Decision of The Hydraulic State of Rivers within Growth Cities using GIS: Al-Hneidiyah River as Example

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Abstract. Generally, the rivers in both the natural and lined form use the open-section system to carry water, either for distribution or conveyance purposes. With time and depreciation effect, this system needs to be changed or modified to become more indirectly suitable with cities' growth, especially with the transformation of land use from agricultural to residential. The present paper aims to reach a proper decision to select the best hydraulic section for a part of Al-Hneidiyah river in Karbala city by determining the remain agricultural lands within the study area, for the distance between stations (0+000) and (4+000), to choose between keeping up the currently open section or change, (modify), it to a closed conduit. For this study, the cadastral maps were used as a reference to determine the agricultural areas served by the river during its route within the study area, and geographic information system to monitor the change like these areas represented by a gradual transformation from agricultural to residential purpose, by using of satellite images for four different years, 2002, 2007, 2013, and 2016. The results of this study showed a significant recession in the agricultural areas on both sides of the chosen length of river route by a percentage of 13.45%, which leads to an urgent need to change or modify the flow system from opened to closed and use it only for conveyance purposes to protect the water quality and water shares. The geographic information system is a good and helpful technique for evaluation and makes water-related subjects decisions by giving a clear vision of the studied problem.

Keywords: City growth; GIS techniques; hydraulic section; rivers; rural environment.

Introduction

Iraq has passed and still by the problem of lack of water supplied to it from the upstream countries of the Tigris and Euphrates rivers and their tributaries, which clearly cast a delusion on agricultural production. In contrast, agricultural land in the regions surrounding cities has shrunk [1] and transformed from agricultural use to residential, commercial, industrial, or other services noticeably in the last two decades [2]. This calls for reconsideration in the distribution of surface water for the rivers feeding these areas and using the water shares that were canceled to revive desert areas or those suffering from desertification due to lack of Incoming water [3]. The geographic information system and remote sensing techniques consider as the best tools in the present time for spatial description, due to the great potential they offer to help diagnose various problems, engineering or otherwise, and try to find appropriate solutions to treat these problems completely or partially [4].

It is considered an effective tool in evaluating public services distribution to urban residential regions, rural regions, and others and re-evaluating the random distribution of these services within city districts [5] and [6]. Using satellite visuals to produce the main information layers such as the land cover, the various land uses the distribution layers of river networks, roads, religious and social landmarks, and others [7], to be utilized for creating a realistic and future vision in any field of life that these technologies can apply. The geographic information system has a tight relationship with the various areas of water resources engineering, as it is a valuable technique in the preparation of many hydrological and hydro-geological studies. One of these studies is the water harvesting. In contrast, this technique enables the spatial expertise support system to become an integrated system by the introduction of special information layers of the hydrological database and producing it as comprehensive formats in terms of form and concept [8] by using many criteria including river streams, slope, rainfall, vegetation index ... etc. [9]. It also estimates the rainfall-runoff erosive factor of the wide range of watersheds for different formative terrain [10].

In addition, the effective contribution to assessing the quality of surface water such as rivers and their tributaries by monitoring the concentrations and distribution of many elements and compounds, and studying the physical properties of the rivers such as water transparency, salinity, electrical conductivity, …. etc, and analyzing the results to build a network of databases that can be used in the geographical distribution of data [11,12]. Also, this technique can be to be used for groundwater. In contrast, it contributes to choosing the best location for drilling wells by studying many variables such as resistivity, depth, thickness, trans-emissivity of aquifer [13], and assessing the validity of this water for various human uses such as drinking, industrial and agricultural use by dividing the land cover into multi-layers as water sources, forest lands, open arid lands, residential areas, and agricultural crops lands [14,15].

