient geostatistical interpolation technique focused on the special correlation of sampled points (Geodose, 2019).

$$\hat{v}_1 = \frac{\sum_{i=1}^{n} \frac{1}{d^p{}_i} v_i}{\sum_{i=1}^{n} \frac{1}{d^p{}_i}}$$

2.2.3 Climate data

Climate data were provided by the Ministry of agriculture and water resources in Erbil province. The data is yearly from 2001 to 2021. There are records from three different weather stations such as (Ankawa, Khabat and Bastora) in the Study area.

Table 2: Data in Weather Station

No	Name	x	y	Average rainfall from 2001 to 2021 (mm)
1	**Bastora**	36.340303	44.167739	**444.1**
2	**Khabat**	36.27865	43.69658	**332.94**
3	**Ankawa**	36.247041	43.995148	**412.9**

2.2.4 Digital Elevation Model (**DEM)**

Digital Elevation Model (DEM) was obtained from the United States Geological Survey (NSA Earth Data) website (http://alaska.edu/). Figure (4) The DEM has 12.5 m resolution. The format of data is raster data. The datum of the data is WGS-84. The highest point of elevation is 513 meter above sea level and the lowest level is 279 meter above sea level.

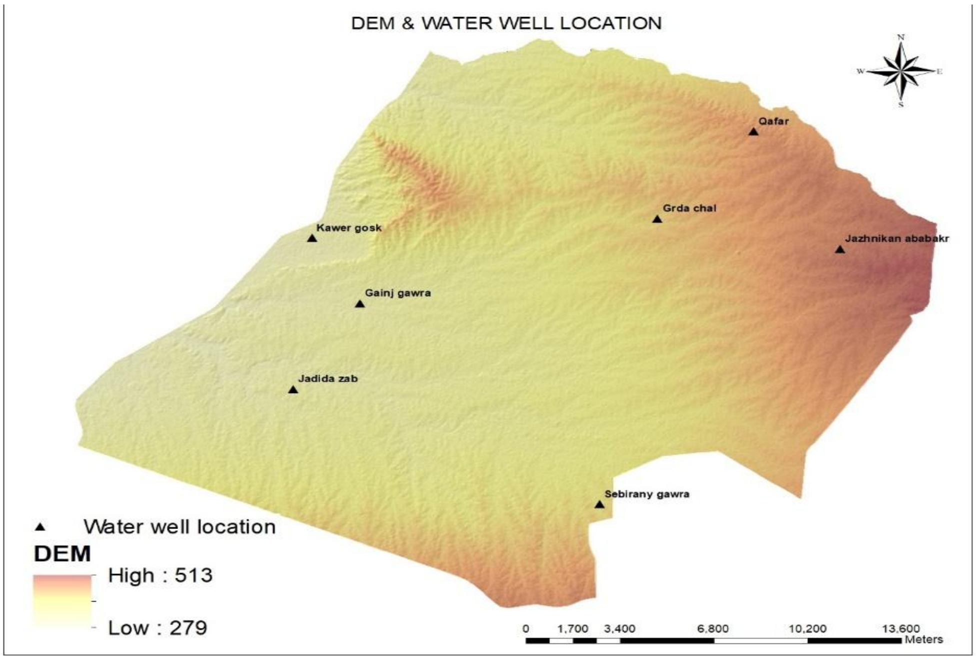
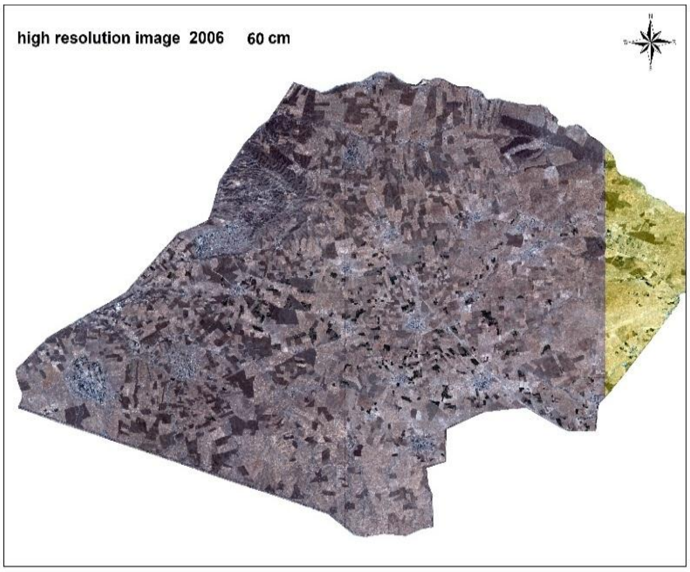


