Water Demand Estimation in Urban Areas Based on Population Forecasting Using GIS Analysis Modeling

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Abstract .The current study relied on the adequacy of drinking water in the city of Sulaimani, and for the purpose of knowing the adequacy of the amount of water produced from projects that feed the city, the actual production amount of these projects is divided by the estimated population of the years 2010-2032 in light of the approved standard for the current year and then compared with water demand in the mentioned period by applying some of statistical analysis techniques for infrastructure projects management . The management of infrastructure in general and water distribution in specific is one of the most important challenges faced by the cities of the developing world, because of the delay in many service and development areas and it becomes more difficult when it comes to a city such as the city of Sulaimani in Kurdistan region of Iraq, which suffered for many years from suppress of political and economic bad conditions. Hence the research as a case study in the management of water demand by using GIS and Satellite remote sensing techniques. The research aims to identify how to manage the water distribution networks in some of urban areas of Sulaimani city to help decision makers reach less costly and timely solutions through the collection, storage, editing, analysis and managing of geodatabase, with focusing on mixed methods analysis of water distribution and demand for problem solving through spatial and statistical analysis. ArcGIS and other database software have been proposed as a means of building database on the systems and networks used to provide more accessible water demand estimation.

Keywords: water demand, GIS Analysis, Sulaimani city, population forecasting

1. Introduction

Water is a major source of life on the surface of the earth. All of this is evident in the noble verse that expressly declares the creativity of the Creator in making water necessary for every living creature where God Almighty said (and makes us from water every living thing that they do not believe) **[1]**

Despite all this importance of water, the rationalization of its use has not received the attention it deserves. The most recent statistics indicate that the proportion of water consumption in the twentieth century doubled in the period between (1900-1995) six times**[2]**, equivalent to more than twice the rate of population increase, and in (2032) a third of the world's population will be faced with dangerous water mothers, due to the increasing need for water because of the increase in the world population and the accompanying development in the agricultural and industrial processes, as well as the urban expansion that has swept large areas of the world. The drinking water network dates back to the middle of the previous century and it has suffered from neglect, and it has not been done the expansion has only limited areas, and this expansion was not consistent with the population growth of the study area, in addition to being a city with a tourist and industrial function and a commercial center and a cultural capital for the Kurdistan region of Iraq is an important city for the Kurds. Modern designs were developed for the development of the drinking water network after 2003 and research here will shed the light highlights a major problem and contributes to developing a current and future image that benefits the interested parties, in the city of Sulaimani to determine the need for drinking water.

Water management becomes particularly important in the Kurdistan region of Iraq because it is a hot, volatile and dry climate. Water is a determining factor for all social and economic development efforts. This paper addresses the definition of GIS and their steps that need to be followed to apply them in various scientific fields, with a focus on reviewing the possibility of making maximum use in the field of water resources science and management. "Geographic information systems are undoubtedly systems of decision support and their impact has been felt in various aspects of life and administrative activities, and the experience of preparing large, multi-purpose databases of large-scale, multi-purpose purposes has enriched different application areas **[3]**. GIS and its integration with e-government has become an urgent issue that every government must work in GIS applications have provided advanced spatial analysis and statistical information in various fields of application and management. **[4]**The need to harness this new technology in the service of the cities of the developing world, including the city of Sulaimani / Kurdistan region of Iraq as an example, where the city suffers from the absence of a system to manage its infrastructure using GIS, as well as the great pressures on the infrastructure. The city's water distribution system aims to transfer potable water from the collection tank or terminal purification and distribution throughout the city under sufficient pressure to be used for different purposes **[5]**. The steady increase in urban population has led to an increase in water demand. In view of the need for a stable water supply, a map of water resources must be developed and a geographical distribution must be made.

2. Problem Statement:

The general study problem is represented by the following question:

Does the actual production amount of water projects feeding the Sulaimani city meet the current needs of the city's drinking water in the required quantity, and can a plan for its future be paint in light of the expansion and growth of its population? .

2.1 Hypothesis of the study:

The general study hypothesis can be formulated with the following phrase:

There is a shortage in the quantities of water produced from projects that feed the city of Sulaimani, caused by the expansion and growth of the population in the city in a way that is not commensurate with the productive projects capacity, and that there is a large deficit in the lack of water purification in the areas connected to it. This calls for studying the amount of water distributed to consumers in the city and determining of its future.

2.2 Objectives of the Study:

The basic aim of this study is to examine, analyze and visualize the impact of the residential and commercial water supply and demand system, based on population distribution estimation to a water main network system in supplying the needs.

3. Study Area:

Sulaimani also called Slemani is a city in Iraqi Kurdistan. It is surrounded by the Azmer Range, Goyija Range and the Qaiwan Range in the northeast, Baranan Mountain in the south and the Tasluja Hills in the west. The city has a semi-arid climate with very hot dry summers and cool wet winters. Sulaimani served as the capital of the historic principality of Baban from 1784 to 1850. The city is known as the capital of enlightenment among the Kurds, but the official nickname of the city on national level is: Sulaimani is the Paris of Iraq or the bride of Iraq's **[6]**French journalist Chris Kucera called the city "the spiritual capital of Kurdish nationalism in Iraq" **[7]**.The geographic coordinates of Sulaimani based on WGS84 are Latitude: 35°33′53″ N and Longitude: 45°25′58″ E, Elevation 847 m AMSL**[11]**..