The urban growth represented by the use of modern housing units with their concepts of construction (adding construction materials to the rural environment) and formative (introducing the modern architectural language to the character of housing and rural buildings) leads to distorting and changing the reality of the formation in the housing fabric of the rural settlement, where the green areas begin to recede, and replaced by the residential areas gradually [16]. This change truly affects the water structures that serve these agricultural lands, such as natural and lined channels, and as a result of neglect and lack of use, another phenomenon is clearly activated, which is the phenomenon of water percolation into the soil face that surrounding these waterways, which definitely leads to the decrease of the water shares that waters the areas located in the tail regions of the river [17], and this calls for an urgent need to use modern technologies to guidance the consumption of this groundwater by sub-surface irrigation techniques via, and it's prominent role in feeding groundwater [18], as well as to investigate and examine the structures that build on water courses, examine them continuously, and a make a periodic evaluation of it [19] in order to increase the efficiency of water use of the remaining and newly developed lands, which cause the increase in the production of permanent and seasonal crops, and using the best methods and modern programs such as dynamic programming [20]. This study aims to determine the remaining agricultural lands on both sides of the Al-Hneidiyah river in the central district of the holy Karbala city for part of its path, which is 4 km, to decide the current river cross-section.

Description of Study Area

Major and Minor Sectors. The primary sector may be described as an area consisting of small regions called minor sectors, and both the major and minor sectors are areas within and form the district survey, see Figure 1.

Al-Huseiniyah River–General Description. Al-Husseiniyah river is one of the two main channels that irrigate the agricultural areas in Kerbala city. It takes its water share from the Euphrates river at the right side of Al-Hindiyah barrage in Al-Musayyib district of Babylon city (the inlet coordinates in WGS 1984 UTM System zone 38N; X = 430777, Y = 3621208) and passes through three districts of Kerbala city, Al-Husseiniyah district, the central district of Kerbala city, and Al-Hurr district. The designed discharge of this river is 55 m^3/s, and the cross-section differs along its route. At the station (29+000) Al-Husseiniyah river is divided into two sub-rivers, ArRushdiyah river on its right side and Al-Hneidiyah river on its left side, see Figure 2 [22].

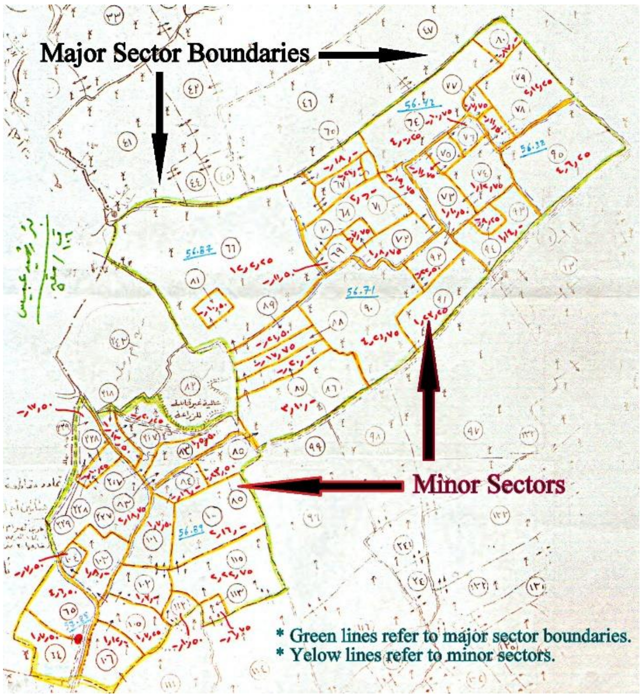

Figure 1. A certain cadastral map views a major sector within a specific district and the minor sectors that form its total area [23].