Figure 4: DEM of the study area

METHODOLOGY

Software used for data analysis

The tools used to display and interpret the study's findings include ArcGIS 10.8 and ERDAS imagine 2015; EXL was used to classify the latest changes in land groups within the research area for image classification and find out the Indexes like NDVI, IDW and TWI. The study employs three different types of satellite imagery: Landsat-8 OLI from 2013 to 2021 with 30-meter resolution, to find out the Normalized different vegetation index (NDVI) within the area of research. Worldview imagery from 2021 with 50 cm resolution Figure (5), and Quick Bird 2006 with 60 cm resolution for classification of the study area Figure (6). The data was collected from the United States geological survey (USGS) website and the other imagery was bought by Geoland Company. Geo-referenced data for UTM Zone 38, WGS 84. The image was taken on 18 Jun 2006 and on 23 July 2021



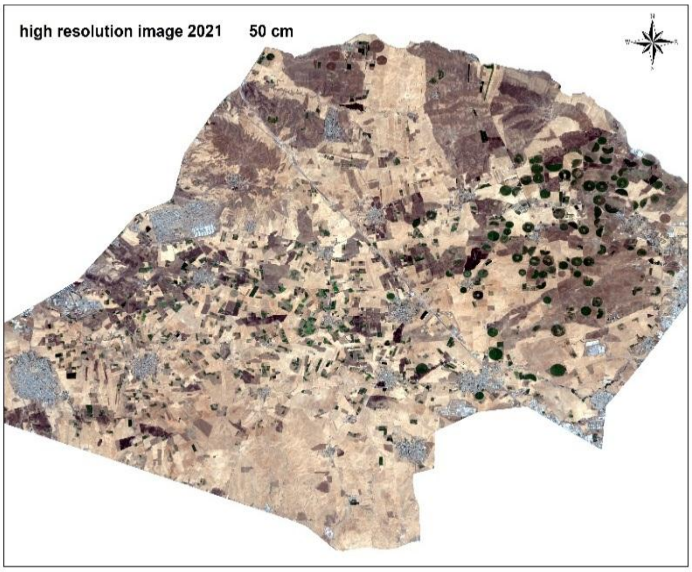


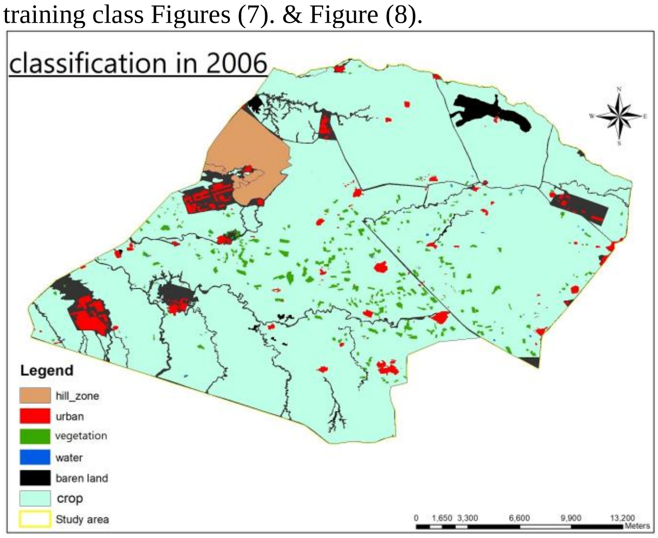
Figure 6: Quick Bird 2006 **Figure 5**: Worldview-3 2021

2.1.4 classification

There are various methods of remote sensing image classification. Researchers can now classify according to image ratio, image regression, image differencing and the maximum likelihood method enables either the formulation of a regression criterion or the determination of the covariance matrix of estimates. After classification (post-classification method) (Bekalo, 2009; Mohammad,2021). This study extracted a map representing differences between initial and final state images. This differencing image process was done via ArcGIS 10.8 software. In areas of change, there will be largely positive or negative values, whereas differences will only be small in areas of no change.

Post-Classification Comparisons

When comparing post-classification derived the- Matic maps, the aim is to identify and classify different types of change. This is more complex than basic change detection. Supervised classification was chosen in this instance. The three LULC classes that had been defined within the classification scheme were: (1) urban/built-up areas, (2) (Vegetation) areas, (3) barren land areas (4) Wheat (5) hilly areas (6) water. a maximum-likelihood classifier based on each date training class Figures (7). & Figure (8).