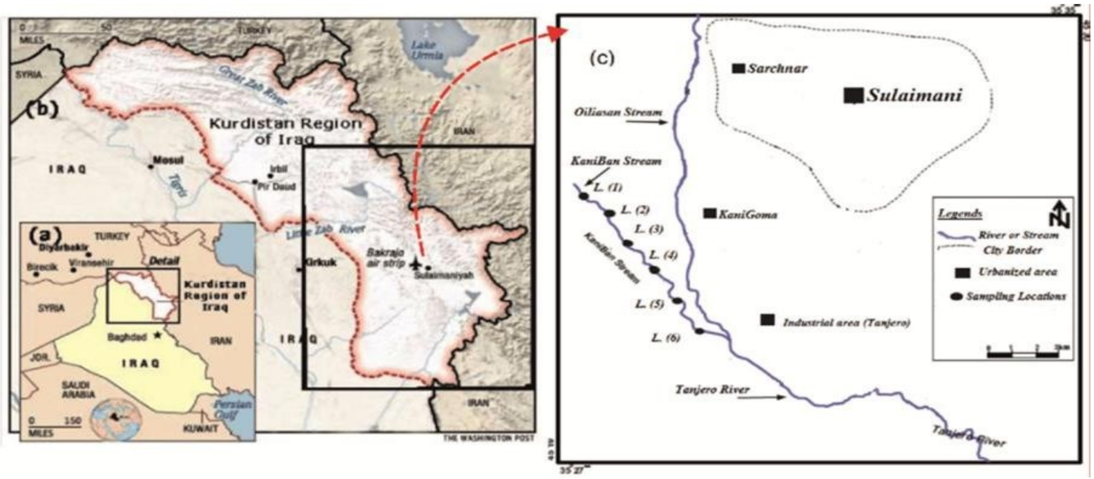

Figure 1. Map of study area (Sulaimani)

4.0 Methodology

In this study the GIS geoprocessing technique has been adopted, which distinguishes the Geographic Information System from the rest of the information systems. The geoprocessing framework provides functionality for organizing and managing the work environment, performing simple and complex analyzes, and making your custom tools usable by others. In the water sector, information system and knowledge management are recognized as important attributes for efficient and effective water works. Mixed method of statistical and spatial analysis applied in this study by using GIS technology that integrates hardware, software, and data required to capture, manage, analyses, and display all forms of geographically referenced information. GIS allows the user to view, visualize, question, interpret, and understand data in different circumstances that clarify patterns, trends, and relationships in the form of reports, maps, and charts**[8]**.. Mixed method refers to combining both quantitative and qualitative approaches to answer the paper questions. In this study, the basic idea in mixed methods research is that to use quantitative and qualitative methods together to get a complete understanding of the phenomenon we are studying. Researchers using this approach to collect analyze and combine qualitative and quantitative data into a single study. They usually have two databases that, at some stage, they bring together and integrate. The methodology is divided into five stages:

A. Determine the objectives of the study
B. Build the database and prepare the data for analysis
C. Perform the analysis

To understand GIS geoprocessing better, the researches broke down some of the main stages into subs-stages order to understand each stage.

A. Determine the objectives of the project; this stage contains sub-stages which are:

- Identify the problem to solve.
- Break down the objectives into measurable criteria.
- Determine data requirements: the required data that cover the study objective and the solution for finding the alternative scenarios are classified to geographic (spatial) data which contained vector and raster data format and attribute (tabular) data.

B. Build the database and prepare the data for analysis: - in this stage, the researchers identify and obtain relevant data; the relevant data include:

1. Spatial data: These data have been created and modified by the researches using ArcGIS geoprocessing operations to create vector layers. Also include high resolution satellite image, digital terrain model as raster data, and GIS Layers (shape files), plane and topographic maps, and CAD files. Figures 2, 3, 4, 5, and 6 illustrate the data...