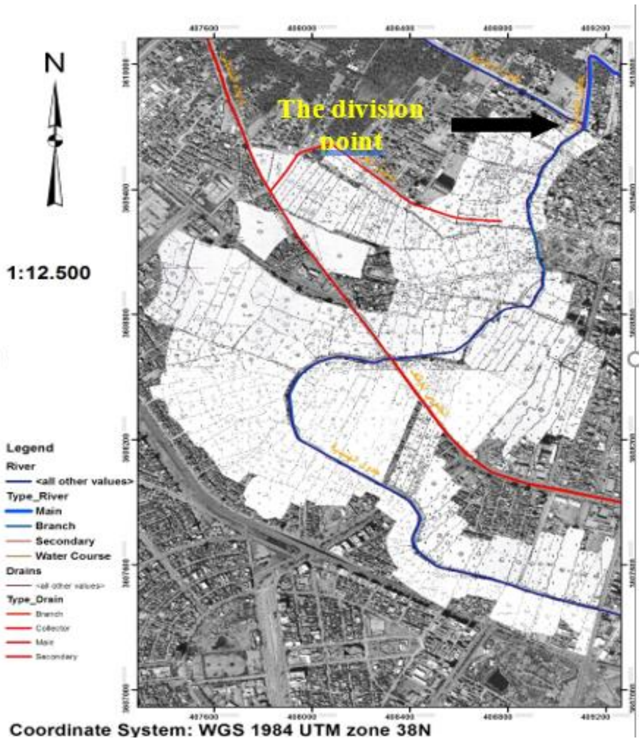

Figure 2. The study area of Al-Hneidiyah river including the division point at the upper right corner [22].

Al-Hneidiyah River–General Description. Al-Hneidiyah river starts its route from the division point of Al-Huseiniyah river at the station (29+000) (the division coordinates in WGS 1984 UTM System zone 38N; X = 409107, Y = 3609692), and flows through several significant sectors of the central district of Kerbala city for a distance of 16 km according to [22]. Table 1 shows the details of the major sectors within the entire river route where according to this route, a total area of 3000 acres of farms and 1600 acres of orchards have been irrigated, and the river-designed discharges are 2.2 m^3/s.

Table 1. Details of the major sectors irrigated by Al-Hneidiyah river [21].

Major sector No.	Area (m^2)	Farm (m^2)	Orchard (m^2)
5	45675	-	45675
6	1792398	-	1792398
7	4200	-	4200
22	89975	-	89975
24	1183825	150000	1033825
40	7144897	3553200	3591697
43	1239030	296800	942230

Focus Description of the Study Area. The study area lies between the coordinates (X = 407300 to 409300, Y = 3607000 to 3610000) in WGS 1984 UTM System zone 38N, and the river flows for a distance of 4 km from the division point mentioned previously in Figure 2. The river provides the water shares for several orchards lie on both sides, about 1204353 m^2 on its right side and 685065 m^2 on its left side, which extends across the minor sectors within several major sectors of the central district of Kerbala city. Figure 3 shows the river cross-section within the study area, and Tables 2 and 3 lists the details of the effective regions within the study area, whereas every effective region consists of a group of minor sectors.

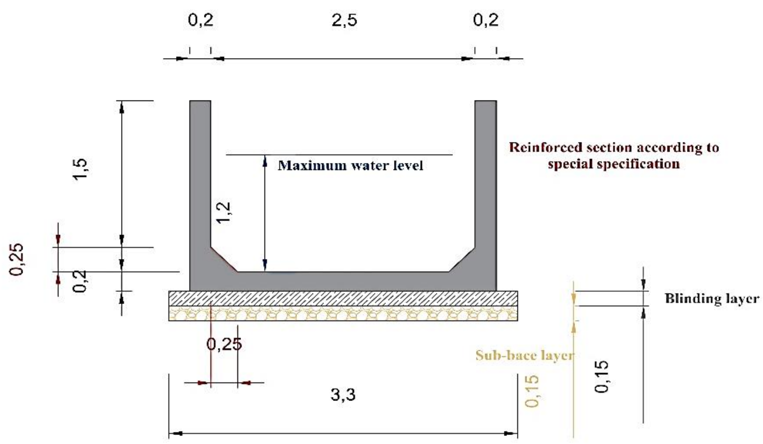

Figure 3. The cross-section of Al-Hneidiyah river within the study area [24].

Table 2. Details of the effective regions irrigated by Al-Hneidiyah river, right side [21].