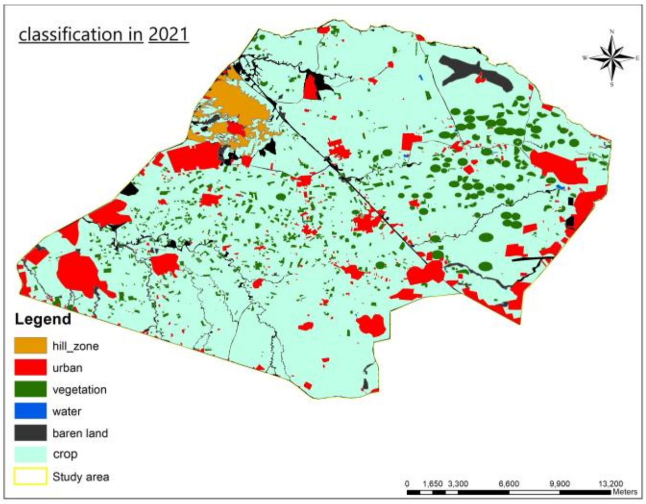


Figure 7: Classification in 2006 . **Figure 8:** Classification in 2021

RESULTS AND DISCUSSION

Supervised classification was used to classify land cover classes. This was done to identify the various land cover classes, based on Worldview imagery from 2021 with 50 cm resolution and Quick Bird 2006 with 60 cm resolution for classification of the study area, and shows the study area classified into six classes (urban, vegetation, Barren land, wheat, hilly areas and water). Visual comparison of the images for 2006 Fig.7 and 2021 Fig.8 showed significant change in the six land use/ land cover classes. For example, the red color from the image represents the build-up (urban) class and this red shading had increased from 2.4% to 10.2% originally.

It can be seen that the built (urban) class indicates urban growth; The most significant urban development was recorded in 2021. In 2006, the urban area was more concentrated in the Kavrgosk subdistrict and Rizgari subdistrict, and this is expanding linearly in different directions outward from its axis. The dark green color represents that vegetation in Baranati area increased from 1.9 % to 6.5%. Here, the wheat rate has decreased from 85 % to 76.7 %, representing light green color. The black color, representing barren land, reduced during study period and decreased more gradually between the years 2006 to 2021. It is shown clearly that in 2006 it was 7. 2%, decreasing by 2020 to 4.7 %. As shown in Table (3), after inputting all the data to ArcGIS to create IDW for all points, some to create IDW for all points.

The total number of wells in 2006 was only 257. However, the number of wells has increased to 627 by 2021 due to an unplanned system and poor government policy Figure (9). This will impact the quality and quantity of water in wells and the rate of water in that area. Furthermore, Table (4) depicts the depth of water in (7) seven different wells that monitoring by the local government, including Gaing Gawra, Grdachal, Jadida Zab, Jazhnikani Babakr, Kawrgosk, Qafar, and Seberani Gawr, and shows the depth of water that has increased from 2001 to 2021 in September. For example, the depth of the Kavrgosk well in 2001 was 31.85 meters, and its 88 meters in 2021. Also, in the Grdachal well, the water depth increased to 13 meters from 2001 to 2021 (10).

The main reason that affects the rate of water is the upland system and the precipitation rate in the last twenty years. The precipitation factor is one of the essential climate elements directly related to the governorate's water resources, especially in Baranati area Figure 12. The decreased rainfall rate below the average for a long time leads to a decrease in the amount of running water in rivers and level of groundwater in the soil and a lack of soil moisture

Table 3: Supervised classification results

Class Name	**2006**		**2021**	
	Quick bird		**Worldview-3**	
	Km	Area %	Km	Area %
urban	10.53	**2.4**	45.53	**10.2**
Crop	380	**85.0**	342.77	**76.7**
vegetation	8.58	**1.9**	29.12	**6.5**
water	0.255	**0.1**	0.43	**0.1**
baren land	32	**7.2**	20.94	**4.7**
hill zone	15.69	**3.5**	9.22	**2.1**

Table 4: Data monitoring wells from 2001 to 2021 (Source: Ministry of Agriculture, Water Resources Department)