Figure 2. Satellite imagery and DTM data

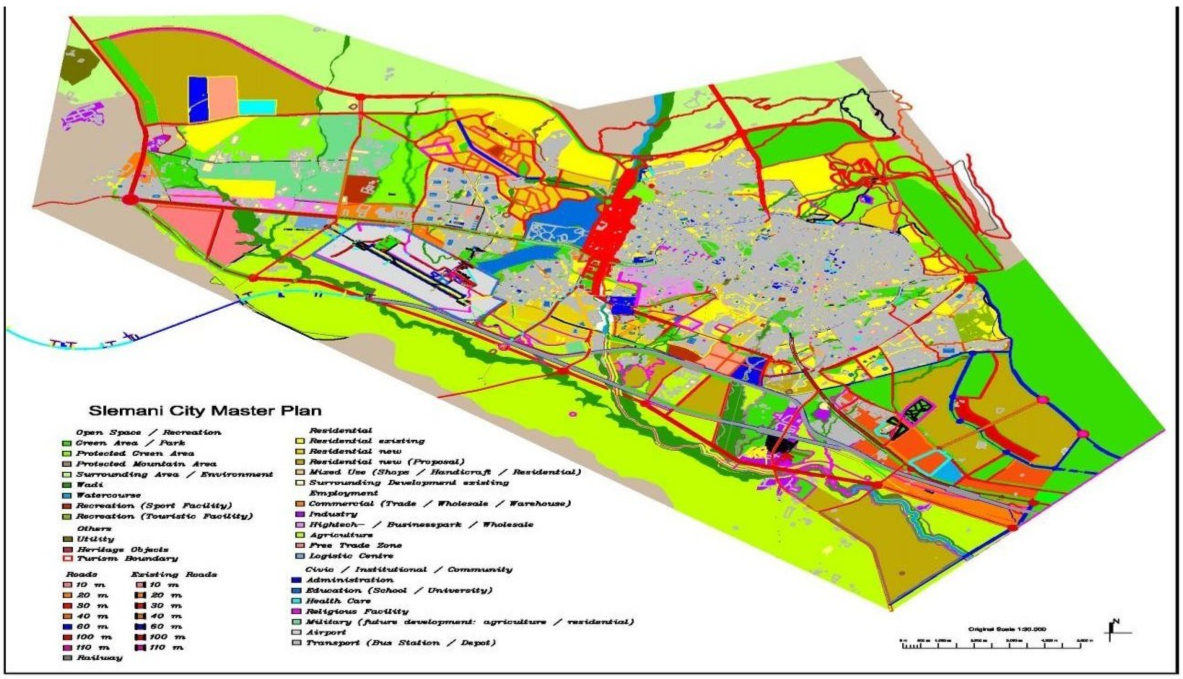

Figure 3. The master plan of study areas

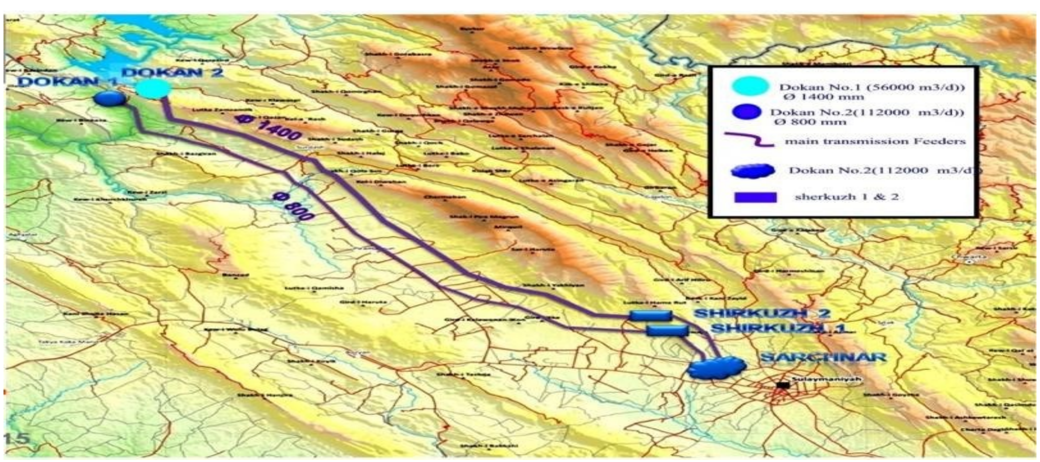

Figure 4. Location of drinking water sources layer. (by researchers using ArcGIS)

Figure 5. Main Transmission Feeders layer. (by researchers using ArcGIS)

2. Attribute (Tabular) data:

Attribute data are descriptive data related to water distribution system, population, drinking water capacity water feeder capacity, water demands. The following tables illustrate the required data for performing analysis and to satisfy the study objectives.

Table 1. Source of water feeding capacity for the city of Sulaimani

No.	Source of water feeding	Water supply for 2018 year/ m^3
1	Sarchnar Water Project	32535559.46
2	Dokan 1 Water Project	16721500.00
3	Dokan 2 Water Project	58893329.87
4	Water project for the karez and wells	360,000
Total		108510389.3

C. Perform the analysis

In order to be able to achieve the optimum balance between the water supply and the average water demand in a good way. Two scenarios are taken:

A. The first scenario; the average of water demand is (200) per capita (liter / day).

B. The first scenario; (average of water demand is (300) per capita (liter / day).

The Analysis operations are classified according to two scenarios to achieve a long-term goal based on some specific factors or variables. In this case, water management will be more reasonable, economical and the expectations of population growth have a role in proposing and identifying the two scenarios.

The analysis method used in the study emphasizes the applications of GIS and descriptive statistics in water demand issues in a mix scale with GIS mapping to show spatial trends. This includes all the analysis procedures deal with the spatial and statistical data that created and updated by the researcher and data obtained from the different sources to achieve the paper objectives. For ensuring, a balance between the demand and the supply of water for the population needs taking in accounts the water resource sustainable**[9]**.. The scenarios have developed for performance analysis according to the three adopted variables, which are Population growth projections, Per capita Water demand, and Land use.in this paper the researchers select the Population growth projections variable. Several basic analyses have been achieved with ArcGIS ESRI Software. This involves tools under Spatial Analyst, 3D Analysis and Statistical Analysis.

1. Population Growth Projections

With this variable the population furcating and population density calculation are applied. For population forecasting calculation, the Uniform Percentage of Increase was applied. This method assumes uniform rate of increase in specific period, which is the rate of increase, is proportional to population) **[10]**..

$$\ln Pt = \ln Po + Ki\ (t - to)$$

Or …. Equ.1

$$\ln Pt = \ln Po + Ki\ \Delta t$$

Where:

Pt: Population at some time in the future

Po: Present or initial population

K1: population growth rate

Δt: period of the projection in years

2. Density population

Meanwhile, the density population calculation was used for describing the spatial distribution of population the simplest method is percentage distribution of population over the geographical areas **[12]**. The density of population is usually computed as population per square kilometer (Km^2) of the land area excluding area occupied by water. In this study, the analysis of population density will be confined to the ratio of the population of a given geographical or administrative unit to the area occupied by that unit **[13]**. The following equation calculates the population density.

Population density = (Number of inhabitants)/ (Residential area) x 100 ……… Equ.2

5. Result Discussion

With this factor the population forecasting and population density calculation were applied, for both scenarios after taking all variables (parameters) that considered are tabulated in the tables below

5.1 Population forecasting results discussion

According to the Iraqi standard (Iraqi Urban Planning Standard, 2010) that used in the study for population project forecasting, the Uniform Percentage of Increase method was applied to compute the population project forecasting. The result illustrated in tables and figures below.