Effective region No.	Major sector No.	Minor sectors No.	Total area of the effective region (m^2)
R01	6	40 (Part1)	350
R02	6	147 (Part2)	9843
R03	6	47, 66 ,67, 68, 69, 70, 118, 140 (Part2) to 147 (Part1), 194, and 195	94775
R04	6	148	4000
R05	6	120, 149 to 152, 172, and 173	24200
R06	6	121 and 154	22,625
R07	6	153	15100
R08	6	71 to 74	41300
R09	6	75 to 78, 81, and 174 to 199	40650
R10	6	79, 80, 85, 200, and 201	354960
R11	22	1 to 6, 91 to 97, 227, 228, 171 to 175, and 224	89975
R12	6	83 to 100, 196 to 198, and 219	252025
R13	6	101 and 102	61175
R14	6	103 to 109	63975
R15	6	110 and 111	14225
R16	6	113	5800
R17	6	114 to 117	32000
R18	6	167	8450
R19	6	175	5075
R20	6	176	4825
R21	6	177	11275
R22	6	178	6375
R23	6	119 and 179	9200
R24	6	218	2750
R25	6	180	16775
R26	6	181	12650

Table 3. Details of the effective regions irrigated by Al-Hneidiyah river, left side [21].

Effective region No.	Major sector No.	Minor sectors No.	Total area of the effective region (m^2)
L01	5	1 and 5	8,400
	7	160	
L02	5	3	4125
L03	5	6, 13, and 14	6375
L04	5	15 and 16	6450
L05	5	72	2025
L06	6	24	3300
L07	6	25	4700
L08	6	60, 158, 159, 204, and 205	26715
L09	6	157, 202, and 230	23850
L10	6	156	11100
L11	6	64, 165, 166, 168 to 171, 208, 225, and 238	109725
L12	6	155, 209 to 211, and 217	13700
L13	6	122 to 125, 200 to 207, 212, and 216	144875
	24	115 to 118, 198, and 199	
L14	6	126, 128, 214, and 215	34175
L15	6	129, and 132 to 139	63600
L16	6	127, 130, and 131	17975
L17	24	114	21000
L18	24	109 (Part1), and 110 to 112	37675
L19	24	108	10275
L20	24	109 (Part2)	7500
L21	24	105	26950
L22	24	104	8000
L23	24	120	5200
L24	24	72	11900
L25	24	58 to 60, 69, and 211	75475

Research Methodology. The methodology of the current study explained in Figure 4.

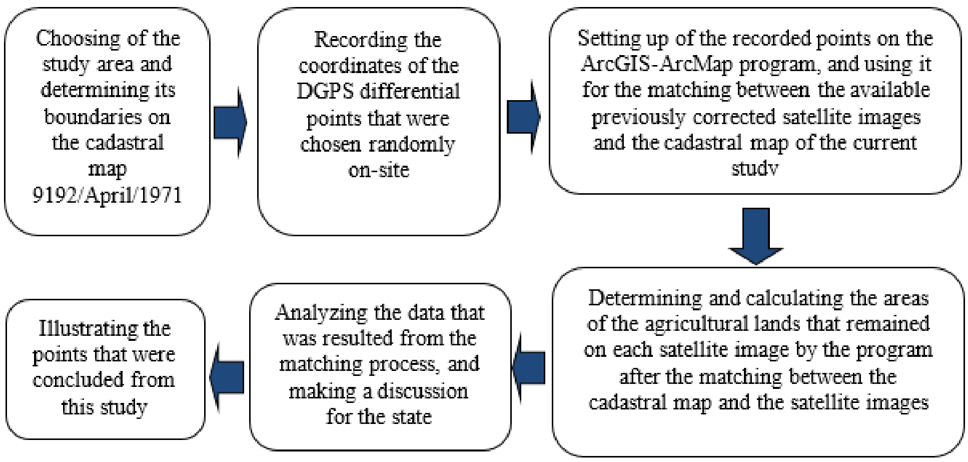

Figure 4. Methodology of research.

Analysis and discussion

Figures 5 to 8 show the available and corrected satellite images of the study area for the years 2002, 2007, 2013, and 2017 with a degree of accuracy equal to 0.5 m, provided by the technical department of the general commission for the survey - Iraqi ministry of water resources, corrected and merged by the part of the cadastral map 9192/April/1971 by using ArcGIS-ArcMap 10.3 program, [25]. The referred cadastral map was projected on the mentioned program and synchronized by each satellite image by using 123 random on-site DGPS differential points with a degree of error equal to 0.01 m to get an accurate matching as much as possible.