No	Name_Water Well	Water level depth in September (Since-m)		Water level depth in September (Since-m)		reduce groundwater level by meter	Elevation (m)	Average rainfall from 2001 to 2021 mm	Topographic Wetness index value	Slope_ value
1	sarkawr harkyi 2	2012	**80**	2021	**96.5**	**-16.5**	392	444.1	11.8	0.0
2	sarkawr harkyi 3	2005	**60**	2021	**75.0**	**-15**	408	444.1	8.7	2.4
3	sarkawr harkyi 1	2014	**90**	2021	**107.1**	**-17.1**	386	444.1	6.4	4.6
4	Qafar	2001	**43.46**	2021	**55.1**	**-11.64**	438	444.1	5.7	2.4
5	shakholan	2017	**90**	2021	**112.0**	**-22**	377	444.1	7.4	2.6
6	barhoshtr	2011	**90**	2021	**107.5**	**-17.5**	387	444.1	9.4	0.0
7	kewrgosk	2009	**50**	2021	**88.8**	**-38.75**	385	332.94	6.7	1.8
8	jazhnekame fandyi	2009	**29**	2021	**43.5**	**-14.5**	447	444.1	5.6	2.6
9	Grda chal	2001	**22.4**	2021	**35.4**	**-13**	405	444.1	8.4	0.8
10	jazhnekane fandyi 3	2010	**35**	2021	**50.0**	**-15**	425	444.1	5.6	2.6
11	Kawer gosk	2001	**31.85**	2021	**88.0**	**-56.15**	297	332.94	6.4	1.1
12	jazhnekane fandyi 1	2009	**18**	2021	**33.0**	**-15**	433	444.1	6.7	1.8
13	jazhnekane fandyi 2	1987	**46**	2021	**61.0**	**-15**	425	444.1	6.8	2.4
14	Jazhnikan ababakr	2006	**22.9**	2021	**41.2**	**-18.25**	478	444.1	5.2	4.1
15	berhoshtr	2010	**77**	2021	**96.0**	**-19**	375	396.64	9.3	0.8
16	grd araq	2013	**50**	2021	**68.1**	**-18.1**	431	444.1	6.4	2.3
17	Gainj gawra	2001	**29.5**	2021	**49.2**	**-19.65**	325	332.94	9.4	0.0
18	saedan	2008	**51**	2021	**77.0**	**-26**	352	332.94	10.1	0.0
19	ashokan	1980	**50**	2021	**69.0**	**-19**	380	444.1	10.2	2.6
20	dara ban	1983	**28**	2021	**52.5**	**-24.5**	372	396.64	6.8	0.8
21	grd araq	2012	**31**	2021	**48.3**	**-17.3**	418	444.1	6.0	1.8
22	mam choxan	2008	**29**	2021	**53.0**	**-24**	343	372.92	6.3	4.0
23	tobzawa	2005	**52**	2021	**85.0**	**-33**	321	332.94	5.5	2.9
24	smayilawa	2013	**61**	2021	**89.0**	**-28**	332	332.94	8.7	5.1
25	Jadida zab	2001	**39.21**	2021	**74.8**	**-35.59**	330	332.294	6.8	2.3
26	grd jotear	2008	**44**	2021	**62.5**	**-18.5**	416	412.9	6.8	2.3
27	tobzawa	2003	**49**	2021	**79.0**	**-30**	346	332.94	7.1	5.4
28	Sebirany	2005	**37**	2021	**56.0**	**-19**	366	412.9	7.1	2.3
29	smayilawa	2004	**50**	2021	**75.0**	**-25**	354	332.94	7.8	2.9
30	jdida zab	2006	**41**	2021	**71.0**	**-30**	373	332.94	7.6	4.1
31	Sebirany gawra	2001	**42.6**	2021	**58.0**	**-15.37**	402	412.9	7.9	2.6
32	Sebirany gawra	2005	**46**	2021	**62.0**	**-16**	394	412.9	5.4	3.3