Table 2 Forecasting population growth for the years 2010 to 2032

Year	2010	2015	2020	2025	2030	2032
Sulaimani total Population	720,950	835,800	968,900	1,096,215	1,240,267	1,303,055

These details of the above tables' values were done by researches based on the equation:

$$\ln p_t = \ln p_o + k\ \Delta t$$

As the population forecasting has been computed, the average water demand computed as shown below:-

-The first scenario (average of water demand is (200) per capita (liter / day)

Table 3 total daily demand & total max demand for Sulaimani city (1st scenario)

Year	Population	water production/ (m3)		per capita (liters / day)
		Average day demand	Maximum day demand	
2010	720,950	257684	386526	200
2015	835,800	267099	400649	200
2020	968,900	298158	447237	200
2025	1,096,215	332827	499240	200
2030	1,240,267	371528	557292	200
2032	1,303,055	388240	582360	200

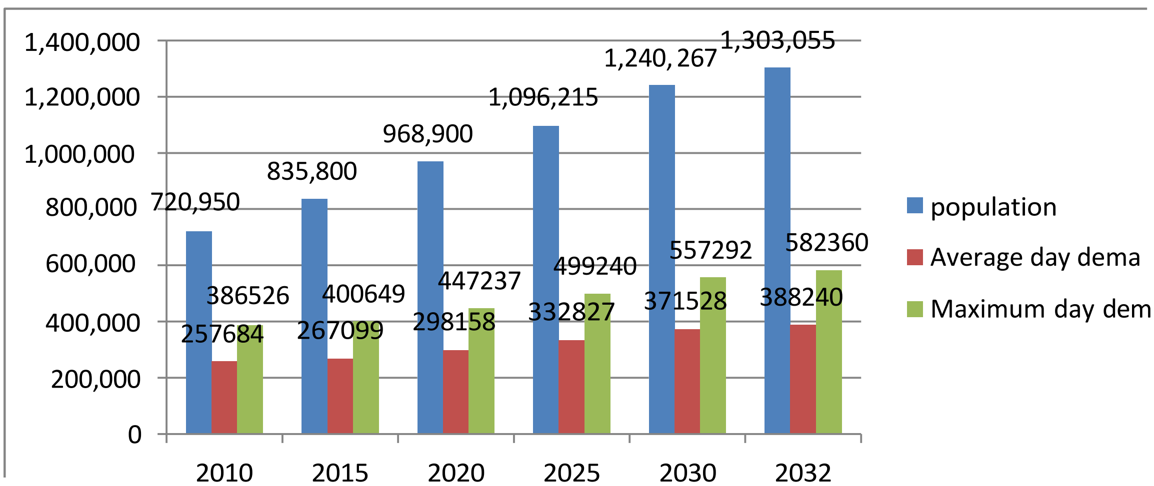

Figure 6. water demand (Average and maximum daily demand) for sulaimani city from 2010 to 2032

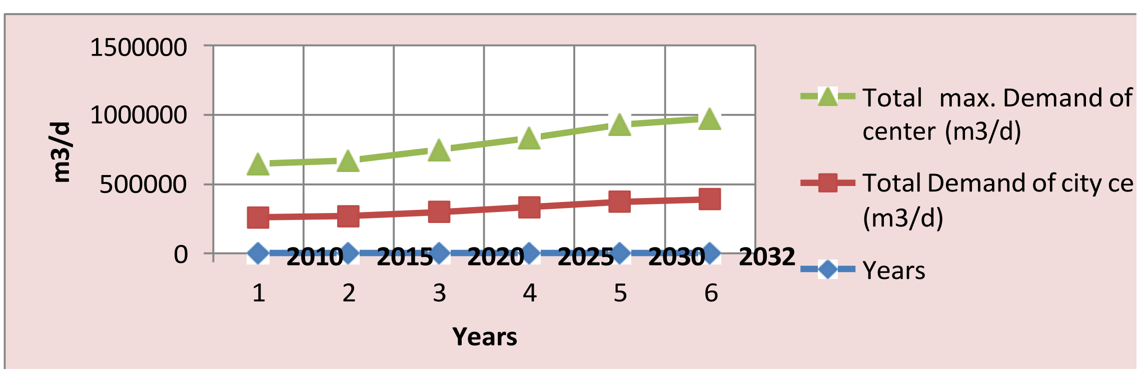

Figure 7 chart of total daily demand & total max demand for Sulaimani city (1st scenario)

The second scenario (average of water demand is (300) per capita (liter / day)

Table 4 total daily demand & total max demand for Sulaimani city (2nd scenario)

Year	Population	water production/ (m3)		per capita (liters / day)
		Average day demand	Maximum day demand	
2010	720,950	386543	579815	300
2015	835,800	400650	600975	300
2020	968,900	447236	670854	300
2025	1,096,215	499240	748860	300
2030	1,240,267	557292	835938	300
2032	1,303,055	582361	873542	300

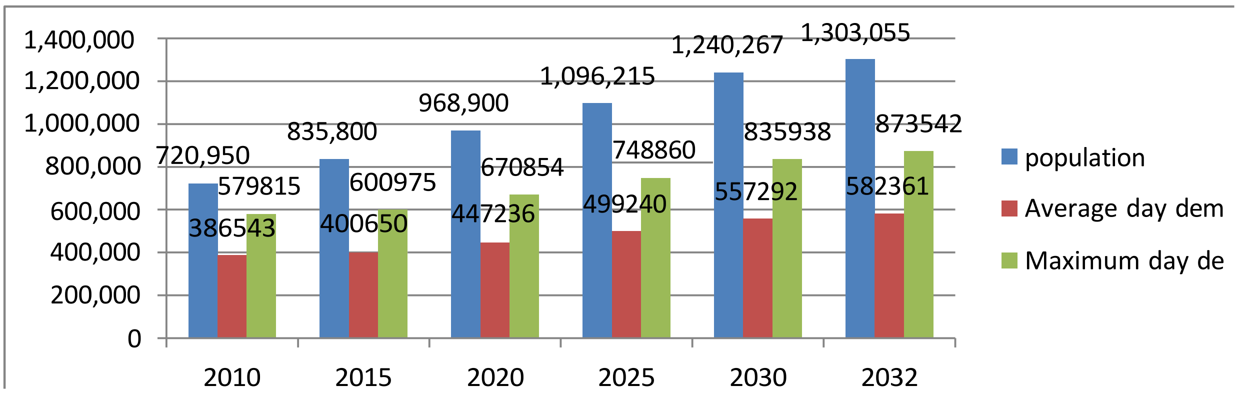

Figure 8 water demand (Average and maximum daily demand) for Sulaimani city from 2010 to 2032