As shown in Figures 5 to 8 in a separate way, it refers to an apparent recession in the total area of the agricultural lands over time within the study area because of the widespread expansion and the change of land use from agricultural to multi-purposes of human use. Table 4 lists the areas of the agricultural lands' effective regions, orchards, which remained in each satellite image, whereas all effective areas were plotted and calculated by the program (ArcGIS-ArcMap 10.3). From the results in Table 4, it's evident that the total area of agricultural lands reduces with time, and that confirms the recession process. Figure 8 shows the relationship between the percentage ratio of the remain agricultural lands and the time, in years, where it can be noticed that the ratio of the agricultural lands for the period bounded by the years 1971 and 2002 in the range between 90.95% to 66.81%. That means the annual ratio is 0.75% due to many considerations such as the national policy followed by the government that preserves the agricultural lands and orchards, encourages the cultivation of various crops, prevents overtaking of water shares or changing the gender of agricultural land use for other uses, and keeps all hydraulic structures in a safe position. While for the period bounded by the years 2002 and 2007, the ratio ranges between 66.81% and 49.42%, for the period bounded by the years 2007 and 2013, the ratio ranges between 49.42% and 25.22%, and for the period bounded by the years 2013 and 2016, the ratio ranges between 25.22% and 13.45%. The annual percentage for these three periods are 3.48%, 4.03%, and 3.92%, respectively. This considerable increment was happened due to many considerations compared with the annual ratio of the first period. These considerations can be described briefly as the opposite of the first-period considerations.

Besides, the water and solid pollutants that fill the irrigation channels and their field water courses due to the fast expansion in residential part in general form inside the study area, and the other fields of work. All these factors lead to an argent need to decide about keeping the hydraulic structures within the new growth cities safe and protecting the water shares quantitatively and environmentally. A relationship may be drawn between parameters of Figure 9, and the best representation of this relationship is the linear form as in Eq. 1.

$$PRRAL = -0.015(T) + 32.10 \qquad R^2 = 0.831 \qquad (1)$$

Where PRRAL is the percentage ratio of the remain agricultural lands, and T is time, in years. Figure 8 a clear separation of periods, which is the first period between the years 1971 and 2002, and the three previous periods are starting from the year 2002 to the year 2016. Drawing the relationship for the three last periods' data will introduce a new equation, Eq. 2.

$$PRRAL = -0.038(T) + 77.49 \qquad R^2 = 0.998 \qquad (2)$$

According to this equation with the continuity of the current situation, all the agricultural area probably to vanish at the beginning of the year 2040. Also, the difference between the two prediction equations' determination coefficient is clear because of the clear difference in data pattern between the first period and the three respective periods.

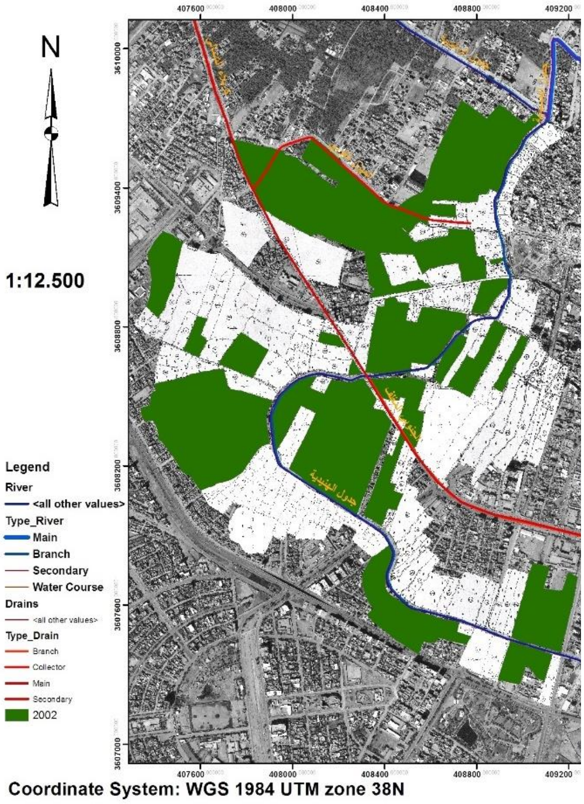

Figure 5. The satellite image of the year 2002 for the study area [25].