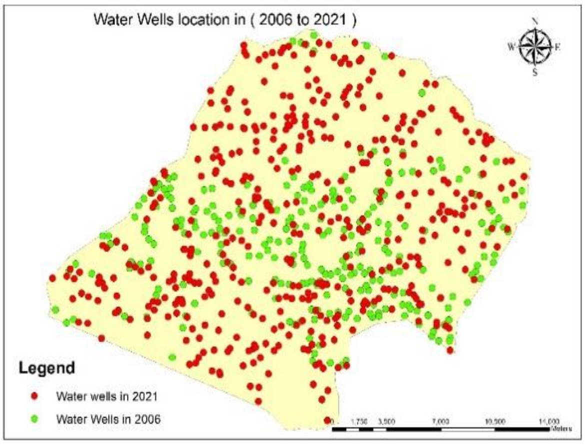


Figure 9: The number of wells has been increased

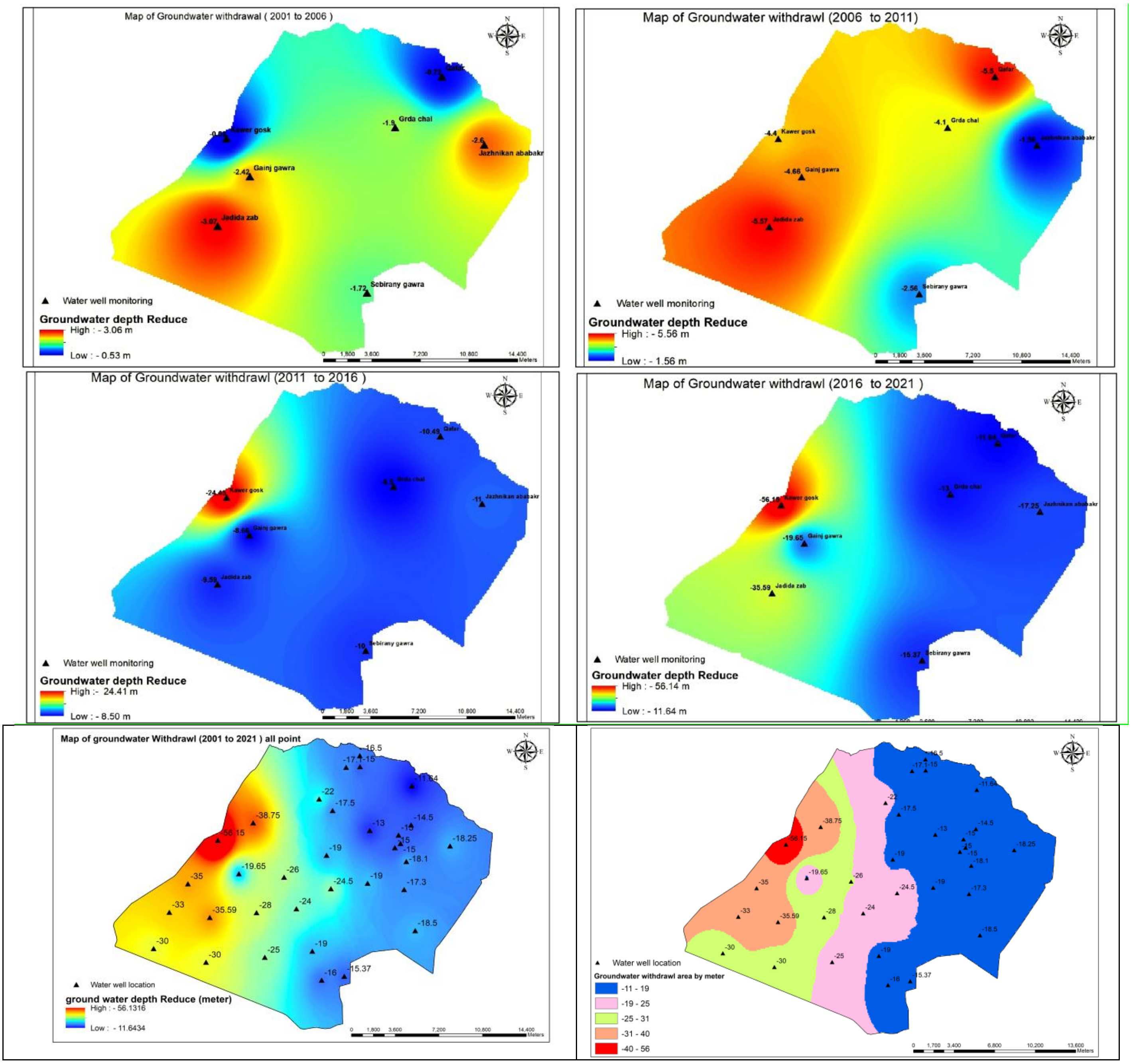


Figure 10: Groundwater level map in the study area

The result of NDVI

The images that are used for NDVI are Landsat 8 OLI 2013 and 2021. The Thermal IR bands (Bands 4 and 5, respectively) were utilized, while the Near-Infrared (NIR) and Red (R) bands were also used to compute the NDVI images for this study (Sun et al., 2009). The NDVI index is calculated based on the reflectance of the red (Red) and the Near-Infrared (NIR) bands of Landsat images, using formula 1, as follows:

$$NDVI = (NIR - Red)/ (NIR+ Red)$$

Theoretically, NDVI image pixel values ranged between −1.0 and +1.0. However, the typical range of the NDVI gauged from vegetation and other earth surface materials is between approximately −0.1 (NIR less than Red) for non-vegetated surfaces and as high as 0.9 for dense vegetative cover. In addition, I get NDVI results to show that the number of wells with center pivot irrigation has increased (Gutman, Skakun, & Gitelson, 2021) (Figure 11).