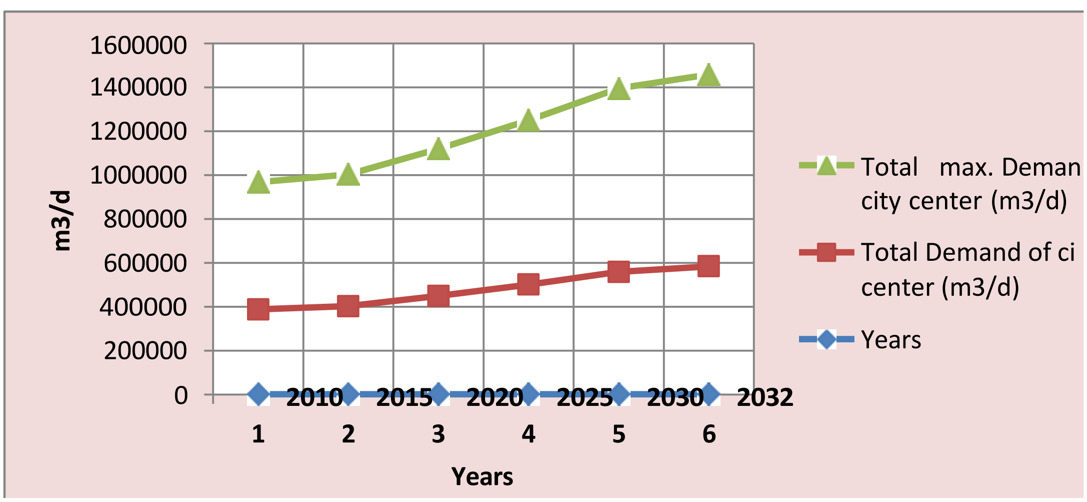

Figure 9 chart of total demand & total max demand for Sulaimani city from 2010 to 2032

For population forecasting calculation, the Uniform Percentage of Increase method was applied.

5.2 Population density result discussion

The population density calculations were applied for the three study areas. The formula that applied for this calculation was s before is showed in analysis section in chapter four, figures and tables below explained the result gained. The Population density of whole Sulaimani City center is

Population density = $\frac{\text{Number of inhabitants}}{\text{Residential area}}$ **x 100**

- Residential Area of Sulaimani city : 17,023 km^2

Table 5 Forecasts of population growth and population density of Sulaimani City

Years	Population forecasting	Population density person/ km^2
2010	720,950	4235.152
2015	835,800	4909.827
2020	968,900	5691.711
2025	1,096,215	6439.611
2030	1,240,267	7285.831
2032	1,303,055	7654.673

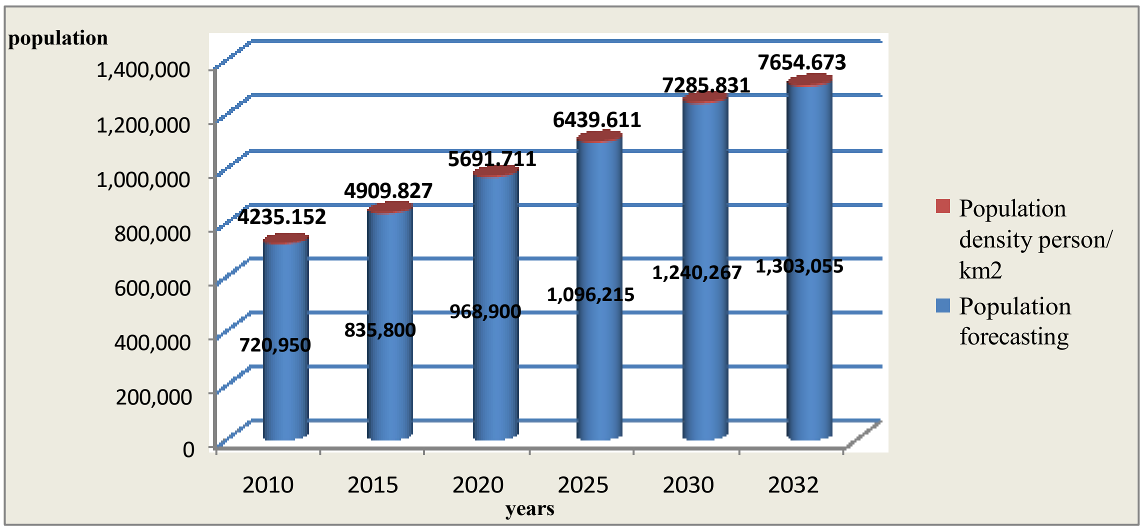

Figure 10 Forecasts of population growth and population density of Sulaimani City