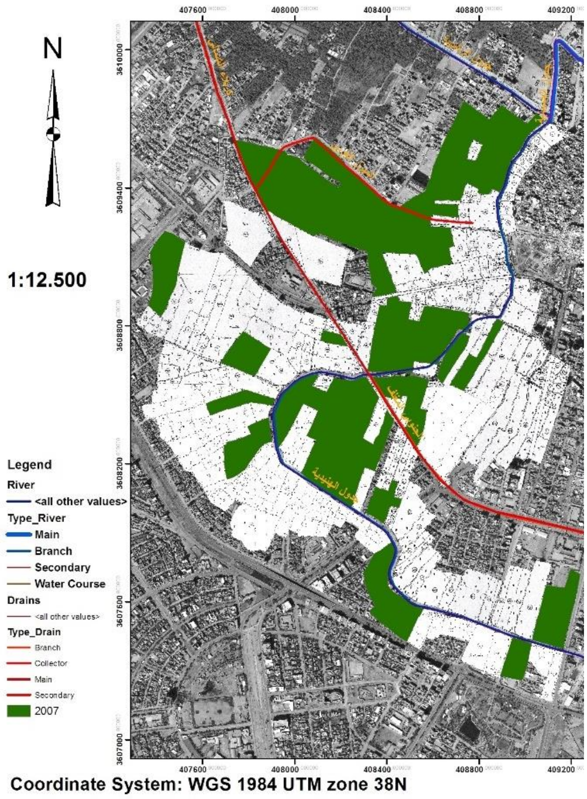

Figure 6. The satellite image of the year 2007 for the study area [25].

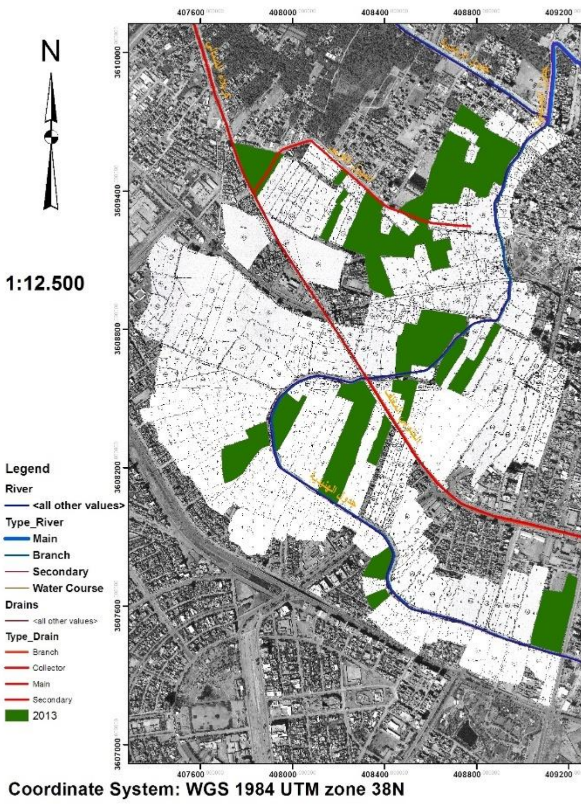

Figure 7. The satellite image of the year 2013 for the study area [25].

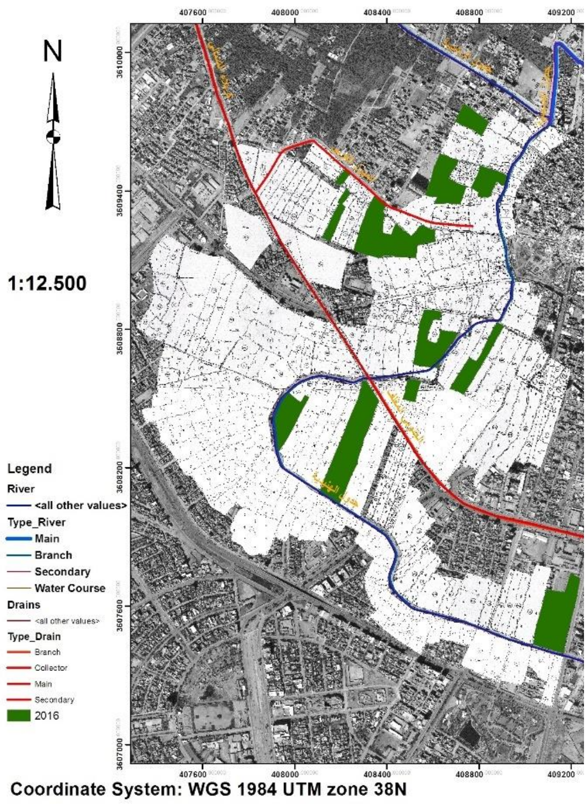

Figure 8. The satellite image of the year 2016 for the study area [25].