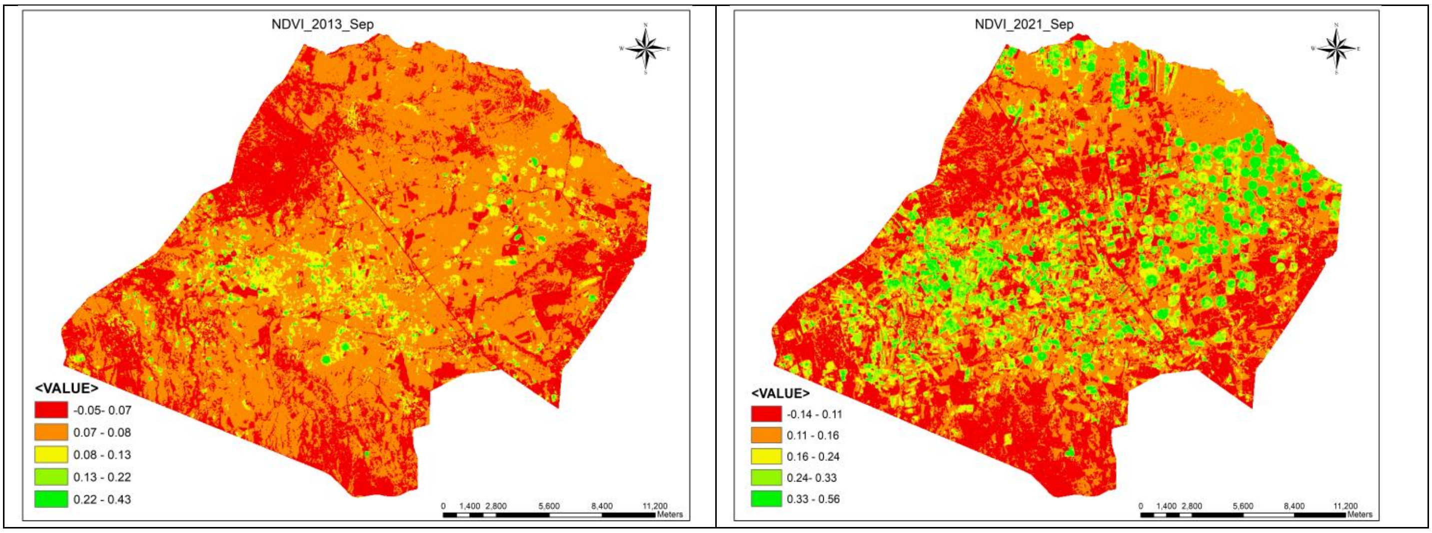


Figure 11: NDVI index comparison in the study area between (September 2013 and 2021)

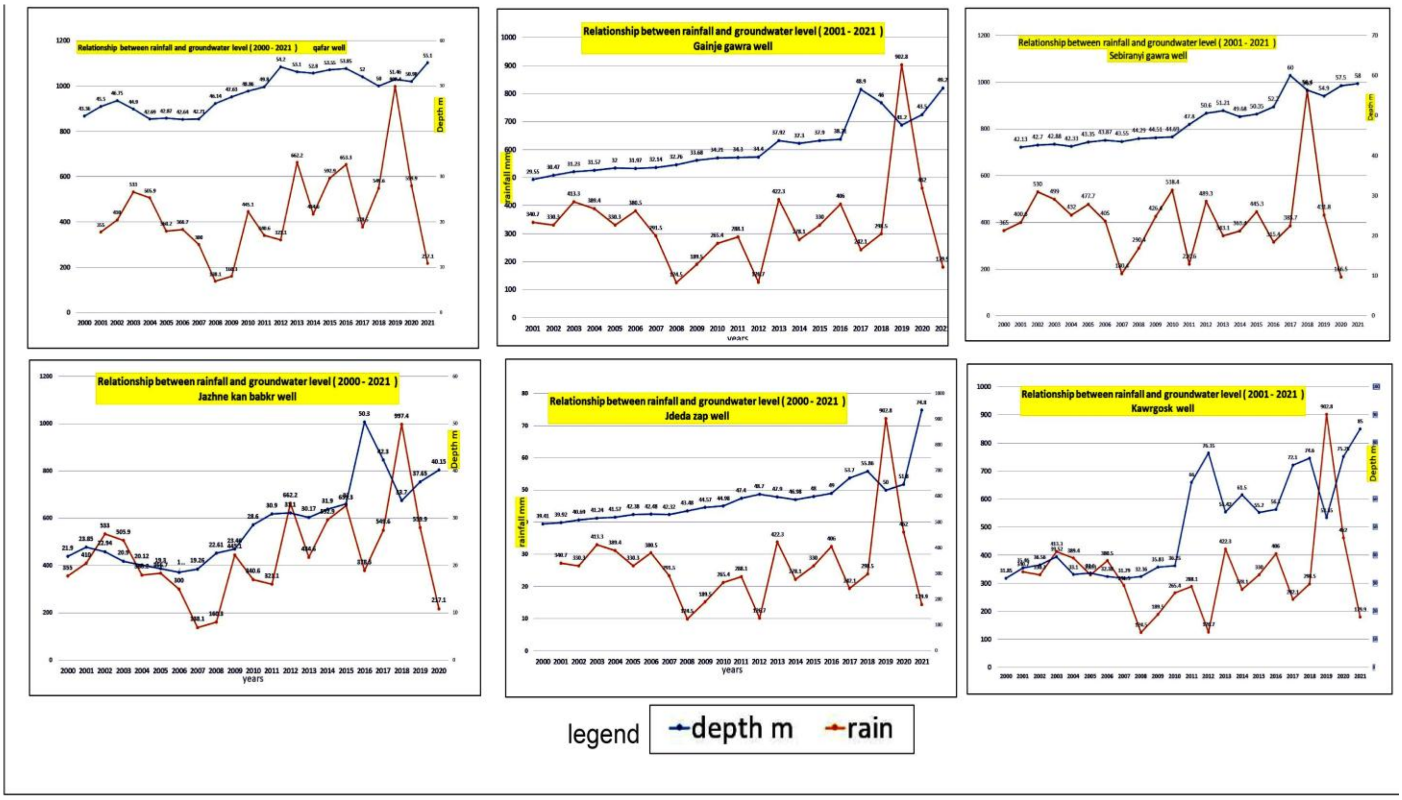


Figure 12: The relationship between Groundwater level and rainfall

Table 5: The relationship between Groundwater level and (precipitation, elevation, slope and topographic wetness index)