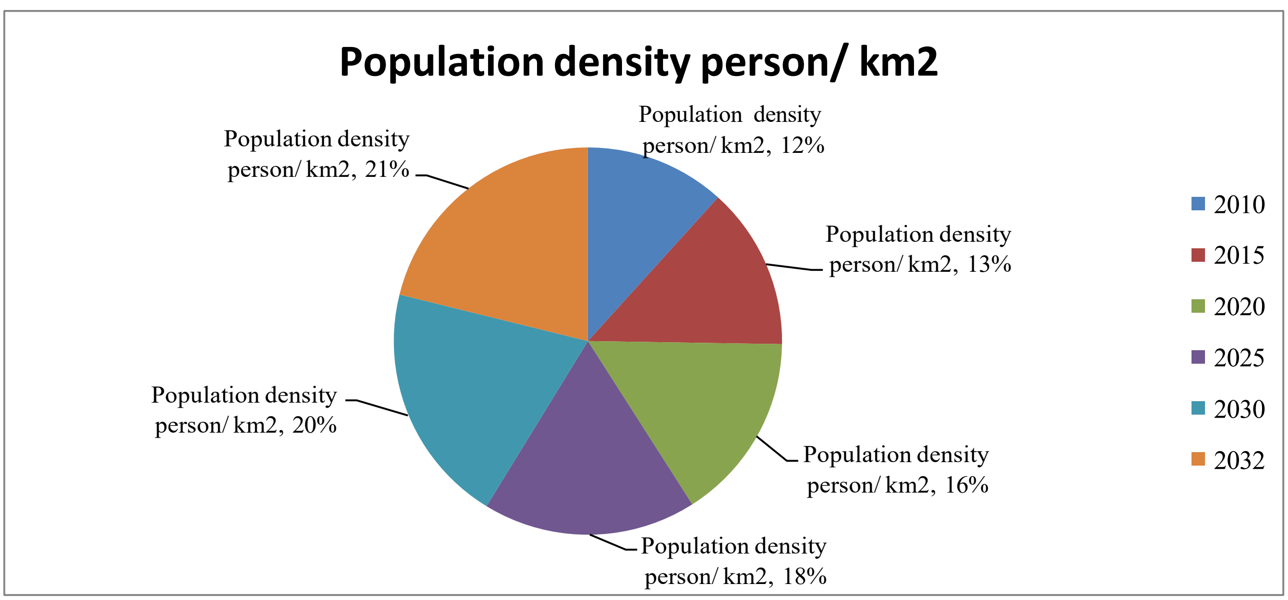

Figure 11 population density for Sulaimani City from 2010 to 2032

5.3 Water demand and water supply

The following tables and figures discussed the amount of water supply and required water demand based on the population forecasting for the study area.

Table 6. the balance plan of water demand (2010 -2032) scenario I (Excess or deficiency)

Main water sources	Supply 2010	Supply *2015*	Supply 2020	Supply 2025	Supply 2030	Supply 2032
Total Supply	216000	374000	374000	374000	374000	484000
Total Demand	257684	267099	298158	332827	371528	388240
Excess or deficiency	-41684	106901	75842	41173	2472	95760

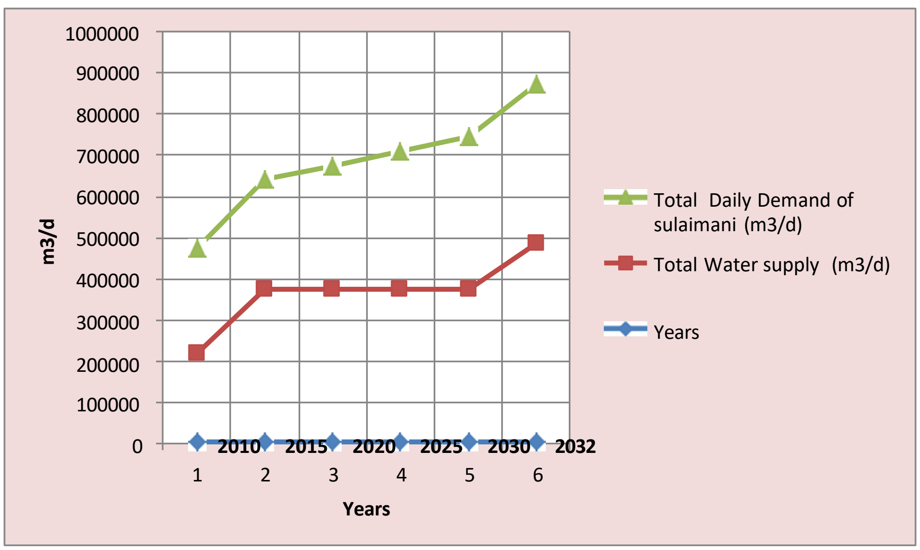

Figure 12. Total Daily demand and total daily water supply for 1st Scenario

Table 7. Water Demand and Supply and Need Excess or deficiency for 1st Scenario

Years	Total Water Supply	Total Daily Demand	Need Excess or deficiency
2010	216000	257684	-41684
2015	374000	267099	+106901
2020	374000	298158	+75842
2025	374000	332827	+41172
2030	374000	371528	+2472
2032	484000	388240	+95760