Table 4. Details of the effective regions within each satellite image for the study area [25].

Year	Effective region No.	Area (m^2)	% of the total study area	Year	Effective region No.	Area (m^2)	% of the total study area
2002	A01/2002	186750.0	0.09883	2007	B01/2007	15961.7	0.00845
	A02/2002	28187.2	0.01491		B02/2007	33325.9	0.01763
	A03/2002	10512.5	0.00556		B03/2007	14570.0	0.00771
	A04/2002	61272.0	0.03243		B04/2007	162448	0.0860
	A05/2002	66646.7	0.03527		B05/2007	39254.2	0.02077
	A06/2002	423784	0.22429		B06/2007	391869	0.20740
	A07/2002	93647.7	0.04956		B07/2007	94043.9	0.04977
	A08/2002	188036.0	0.09952		B08/2007	4718.7	0.00250
	A09/2002	74275.4	0.03931		B09/2007	22876.2	0.01211
	A10/2002	35831.9	0.01896		B10/2007	35785.9	0.01894
	A11/2002	10103.6	0.00535		B11/2007	14881.8	0.00788
	A12/2002	23094.9	0.01222		B12/2007	4.7	0.00000
	A13/2002	11335.8	0.00600		B13/2007	27548.9	0.01458
	A14/2002	1021.6	0.00054		B14/2007	48965.3	0.02592
	A15/2002	13952.9	0.00739		B15/2007	16215.0	0.00858
	A16/2002	2172.2	0.00115		B16/2007	11313.6	0.00599
	A17/2002	4745.1	0.00251		**Total**	**933782.8**	**49.423%**
	A18/2002	26994.1	0.0143	2016	D01/2016	15965.8	0.00845
	Total	**1,262,364**	**66.810%**		D02/2016	5114.5	0.00271
2013	C01/2013	182743	0.0967		D03/2016	49136.5	0.02600
	C02/2013	25198.2	0.01333		D04/2016	19315.8	0.01020
	C03/2013	2318.3	0.00123		D05/2016	39101.1	0.02070
	C04/2013	7555.4	0.00400		D06/2016	25101.1	0.01330
	C05/2013	54683.9	0.02894		D07/2016	45230.1	0.02394
	C06/2013	27522.5	0.01457		D08/2016	7434.1	0.00393
	C07/2013	4917.0	0.00260		D09/2016	2257.6	0.00119
	C08/2013	15913.2	0.00842		D10/2016	23015.4	0.01218
	C09/2013	10876.9	0.005757		D11/2016	12347.3	0.00654
	C10/2013	11342.9	0.00600		D12/2016	10134.5	0.00536
	C11/2013	54722.1	0.02896		**Total**	**254153.8**	**13.450%**
	C12/2013	19386.5	0.01026	**Note 1**: In each satellite image, the names and values of the effective areas differ according to the appearance in the taken image.			
	C13/2013	9164.4	0.00485				
	C14/2013	39219.8	0.02076				
	C15/2013	11003.6	0.00582				
	Total	**476567.7**	**25.219%**				