Correlation/-	Groundwater level by meter	Elevation (m)	Average rainfall from 2001 to 2021 mm	Topographic Wetness index value	Slope_value
reduce groundwater level by meter	1				
Elevation (m)	0.716488108	1			
Average rainfall from 2001 to 2021 mm	0.771636039	0.799123891	1		
Topographic Wetness index value	0.0866943	-0.282612416	-0.073687945	1	
Slope value	-0.063889537	0.031770105	-0.123565072	0.479158967	1

Table 6: The relationship between Groundwater level and (Urban, Crops , Vegetation, Barren land)

Correlation/-	Urban			Crops	Vegetation	Baren land	Groundwater level reduces
Urban	1.0						
Crops	-1.0			1.0			
Vegetation	1.0	-1.0	1.0				
Baren land	-1.0	1.0	-1.0	1.0			
Ground water level reduces	1.0	-1.0	1.0	1.0	1.0		

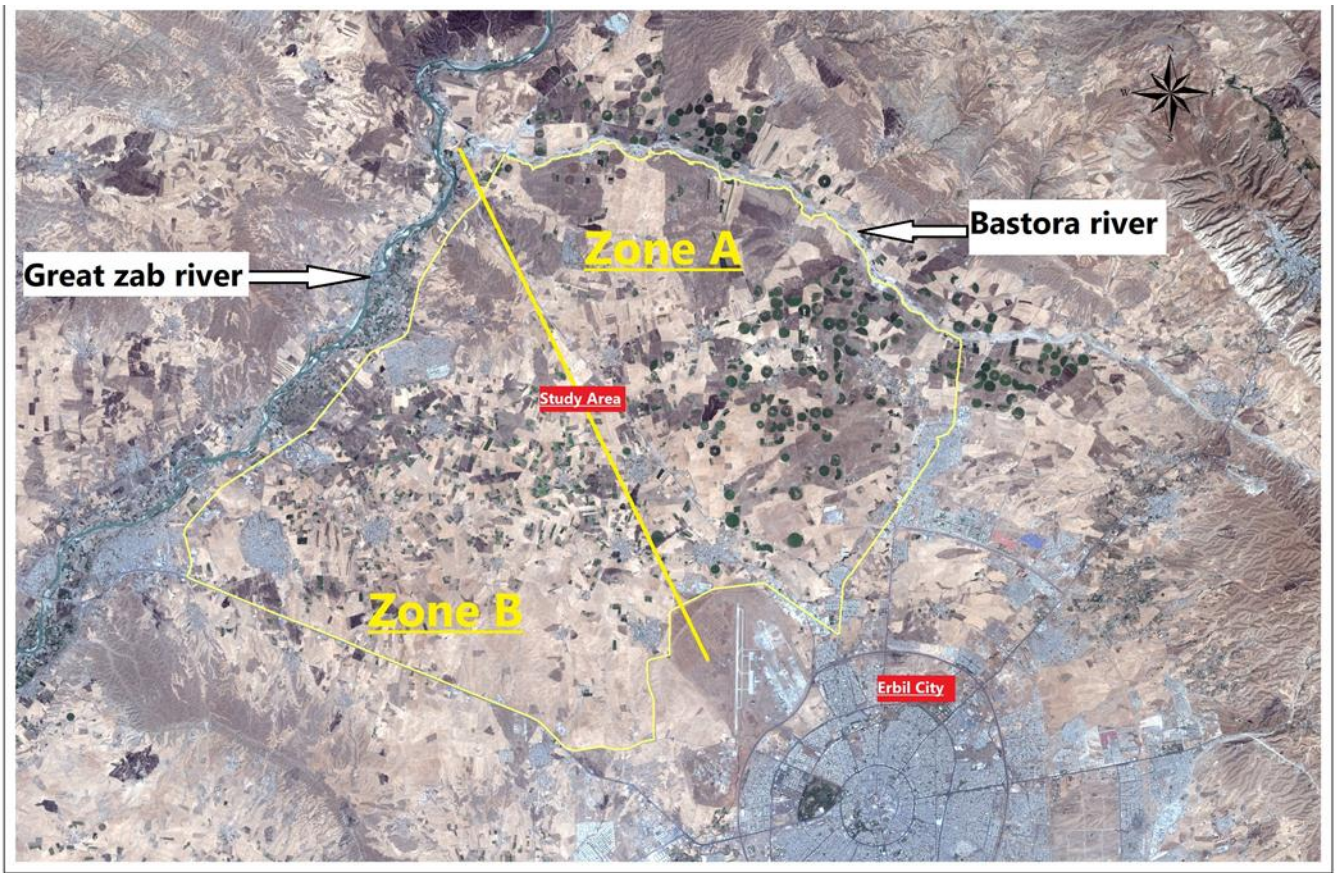


Figure 13: The study area divided into two zones

Figure 13 illustrates the result from the previous figures and shows that the study area is divided into zones (A) and zone (B). It is clear that Zone (A) contains three wells that are monitored by the local government (Grdachal, Jazhnikan Babakr, and Qafar), and it is clear that the average amount of water that is reduced in these wells is about 13.9 meters. On the other hand, zone (B), which includes four wells, Gaenji Gawra, Jadida zab, Kawrgosk, and Sebirani Gawra, reduced the average amount of water in these four wells is 30.94 meters. Furthermore, in Gawrgosk well, the water level was reduced by about 53.13 meters because around that well, there are two huge industries, such as Coca-Cola and the Kar Group refinery. In comparison, the amount of water level that was reduced between zone (A) zone and zone (B) is (16) sixteen meters. This means that the study area in the future, after 20 to 30 years, the amount of water level will be reduced more.

CONCLUSION

Methods used in this research have been shown as suitable and effective in achieving the study objectives and addressing the research question. A remote sensing approach is essential for identifying the causes of reducing Groundwater levels in the study area. Moreover, the type of irrigation system that impacts Groundwater Levels and land use/ land covers Groundwater Levels and land use/ land cover to support Groundwater Levels and land use/ land cover supports effective management and decision-making processes relevant to the study. RS is a vital tool for monitoring groundwater as it can support visualization.