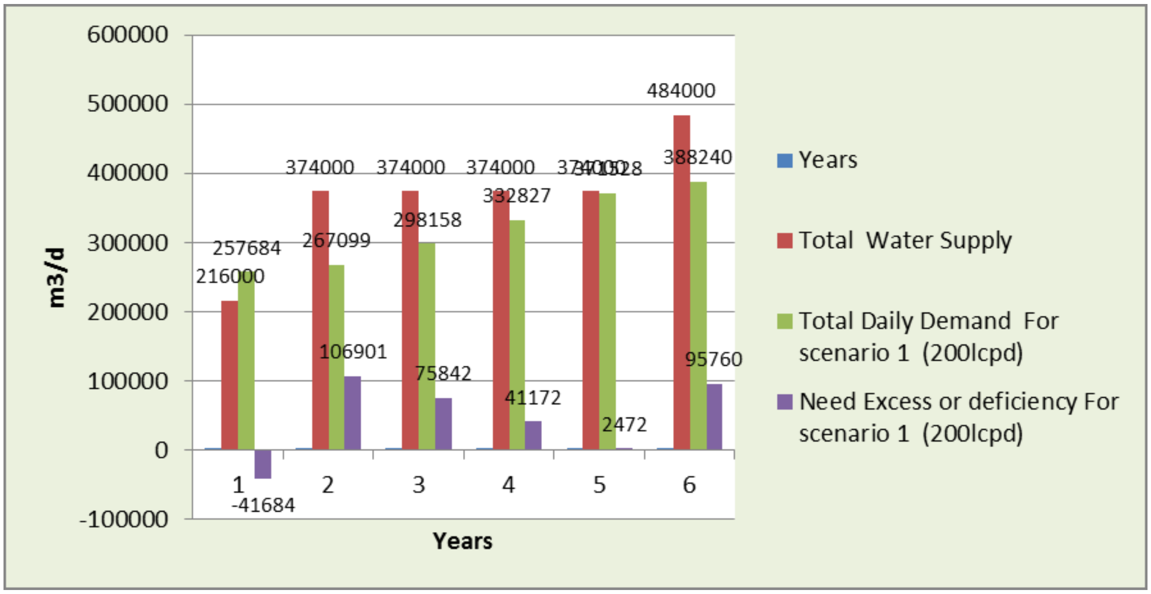

Figure 13. Water Demand and Supply and Need Excess or deficiency for 1st Scenario

Table 8. Showing the balance plan of water demand (2010 -2032) scenario II

Main water sources	Supply 2010	Supply 2015	Supply 2020	Supply 2025	Supply 2030	Supply 2032
Total Supply	216000	374000	374000	374000	374000	484000
Total Demand	386543	400650	447236	499240	557292	582361
Excess or deficiency	-170543	-266650	-73236	-125240	-170543	-266650

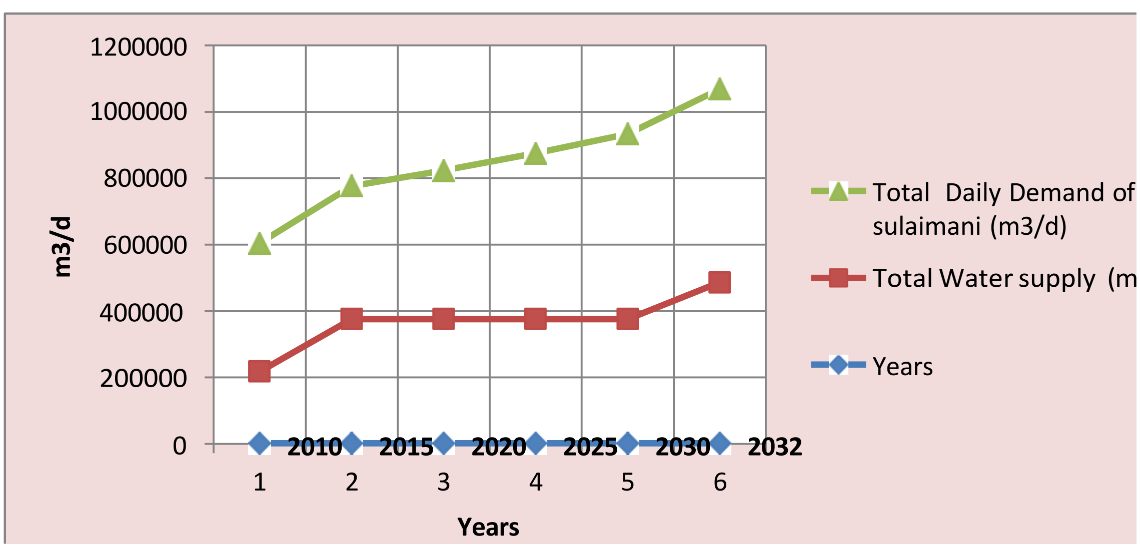

Figure 14. Total Daily demands and total daily water supply for (2nd Scenario)

Table 9. Water Demand and Supply and Need Excess or deficiency for (2nd Scenario)

Years	Total Water Supply	Total Daily Demand	Need Excess or deficiency
2010	216000	386543	-170543
2015	374000	400650	-266650
2020	374000	447236	-73236
2025	374000	499240	-125240
2030	374000	557292	-183292
2032	484000	582361	-98361