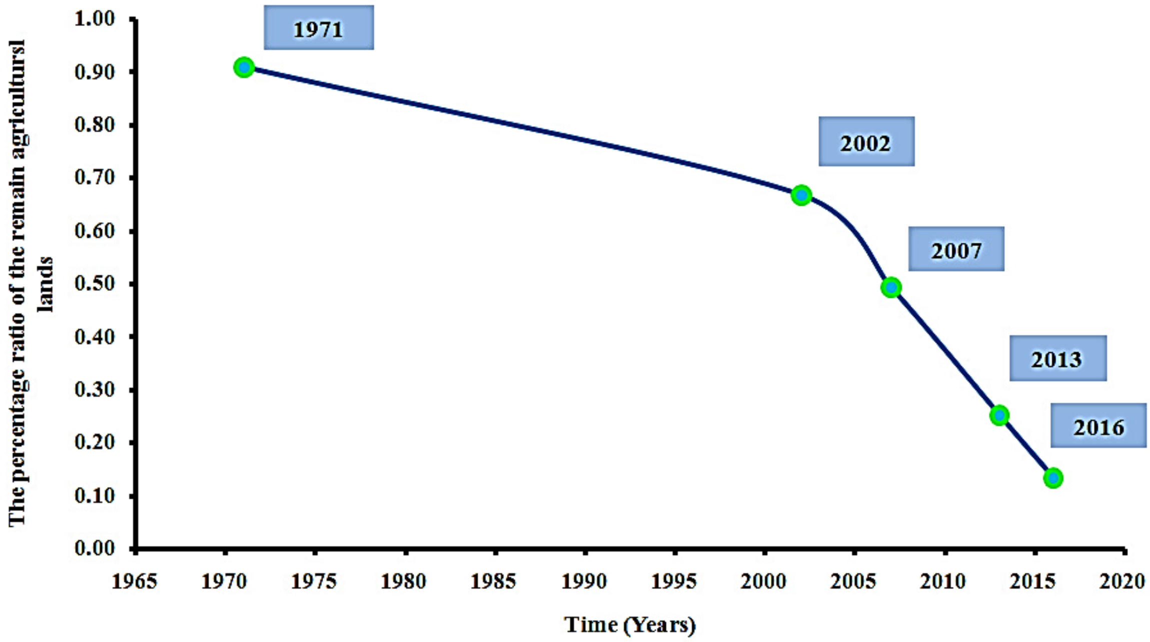

Figure 9. The relationship between the percentage ratio of the remain agricultural lands and the time (years).

From the technical point of view and the low ratio of the remain agricultural lands within the study area in the present time, transforming the river cross-section within the study area into a closed conduit and making its use for conveyance purposes to ensure safe and fear delivery of the water shares for the agricultural lands feed by Al-Hneidiyah river after the study area may be considered as the best decision for this study. The remain green lands should be taken into consideration by redistributing and redesigning for the current field outlets.

Conclusions

The new growth of cities is a series issue for the fields of agriculture and water resources with the absence of the proper and synchronous planning for these fields with the urban planning, and the results of this absence are more hydraulic, environmental, and social issues added as obstructions in the future of societies. From the current study, the following points can be concluded:

- The total area of agricultural lands of the study area recedes with the advancement of time.
- Linear equations represented the relationship between the percentage ratio of the remain agricultural lands and time.
- Two clear periods represent the recession of the agricultural lands. The first was between the years 1971 and 2002, and the second between the years 2002 and 2016.
- According to the period between 2002 and 2016, the agricultural lands may have vanished from the study area at the beginning of 2040.
- Transforming the river cross-section within the study area into a closed conduit and making its use for conveyance purposes to ensure safe and fear delivery of the water shares for the agricultural lands feed by Al-Hneidiyah river after the study area may be considered as the best decision for this study.
- The geographic information system is a good and helpful technique for evaluating river section state and decide its future use purpose by viewing all possible visions of the river study area.

Recommendations

The following recommendations may be helpful as solutions for the study case:

1)Transforming the river cross-section into a closed conduit may be done by:

a) Close the section partially by using removable concrete covers along the studied river route to be easily moved during the maintenance process.
b) Close the section fully by constructing an unmovable reinforced roof and using manholes at studied distances along the river route for the flushing process during its maintenance.
c) Replace the whole section with a pipe system with an equivalent cross-section to ensure throwing the decided discharge.

2) Re-distributing the field outlets of the watercourses by removing the canceled ones from the river route within the study area and using its water shares to:
a) Enhancing the water shares of the agricultural lands that irrigate from the river after the study area.
b) Resumption of reclamation works in the major sectors no.61 and no.20 at the southern part of Kerbala city.

3) Activating groundwater's role within the study area as an alternative resource to irrigate the remaining agricultural lands.

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