Using remote sensing method, the study has successfully zed the causes of reducing Groundwater levels in the study area from 2001 to 2021 and the impact of irrigation systems on Groundwater Levels of changes in the urban land use/land cover classes. This study assessed the changes in water level during the twenty years from 2001 to 2021 in Erbil Branati land, Iraq. It can be seen that from the results of a classification in the study area, urban land use from 2006 was 2.4 % and in 2021, it increased to 10.2 %. The reason for increasing urban land use is economic development and the growing population numbers due to many refugees and IDPs coming to Erbil after 2014 when ISIS attacked Syria and Mosul, which are effective groundwater consumption. Moreover, Kawrgosk district has a refugee camp that uses water and agricultural and industrial projects, which consume massive amounts of water, particularly groundwater. The study used three different types of satellite imagery to classify the area: Landsat-8 OLI from 2013 to 2021, Worldview imagery from 2021, and Quick Bird 2006. In addition, this study looked at wells to see if the water was enough for irrigation and agriculture. The results of seven different wells that the government monitored monitored monitored show reduced water level wells in the study area (Kawrgosk, Jadida zab, Gainji Gawra, Jazhnikan Babakr, Sebirani Gawra, Grdachal, and Qafer) were reduced to 53.15, 35.59, 19.65, 17.25, 15.4, 13, and 11.64 meters, respectively.

This lowered the average groundwater level by 1.85 m from 2001 to 2006 and 4.05 m from 2006 to 2011; from 2011 to 2016, the average amount of water decreased by around 11.81 m and from 2016 to 2021 by 24.09 m. According to the above results, the amount of water is reduced and affects drinking water and future agriculture. The main reasons for lowering the study area's water level are the following.

Increasing the number of legal and illegal water wells in the study area in 2006 was only 257 wells, but in 2021 it increased to 627 wells. This is because the highest number of populations affect groundwater level consumption. As a result, the number of people has increased, and the demand for agriculture has also increased.

1. Reducing the precipitation rate, especially rainfall and snow in the last 10 years, will affect groundwater levels.
2. The type of irrigation that affects reduces the water in the wells. For example, the farmers who use centre pivot their wells are reduced to flood irrigation.
3. The type of crops such as (maize, wheat, alfalfa and watermelon …. etc) need more water.
4. The topography of the study area has an effect on the level of water, which is one of the natural causes.

Recommendations

To solve the problem of the reduction of groundwater levels in Baranati land, the following points will solve some problems.

1. Surface water is one of the leading solutions to create water channels for agricultural lands in the study area because the Great Zab surrounds the Great Zab river.
2. Awareness and supporting farmers to use intelligent irrigation systems help to use little water.
3. Creating small ponds to be used during dry seasons and recharge groundwater levels.

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