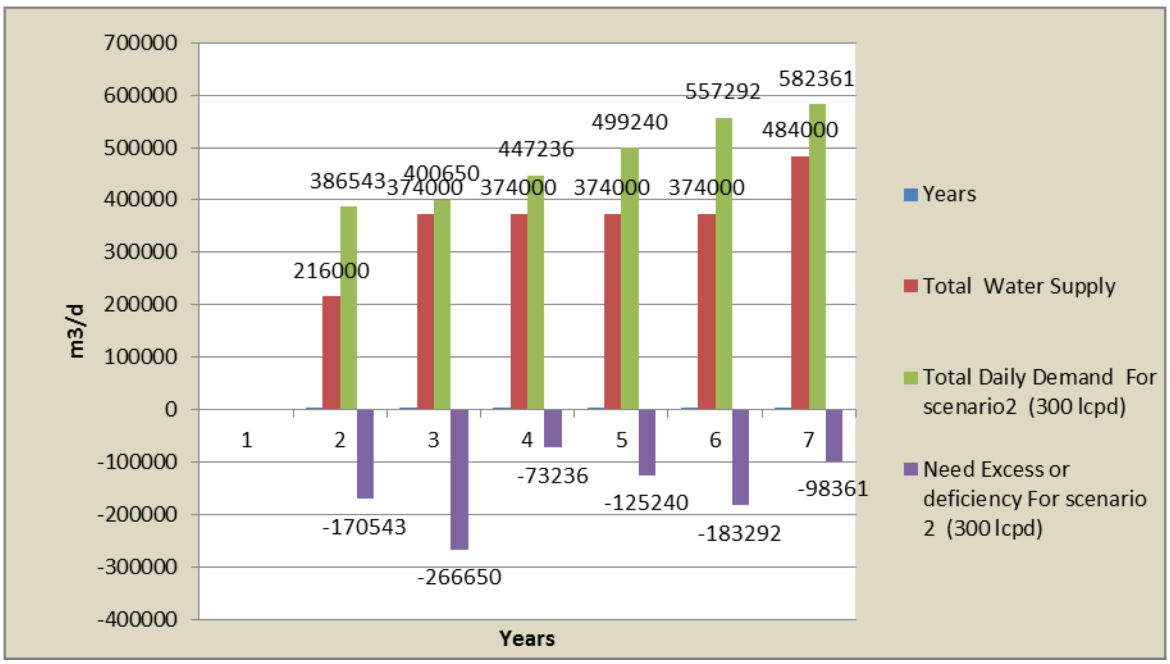

Figure 15. Water Demand and Supply and Need Excess or deficiency for (2nd Scenario)

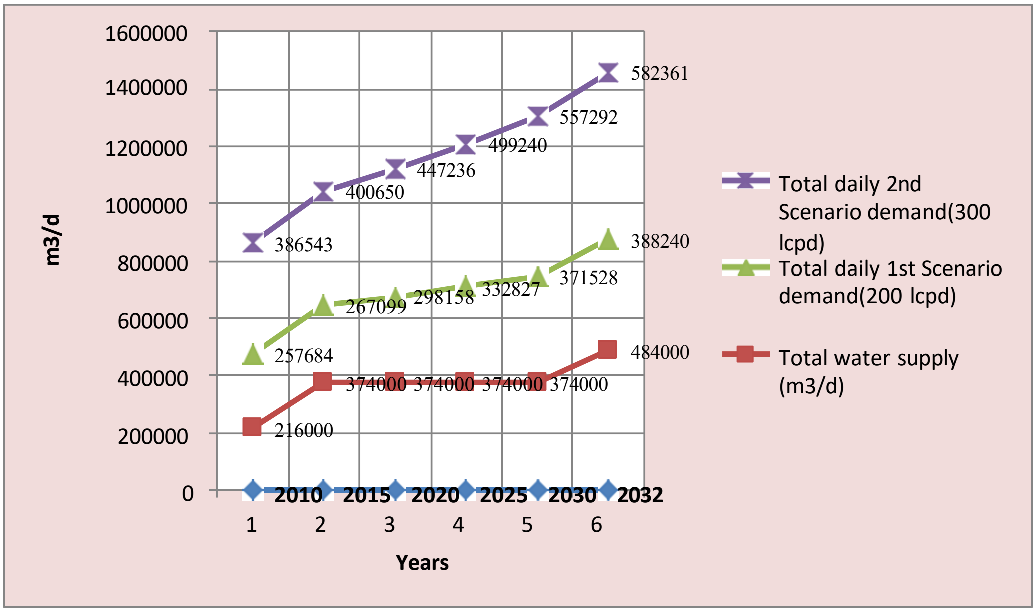

Figure 16 Total productivities (supply) and Total daily demand for 1st and 2nd Senarios

5. Conclusions

The results showed that the actual production of projects that supply the city in 2010 is (216,000m3 / day), and in according to which the actual individual share of drinking water, which was calculated by researchers, is (324 liters / person / day) in light of the standard adopted for this year, which amounts to (285 liters / person / day).and actual production of projects that supply the city in 2015 is (374,000 m3/day) and in according to which the actual individual share of drinking water, which was calculated by researchers, is (355 liters / person / day) in light of the standard adopted for this year, which amounts to (299 liters / person / day). The results also showed that the actual production amount in the city expected for the year (2020, 2032) is same (416000 m3 / day) However, the average daily demand decreased according to 1st scenario for city center (200 liters per person /day) (2020= 280288 lcpd, 2032 = 36497 1cpd).but city center with Bakrajo increased (2020= 447237 lcpd) (2032= 582360 lcpd).

1- Also increased for 2nd scenario city center (300 liters per person / day) for the years (2020=420433 lcpd, 2032=574455 lcpd). And city center with bakrajo for the years (2020= 447236 lcpd, 2032 = 582361 lcpd)

2- The study reached the determination of the total average demand for drinking water in 2010 for 1st scenario, when it reached (257684 m3 / day), and when comparing the demand with supply in this year, it became clear that there is a deficit in the amount of production estimated at--41684m3 / day) and total demand for 2015 is reached (267099 m3 / day) and when comparing the demand with supply in this year, it became clear that there is an increase in the amount of production estimated at +106901. The determination of the total average demand for drinking water in 2020(298158 m3 / day) and when comparing the demand with supply in this year, it became clear that there is an increase in the amount of production estimated at (+75,842 m3 / day), the total average demand for drinking water in 2032 when it reached (388,240 m3 / day) there is an increase in the amount in the amount of supply estimated at (+95760 m3 / day).

3- According to the results of 1st and 2nd scenarios specifying(200 L/d and300 L/d) for both scenarios that Excess or deficiency (200 lcpd) means that Excess for the target year 2020 equals(+75,842 m3 / day) and also Excess for the year 2032 equals(+95760 m3 / day) as in 2nd scenario any (300 L/d) that the deficiency for the year 2020 equals(-73,236 m3/day)also the deficiency for the year 2032 equals (-98361m3/day).

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